
Minimally Invasive Ophthalmic Surgery

I. Howard Fine
Daniel S. Mojon (Eds.)

Minimally Invasive Ophthalmic Surgery

Prof. Dr. I. Howard Fine
Oregon Health and Science University
1550 Oak Street, Suite 5
Eugene, OR 97401-7701
USA
hfine@finemd.com

Prof. Dr. Daniel S. Mojon
Department of Ophthalmology
Kantonsspital St. Gallen
Rorschacherstrasse
9007 St. Gallen
Switzerland
daniel.mojon@kssg.ch

Additional material to this book can be downloaded from <http://extras.springer.com>

ISBN 978-3-662-50195-5 ISBN 978-3-642-02602-7 (eBook)

DOI 10.1007/978-3-642-02602-7

Springer Heidelberg Dordrecht London New York

© Springer-Verlag Berlin Heidelberg 2010

Softcover reprint of the hardcover 1st edition 2010

This work is subject to copyright. All rights are reserved, whether the whole or part of the material is concerned, specifically the rights of translation, reprinting, reuse of illustrations, recitation, broadcasting, reproduction on microfilm or in any other way, and storage in data banks. Duplication of this publication or parts thereof is permitted only under the provisions of the German Copyright Law of September 9, 1965, in its current version, and permission for use must always be obtained from Springer. Violations are liable to prosecution under the German Copyright Law.

The use of general descriptive names, registered names, trademarks, etc. in this publication does not imply, even in the absence of a specific statement, that such names are exempt from the relevant protective laws and regulations and therefore free for general use.

Product liability: The publishers cannot guarantee the accuracy of any information about dosage and application contained in this book. In every individual case the user must check such information by consulting the relevant literature.

Cover design: eStudio Calamar, Figueres/Berlin

Printed on acid-free paper

Springer is part of Springer Science+Business Media (www.springer.com)

Dedication

“We dedicate this book to our patients who entrust their vision to our care, and by their trust and gratitude stimulate us to provide better outcomes by minimizing invasiveness.”

I. Howard Fine and Daniel S. Mojon

Preface

Minimally invasive surgical techniques constitute one of the most important revolutions in surgery since the early 1900s. In many operating disciplines, they allow us to minimize tissue trauma, postoperative patient discomfort, hospital stay, and work disability.

In ophthalmology, many minimally invasive procedures have been developed over the last decades. They have already and will continue to greatly improve eye surgery. Minimal techniques in use are, e.g., phacoemulsification for cataracts, nonpenetrating techniques and miniature drainage implants for glaucoma, transconjunctival approaches and minimal buckling for vitreoretinal surgery, endoscopic techniques for the lacrimal system, and small incisions for lid and strabismus surgery.

Minimally Invasive Ophthalmic Surgery is the first textbook providing a complete overview of minimally invasive surgical techniques in ophthalmology. It presents state of the art procedures using many illustrations and video-clips and serves as a textbook and reference guide to this rapidly growing sector of ophthalmic surgery.

Eugene, OR, USA
St. Gallen, Switzerland

I. Howard Fine
Daniel S. Mojon

Acknowledgements

The creation of a book about minimally invasive surgery across the ophthalmic subspecialties would not have become reality without the many contributing authors. We thank each of them for their time and expertise in writing their chapters. Special thanks go to Marion Krämer and Stephanie Benko from Springer who supported our idea. Finally, we thank all the surgeons who have innovated techniques that have incrementally increased the safety and efficacy of surgical intervention in the eye.

I. Howard Fine and Daniel S. Mojon

Contents

1 Minimally Invasive Oculoplastic Surgery	1
Michèle Beaconsfield and Richard Collin	
2 Minimally Invasive Conjunctival Surgery	23
Shigeru Kinoshita, Norihiko Yokoi, Tsutomu Inatomi, and Osamu Hieda	
3 Minimally Invasive Lacrimal Surgery	33
Rainer K. Weber	
4 Minimally Invasive Corneal Surgery	59
Heather M. Skeens and Edward J. Holland	
5 Minimally Invasive Refractive Surgery	97
Jorge L. Alio, Mohamad Rosman, and Samuel Arba Mosquera	
6 Minimally Invasive Strabismus Surgery	123
Daniel S. Mojon	
7 Minimally Invasive Iris Surgery	153
Roger F. Steinert	
8 Minimally Invasive Glaucoma Surgery	161
Elie Dahan, Stefan de Smedt, Juliàn Garcia Feijoo, José Maria Martinez de la Casa, André Mermoud, Bojan Pajic, and Sylvain Roy	
9 Minimally Invasive Cataract Surgery	197
I. Howard Fine, Richard S. Hoffman, and Mark Packer	
10 Minimally Invasive Vitreoretinal Surgery	217
Loh-Shan Leung, Woo Ho Nam, and Stanley Chang	
Index	233

Contributors

Jorge L. Alio Vissum, Instituto Oftalmológico de Alicante, Avda de Denia s/n, Edificio Vissum, 03016 Alicante, Spain
jlalio@vissum.com

Division of Ophthalmology, Universidad Miguel Hernandez, Alicante, Spain

Michèle Beaconsfield Moorfields Eye Hospital, 162 City Road, London EC1V 2PD, UK
mb@lidsurgery.co.uk

José Maria Martínez de la Casa Departamento de Glaucoma, Servicio de Oftalmología, Hospital Clínico San Carlos, Instituto de Investigaciones Ramón Castroviejo, Universidad Complutense, Madrid, Spain

Stanley Chang Department of Ophthalmology, Columbia University, New York, New York
Edward Harkness Eye Institute, New York Presbyterian Hospital, New York, New York

Richard Collin Moorfields Eye Hospital, 162 City Road, London EC1V 2PD, UK
richard.collin3@bopenworld.com

Elie Dahan Ha-teena 4, Cluster 8, P. O. Box 4754, Caersaria, 38900, Israel

Julián García Feijó Departamento de Glaucoma, Servicio de Oftalmología, Hospital Clínico San Carlos, Instituto de Investigaciones Ramón Castroviejo, Universidad Complutense, Madrid, Spain
mherrerad@sego.es

I. Howard Fine Oregon Health and Science University, 1550 Oak Street, Suite 5, Eugene, OR 97401-7701, USA
hfine@finemd.com

Osamu Hieda Department of Ophthalmology, Kyoto Prefectural University of Medicine, Kyoto 602-0841, Japan

Richard S. Hoffman Oregon Health and Science University, Eugene, OR, USA

Edward J. Holland Cincinnati Eye Institute, 580 South Loop Road, Suite 200, Edgewood, KY 41017, USA
eholland@fuse.net

Tsutomu Inatomi Department of Ophthalmology, Kyoto Prefectural University of Medicine, Kyoto 602-0841, Japan

Shigeru Kinoshita Department of Ophthalmology, Kyoto Prefectural University of Medicine, 465 Kajicho, Hirokoji, Kawaramachi, Kamigyoku, Kyoto 602-0841, Japan
shigeruk@koto.kpu-m.ac.jp

Loh-Shan Leung Edward S. Harkness Eye Institute, New York Presbyterian Hospital
Department of Ophthalmology, Columbia University, New York, New York, USA
sc434@columbia.edu

Daniel S. Mojon Department of Ophthalmology, Kantonsspital St. Gallen,
Rorschacherstrasse, 9007 St. Gallen, Switzerland
daniel.mojon@kssg.ch

André Mermoud Glaucoma Center, Montchoisi Clinic, Chemin des Allinges 10,
1006 Lausanne, Switzerland
amermoud@montchoisi.ch

Samuel Arba Mosquera Schwind eye-tech-solutions, Germany
samuel.arba.mosquera@eye-tech.net

Woo Ho Nam Department of Ophthalmology, Columbia University, New York,
New York
Hallym University Medical School, Kangnam Sacred Heart Hospital, Seoul, Korea

Mark Packer Oregon Health and Science University, Eugene, OR, USA

Bojan Pajic Department of Ophthalmology, Vedis, Klinik Pallas,
Louis Giroud Strasse 20, 4600 Olten, Switzerland
bpajic@datacomm.ch

Mohamad Rosman Refractive Surgery Service, Singapore National Eye Centre,
11, Third Hospital Avenue, S168751, Singapore
rosman_sg@yahoo.com
Singapore National Eye Centre, Singapore Eye Research Institute and Singapore
Armed Forces, Singapore
Vissum, Instituto Oftalmologico de Alicante, Spain

Sylvain Roy Centre du Glaucome Clinique de Montchoisi,
Ch. des Allinges 10 CH-1006 Lausanne Switzerland,
sylvain.roy@epfl.ch

Heather M. Skeens Storm Eye Institute, 167 Ashley Avenue, MSC 676,
Charleston, SC 29425, USA
skeens@musc.edu

Stefan de Smedt Department of Ophthalmology, Katholieke Universiteit Leuven,
Leuven, Belgium

Roger F. Steinert University of California, The Gavin Herbert Eye Institute,
118 Med Surge1, Irvine, CA 92697-4375, USA
roger@drsteinert.com

Rainer K. Weber Department of ENT, Hospital Karlsruhe, Moltkestrasse 90,
76133 Karlsruhe, Germany
rainer.weber@klinikum-karlsruhe.com

Norihiko Yokoi Department of Ophthalmology, Kyoto Prefectural University of
Medicine, Kyoto 602-0841, Japan

1.1 General Points

Although the term “minimally invasive” has now entered medical vocabulary, the concept of doing the smallest intervention that has the greatest effect with minimum collateral damage is the basis of good medical practice. Many minimally invasive procedures in lid surgery have been established for decades, some of which have enjoyed a renaissance, whereas others are relatively new [37, 60, 61]. The examples described here are performed under vasoconstrictive local anaesthesia (e.g. bupivacaine 0.5% with adrenaline 1:100,000) unless otherwise indicated. All of these procedures aim to keep morbidity and recovery time of the patient to a minimum.

The surgical anatomy of the lids divides them into anterior and posterior lamellae, the anterior lamella consisting of skin and orbicularis and the posterior, of tarsal plate and conjunctiva. The grey line of the lid margin is the demarcation anterior to which is the squamous epithelium and the lashes, and posterior to which is the conjunctiva pierced by the openings of the tarsal meibomian glands (Fig. 1.1).

The upper and lower lids are retracted by the levator palpebrae superioris/Muller’s muscle complex and inferior retractors respectively. The latter are a fibrous sheet extending from the inferior rectus muscle sheath to the inferior border of the inferior tarsus, with a few slips of smooth muscle similar to Muller’s muscle. This sheet splits to enclose the inferior oblique muscle which runs across it (Fig. 1.2).

1.2 Lower Lid Entropion

1.2.1 Introduction

The term entropion comes from the Greek words *en* (towards) and *tropein* (to turn), and describes the turning in of the lid margin towards and onto the globe. The two main categories of entropion are involutional and cicatricial, with involutional being by far the most common. Natural ageing changes of the lid tissues express themselves as laxity. In the vertical plane, disinsertion of the lower lid retractor attachment to the inferior border of the tarsal plate (equivalent to aponeurosis dehiscence of the levator in the upper lid)

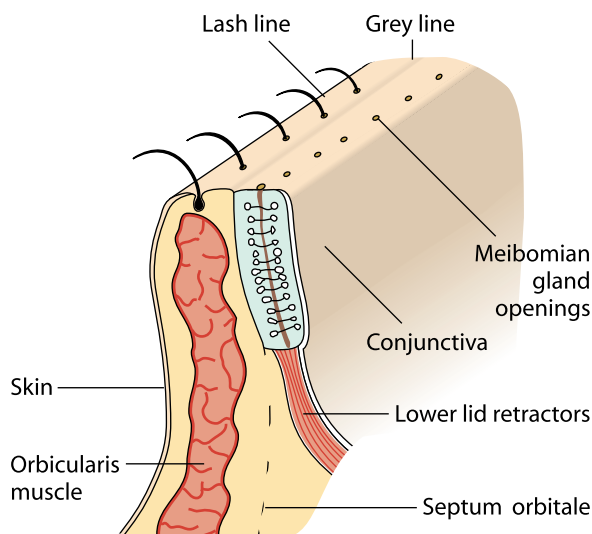
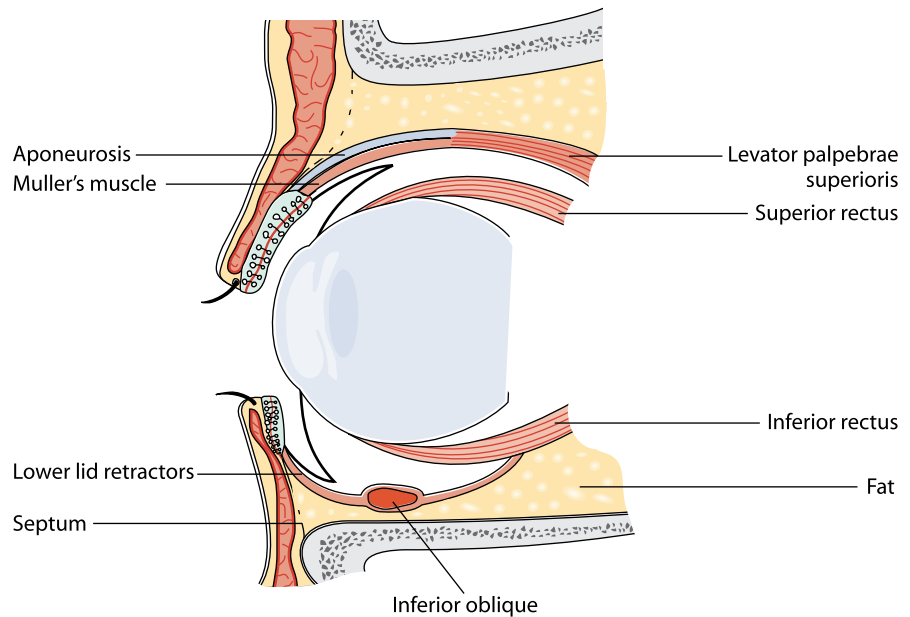


Fig. 1.1 Cross section of lid margin. *CONJ* conjunctiva; *GL* grey line; *LL* lashline; *LLR* lower lid retractors; *MG* meibomian gland openings; *ORBIC* orbicularis muscle; *S* septum; *Sk* skin. Illustration by Christiane Solodkoff, Neckargemünd/Heidelberg, Germany

M. Beaconsfield (✉)
Moorfields Eye Hospital, 162 City Road,
London EC1V 2PD, UK
e-mail: mb@lidsurgery.co.uk

Fig.1.2 Cross section of upper and lower lids. *A* aponeurosis; *F* fat; *IO* inferior oblique; *IR* inferior rectus; *LLR* lower lid retractors; *LPS* levator palpebrae superioris; *M* Muller's muscle; *S* septum; *SR* superior rectus. Illustration by Christiane Solodkoff, Neckargemünd/Heidelberg, Germany



weakens its power. Weakness of the lower lid retractors is considered to be the most important contributor to the development of entropion; the horizontal plane is lengthened by stretching of the canthal tendons and some atrophy of the tarsus [11, 13, 38]. These changes allow slippage and instability of the usual anatomical relations of the lamellae, with the preseptal orbicularis riding up, thus tipping the lid margin inwards (Fig. 1.3).

1.2.2 Lower Lid Entropion Sutures

Formal surgical procedures address the weakened attachments of the retractors, the horizontal laxity and the overriding orbicularis – ideally all three [19]. However, it is possible to temporise with a minimally invasive procedure, particularly if there is little or no horizontal laxity. Sutures were known to be in use at the time of Hippocrates [9]. Two types are distinguished. Transverse sutures are placed horizontally through the lid (from the base of the tarsal plate and out onto the skin) so as to form a barrier to prevent the upward movement of the pretarsal orbicularis. Everting sutures are placed at an angle so as to bring the lower lid retractors up to the tarsal plate and use their power to pull the lid margin forward [20, 61].

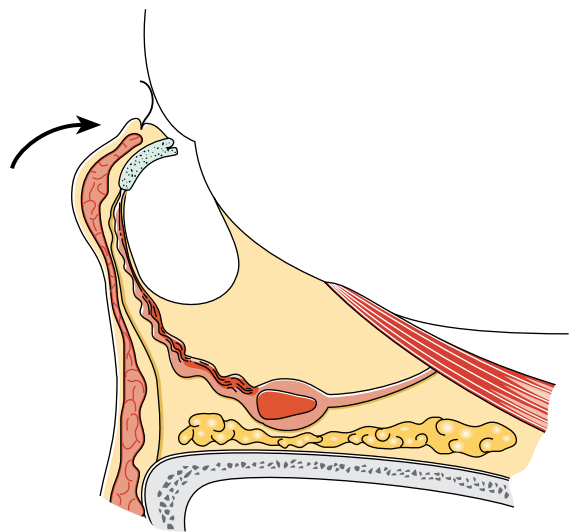


Fig. 1.3 Preseptal orbicularis over ride in entropion. Illustration by Christiane Solodkoff, Neckargemünd/Heidelberg, Germany

Patient selection: sutures depend on the scarring they create and leave behind once they have dissolved or been removed. It is the scarring that holds the lid in its new corrected position. The less severe the involutional entropion, the longer the effect will last. It may last many months, possibly even years, in a patient with intermittent entropion with little or no lid laxity,

i.e. before the ageing changes have a chance to worsen horizontal laxity and lamellar slippage. It is these continual ageing changes which lead to recurrence. Sutures alone will have little or no long-term effect on cicatricial entropion and their use alone would be inappropriate in such cases; here, the scarred and shortened posterior lamella would need to be corrected.

Correct placement of the suture: to overcome the anterior lamellar override caused by the preseptal orbicularis pushing the lid in, three or more double-armed sutures are placed transversally across the full thickness of the lid, at a level just below the inferior border of the tarsus (Fig. 1.4a). The everting sutures need to pick up the detached lower lid retractors and pull them upwards and forwards so they can pull the tarsus outwards. The vector of pull needed to restore normal margin position is from low in the posterior lamella to high in the anterior lamella (Fig. 1.4b). This is also achieved by using three or more double-armed 4/0 sutures entering the conjunctiva below the inferior border of the tarsal plate, to catch the retractors. The needles are pushed forwards and superiorly to exit the skin below the lash line anterior to the tarsal plate and the sutures are tied. The exit points on the skin are much higher than the level of entry on the conjunctival surface, and above the preseptal orbicularis. How far below the inferior border the sutures enter the conjunctiva depends on the degree of entropion which is related to how far the retractors have dropped. The more the anterior rotation required, the lower is the suture entry posteriorly. For mild rotation, the entry is made 3–4 mm below the inferior border of the tarsal

plate. If the entropion is more severe, so is the laxity of the lower lid retractors; the needle entry is therefore made lower at 8–10 mm below the inferior border of the tarsal plate.

Correct type of suture: a suture which produces a minimal reaction from tissues such as nylon can be used if the temporising measure is only for a matter of days, or weeks at the most, with the intention of proceeding to formal surgical correction of the entropion. If, on the other hand, the procedure is intended to last longer, then a suture which generates an inflammatory response, such as silk catgut or Vicryl, will be more effective, as the resulting scar will outlive the sutures once these have been removed or fallen out. Postoperatively, patients are treated with topical antibiotics for a week. The sutures loosen within 3–4 weeks, after which they can be removed. Their removal prior to this time should be avoided so as to allow fibrosis to establish itself.

1.2.3 Lower Lid Entropion Botulinum Toxin

This toxin is the most powerful and lethal poison known to man, with a median lethal intravenous dose of 1 ng/kg [3]. It was originally introduced in ophthalmology over 25 years ago as an alternative to surgical treatment of strabismus and its safety in this field and for idiopathic blepharospasm was recognised early [62, 63]. Botulinum toxin A is one of seven antigenically distinguishable

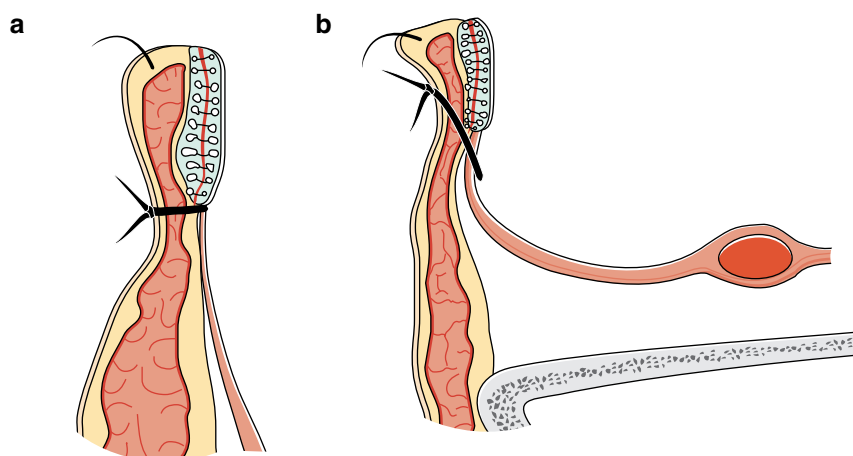


Fig. 1.4 Entropion sutures. (a) Transverse suture; (b) everting suture. Illustration by Christiane Solodkoff, Neckargemünd/Heidelberg, Germany

toxins (A to G) produced by the anaerobic bacterium *Clostridium botulinum*. The toxin is a two-chain polypeptide, with a heavy chain joined by a disulphide bond to a light chain. The heavy chain adheres to axonal terminals and the toxin is brought into the terminal by endocytosis [24]. The light chain then leaves the endocytic vesicle to enter the cytoplasm. The light chain is a protease enzyme which selectively degrades SNAP-25, a SNARE protein which is a fusion protein at the neuromuscular junction necessary for docking neurosecretory vesicles [31].

Failure of the vesicles to dock on the axonal synapse plasma membrane prevents release of their acetylcholine content. The lack of acetylcholine dampens the nerve impulse, leading to flaccid paralysis. This is overcome and neuromuscular function returns by new axonal sproutings; the process of recovery begins within days and takes some weeks to be functionally effective [56].

For over two decades botulinum toxin has enjoyed widely accepted use, initially off label, for many other pathological conditions [12]. In ophthalmology this includes entropion, blepharospasm and the induction of a temporary ptosis for corneal protection [15, 17, 29, 42, 67]. Although taping the entropic lower lid outwards is a useful temporising measure, it requires some patient dexterity and the tape can be irritating to the skin. Botulinum toxin does not involve the patient in continued management. It is effective in overcoming the overriding orbicularis of entropion while waiting, for whatever reason, to proceed to formal surgical correction. Occasionally, the effect of the toxin is prolonged as the cycle of spasm, secondary to pain from corneal trauma due to in-turned lashes, is broken. The toxin is injected without the need for local anaesthetic. An injection of 5–7 U Botox (approximately 20–28 U of Dysport) will effectively dampen the orbicularis override and reverse the entropion. It should be injected above the inferolateral orbital rim in the preseptal fibres of the orbicularis, over 5 mm below the lid margin so as to avoid the pre tarsal fibres as these are needed for lid closure. The needle (30 gauge) is inserted into the muscle fibres for direct delivery of the toxin.

As with any toxin injection, it takes a few days to take effect and wears off on average some 8–12 weeks later. Complications are unusual and include inadvertent bruising and spreading of the toxin inferiorly into cheek muscles with resultant temporary loss of movement. These signs resolve with time.

1.3 Lower Lid Ectropion

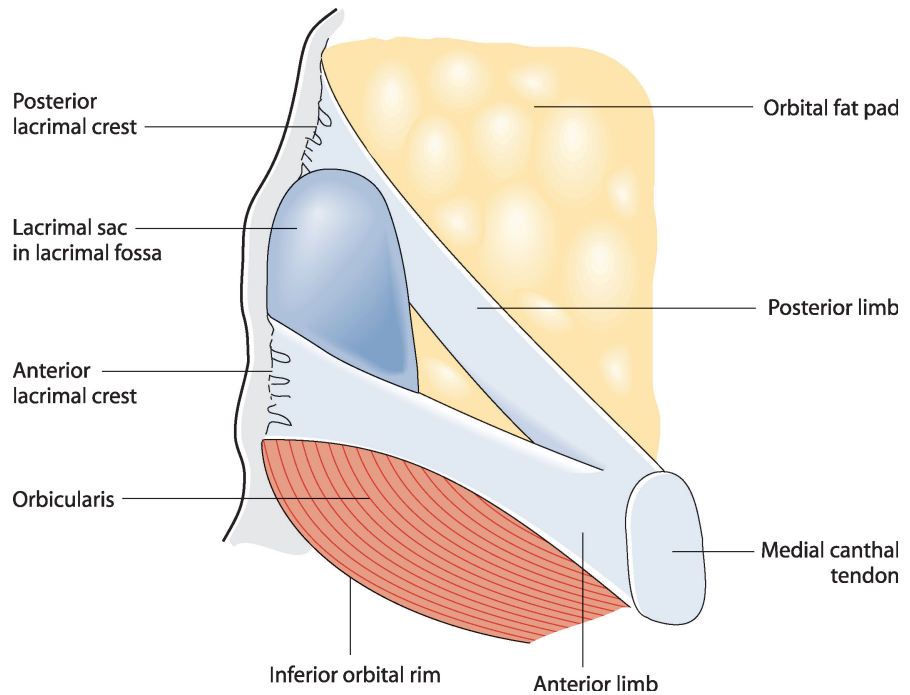
1.3.1 Introduction

The term ectropion comes from the Greek words *ec* (away from) and *tropein* (to turn). As for entropion, the commonest cause of ectropion is involutional. Less common categories are paralytic, cicatricial and mechanical. The outward displacement of a lid margin from ageing changes is predominantly due to horizontal laxity of its components (lateral canthal tendon, tarsus, and medial canthal tendon) and less commonly from laxity/loss of the lower lid retractors resulting in total tarsal ectropion [32, 58, 71, 6, 68]. Initially, the latter leads to loss of the lower skin crease but can, in severe cases, produce total tarsal eversion. Surgical procedures are well established, the lateral tarsal strip and a full thickness pentagon excision being the standard operations for laxity of the lateral canthal tendon and tarsus respectively [1, 13]. Several operations are available to correct medial laxity but its repair is more complicated than its lateral counterpart, as anatomically it has two limbs, anterior and posterior (Fig. 1.5). The amount of lid laxity due to medial canthal tendon depends on which limb is affected. The severity of the laxity is assessed by seeing how far laterally the punctum can be dragged across the globe [7].

Punctal ectropion alone can be addressed by excising a small tarso-conjunctival diamond from the posterior lamella, the so-called medial spindle, ensuring the lower lid retractors are picked up in the single stitch that closes the wound; if the punctal ectropion is associated with mild to moderate medial laxity of the lid tissues, where the punctum can be dragged laterally but no further than the level of the medial corneal limbus, various surgical interventions are available including the so-called Lazy-T procedure and medial canthal anterior limb plication [54, 66].

If the punctum can be pulled laterally beyond the medial corneal limbus, and laxity may be severe enough for the punctum to reach the mid-pupillary line, this is seen as evidence of loss of the posterior limb of the medial canthal tendon. Those procedures which only address the anterior limb would be ineffective. The posterior limb can be recreated by horizontally resecting part of the lid medially thus shortening it, marsupialising the cut canaliculus and reattaching the newly shortened medial end of the tarsus to the

Fig. 1.5 Schematic anterior view of left medial canthal tendon. *AL* anterior limb; *ALC* anterior lacrimal crest; *IOR* inferior orbital rim; *LLF* lower lid medial fat pad; *LS* lacrimal sac in lacrimal fossa; *MCT* medial canthal tendon; *PL* posterior limb; *PLC* posterior lacrimal crest; *ULF* upper lid medial fat pad. Illustration by Christiane Solodkoff, Neckargemünd/Heidelberg, Germany



posterior lacrimal crest. Although less complex operations have been proposed [39], durable long term results have been shown with this resection procedure [22, 69]. This open surgical procedure may not be suitable in elderly or frail patients. A less invasive procedure involves reattaching the medial end of the tarsus without shortening the lid, by the use of a suspensory non-dissolving suture, the Royce Johnson suture [43].

1.3.2 The Royce Johnson Suture

The medial lower lid is injected with vasoconstrictive local anaesthetic, as is the upper lid medially. The bolus is then massaged down so as to reach the deeper tissues. A small horizontal incision is made with a D15 blade, inferolateral to the lower punctum, at the level of the medial edge of the tarsal plate. Orbicularis fibres are divided by blunt dissection to expose the medial edge of the tarsus. The tip of a blunt ended instrument, such as an artery clip, is placed just behind the plica semilunaris and pushed posteriorly to identify the posterior lacrimal crest by palpation, thus giving the surgeon an indication of its position. A double armed 4/0 Prolene stitch is then passed through the exposed tarsal

edge and the needles passed “blind”, one needle at a time, medial to the globe and lateral to the lacrimal sac, pointing backwards, upwards and medially through the connective tissue towards the superior end of the posterior lacrimal crest. The needle tips pick up periosteum before continuing a short distance upwards to tent the skin of the upper lid superomedially. A D15 blade is used to cut down on this tenting to allow the needle out. The second needle is passed in the same way, and exits through the skin opening fashioned by the first one (Fig. 1.6). The stitches are then gently pulled upwards to judge how far up the medial end of the lower lid needs to be elevated. They are then tied and the knot buried close to periosteum, well under orbicularis which is closed with an absorbable stitch such as 6/0 vicryl, as is the skin. Only one or two interrupted sutures are required for each layer.

1.3.3 The Pillar Tarsorrhaphy

Strengthening a weak muscle is easier than compensating for a paralysed one, and managing paralytic ectropion is no exception. In this clinical setting, there is descent as well as forward displacement of the lid margin. This is due to loss of orbicularis muscle tone

Fig. 1.6 Royce Johnson suture. (a) Preoperation; (b) RJ suture through but untied; (c) suture tied and skin closed

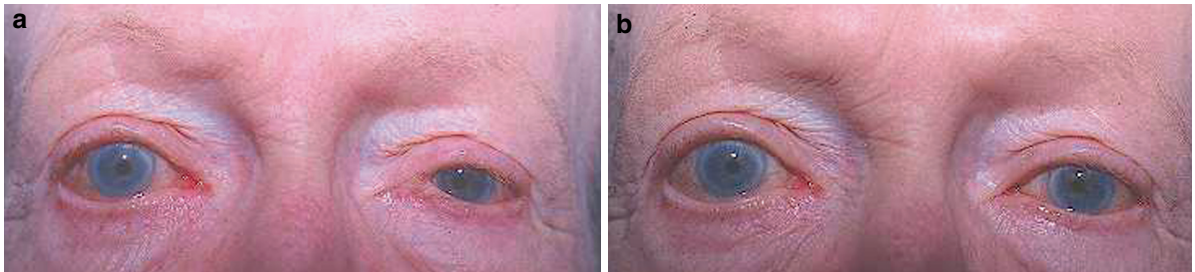
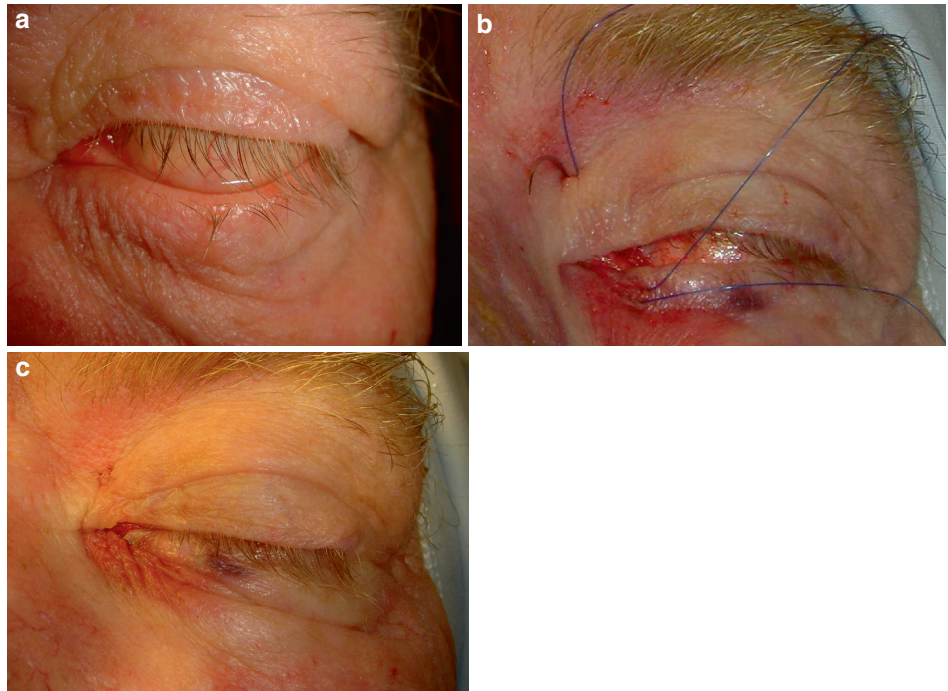


Fig. 1.7 Pillar tarsorrhaphy. (a) After 6 weeks; (b) opened after resolution of palsy

as a result of damage of some kind to the facial nerve that supplies it. In severe cases, where there is corneal exposure that cannot be lubricated adequately, but there is every hope the palsy will recover, a reversible procedure that can support the lid margin temporarily is required. As the recovery may take several months, the procedure needs to hold for that long.

The traditional temporary tarsorrhaphy, where the margins are freshened and then sutured together on bolsters, tends to stretch vertically, or even give way, sometimes within weeks. Moreover, tarsorrhaphies, whether temporary or permanent, are traditionally placed laterally. The lower lid sag and resultant widening of the vertical palpebral aperture in paralytic ectropion is

often more severe medially than laterally. Therefore a lateral procedure, whether temporary or permanent, will not correct this well. Furthermore, an equivalent medial procedure to the temporary lateral tarsorrhaphy would need to last longer than a few days or weeks. The pillar tarsorrhaphy fulfils these requirements [43]. Its closing of the lid margins medially protects the globe at the expense of cosmesis, but with the advantage that they can be reopened when required at a later date with good cosmetic outcome (Fig. 1.7).

The effect of this procedure depends on the principle that raw surfaces will stick together and heal in that position, and that the larger the raw surface area the better the healing. After infiltration with

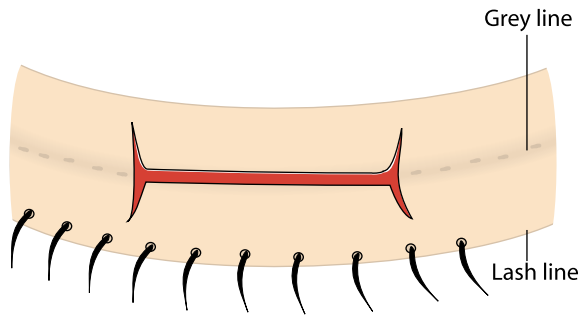


Fig. 1.8 H incision in lid margin. *GL* grey line; *LL* lash line. Illustration by Christiane Solodkoff, Neckargemünd/Heidelberg, Germany

vasoconstrictive local anaesthetic, the upper and lower lid margin grey lines are scored 2–3 mm deep with a thin pointed blade (e.g. D11 or a feather blade as used for paracentesis through a cornea) from the level of the medial limbus of the cornea to just lateral to the puncta. The incisions are then extended anteriorly and posteriorly to form an “H” (Fig. 1.8). The posterior margins are sutured together with a long acting absorbable suture such as 6/0 vicryl. The anterior margins are everted forwards and sutured together with 4/0 silk or vicryl over bolsters like pouting lips, ensuring the extended raw surfaces are in close contact (Fig. 1.9). The stitches remain in situ for at least 3 weeks or until they loosen and can be removed with the bolsters, without disturbing the newly healed pillar. This can be left as is, or reopened with a blade under vasoconstrictive local anaesthetic when it is no longer required.

1.3.4 Lower Lid Ectropion Sutures

Acute ectropion can be congenital or acquired. If the conjunctiva becomes sufficiently oedematous, then the lid cannot return to its usual position. In congenital cases, this occurs soon after birth, is usually bilateral and associated with anterior lamellar shortage. Conservative management involves lubricating the conjunctiva, then pushing it back into place by manually inverting the everted lids and applying pressure pads. These are kept in place for 24–48 h; this is usually sufficient for the conjunctival oedema to resolve enough not to push the lid out into an ectropion. Rarely, inverting sutures are required for formal corrective surgery for laxity/skin shortage.



Fig. 1.9 Bolstered stitch in anterior lamella of Pillar tarsorrhaphy

In adults, a certain amount of horizontal age-related laxity is usually necessary to acquire an acute ectropion. In the presence of involutional changes, a trigger such as blepharospasm or conjunctival oedema may result in transient ectropion. Ocular pain or irritation from a corneal foreign body or ulcer may be sufficient to cause orbicularis spasm; sudden onset of conjunctival oedema, as in allergic reactions, may cause tarsal ectropion (Fig. 1.10). Clearly, the stimulating cause needs to be corrected and, in the case of allergy, the offending chemical needs to be removed from the

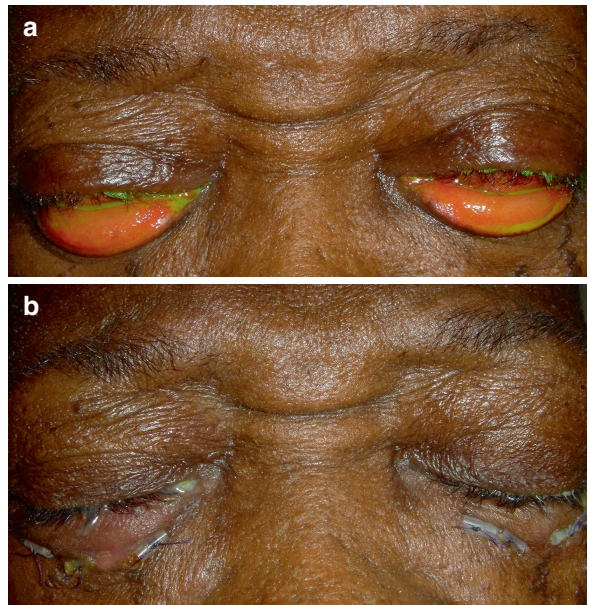
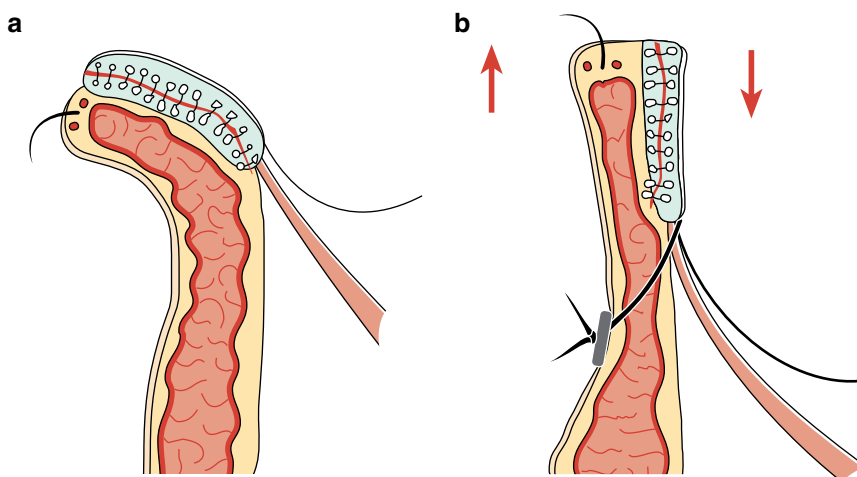


Fig. 1.10 Acute allergic ectropion. (a) Eversion with conjunctival oedema; (b) inverting sutures on bolsters

Fig. 1.11 Inverting suture.
(a) Ectropion; (b) suture on
bolster inverting lid.
Illustration by Christiane
Solodkoff, Neckargemünd/
Heidelberg, Germany



patient's environment. If the allergen is a necessary topical medication, such as glaucoma therapy, then an alternative should be found. Meanwhile, the conjunctival oedema may take some time to resolve. The lid position can be improved with inverting sutures.

Temporary inverting sutures are placed through the full thickness of the lower lid at an angle so that the anterior lamella is advanced or rises with respect to the posterior lamella (Fig. 1.11). After subcutaneous infiltration with vasoconstrictive local anaesthetic (1–2 mL of local anaesthetic with 1:80,000 adrenaline is usually sufficient) and topical anaesthetic drops to the conjunctiva, 3 or 4 double armed long acting absorbable sutures such as 4/0 vicryl are placed, entering from the conjunctival surface just under the lower border of the tarsal plate. The needles are then passed anteriorly and inferiorly to come through the skin at a level below that of the entry on the conjunctival surface. The sutures are tied over bolsters and should be removed by 10–14 days.

1.4 Distichiasis

1.4.1 Introduction

Distichiasis is the term used to describe the abnormal growth of hair follicles from what should normally be meibomian glands, and can be congenital or acquired. Congenital distichiasis is rare and is transmitted by dominant inheritance. Due to an error in differentiation, the putative meibomian glands develop into pilo-sebaceous

units. Distichiasis, from metaplasia of the meibomian glands on the posterior lamella into pilo-sebaceous units, can be acquired following chronic inflammatory insults. Examples include chronic blepharitis, cicatricial diseases such as ocular cicatricial pemphigoid and Stevens-Johnson syndrome, and long term sequelae from infection as in trachoma. These abnormal lashes range in type from fine non-pigmented stumps, to the more recognisable long pigmented ones, and can be few and sparse or multiple. They can be treated by a variety of methods, all of which involve destruction of the lash root, or follicle, to prevent new growth. As not all lashes are in the same part of their growth cycle, these treatments often need to be repeated.

Cryotherapy will destroy broad areas of abnormal lashes. Its application to the lid margin is not pinpoint, even when using the small round tipped cryotherapy probes used in retinal detachment surgery. Inevitably, the freezing time needed to cause death of the lash follicle means that there is also time for the ice to spread further than perhaps desired. Splitting the lid margin so as to separate the anterior from the posterior lamellar edge, prior to treating the posterior edge, helps to prevent the spread of ice onto the normal more anteriorly placed lashes [2, 55]. Cryotherapy cannot be used on pigmented patients as melanin carrying cells die at a higher temperature (c. -10°C) than that required to destroy lash follicles (c. -20°C), potentially leaving these patients with cosmetically unacceptable depigmented patches. The use of a specially designed cryoprobe and its posterior (conjunctival) placement has been shown to minimise these effects in patients with trichiasis [57].

1.4.2 Direct Excision of Lashes

Distichatic lashes can be removed by direct cut down and excision of individually targeted lash follicles through a tarso-conjunctival trap door or a lash margin split [25, 74]. The access can be obtained even more simply by direct cut down. This should ideally be performed with the surgeon wearing loupes or under a microscope. After infiltration with vasoconstrictive local anaesthetic, the lid is everted over a Desmarres retractor using a 4/0 nylon traction stitch. Alternatively, the lid can be immobilised with a chalazion clamp. The lashes to be targeted are identified. A direct cut down is performed onto the shaft with a feather blade, such as those used for corneal paracentesis. The shaft and its follicle are thus exposed and can be electrolysed and excised (Fig. 1.12). The surgical incision heals rapidly and the patient is treated with topical antibiotic ointment nightly for 1 week.

1.5 Ptosis

1.5.1 Introduction

Ptosis is one of the most common reasons for an oculoplastic referral. In primary gaze, the upper lid margin normally sits at a level of 1–2 mm below the upper limbus. An upper lid is said to be ptotic when its margin is

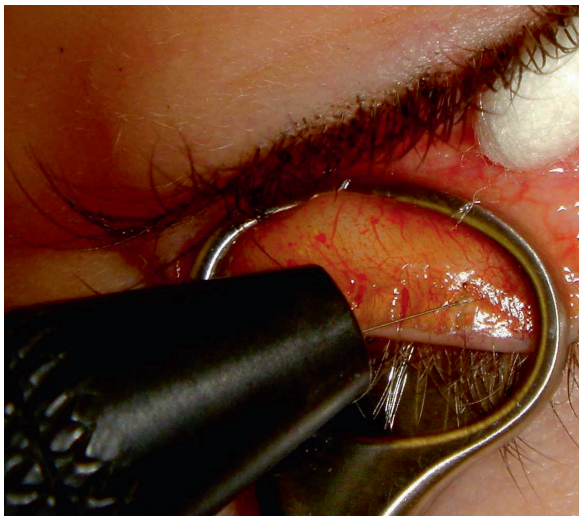


Fig. 1.12 Electrolysis to lash root under direct vision

lower than this. It may block part of the upper field of vision and if severe enough will obscure the visual axis. Its aetiology is varied and acquired cases are classified as due to aponeurotic defects (by far the most common), or are neurogenic (e.g. third nerve palsy, Horner's syndrome, myaesthesia), myogenic (e.g. ocular myopathy, external ophthalmoplegia) or mechanical in origin [8].

Various well-established surgical methods have been described for the correction of ptosis. The choice of procedure is based on the degree of ptosis and perhaps more importantly the strength, or lack of it, of levator function [19]. In cases of age related aponeurosis dehiscence, where levator function is good and the ptosis is mild, minimally invasive repairs can be done either by the posterior or anterior approach.

1.5.2 Posterior Approach Muller's Muscle-Conjunctival Resection

In patients with a small ptosis and good levator function, the ptosis can be repaired through a posterior approach by excision of Muller's muscle and conjunctiva. This was first popularised by Putterman over 30 years ago and has enjoyed a renaissance of late [60].

Patient evaluation: this procedure is best used for mild involutional ptosis of 2 mm or less, with good levator function of 10 mm or more. It can be done unilaterally or bilaterally. It is not an appropriate procedure for patients with traumatic levator dehiscence, nor for ptosis from causes other than age related involution (e.g. neurogenic or myogenic), nor in patients with poor or absent levator function. Ptosis is gauged by measuring the vertical palpebral aperture in primary gaze, i.e. the distance between the upper and lower lid margins at the mid-pupillary line. The palpebral aperture has upper and lower components, the MRD1 and MRD2 respectively. MRD stands for margin-reflex distance and is the distance from the light reflex in the mid-pupil to the upper lid margin (1) and lower lid margin (2). The combined measurements of MRD1 and MRD2 equal the palpebral aperture (Fig. 1.13). Levator function is documented by measuring the upper lid margin excursion from downgaze to upgaze with a millimetre ruler held vertically in the mid-pupillary line, while preventing any brow elevation by pressing on it.

Patient selection: to assess whether a conjunctival – Muller's muscle excision is likely to be effective,

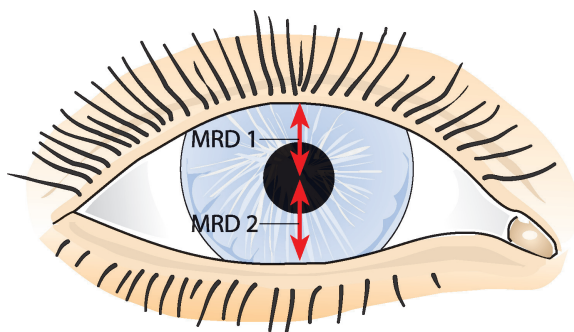


Fig. 1.13 MRD margin reflex distance. 1: superior; 2: inferior. Illustration by Christiane Solodkoff, Neckargemünd/Heidelberg, Germany

measurements are taken as indicated above. Then one drop of 2.5% phenylephrine is instilled in the superior fornix of the patient's ptotic lid. After a period of 5 min, measurements are taken again. If the height of the previously ptotic lid now matches the contralateral normal side in unilateral cases, or the heights of both previously ptotic lids are now normal, then this procedure is advisable and 8 mm of Muller's muscle and conjunctiva can be excised; if the lid is too high, the excision should be reduced to between 6.5 and 8 mm; if a millimetre too low then 8–9.5 mm should be excised. If the ptotic lid response is inadequate, a levator aponeurosis advancement or repair should be considered.

Method: after instillation of local anaesthetic at the lid margin, without any vasoconstrictive agents, and

topical anaesthetic drops to the conjunctival surface, the lid is everted on a Desmarres retractor by a traction stitch through the lid margin. The amount to be resected is marked on the conjunctiva with small cautery burns. Three sutures are placed half way between these marks to tent up the conjunctiva and Muller's muscle away from the aponeurosis. The tent is then clamped just shy of the cautery marks. A double armed absorbable suture (e.g. 6/0 Vicryl) is sewn in mattress fashion, 1 mm above the clamp edge, to allow room for a D15 blade to shave the clamp and its tissues off the lid once the mattress suture is in place. The unused half of the double-armed stitch then oversews the cut edge and is tied on the end of the first half (Fig. 1.14). Antibiotic ointment is instilled, and as many surgeons pad the eye for a few hours afterwards as don't. At review, if the new lid height is too high, the lid is everted after instillation of topical anaesthetic drops and the suture removed and the wound edges opened slightly. If the height is under-corrected, the surgery should be repeated with an alternative procedure which involves the aponeurosis.

1.5.3 Anterior Approach – One Stitch Aponeurosis Repair

Patient selection: if the ptosis is more than 2 mm, but still mild to moderate (3–4 mm) and in the presence of normal levator function, then an aponeurosis repair or

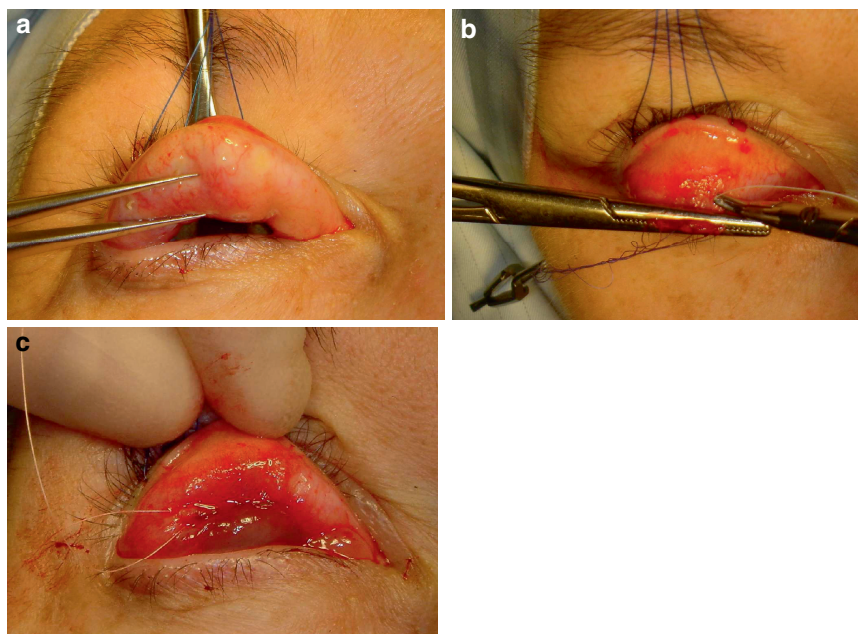
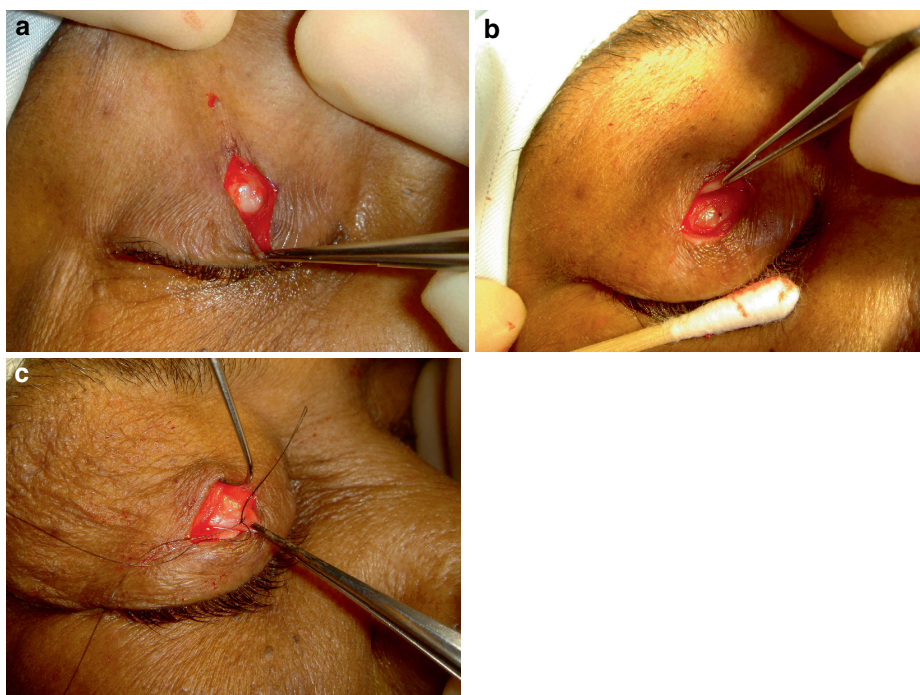


Fig. 1.14 Muller's muscle-conjunctival resection. (a) 6.5 mm measured between cautery marks; (b) suturing above clamp; (c) resection done and suture about to be tied

Fig. 1.15 One stitch aponeurosis repair. (a) Anterior surface of tarsus exposed; (b) aponeurosis edge advanced; (c) edge sutured to tarsus



advancement is desirable. In an otherwise healthy lid with no previous surgery, this can be achieved through a small incision, allowing just one stitch to reattach the aponeurosis [10, 33, 45].

Method: the level of the incision is selected pre-operatively with a marker pen. The skin incision needs to be short and match the skin crease level of the unaffected contra-lateral side. When performing this procedure bilaterally, the skin incisions need to match. A small amount (1 mL) of vasoconstrictive (1:200,000 adrenaline) local anaesthetic is injected in the sub orbicularis/pre tarsal space under the skin crease mark and massaged in. The incision is duly made at the marked site and the orbicularis fibres are separated by blunt dissection until the anterior surface of the tarsus comes into view. The dissection is then continued superiorly. This will lead to the exposure of the conjunctiva as the aponeurosis has thinned or even detached. Dissection further up will reveal the reflected edge of the dehiscent aponeurosis and this is reattached to the top of the tarsus with one non-absorbable suture (e.g. 6/0 nylon) or a thicker long acting absorbable suture (e.g. 5/0 vicryl) on a bow (Fig. 1.15). The new height of the lid is assessed with the patient looking in primary gaze and adjusted until satisfactory. Once the desired level is achieved, the tarsal suture is tied and

the skin closure made with a fast-acting absorbable stitch such as 7/0 vicryl rapide.

This method is ideal for patients with high sulci as it leaves the pre-aponeurotic fat pad undisturbed. In those with full/hooded lids, the reflected edge of the aponeurosis is opened; blunt dissection anterior to it will release the fat pad, enabling it to drop to the level of the skin incision. If a considerable amount of aponeurosis has disintegrated, the stitch reattaching its healthy remnant to the tarsus may need to be on a hangback to compensate for the loss of tissue, as reattaching it directly will be equivalent to a resection, thereby raising the lid too high.

Suture selection: If the incision is to become the skin crease, the skin closure stitch should include the aponeurosis (or the tarsus if the aponeurosis is on a hangback) to match the skin crease of the contra-lateral unaffected side. The skin is closed with one or two fast dissolving sutures such as 7/0 vicryl rapide. If the skin incision is not to be the skin crease (as in patients with high sulci), the incision can be closed directly with sub-cuticular nylon to minimise scarring or fast dissolving sutures.

If the tissues are thin and friable or of poor quality, the post-operative inflammatory response and subsequent scarring may be less than can normally be expected. A dissolving suture may therefore weaken before sufficient

reparatory fibrosis has set in. Under these circumstances it may be preferable to use a permanent suture, such as 6/0 nylon to reattach the aponeurosis edge to the tarsus, whether this be directly or on a hangback.

1.5.4 Supramid Brow Suspension

If the ptosis is severe and there is poor levator function (4 mm or less), surgery on the clearly weak levator muscle will be ineffective. The patient often relies on lifting the brows (frontalis recruitment) to help lift the ptosis to clear the visual axis. Brow suspension procedures harness this reflex frontalis muscle action and transfer its power to the tarsus by connecting to it with various materials. The ideal material is the patient's own tissue and the use of fascia lata from the thigh is well established [23].

Patient selection: there are times when the harvesting of autogenous fascia lata is not possible. A child may be too young for the leg to be long enough to harvest enough material. In some adults, a general anaesthetic may be undesirable either because of health reasons or because the patient prefers not to have one. The patient may wish to avoid a second site of surgery, i.e. the leg. In patients who are at high risk of corneal exposure (external ophthalmoplegias and ocular myopathies), the suspension may need to be reversed. In all these circumstances, synthetic materials are used [16, 26, 41, 44, 49, 64]. Fascia lata and many synthetic materials are introduced and placed in the lid and brow

tissues with a large needle (Wright's fascial needle). They are often relatively thick and not without complications such as slippage, extrusion and granulomas. Supramid also carries these risks but is thinner and easier to insert, with quicker surgical turnover and less recovery period required for the patient. It is a non-absorbable synthetic suture of the nylon variety (polyamide). Originally proposed as a replacement for fascia lata, long term studies showed it not to be as effective but nevertheless remained very useful in the shorter term particularly in high risk patients [40]. It consists of a cable, or core, and a very smooth polyamide sheath. This allows it to glide easily through the tissues on insertion. An even greater advantage is its needle. It is an integral part of the stitch, whereas other materials need threading; it is much smaller than that used to insert the other materials mentioned above, and it has the right curvature and length for a brow suspension.

Method: Vasoconstrictive local anaesthetic is injected along the tracks of the suspension material. Local anaesthetic is also infiltrated in children having a general anaesthetic as it helps greatly with post-operative discomfort. Using the Fox technique, 5 small stab incisions are made at each angle of the pentagon, with a straight blade (e.g. E11). Two stab incisions through pretarsal skin and orbicularis are usual. These can be extended into a longer single incision made down to the anterior tarsal surface, thus allowing suturing of the stitch to the tarsus to prevent slippage. Of the remaining three stab incisions, two are placed at the top of the brow, and one in the forehead (Fig. 1.16). These three form an isosceles triangle which is the most efficient

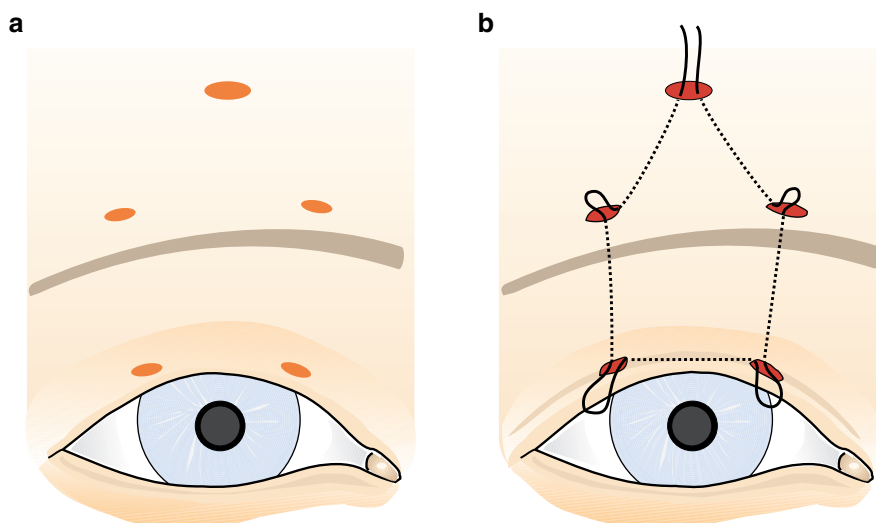


Fig. 1.16 Fox pentagon brow suspension. (a) Stab incisions; (b) suture threaded through. Illustration by Christiane Solodkoff, Neckargemünd/Heidelberg, Germany

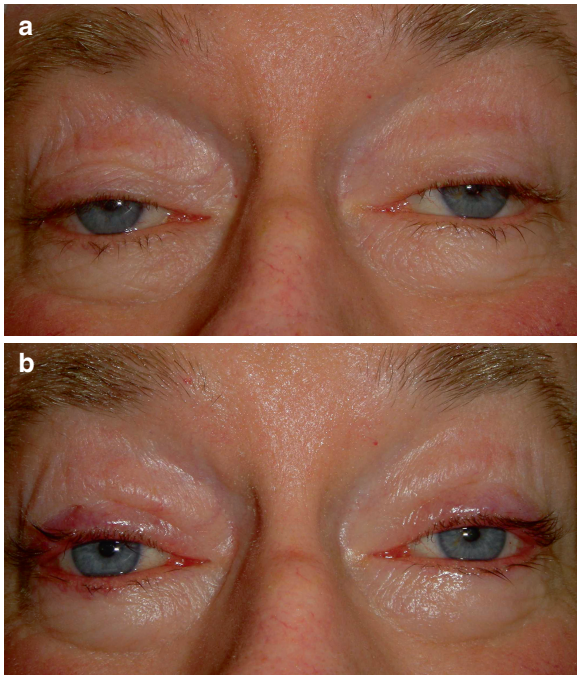


Fig. 1.17 Chronic progressive external ophthalmoplegia. (a) Frontalis recruitment preoperative; (b) frontalis recruitment postop with Supramid

way of imparting lifting power from the frontalis muscle. The stitch is passed through, starting at the tarsal stab incisions, and tightened until the lid margin has been lifted to the desired level; this cannot be too much in patients at corneal risk (Fig. 1.17). The stitch is then tied in the forehead wound and the knot is sutured to the under-surface of the frontalis muscle in the forehead wound with a long acting absorbable suture (e.g. 6/0 Vicryl). The forehead wound is closed with similar sutures, in two layers (subcutaneous then cutaneous) to avoid extrusion, whereas the skin of the other stab incisions can be closed directly. It is possible to minimise surgery further by deleting the top forehead incision altogether if the brow lift is particularly powerful, and passing the suspension material in a rectangular shape (four stab incisions), rather than a pentagon.

1.6 Lid Retraction

1.6.1 Introduction

The upper lid margin normally sits 1–2 mm below the upper limbus. Retraction is defined as an upward

displacement and has a variety of causes including trauma, iatrogenic (for example post ptosis repair), neurogenic (unopposed levator contraction in VII nerve palsy) and metabolic, of which the most common is thyroid associated ophthalmopathy (TAO). Factors contributing to TAO retraction include inflammation, fibrosis and adrenergic stimulation of the eyelid retractors. Retraction leads to both cosmetic and functional problems, including exposure keratopathy. Medical treatment is the first option but, if this fails, surgical intervention may be required. This, however, should be performed when the disease has been quiescent for 6–12 months, and performed earlier only in exceptional circumstances, such as severe exposure keratitis. Where surgery is required, orbital surgery for proptosis should precede extra-ocular muscle surgery, which in turn should precede lid surgery [65].

Most mild to moderate TAO upper lid retraction responds well to levator weakening procedures. Various modifications of these have been introduced over time, including either complete recession or formal excision of Muller's muscle, graded division of the lateral horn of the levator aponeurosis, graded myomectomies, and the use of adjustable sutures [18, 34, 35, 36, 59, 72]. However more serious upper lid retraction with obvious upper scleral show and severe lag on downgaze usually indicates a considerable amount of fibrosis. To lower the lid, additional vertical height is required. This is provided by grafting a spacer. The favoured material for this is donor sclera. However, owing to the variability in resorption of the sclera, long-term results have been disappointing particularly in the upper lid [27, 52]. As a result, other methods have been sought, particularly in northern Europe where the use of banked/donor sclera has been partly abandoned following the advent of variant Creutzfeldt–Jakob disease for fear of prion contamination.

1.6.2 Koornneef Blepharotomy

Koornneef was developing a much simpler method of total blepharotomy. This was a radical extension of Harvey and Anderson's technique and involved detachment of all structures from the superior tarsal border through an anterior approach. It has been promoted by those he taught prior to his untimely death, and widely adopted, with some modifications, owing to its more satisfactory and predictable results [28, 30, 37, 53].

Patient selection: the salient changes in thyroid eye disease are upper lid retraction with lid margin contour deformity and consequent exposure keratopathy. The Koornneef blepharotomy procedure was originally designed for patients with severe upper lid retraction in thyroid ophthalmopathy, who would have normally required lid lowering by adding a spacer, such as a scleral graft, in order to lower the lid to allow normal closure. Increasingly it is also being used in a graded manner for less severe retraction.

Method: after deciding where to set the skin crease with a marker pen, the lid is everted and 1–2 mL of vasoconstrictive local anaesthetic is injected sub-conjunctivally. A similar volume is injected subcutaneously, followed by a little pressure on the lid to dissipate the fluid. After the skin incision is made, the skin and orbicularis above it are dissected free from the septum. A protective guard is then placed between the lid and the globe. A full thickness blepharotomy is achieved just above the superior border of the tarsus by incising septum/aponeurosis, Muller's muscle and conjunctiva, extending horizontally all the way to the lateral canthal corner. Following haemostasis, the skin is closed with interrupted or running skin sutures, reforming the skin crease, by including the tarsus in the suture. The lid is

padded for 24 h. This encourages stability of the clot that forms in the space created by the incision, and its subsequent organisation and scarring acts as the spacer.

Modifications: because the lid curve can be flattened by this procedure, certain modifications have been introduced to counteract this. Rather than including the entire conjunctiva in the full thickness horizontal incision, a small web can be preserved centrally or para-centrally, where the natural peak of the lid curve would be (Fig. 1.18). It can be thinned or Z-plastied to lengthen it as required. Alternatively, a single long acting absorbable mattress suture on hangback – reaching across the blepharotomy from the tarsus to the recessed levator complex – can be introduced to restore curvature of the upper lid margin. However it has the disadvantage of irritating the top third of the cornea on lid closure. A temporary bandage contact lens should therefore be placed on the cornea until the discomfort has resolved.

If the medial end of the lid is in a normal position or already slightly ptotic, the blepharotomy is not extended medial to the natural peak of the lid curvature. In cases of temporal flare, the full-thickness dissection is extended laterally to the superior crus of the lateral



Fig. 1.18 Koornneef blepharotomy in TAO. (a) Lag on downgaze preop; (b) modified blepharotomy with conjunctival web; (c) immediately post-operative

canthal ligament, and the lateral horn of the levator aponeurosis is cut. In all cases the skin crease is reformed by including tarsus in the closure.

1.6.3 Botulinum Toxin

In early active TAO, when medical treatment is still ongoing and/or while waiting for the thyroid function to stabilise, lid surgery for upper lid retraction is inadvisable, except in severe cases of corneal exposure. This is because both the short- and long-term results of surgery performed at this active stage of the disease are extremely variable and associated with a high failure rate, and as a result often require several further corrective operations. During this time, temporary lid lowering may be required to alleviate symptoms of exposure if topical treatment and nocturnal taping is ineffective. This can be achieved with botulinum toxin.

Patient selection: ocular discomfort is very often a complaint of patients with upper scleral show associated with early TAO. This is due to inflammation as well as exposure from incomplete blinking by day and incomplete lid closure at night (lagophthalmos). They are also distressed by their appearance. Conventional treatment with topical lubrication and taping the lids/creating moisture chambers at night may be ineffective. Patients may also be allergic to certain topical treatments. Even after the acute phase is over, patients may decline conventional surgery. In all these cases, the injection of botulinum toxin in the upper lid will give patients temporary relief of their symptoms [21, 73]. They must be made aware that this is only a temporary measure.

Method: botulinum toxin can be injected through the cutaneous or conjunctival route. The cutaneous route, high through the upper lid with the patient looking down, leads directly to the levator palpebrae superioris muscle in the superior orbit. Between 2.5 and 5 U of Botox (c.10–20 U of Dysport) are injected. It is usual to start with a low dose and top up if required. For the conjunctival approach, a few drops of topical anaesthetic drops are instilled into the upper fornix before everting the upper lid. Again starting with the lower dosage, between 2.5 and 5 U of Botox (c. 10–20 U of Dysport) are injected sub-conjunctivally 5 mm above the upper border of the tarsal plate, and

this can be topped up as required. By this route, the toxin will affect Muller's muscle and possibly, by diffusion, some of the lower fibres of levator palpebrae superioris.

Within 2 or 3 days, most, if not all, patients experience some improvement in the amount of lid retraction, but the amount varies and includes ptosis. Some also experience transient diplopia. Both ptosis and diplopia can last up to 3 or 4 weeks, depending on the amount of toxin injected and the state of the levator and rectus muscles prior to the injection. The sub-conjunctival approach may cause less diplopia as the bolus of toxin is further away from the superior rectus than that injected directly through the skin into the levator muscle. It is also easier to administer.

Ptosis induction for corneal protection: botulinum toxin produces a temporary ptosis of the levator muscle which can last several weeks. A protective ptosis may be required, for example, in patients with indolent corneal ulcers. The amount of toxin required to produce a sufficiently effective ptosis will depend on the state of the levator and its aponeurosis. It will also affect superior rectus function, particularly if injected through the skin. This in turn will temporarily disturb the normal Bells' phenomenon, which is necessary for nocturnal corneal protection. Generally, in a non-inflamed or fibrotic levator palpebrae muscle (unlike in TAO), up to 5 U of Botox injected by the conjunctival approach (c. 20 U Dysport) will result in total ptosis within 2 days and will last several weeks.

1.7 Lid Tumours

1.7.1 Mohs' Micrographic Surgery

When removing a well defined cutaneous basal cell carcinoma (BCC) or squamous cell carcinoma (SCC), orthodox teaching suggests that a rim of up to half a centimetre of clinically normal looking skin be taken as part of the excision to ensure clearance; 9–10 mm margins are necessary for complete removal of morpheiform BCCs and tumours larger than 2 cm in diameter [14]. Traditional histological examination of excised tumour involves vertical sections, which "bread-loaf" the specimen and its few extra millimetres of "normal" tissues to account for microscopic

extensions. This method not only sacrifices normal tissue but also examines histologically only a small percentage of the tumour area. Mohs' micrographic surgery (MMS) allows for a much higher percentage of the tumour margin to be microscopically examined and better preserves unaffected tissue.

The essence of MMS is to minimise normal tissue loss while ensuring histological clearance. As a result, it aims to keep to a minimum the size and depth of defects following tumour excision, thus simplifying reconstruction of the defects. The history of its development is worth telling as it is an example (not unlike Ridley and the intraocular lens) of a good idea ahead of its time, which was finally adopted as a gold standard when some of its logistics had been simplified.

Mohs was a general surgeon at the University of Wisconsin and pioneered a form of tumour excision in the 1930s. He found that injecting a 20% zinc chloride solution into a tumour induced necrosis in both tumour and the immediately surrounding normal tissue. He also noted that microscopic examination of this necrotic tissue showed well-preserved tumour and cell histology, the same as when the tissue has been excised and immersed in a fixative solution. This fixed tissue technique formed the basis for a method by which cancers could be excised under complete microscopic control [50, 51].

A zinc chloride paste, rather than an injection, was developed. When applied to the patient's lesion, it allowed in vivo tissue fixation and microscopic excision. This fixed-tissue chemosurgery provided very high cure rates. However, the zinc chloride application was uncomfortable and obtaining histological clearance was very time consuming. Additionally, the surgeon had to wait for sloughing of any remaining fixed tissue postoperatively before reconstruction could be performed. Furthermore, when the defects were left to heal by secondary intention, some led to cosmetically unacceptable results. The combination of these factors led to minimal adoption of this method by others.

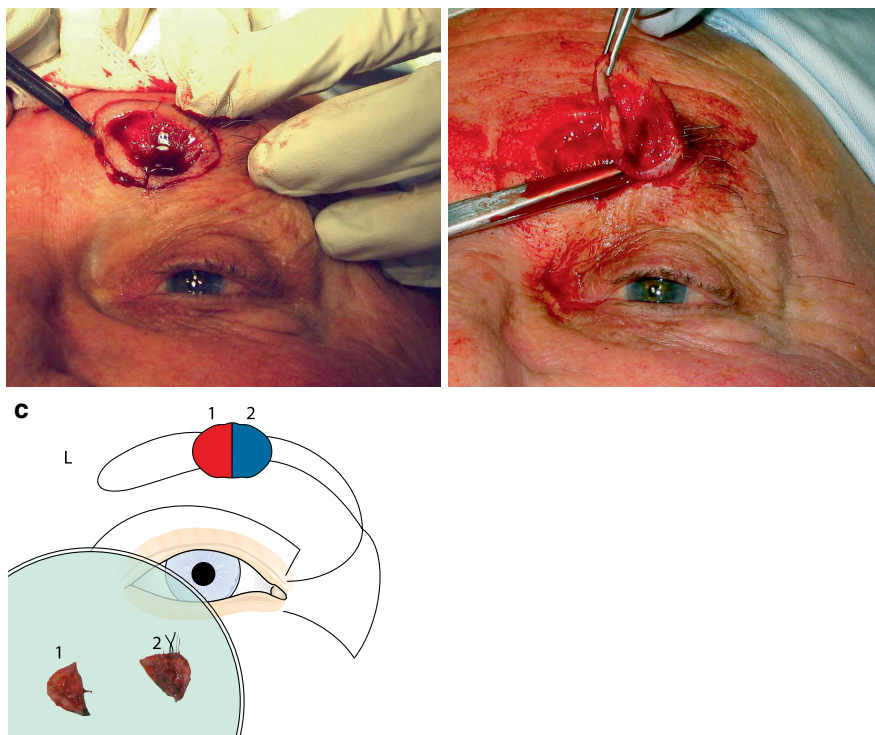
In 1953, whilst filming his technique, an involved margin led to a delay. Mohs processed the last few layers using horizontal frozen sections, without fixative, in order to speed up the process. This worked so well that he continued to apply this method and the fresh tissue technique was established. By the late 1960s, it became evident that the fresh tissue technique obtained close to a 0% recurrence rate for basal

and squamous cell carcinomas excised in this way. Wide acceptance of the fresh-tissue technique increased substantially after the publication of Tromovitch and Stegman's series in 1974 and Mohs' series in 1976, forty years after the original idea was formulated [70]. The fresh-tissue technique has the additional advantage of being less painful than the fixed tissue method and allowing faster reconstruction. This method is now the most commonly performed approach to Mohs' surgery.

Fresh tissue technique method: after marking the tumour margins with a pen, the area is infiltrated with vasoconstrictive local anaesthetic. Sometimes the central "core" tumour is debulked with a curette. The tumour is then carefully orientated and either tattooed (e.g. with methylene blue) or marked (e.g. with sutures, or superficial incisions). Following this, the tissue is excised with the scalpel angled at 45° to the skin to bevel the edge, to facilitate histological processing using a small border (1–3 mm). The excision is continued circumferentially around the tumour at a 45° angle and under the skin parallel to the surface so that the deep margin is excised horizontally. Using the same method of orientation as above, a map of the defect is drawn and the excised disc of tissue is divided and the edges of the specimen are colour-coded with tissue dyes (Fig. 1.19). Horizontal "en face" frozen sections of 5–7 µm thickness are shaved off the entire surface of the base of each section of the disc using a cryostat. The sections are then stained with hematoxylin-eosin and the Mohs' surgeon, who also serves as the histopathologist, examines the slides (Fig. 1.20). Any residual neoplasm is marked on the map in red ink. The surgeon can then precisely remove additional tissue where residual tumour is identified. In this manner, uninvolved tissue is preserved because only the areas with residual tumour are removed. The patient is then sent on for reconstruction of the defect.

Patient selection: Mohs' surgery lends itself to tumours that grow continuously, with root-like extensions not evident clinically. In these situations, the traditional excision of removing clinically evident tumour will fail either to remove it adequately or require a large volume of macroscopically normal tissue to be sacrificed to ensure clearance. The bulk of Mohs' surgery is performed on BCCs and SCCs and the technique is especially helpful where better cosmetic results are

Fig. 1.19 Mohs tumour excision. (a) Periphery of tumour incised (necrotic centre already removed); (b) peripheral disc excised; (c) disc divided and marked. Illustration part (c) by Christiane Solodkoff, Neckargemünd/Heidelberg, Germany



desired (especially on the face). In the US and Australia, access to a Mohs' surgeon is almost universal. In Europe, and the rest of the world, this is not the case and selection criteria need to be applied. Mohs' surgery is therefore reserved for certain cases including the following: recurrent or incompletely excised BCC or SCC; primary BCC or SCC with indistinct borders; lesions located in high-risk areas such as the medial canthus; tumours with aggressive clinical behaviour (e.g. rapidly growing); large tumours (>15mm diameter); tumours with an aggressive histological subtype (e.g. morpheaform BCC, perineural invasion or poorly differentiated); tumours arising in sites of previous radiation therapy; tumours arising in immuno-suppressed patients, high risk hereditary or genetic predisposition (e.g. Gorlin's syndrome patients); tumours in young patients.

In general, complications from MMS are few and usually minor. Similar to other skin defect repairs, the most common complications include post-operative haematoma formation, wound dehiscence, flap necrosis, graft failure, infection, contact dermatitis to antibiotic ointments or dressing materials, excessive

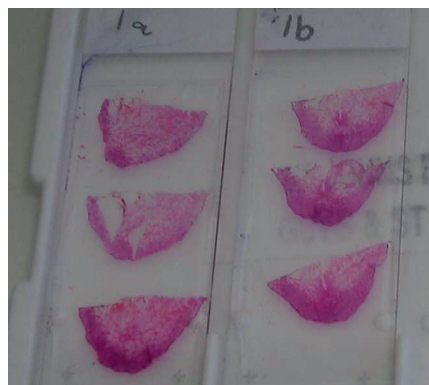


Fig. 1.20 H and E stained "en face" frozen sections

granulation formation, keloid and/or hypertrophic scar formation, hyper-pigmentation and/or hypo-pigmentation, and recurrence of the tumour.

MMS is a minimally invasive technique which has several major advantages. By using a microscopically controlled method of tumour excision, it minimises the healthy tissue sacrifice upon which traditional methods rely, thus leaving smaller defects requiring repair.

Another benefit is that it is the same person who excises the tumour, orientates the tissue specimen and examines its entire periphery, repeating the process until tumour free margins are confirmed, tracing and eradicating areas of tumour that are invisible to the naked eye. It has proved to be a highly effective means of treating common skin cancers and has an unrivalled low recurrence rate. Five-year recurrence free rates have been reported as high as 100% for primary BCCs and over 92% for recurrent BCCs [47, 48]. MMS has also been reported to have a low recurrence rate for SCC at under 4% [46]. Although these two tumours numerically make up the vast bulk of periocular skin malignancies, MMS has also been successfully applied to other periocular tumours [4]. Lastly, when other standard methods have been unsuccessful, MMS surgery offers another chance for cure.

However MMS still has a number of disadvantages over standard techniques. It is potentially much more time consuming in relation to direct excision, which is especially true if several stages are required. MMS is performed by specially trained dermatologists who are not universally available. Both these features make the procedure relatively expensive. Although MMS is the most efficacious manner to eradicate periocular BCCs and SCCs when looking at long term cure rate, there is a growing debate when considering parameters other than long-term cure rate [5, 75]. MMS's main indication is in the treatment of skin tumours that primarily spread by direct extension, that is, tumours that grow contiguously. The use of MMS for the treatment of certain tumours, such as sebaceous gland carcinoma, where there is multi-focality and discontinuous growth patterns, or malignant melanoma with its in-transit metastasis, is controversial as it may fail to adequately treat the full extent of the tumour. Similarly, in very large tumours, for example, with deep penetration into bone, or with extensive perineural invasion or requiring adjuvant treatment, surgical excision will not offer a cure although it will improve patient comfort. Access to MMS may be limited owing to the specialist dermatologist being located at too far a distance from the patient. In these cases, MMS would not be the first choice of treatment.

Optimal functional and aesthetic results are achieved when the dermatologist who excises the tumour works seamlessly with the reconstructive surgeon. Mohs' surgeons are in the majority dermatologists and they have

assertively increased their own repertoire of experience with flaps and grafts in the past two decades: this has, on occasion, resulted in territorial battles and likely decreased referrals from surgical specialists who would otherwise consider referral of these patients [5]. All the above factors feed into the patient's decision as to whether MMS is an appropriate technique or a tolerable procedure for them.

1.7.2 Lamella Sparing Tumour Excision

It is traditional for a tumour to be removed by making a full thickness lid resection when the tumour is within 4mm of the margin. As is often the case with BCCs, particularly the nodular ones with distinct edges, the deep surface of the tumour has not breached or has barely reached the superficial fibres of the orbicularis muscle. If that is so, there would appear to be little reason to remove the posterior lamellar portion of a full thickness excision. Anterior lamellar excision, with fast paraffin histological control, is a useful procedure as it preserves unaffected posterior lamellar tissue. It reduces the amount of reconstruction required and unnecessary morbidity to the patient.

Patient selection: patients with all the following criteria are ideal for this lamella sparing procedure – nodular BCC with distinct margins, less than 15 mm in diameter, primary lesion, not encroaching the horizontal part of the lid margin (i.e. not posterior to the lash line).

Method: After marking a 3-mm margin of apparently clear skin around the tumour, the area is infiltrated with vasoconstrictive local anaesthetic (1:80,000 adrenaline) at the level of orbicularis, to create a natural plane. A chalazion clamp is a useful instrument to stabilise the lid margin, while the marked area is excised with a blade (Fig. 1.21). Haemostasis is achieved with bipolar cautery. The area is padded for 24 h. As the defects are often small, the surgical site is left to heal by secondary intention. The patient is shown how to grease the defect with antibiotic ointment twice daily until a dry crust is formed. This is a combination of serous ooze from the wound and antibiotic cream. This crust loosens and falls off once the wound has epithelialised under it. If the margin defect is repaired surgically, stitches are removed after 5–7

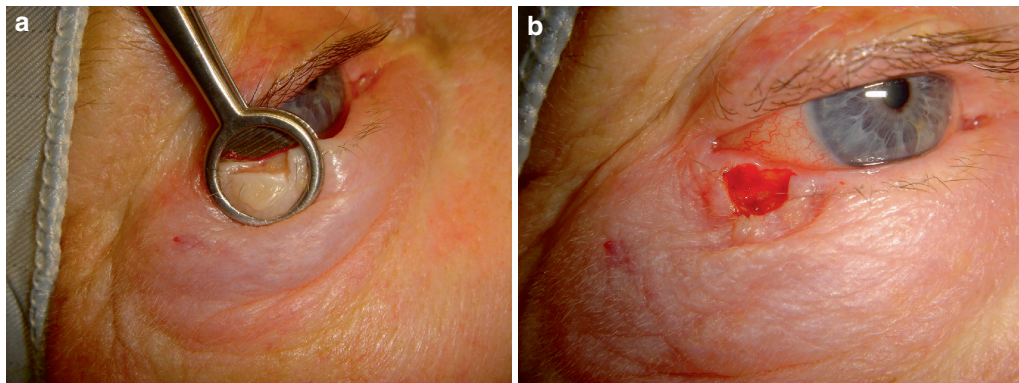


Fig. 1.21 Lamella sparing tumour excision. (a) Anterior lamella removed only; (b) raw area left to granulate

days and the patient is prescribed topical antibiotics in the usual manner (drops to the eye by day and ointment at night).

References

1. Anderson RL, Gordy DD (1979) The tarsal strip procedure. *Arch Ophthalmol* 97:219–226
2. Anderson RL, Harvey JT (1981) Lid splitting and posterior lamellar cryosurgery for congenital and acquired distichiasis. *Arch Ophthalmol* 99:631–634
3. Arnon S, Schechter R, Inglesby TV (2001) Botulinum toxin as a biological weapon. *JAMA* 285:1059–1070
4. Barlow RJ, Ramnarain N, Smith NP, et al (1996) Excision of selected skin tumours using Mohs' micrographic surgery with horizontal paraffin-embedded sections. *Br J Dermatol* 135:911–917
5. Bartley GB (2004) Mohs surgery: proclamation, proof, principles, and promise. *Ophthalmology* 111:615–616
6. Bashour M, Harvey J (2000) Causes of involutional ectropion and entropion—age related tarsal changes are the key. *Ophthal Plast Reconstr Surg* 16:131–141
7. Beaconsfield M, Ectropion (2001) In: Collin R, Rose G (eds) *Fundamentals of clinical ophthalmology: plastic and orbital surgery*. BMJ Books, London
8. Beard C (1976) *Ptosis*. Mosby, St Louis
9. Beard CH (1914) *Ophthalmic surgery*, 2nd edn. Blakiston Co, Philadelphia
10. Ben Simon GJ, Lee S, Schwarcz RM et al (2005) External levator advancement vs Muller's muscle-conjunctival resection for correction of upper lid involutional ptosis. *Am J ophthalmol* 140:426–432
11. Benger RS, Musch DC (1989) A comparative study of eyelid parameters in involutional entropion. *Ophthalmic Plast Reconstr Surg* 5:281–287
12. Bentsianov B, Zalvan C, Blitzer A (2004) Noncosmetic uses of botulinum toxin. *Clin Dermatol* 22:82–88
13. Bick MW (1966) Surgical management of orbital tarsal disparity. *Arch Ophthalmol* 75:386–389
14. Burg G, Hirsch RD, Konz B, et al (1975) Histographic surgery: accuracy of visual assessment of the margins of basal-cell epithelioma. *J Dermatol Surg* 1:21–24
15. Carruthers J, Carruthers A (2004) Botox: beyond wrinkles. *Clin Dermatol* 22:89–93
16. Carter SR, Meecham WJ, Seiff SR (1996) Silicone frontalis slings for the correction of blepharoptosis: indications and efficacy. *Ophthalmology* 103:623–630
17. Clarke JR, Spalton DJ (1988) Treatment of senile entropion with botulinum toxin. *Br J Ophthalmol* 72:361–362
18. Collin JR, O'Donnell BA (1994) Adjustable sutures in eyelid surgery for ptosis and lid retraction. *Br J Ophthalmol* 78:167–174
19. Collin JRO (2006) *A manual of systematic eyelid surgery*, 3rd edn. Elsevier, Amsterdam
20. Collin JRO, Rathbun JE (1978) Involutional entropion – a review with evaluation of a procedure. *Arch Ophthalmol* 96:1883–1885
21. Costa PG, Saraiva FP, Pereira IC et al (2008) Comparative study of Botox (R) injection for upper eyelid retraction with 6-month follow up in patients with thyroid eye disease in the congestive or fibrotic stage. *Eye advance online publication*;doi:10.1038/eye.2008.165
22. Crawford GJ, Collin JR, Moriarty PA (1984) The correction of paralytic ectropion. *Br J Ophthalmol* 68:639–641
23. Crawford JS (1956) Repair of ptosis using frontalis muscle and fascia lata. *Trans Am Acad Ophthalmol Otolaryngol* 60:672–678
24. Dolly JO, Black J, Williams RS et al (1984) Acceptors for botulinum neurotoxin reside on motor nerve terminals and mediate its internalisation. *Nature* 307:457–460
25. Dortzbach RK, Butera RT (1978) Excision of distichiasis lashes through a tarsoconjunctival trapdoor. *Arch Ophthalmol* 96:111–112
26. Downes RN, Collin JR (1990) The Mersilene mesh ptosis sling. *Eye* 4:456–463

27. Doxanas MT, Dryden RM (1981) The use of sclera in the treatment of dysthyroid eyelid retraction. *Ophthalmology* 88:887–894
28. Elner VM, Hassan AS, Frueh BR (2003) Graded full thickness anterior blepharotomy for upper eyelid retraction. *Trans Am Ophthalmol Soc* 101:67–73
29. Elston JR, Russel RWR (1985) Effect of treatment with botulinum toxin on neurogenic blepharospasm. *Br Med J* 290:1857–1859
30. Ettl A (2005) Koornneef's graded upper lid lengthening in Graves disease. *Arch Ophthalmol* 123:871–872
31. Foran P, Mohammed N, Lisk GO et al (2002) Evaluation of the therapeutic usefulness of botulinum neurotoxin. *J Biol Chem* 278:1363–1371
32. Fox SA (1960) Marginal (tarsal) ectropion. *Arch Ophthalmol* 63:660–662
33. Frueh BR, Mush DC, McDonald HM (2004) Efficacy and efficiency of a small incision, minimal dissection procedure vs a traditional approach for correction of aponeurotic ptosis. *Ophthalmology* 111:2158–2163
34. Grove AS Jr (1980) Eyelid retraction treated by levator myotomy. *Ophthalmology* 87:1013–1018
35. Harvey JT, Anderson RL (1981) The aponeurotic approach to eyelid retraction. *Ophthalmology* 88:513–524
36. Henderson JW (1965) Relief of eyelid retraction: a surgical procedure. *Arch Ophthalmol* 74:205–216
37. Hintschich C, Haritoglou C (2005) Full thickness eyelid transaction for upper eyelid lengthening in lid retraction associated with Graves' disease. *Br J Ophthalmol* 89: 413–416
38. Jones LT (1960) The anatomy of the lower eyelid and its relation to the cause and cure of entropion. *Am J Ophthalmol* 49:29–36
39. Jordan DR, Anderson RL, Thiese SM (1990) The medial tarsal strip. *Arch Ophthalmol* 108:120–124
40. Katowitz JA (1979) Frontalis suspension in congenital ptosis using a polyfilament, cable type suture. *Arch Ophthalmol* 97:1659–1663
41. Kemp EG, MacAndie K (2001) Mersilene mesh as an alternative to autogenous fascia lata brow suspension. *Ophthalm Plast Reconstr Surg* 17: 419–422
42. Kirkness CM, Adams GGW, Dilley PN et al (1988) Botulinum toxin A induced protective ptosis in corneal disease. *Ophthalmology* 95:473–480
43. Lee V, Currie Z, Collin JR (2004) Ophthalmic management of facial nerve palsy. *Eye* 18:1225–1234
44. Leone CR Jr, Shore JW, Van Gemert JV (1981) Silicone rod frontalis sling for the correction of blepharoptosis. *Ophthalmic Surg* 12:881–887
45. Lucarelli MJ, Lemke BN (1999) Small incision external levator repair. *Am J Ophthalmol* 127:637–644
46. Malhotra R, Huilgol SC, Huynh NT et al (2004) The Australian Mohs database: periocular squamous cell carcinoma. *Ophthalmology* 111:617–623
47. Malhotra R, Huilgol SC, Huynh NT et al (2004) The Australian Mohs database, part 2: periocular basal cell carcinoma outcome at 5-years follow-up. *Ophthalmology* 111:631–636
48. Malhotra R, Huilgol SC, Huynh NT et al (2004) The Australian Mohs database, part 1: periocular basal cell carcinoma experience over 7 years. *Ophthalmology* 111:624–630
49. Manners RM, Tyers AG, Morris RJ (1994) The use of prolene as a temporary suspension material for brow suspension in young children. *Eye* 8:346–348
50. Mohs FE (1948) Chemosurgical treatment of cancer of the eyelid; a microscopically controlled method of excision. *Arch Ophthalmol* 39:43–59
51. Mohs FE (1941) Chemosurgery: a microscopically controlled method of cancer excision. *Arch Surg* 42:279–295
52. Mourits MP, Koornneef L (1991) Lid lengthening by sclera interposition for eyelid retraction in Graves' ophthalmopathy. *Br J Ophthalmol* 75:344–347
53. Mourits MP, Sasim IV (1999) A single technique to correct various degrees of upper lid retraction in patients with Graves' orbitopathy. *Br J Ophthalmol* 83:81–84
54. Nowinski TS, Anderson RL (1985) The medial spindle procedure for involutional ectropion. *Arch Ophthalmol* 103: 1750–1753
55. O'Donnell BA, Collin JR (1993) Distichiasis: management with cryotherapy to the posterior lamella. *Br J Ophthalmol* 77:289–292
56. Pamphlett R (1989) Early and terminal nodal sprouting of motor axons after cotulinum toxin. *J Neurol Sci* 92: 181–192
57. Peart DA, Hill JC (1986) Cryosurgery for trichiasis in black patients. *Br J Ophthalmol* 70:712–714
58. Putterman AM (1978) Ectropion of the lower lid secondary to Muller's muscle-capsulopalpebral fascia detachment. *Am J Ophthalmol* 85:814–817
59. Putterman AM, Urist M (1972) Surgical treatment of upper eyelid retraction. *Arch Ophthalmol* 87:401–405
60. Putterman AM, Urist MJ (1975) Muller's muscle – conjunctival resection. *Arch Ophthalmol* 93:619–623
61. Quickert MH, Rathbun E (1971) Suture repair of entropion. *Arch Ophthalmol* 85:304–305
62. Scott AB (1980) Botulinum toxin A injections into extraocular muscles as an alternative to strabismus surgery. *Ophthalmology* 87:1044–1049
63. Scott AB, Rosenbaum A, Collins CC (1973) Pharmacological weakening of external ocular muscles. *Invest Ophthalmol Vis Sci* 12:924–927
64. Sharma TK, Willshaw H (2003) Long term follow up of ptosis correction using Mersilene mesh. *Eye* 17:759–761
65. Shorr N, Seiff SR (1986) The four stages of surgical rehabilitation of the patient with dysthyroid ophthalmopathy. *Ophthalmology* 93:476–483
66. Smith BC (1976) 'Lazy-T' operation for the correction of ectropion. *Arch Ophthalmol* 90:1149–1150
67. Steel DA, Hoh HB, Harrad RA et al (1997) Botulinum toxin for the temporary treatment of involutional entropion. *Eye* 11:472–475
68. Stefanyszyn MA, Hidayat AA, Flanagan JC (1985) The histopathology of involutional ectropion. *Ophthalmology* 92:120–127
69. Sullivan TJ, Collin JR (1991) Medical canthal resection: an effective long-term cure for medial ectropion. *Br J Ophthalmol* 75:288–291
70. Tromovitch TA, Stegman SJ (1978) Microscopic-controlled excision of cutaneous tumors: chemosurgery, fresh tissue technique. *Cancer* 41:653–658

71. Tse DT, Kronish JW, Buus D (1991) Surgical correction of lower eyelid tarsal ectropion by re-insertion of the retractors. *Arch Ophthalmol* 109:427–431
72. Tucker SM, Collin R (1995) Repair of upper eyelid retraction: a comparison between adjustable and non-adjustable sutures. *Br J Ophthalmol* 79:658–660
73. Uddin JM, Davies PD (2002) Treatment of upper eyelid retraction associated with thyroid eye disease with subconjunctival botulinum toxin injection. *Ophthalmology* 109:1183–1187
74. Vaughn GL, Dortzbach RK, Sires BS et al (1997) Eyelid splitting with excision or micro hyfrecation for distichiasis. *Arch Ophthalmol* 115:282–284
75. Welch ML, Anderson LL, Grabski WJ (1996) How many non-melanoma skin cancers require Mohs micrographic surgery? *Dermatol Surg* 22:711–713

Shigeru Kinoshita, Norihiko Yokoi, Tsutomu Inatomi,
and Osamu Hieda

2.1 Conjunctival Surgery

The ocular surface is composed of both the cornea and conjunctiva, which constitute a unit of the mucosal epithelial layer with subepithelial fibrous tissues. As the area of the conjunctiva is 7–8 times larger than that of the cornea, even a minor involvement of a conjunctival disease can greatly affect the ocular surface and corneal integrity. The same holds true for ocular surface surgery, as any damage to the conjunctiva can easily produce tissue fibrosis, thus resulting in symblepharon and sustained conjunctival inflammation. Therefore, it is essential that there be a minimal amount of manipulation of the conjunctiva when performing conjunctival surgery, and in cases where extensive conjunctival surgery must be performed, proper additional treatments that include the use of mitomycin C (MMC) and/or amniotic membrane transplantation (AMT) must be combined with the primary surgery to minimize subepithelial fibrosis. Postoperative medical treatments using the topical application of steroids and/or systemic administration of steroids and immunosuppressives are also effective in controlling the scarring events.

In this chapter, several conjunctival surgeries which incorporate the concept of minimally invasive surgery, such as those for conjunctivochalasis, recurrent pterygium, limbal dermoid, and strabismus surgery, are summarized. However, specific extensive conjunctival surgeries for scarred-stage chemical injury, ocular

cicatricial pemphigoid, Stevens-Johnson syndrome, and glaucoma filtering surgery have been excluded as they involve different surgical concepts.

2.2 Conjunctivochalasis

2.2.1 Background of the Disease

Conjunctivochalasis (CCh) [1] is a very common ocular surface disorder that is generally seen among elderly people. According to Meller and Tseng, CCh is defined as redundant, loose, nonedematous conjunctiva between the globe and eyelid which tends to be bilateral and prevalent in older patients [2]. Pathologically, the breakdown of elastic fibers in the redundant conjunctival tissue was seen in all examined cases without any inflammatory cell infiltrates [3, 4]. Lymphangiectasia was found to be associated with this disease in more than 80% of the cases [3], although the other theories emphasize the association of inflammation with this disease [5, 6]. In our recent in vivo study, however, we confirmed the breakdown of subconjunctival tissue and lymphangiectasia by using optical coherence tomography (Fig. 2.1).

Although common, CCh is a very unique disease in that it can become a common risk factor for eyes with epiphora as well as for dry eyes [7], because redundant conjunctiva is likely to distribute at the lower tear meniscus and may inhibit the meniscus tear flow, thus leading to a dysfunction of the lower tear meniscus. This dysfunction can cause delayed tear clearance in dry eye which leads to the exacerbation of dry eye-associated inflammation. On the other hand, CCh-related blockage of the meniscus can cause exacerbation of epiphora symptoms in an eye with lacrimal duct stenosis.

S. Kinoshita (✉)

Department of Ophthalmology, Kyoto Prefectural University of Medicine, 465 Kajicho, Hirokoji, Kawaramachi, Kamigyoku, Kyoto 602-0841, Japan
e-mail: shigeruk@koto.kpu-m.ac.jp



Fig. 2.1 In vivo imaging of prominent conjunctivochalasis which appears in a case after grafting using anterior optical coherence tomography (Visante™). Breakdown of subconjunctival connective tissues as well as presumed lymphangiectasia can be observed (asterisk)

In addition to tear meniscus dysfunction, redundant conjunctiva may cause precorneal tear film instability adjacent to the redundant conjunctiva and mechanical friction may be exerted between the redundant conjunctiva and the ocular surface, especially in cases of dry eye. In cases of CCh accompanied by dry eye, dry eye-related corneal damage and the patients' symptoms may be worsened via the CCh-related mechanisms compared to dry eye alone.

2.2.2 Indication for Surgery

The most important point to be noted is that surgery for CCh is considered only for cases with symptoms. An asymptomatic case, even if there is prominently redundant conjunctiva distributed along the meniscus, is not an indication for surgery. Cases with irritation, epiphora, and recurrent subconjunctival hemorrhage are the appropriate indications for surgery when those symptoms can be explained by tear meniscus dysfunction and/or the mechanical action of redundant conjunctiva.

Before determining the symptom for surgery, it is important to examine the eye with a slit-lamp biomicroscope under forced blinking because some CCh is hidden under the lower eyelid. In such cases, however, forced blinking may exert friction on the cornea which results in superficial punctate keratopathy. When CCh is accompanied by dry eye, which may be diagnosed based on an abnormal Schirmer I test value and/or short fluorescein breakup time in addition to the superficial punctate keratopathy, surgery should be considered, if the case cannot be managed with eye-drop treatment alone and due to the fact that the accompanying CCh is prominent.

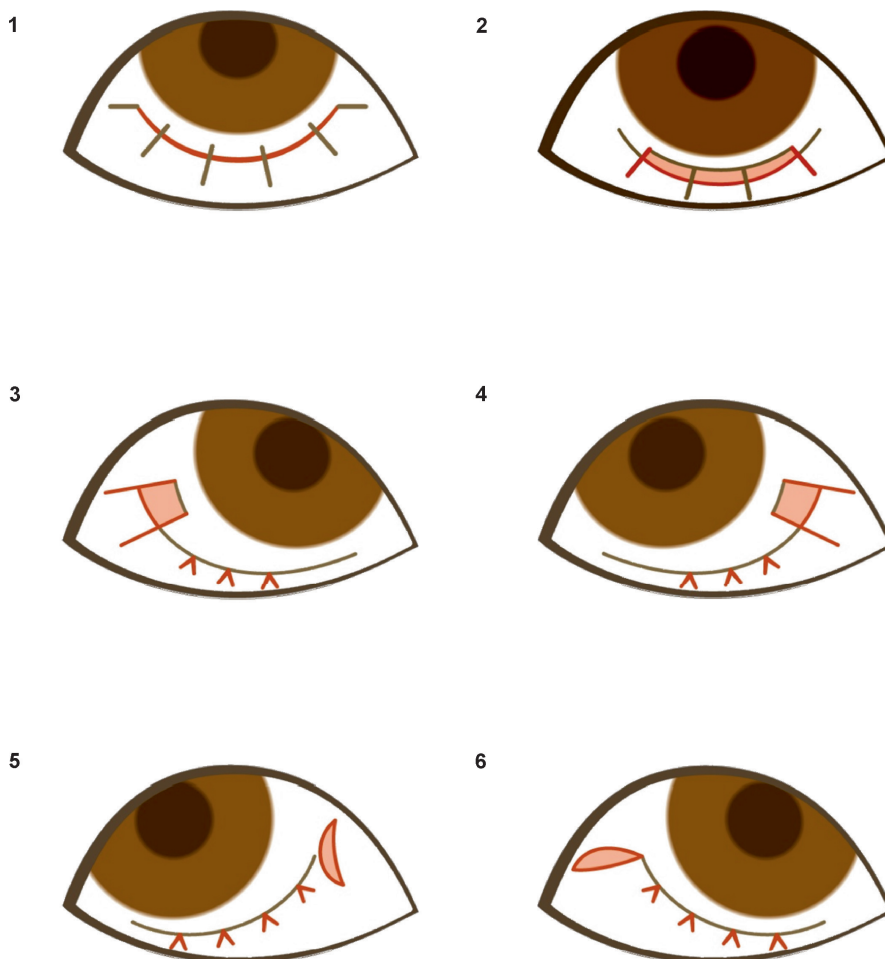
2.2.3 Basic Concept of Surgery

The objectives of CCh surgery are to establish the lower tear meniscus from the lateral canthus to the punctum, and make the surface of the conjunctiva as smooth as possible, to restore the tear meniscus function and reduce mechanical friction between the redundant conjunctiva and the ocular surface [4]. Many surgical methods have been reported, such as a crescent resection, resection combined with inferior peritomy and radial relaxing incision, and excision with AMT and scleral fixation [2, 8]. However, these methods involve no firm concept for tear meniscus reconstruction and most of the procedures target only the redundant conjunctiva inferior to the cornea, while redundant conjunctiva in the nasal and temporal areas are ignored, although all those procedures can provide an effective reduction in the extent of CCh. Especially in eyes with epiphora, complete establishment of the lower tear meniscus from the lateral canthus to the punctum is required to restore the meniscus route for the lacrimal drainage pathway. Therefore, the ideal surgical method must include a surgical step for the treatment of redundant conjunctiva in the nasal and temporal areas, and the reconstruction of the entire lower tear meniscus as well as the elimination of ocular surface undulations should be achieved in any variations of CCh.

2.2.4 Surgical Procedure (Figs. 2.2 and 2.3)

To completely reconstruct the lower tear meniscus and totally smooth the conjunctival surface (Fig. 2.4), the

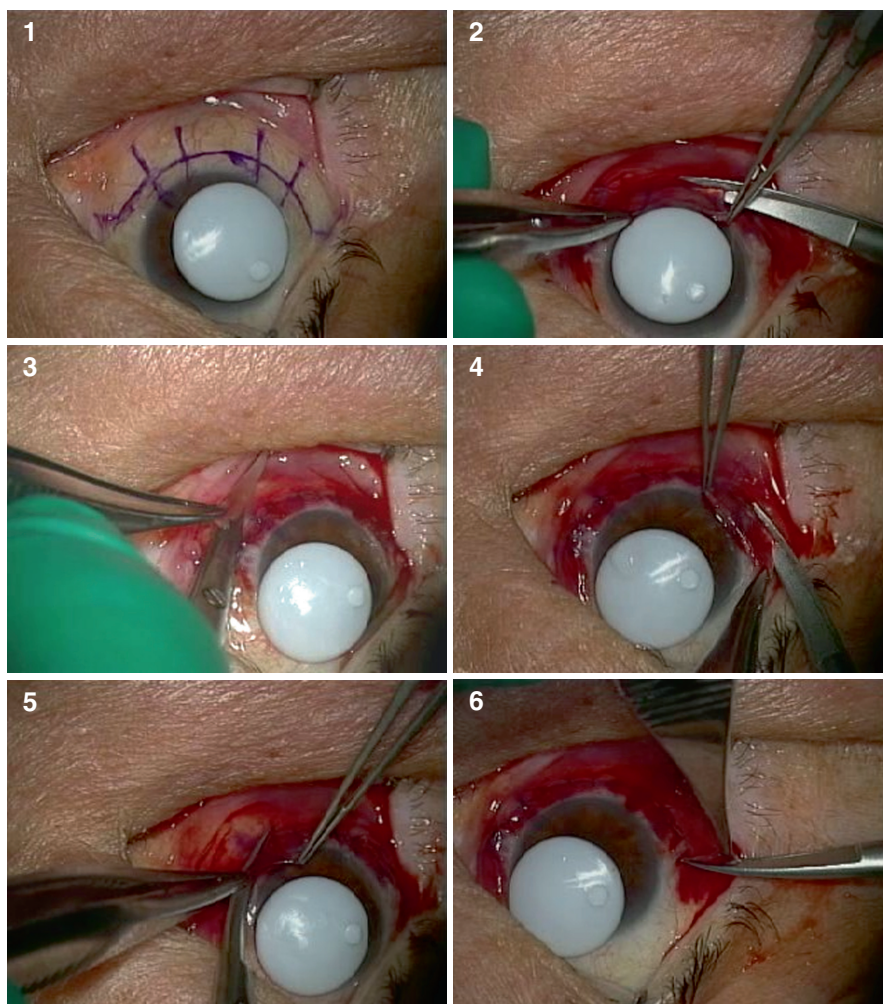
Fig. 2.2 The lower part of the conjunctiva with redundancy is first marked by the use of a newly developed chalasis marker (1) and then divided into 3 blocks (2, 3, 4; areas shown in red). The redundant conjunctiva is then resected according to the amount of redundancy within each block. Resection of a semilunar conjunctival fold (4) and minor adjustment of conjunctival redundancy around the temporal (6) and/or nasal part of the conjunctiva for more precise smoothing of the conjunctival surface are added if necessary. Stitches are also shown (from 3 to 6)



lower half of the bulbar conjunctiva, where CCh is predominantly distributed, is divided into three blocks. The redundant conjunctiva within each block is then independently resected depending on the redundancy within the block. The surgical procedure for simple CCh is comprised of the following steps:

1. Topical anesthetic eye drops including 2% oxibuprocaine and epinephrine are instilled.
2. Planned incision lines are made using a newly developed marker (Chalasis Marker M-1405; Inami Co., Ltd., Tokyo, Japan); for small eyes, forced bilateral eye movement is necessary to obtain appropriate marking.
3. Subconjunctival anesthesia is performed using 2% lidocaine, followed by making an arc-like incision to the anesthesia-ballooned conjunctiva using newly developed scissors (Chalasis Scissors M-1406; Inami Co., Ltd.) along the line created by the marker at the lower half of the bulbar conjunctiva.
4. Subconjunctival fibrous tissues are excised distal to the arc-like incision to easily stretch the lax conjunctiva and obtain a firm attachment of the conjunctiva to the episclera.
5. Radial incisions are made with the chalasis scissors in the lax conjunctiva to create three conjunctival blocks distal to the arc-like incision.
6. The conjunctiva in the lower block is pulled upward and redundant conjunctival tissue that can be overlaid on the limbal conjunctiva is then resected and sutured using approximately five 9-0 silk stitches.
7. For treating lateral blocks, resection of redundant temporal and nasal conjunctiva is performed, with the eye being positioned in a contra-lateral direction to avoid postoperative wound breakage due to postoperative eye movement, and then tightly sutured with 9-0 silk stitches.
8. Plica semilunaris is subsequently resected when it is encountered and is left un-sutured.

Fig. 2.3 Surgical steps of operation for conjunctivochalasis at the time of operation. Operational steps correspond to those shown in Fig. 2.2



2.2.5 Postoperative Follow-Up

Postoperatively, patients are advised to wear an eye patch for a period of 1 week to prevent any conjunctival breaks while sleeping; sutures are removed 2 weeks after the operation. During the first two postoperative weeks, 0.1% betamethazone sodium phosphate and 0.3% levofloxacin are instilled 4 times daily; after the removal of stitches, 0.1% fluorometholone is instilled instead of betamethazone 4 times daily, together with 0.3% levofloxacin twice daily. Instillation times for the 0.1% fluorometholone are reduced according to the extent of postoperative inflammation and are then discontinued within 2 months after the operation.

In dry eye patients, preservative-free artificial tears are instilled 7 times daily in addition to the postoperative eye drops, and are then replaced within 2 months after the surgery with the same combination of eye

drops used before the surgery. Early postoperative complications may include secondary lymphangiectasia, disconnection of operative wound sutures, and pyogenic granuloma due to a reaction to the 9-0 silk suture. The secondary lymphangiectasia can be managed by needling or excision, and pyogenic granuloma can be managed with topical steroids or surgical removal.

2.3 Pterygium

2.3.1 Background of the Disease and the Concept of Minimally Invasive Surgery

Pterygium is a common ocular surface disorder with clinical features involving chronic injection of

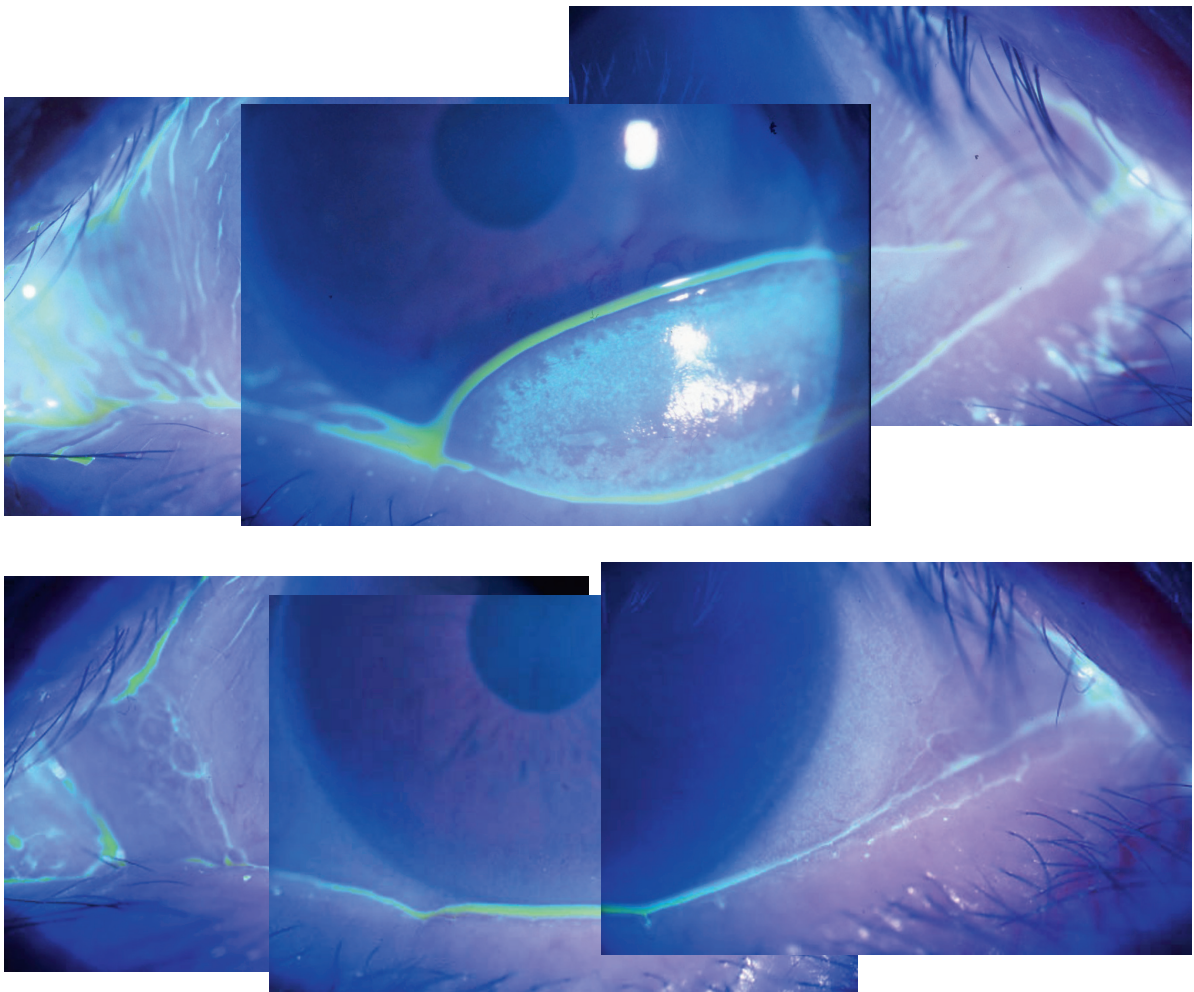


Fig. 2.4 Panoramic picture of representative sample case with conjunctivochalasis without dry eye (*upper*: before operation; *lower*: 3 months after operation). No redundant conjunctiva is

seen in the interpalpebral zone and the operation resulted in complete reconstruction of the tear meniscus

conjunctiva and slow invasion of conjunctiva beyond the limbus onto the cornea. The prevalence rate of primary pterygium ranges between 0.7 and 31% in various regions around the world [9]. Early pterygium and pinguecula, a common type of conjunctival degeneration, are generally not problematic, except cosmetically, and therefore should not be considered for surgery. However, severe progression or recurrence of pterygium sometimes leads to clinical problems such as corneal scarring and irregular astigmatism. Advanced scarring may extend close to the optical zone and extraocular muscles, resulting in visual loss and restriction of ocular mobility, respectively. Therefore, determination of the appropriate time point for surgical treatment is essential for the prevention of visual dysfunction. Choice of the correct surgical procedure to fit

the clinical features is also crucial for the prevention of recurrence. A minimally invasive and safe surgical modality is the key for reducing prolonged postoperative inflammation, one of the risk factors that greatly affects the prognosis. In addition to the various adjunctive measures such as treatment with MMC, AMT minimizes recurrence and postoperative complications. Also, AMT appears to promote early conjunctival epithelial wound healing. The current trend of performing a sutureless conjunctiva graft or AMT using fibrin glue contributes to the minimally invasive surgical concept. This type of surgical modality results in a secured graft attachment with minimal inflammation and shortens surgical time. Many current reports have demonstrated the advantage of using fibrin gel for improving the clinical success of pterygium removal, as it provides

for a minimally invasive surgery and results in less chance of recurrence of the disease.

2.3.2 Indication for Surgery

There are numerous reports that explore the surgical treatment of pterygium, yet medical treatment such as anti-inflammatory medications should be tried before resorting to surgery [10]. Although the main objectives of surgical treatment are apparent, the indication and timing for surgery are not clearly defined. The most important point of pterygium surgery is to excise the pterygium and inhibit recurrence of the disease. Reoperation requires substantially more invasive surgery, reduces the chances for a successful prognosis, and increases the risk of complications. The appropriate minimum area of resection and minimally invasive surgical procedure should be selected on the basis of clinical features (e.g., chronic injection, bilateral pterygium, and thickening of the Tenon's tissue).

2.3.3 Basic Concept of Surgery

The purpose of surgery in primary pterygium is to remove hyperproliferating subconjunctival tissue and the abnormal pterygium head, thus minimizing the risk of recurrence. Attention should be focused on: (1) minimizing the area of excision; (2) the use of intraoperative chemicals; (3) technique or innovative usage of adhesives for wound closure; and (4) transplantation of tissue to the area of excision to promote epithelial healing and inhibit recurrence. The size of the resection and prompt wound healing are fundamental issues for minimizing surgical invasion, especially in primary cases.

In advanced and recurrent pterygium, to prevent further recurrences and/or reconstruct surgically induced conjunctival cicatrization, additional concepts have been proposed. These include: (1) reconstruction of the limbal barrier to block pterygium reinvasion and (2) reconstruction of the conjunctival area lost by excessive surgical resection and scarring. For the treatment of advanced or recurrent cases, these factors must take precedence over the concept of noninvasive surgery.

2.3.4 Surgical Procedures

Previously, simple resection with bare scleral closure was used for cases of early or small pterygia. Although this surgery is the most noninvasive procedure, a variety of studies have shown a high rate of recurrence associated with this technique when not accompanied by adjunctive therapy.

It is now widely accepted that adjunctive therapy and the creation of a physical barrier such as limbal transplantation dramatically reduce the risk of recurrence. The adjunctive intraoperative application of MMC has been commonly used and is found to improve the prognosis [11–14]. MMC suppresses the proliferation of conjunctival fibroblasts, which appear to be responsible for the etiology and recurrence of pterygium. The safe concentration and the time of MMC treatment range between 0.02 and 0.04% for 3–5 min. The intraoperative application of MMC is relatively safe; however, excessive use of MMC has a risk of invasive damage to both the cornea and sclera. Postoperative complications such as scleromalacia and persistent epithelial defects have resulted from over-invasive surgery [15, 16]. Therefore, from the point of minimally invasive surgery, it is important that MMC is not applied to surgically damaged or thin sclera and that the application period is minimized.

Conjunctival rotational flaps and conjunctival transplantation are commonly used surgical methods to prevent recurrence [17]. Although both procedures are invasive forms of surgery that damage the healthy region of the conjunctiva, these ectopical conjunctival grafts result in fast epithelial closure and provide a new barrier against pterygium invasion. Transplantation of a free conjunctival graft is especially useful for cases of recurrent pterygia, where a large epithelial defect may result from resection. Clinical trials have also demonstrated that conjunctival grafts secured with fibrin gel are not only as stable as those secured with sutures, but also reduce inflammation significantly [18–20]. Amniotic membrane (AM) is now widely accepted as an effective biological tool to inhibit pterygium recurrence (Fig. 2.5), as it promotes epithelial wound healing and prevents inflammation. AMT appears to successfully improve the prognosis of severely recurrent pterygium by minimizing surgically induced invasion. Freeze-dried AM can also be used for this purpose [21, 22].

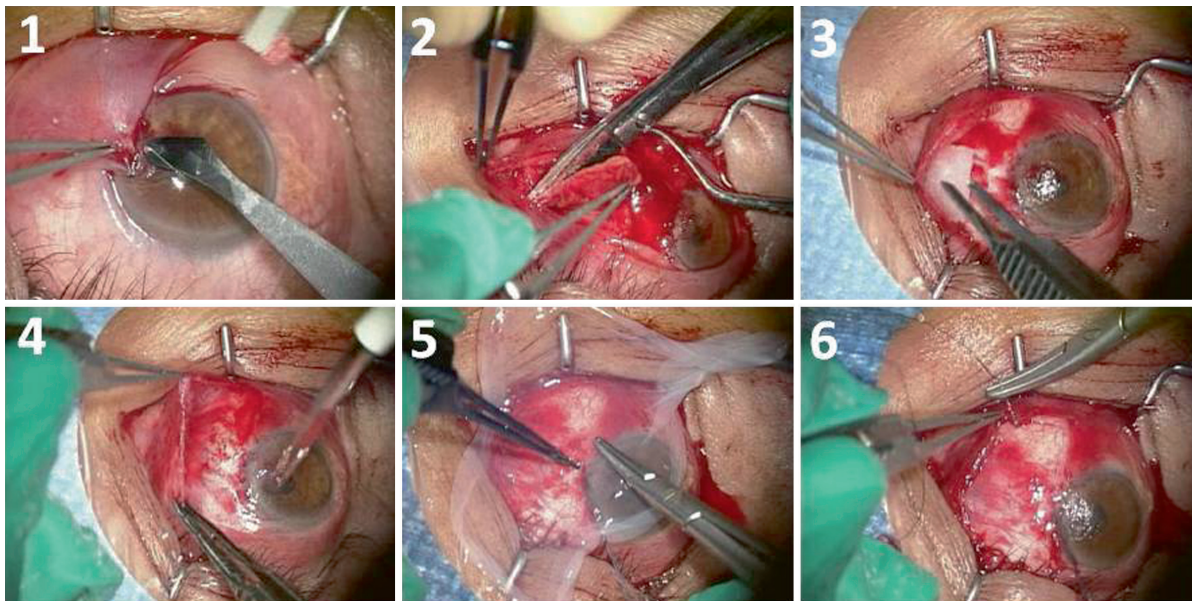


Fig. 2.5 Pterygium surgery with MMC and AMT. (1) Head part of pterygium is removed from the cornea; (2) fibrovascular tissue in subconjunctival space is removed; (3) 0.04% MMC absorbed in microsponges is applied under the conjunctival

space for 1–5 min; (4) MMC is rinsed by the excess sodium saline solution; (5) amniotic membrane and (6) conjunctiva are sutured onto the bare sclera

2.3.5 A Biologic Adhesive for Sutureless Pterygium Surgery

A biologic adhesive such as fibrin glue (or Tisseel) is a new surgical tool that provides an alternative to sutures for conjunctival grafts and AM transplantation. The tissue glue consists of a biological two-component sealant. Lyophilized fibrinogen is reconstituted in aprotinin solution to provide the first component, and lyophilized thrombin is reconstituted in calcium chloride to provide the second component. The use of fibrin gel provides a noninvasive surgical response compared to a suture procedure. Koranyi et al. [19] reported a pterygium recurrence rate of 5.3% with glue versus 13.5% with sutures. Early reduction of inflammation and adherence of the graft may contribute to the reduction of immunoresponse. The short surgical time also contributes to the minimal-invasiveness of the surgery. Thus, our group has been seeking to create a new type of biologic adhesive made entirely of plant-based materials [23].

2.3.6 Postoperative Follow-Up

Minimally invasive surgery reduces the risk of intraoperative and postoperative complications, including damage to the medial rectus. Sufficient caution should therefore be paid during the removal of subconjunctival tissue, especially in cases of recurrent pterygia. Major postoperative complications associated with pterygium surgery include infection, corneal ulcers, and scleromalacia. Scleromalacia is the least desirable complication due to the fact that it can reappear even after years of MMC treatment. Therefore, the minimum amount of MMC should be applied to prevent recurrence.

Although the precise pathogenesis of pterygium is unclear, postoperative inflammation is associated with the recurrence of pterygium. Therefore, a minimally invasive surgery reduces inflammation and the cicatrizing response that is crucial for the prevention of fibroblast activity. The combination of minimally invasive surgery with adjunctive therapy is essential to prevent

pterygium recurrence. Current nonsuture techniques using fibrin gel successfully reduce surgically induced inflammation and shorten surgical time.

2.4 Limbal and Conjunctival Dermoids

2.4.1 Background of the Disease

A limbal dermoid is a congenital disorder, seen mostly at the lower-temporal limbus, and its size becomes slowly larger in proportion to the size of the cornea. It is often associated with a conjunctival dermoid at the temporal area, the size and thickness of which vary in each patient. It can cause both cosmetic abnormality and decreased visual acuity by causing astigmatism. An amblyopic eye must be treated properly by visual rehabilitation, such as the wearing of an eye patch or corrective eye glasses as removal of the limbal dermoid itself does not change the best corrected visual acuity. In addition, preoperative penalization treatment improves the postoperative visual acuity.

2.4.2 Basic Concept of Surgery

To remove limbal dermoid tissue completely and to prevent the occurrence of pseudopterygium after surgery, peripheral tectonic lamellar keratoplasty over the limbus and its adjacent conjunctiva is preferable. Both fresh and preserved donor corneas may be used for this surgery. Limbal dermoids that receive a simple resection frequently develop pseudopterygium due to adjacent conjunctival over-proliferation on the residual dermoid tissue in the cornea. Furthermore, a simple resection cannot remove all the dermoid tissue from the cornea due to corneal thinning. Patients usually undergo the operation when they are 4–6-years-old due to the ease of postoperative care at that age.

2.4.3 Surgical Procedure (Fig. 2.6)

First, a minimal conjunctival resection is performed before lamellar keratoplasty. Then, the dermoid is marked by a trephine of appropriate size, and the lamellar dissection is performed from the central

cornea. A donor cornea of the same size is then placed in that area and fixed with 10–12 interrupted 10–0 nylon sutures. If the dermoid is large, the conjunctiva is treated with 0.04% MMC for 3 min. It is preferable to remove the conjunctival dermoid at the same time. However, a conjunctival dermoid that has penetrated deeply into the upper-temporal sclera should be left as it is and should not be excised extensively, to avoid severe postoperative complications. Cosmetic recovery is easily achieved.

2.4.4 Postoperative Follow-Up

After keratoplasty, topical antibiotics (e.g., 0.3% ofloxacin eye drops four times daily) and corticosteroids (e.g., 0.1% dexamethasone or 0.1% fluorometholone drops four times daily) are applied for approximately 6 months. Intraocular pressure should be checked regularly as children often suffer from steroid-induced glaucoma. Systemic steroids are not usually necessary for children. Penalization treatment is not usually effective after surgery, and sutures are usually removed during the initial six postoperative months.

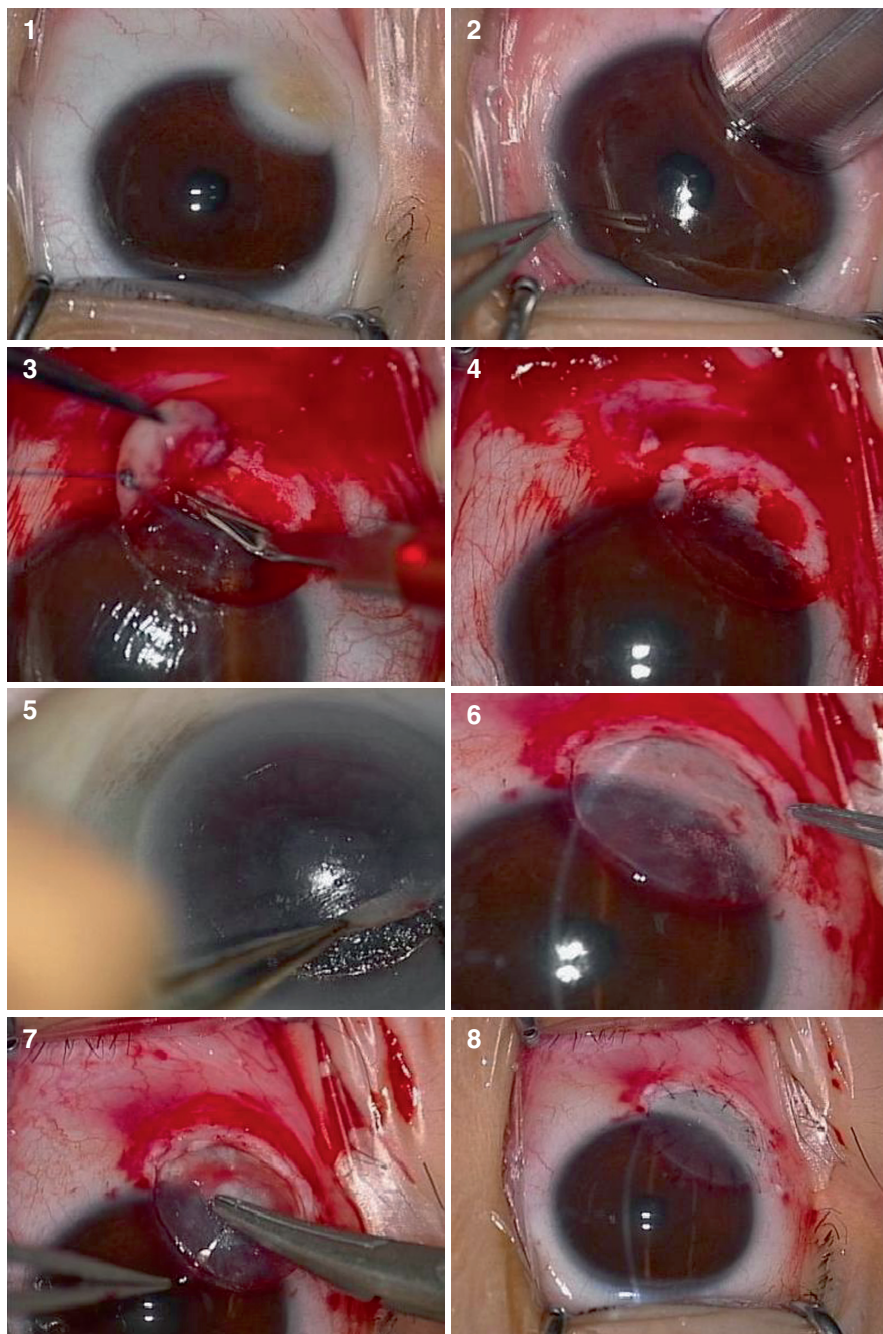
2.5 Strabismus Surgery (Fig. 2.7)

Debate can surround the question of the incision size of the conjunctiva in strabismus surgery. It can be proposed that a wider incision, and thus a wider field of operation, must be made to perform a safe and secure surgery. Conversely, it can be argued that a smaller/narrower incision will result in minimizing the amount of conjunctival damage, thus resulting in rapid cosmetic recovery, with white conjunctiva that is good in appearance. In fact, it has been found that careful management of the outer eye muscles through a small incision can be satisfactorily performed once a physician gains adequate experience with this type of surgery.

2.6 Conclusion

In general, a surgery tends to evolve in the direction of becoming less and less invasive. The same holds true for ophthalmic surgery. The purpose of performing

Fig. 2.6 Surgical steps of operation for limbal dermoid. Preoperative limbal dermoid (1) is marked with a slightly over-sized trephine (2), dissect out a limbal dermoid and a diseased peripheral cornea with one-half thickness from a central cornea (3), through an adjacent sclera (4). A lamellar cornea graft of the same size is created from a donor cornea (5), placed on the keratectomized bed (6), and sutured with 10-0 nylon interrupted sutures (7). Postoperative manifestation (8)



minimally invasive surgery is to avoid excessive postoperative wound healing, especially in areas with fibrovascular overgrowth. As the conjunctiva is a soft, delicate tissue, surgeons must avoid using invasive surgical modalities that promote excessive wound healing

after surgery. One such approach is the use of a small incision. The other approach is the use of AM, MMC treatment, and the postoperative use of immunosuppressives that presumably suppress the TGF-beta signaling pathway and inflammatory cytokine release.

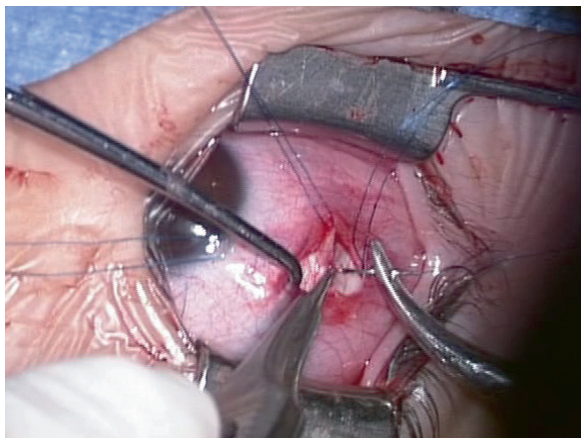


Fig. 2.7 Small incision made at the bulbar conjunctiva is seen at strabismus surgery

References

1. Hughes WL (1942) Conjunctivochalasis. *Am J Ophthalmol* 25:48–51
2. Meller D, Tseng SC (1998) Conjunctivochalasis: literature review and possible pathophysiology. *Surv Ophthalmol* 43:225–232
3. Watanabe A, Yokoi N, Kinoshita S et al (2004) Clinico-pathologic study of conjunctivochalasis. *Cornea* 23: 294–298
4. Yokoi N, Komuro A, Nishii M et al (2005) Clinical impact of conjunctivochalasis on the ocular surface. *Cornea* 24: S24–S31
5. Li DQ, Meller D, Liu Y et al (2000) Tseng SC: overexpression of MMP-1 and MMP-3 by cultured conjunctivochalasis fibroblasts. *Invest Ophthalmol Vis Sci* 41:404–410
6. Meller D, Li DQ, Tseng SC (2000) Regulation of collagenase, stromelysin, and gelatinase B in human conjunctival and conjunctivochalasis fibroblasts by interleukin-1 β and tumor necrosis factor- α . *Invest Ophthalmol Vis Sci* 41:2922–2929
7. Höh H, Schirra F, Kienecker C et al (1995) Lidparallele konjunktivale Falten (LIPCOF) sind ein sicheres diagnostisches Zeichen des trockenen Auges [Lid-parallel conjunctival folds are a sure diagnostic sign of dry eye]. *Ophthalmologe* 92:802–808
8. Otaka I, Kyu N (2000) A new surgical technique for management of conjunctivochalasis. *Am J Ophthalmol* 129: 385–387
9. Detels R, Dhir SP (1967) Pterygium: a geographic survey. *Arch Ophthalmol* 78:485
10. Hirst LW (2003) The treatment of pterygium. *Surv Ophthalmol* 48:145–180
11. Cano-Parra J, Diaz-Llopis M, Maldonado MJ et al (1995) Prospective trial of intraoperative mitomycin C in the treatment of primary pterygium. *Br J Ophthalmol* 79:439–441
12. Cardillo JA, Alves MR, Ambrosio LE, Poterio MB et al (1995) Single intraoperative application versus postoperative mitomycin C eye drops in pterygium surgery. *Ophthalmology* 102:1949–1952
13. Chen PP, Ariyasu RG, Kaza V et al (1995) A randomized trial comparing mitomycin C and conjunctival autograft after excision of primary pterygium. *Am J Ophthalmol* 120: 151–160
14. Frucht-Pery J, Sigano CS, Ilsar M (1996) Intraoperative application of topical mitomycin C for pterygium surgery. *Ophthalmology* 103:674–677
15. Dunn JP, Seamone CD, Ostler HB et al (1991) Development of scleral ulceration and calcification after pterygium excision and mitomycin therapy. *Am J Ophthalmol* 112: 343–344
16. Dougherty PJ, Hardten DR, Lindstrom RL (1996) Corneoscleral melt after pterygium surgery using a single intraoperative application of mitomycin-C. *Cornea* 15: 537–540
17. McCommbes JA, Hirst LW, Isbell GP (1994) Sliding conjunctival flap for the treatment of primary pterygium. *Ophthalmology* 101:169–173
18. Uy HS, Reyes JM, Flores JD, Lim-Bon-Siong R (2005) Comparison of fibrin glue and sutures for attaching conjunctival autografts after pterygium excision. *Ophthalmology* 112:667–671
19. Koranyi G, Seregard S, Kopp ED (2004) The cut-and-paste: a no suture, small incision approach to pterygium surgery. *Br J Ophthalmol* 88:911–914
20. Marticorena J, Rodriguez-Ares MT, Tourino R et al (2006) Pterygium surgery: conjunctival autograft using a fibrin adhesive. *Cornea* 25:34–36
21. Nakamura T, Inatomi T, Sekiyama E et al (2006) Novel Clinical application of sterilized, freeze-dried amniotic membrane to treat patients with pterygium. *Acta Ophthalmol Scand* 84(3):401–405
22. Sekiyama E, Nakamura T, Kurihara E et al (2007) Novel sutureless transplantation of bioadhesive-coated freeze-dried amniotic membrane for ocular surface reconstruction. *IOVS* 48:1528–1534
23. Takaoka M, Nakamura T, Sugai H et al (2008) Sutureless amniotic membrane transplantation for ocular surface reconstruction with a chemically defined bioadhesive. *Biomaterials* 29:2923–2931

3.1 Introduction

Stenoses of the lacrimal drainage system can lead to symptoms such as abnormal tearing or epiphora (which can be very troublesome for the patient), recurrent or chronic conjunctivitis, a more or less permanently increased film of secretions or yellowish secretions in the conjunctival sac, and acute or chronic dacryocystitis.

3.1.1 Causes of Stenoses of the Lacrimal Drainage System

The causes include:

- (Not yet perforated) membranous obstruction of the ostium of the nasolacrimal duct at the level of the valve of Hasner (neonates – children)
- Post-inflammatory stenoses (usually in the nasolacrimal duct, less often in the canaliculi)
- Dacryoliths in the lacrimal sac [97]
- Tumours of the lower lacrimal drainage system [18, 80]
- Nasal and paranasal sinus tumours
- Extensive chronic polypoid sinusitis
- Chronic inflammatory conditions such as sarcoidosis [1, 15]
- Status post-midface fracture [2]
- Status post surgery of the nose and paranasal sinuses (injury of the nasolacrimal duct during osteotomy

performed in the context of rhinoplasty or maxillary fenestration [10])

- Increased venous plexuses in the nasolacrimal duct (functional stenosis with passive patency of the lacrimal passages but inadequate active transport)

3.1.2 Diagnosis of Stenoses of the Lacrimal Drainage System

The diagnostic workup includes:

- History.
- External inspection and palpation (abnormalities in the region of the medial canthus, lids and lacrimal puncta – are these properly submerged in the lacrimal lake, lid margin, palpable mass). Tearing due to ectropion, for example, will of course not be improved by dacryocystorhinostomy (DCR).
- Endoscopy of the nose: In addition to the exclusion of any endonasal causes (tumour, granulomatous inflammation, polyps, scars after surgery or trauma), it is important to evaluate the topography for surgical planning. Is septoplasty necessary to obtain sufficient space for the operation and post-operative care and to reduce the risk of formation of adhesions between the septum and the lateral nasal wall? Is reduction of the middle turbinate necessary? Does the endoscopic picture suggest that operative measures to enlarge the middle nasal meatus will be useful (resection of the uncinate process, opening of the ethmoid bulla)? Is there chronic sinusitis which indicates the need for a more extensive paranasal sinus procedure?
- Probing to locate the site of the stenosis (stop in the region of the canaliculi already or in the lacrimal

R. K. Weber
Department of ENT, Hospital Karlsruhe, Moltkestrasse 90,
76133 Karlsruhe, Germany
e-mail: rainer.weber@klinikum-karlsruhe.com

sac) and irrigation to check for passive patency. Probing is not entirely uncontroversial as a lesion of the canaliculi and subsequent development of a pre-saccal stenosis cannot be entirely ruled out. It must therefore be performed particularly carefully. On the other hand, it is a very simple and valuable procedure which provides rapid and reliable information about the location of a lacrimal stenosis. The theoretical risk of a lesion of the canaliculi applies equally to the dacryocystography which would be necessary if probing and irrigation were not performed.

- Dye disappearance test, e.g. with fluorescein solution, to examine active tear transport. This is important because a number of lacrimal stenoses can be overcome by irrigation, thus falsely suggesting that the lacrimal ducts are sufficiently patent. The functional relevance of partial obstruction through scars or thickened mucosa is only revealed by physiological testing. The test is performed by placing a drop of the yellow fluid (caution: permanently stains clothing) in the conjunctival sac of both eyes and measuring the time to complete disappearance of the dye. With normal blinking the fluid should have disappeared from the conjunctival sac within 2 min [12]. Differences between the two eyes, delayed disappearance and/or external overflow indicate stenosis. The successful transport into the nose can be objectified endoscopically or by insertion of swabs which are then examined.

We consider the examination and diagnostic procedures described above to be indispensable. The following are useful in individual cases and should be employed as appropriate.

- Dacryocystography [88], nowadays preferably performed using the subtraction technique, has proved valuable for documentation and precise topographic localisation of the stenosis. However, in our opinion, it is not necessary if the remaining findings obtained from the history, inspection and palpation, probing and irrigation and dye test are unambiguous, because in our experience, it provides no relevant gain in information which might influence the treatment. Unnecessary radiation exposure, expenditure and discomfort to the patient can be avoided. Dacryocystography carries the same inherent risk of inducing a pre-saccal stenosis through damage to the canaliculi.
- A plain film of the paranasal sinuses provides little useful information. It does not show the lacrimal

system. The information required for possible paranasal sinus surgery should be obtained by CT.

- CT is necessary if there is a suspicion of paranasal sinuses which would require further operative measures, but not in the case of an uncomplicated stenosis.
- Other procedures such as scintigraphy, magnetic resonance imaging or MR-dacryocystography [29] are not recommended for routine diagnostic evaluation.
- Pre-operative endoscopy of the lacrimal drainage system may become relevant in the future. Through the development of suitably thin and powerful endoscopes, it appears to permit successful pre-operative evaluation increasingly often in the hands of experienced users [21, 39, 53, 59–61]. However, endoscopy should lead to a less invasive and at the same time equally effective treatment for it to become an established procedure, and should have at least the same informative value as dacryocystography. It cannot currently be said that this is the case. Nevertheless, the option of opening up a diagnosed stenosis by means of transcanicular endoscopy appears interesting and the results must be observed.

3.1.3 General Remarks Regarding Surgical Management

External DCR is considered the gold standard for surgical management of stenosis of the lacrimal system, at least in ophthalmological literature. It was first described by Toti in 1904 and has been modified several times, technical modifications concerning mainly the creation and suture of mucosal flaps. A standard component of external DCR is stenting of the lacrimal passages with silicone tubing for several weeks to several months. Success rates of 85–90% and more are reported [12, 18, 67, 77]. The main criterion used for defining success is freedom from clinical symptoms. Only some of the authors examined and documented additional outcome criteria such as probing, irrigation or the dye disappearance test. Methodological problems are the use of retrospective analysis in most cases and the heterogeneity of the procedures and patient populations studied.

In an editorial in 1999, Struck described success rates of transcutaneous external DCR of between 80 and 100%, and of 95% at specialised centres [77]. The most common reasons for failure are insufficient size

and location of the ostium, post-operative stenosis of the common canaliculus and endonasal scarring [86].

In the context of minimal invasive procedures, which is the topic of this book, the following alternative operations have to be discussed. They all provide less morbidity for the patient and less operative time:

- Endonasal endoscopic (microscopic) dacryocystorhinostomy (EDCR)
- Endonasal endoscopic laser dacryocystorhinostomy (ELDCR)
- Dacryoendoscopy with transcanicular Laserdacryoplasty (TLDP)
- Dacryoendoscopy with transcanicular microdrill procedure (MDP)
- Interventional radiology
- Balloon dilatation
- Stenting

3.2 Endonasal Endoscopic (Microscopic) Dacryocystorhinostomy (EDCR)

Endonasal dacryocystorhinostomy allows the simultaneous surgical management of endonasal pathologies such as septal deviation, chronic sinusitis, ethmoid cells impinging medially on the lacrimal sac or an enlarged middle turbinate extending too far anteriorly. These anatomical corrections not only treat the pathologies but also facilitate follow-up treatment and should therefore provide better results in the end. Moreover, with the endonasal approach, there is no externally visible scar; division of the medial palpebral ligament and removal of the bony framework for the suspension of the horizontal lacrimal ducts are avoided. In addition, the operating time is shorter and post-operative morbidity is lower than with the external procedure [16].

3.2.1 Indication for EDCR

Indications include all forms of post-saccal and intrasaccal stenosis. In particular, dacryoliths can be removed in this way. Acute dacryocystitis is also an ideal indication for endonasal procedure as an operation in the acute stage can both evacuate the empyema and treat the underlying post-saccal stenosis [45, 47]. A two-



Fig. 3.1 Dacryolith: indication for endonasal DCR

stage procedure with external incision and later operation is not necessary. It also reduces patient morbidity. Dacryoliths too are good indications for endonasal DCR (Fig. 3.1). Sometimes patients report that symptoms are less severe they lie down for sleeping because the dacryolith moves upwards.

Primary endonasal management of pre-saccal stenoses is also not a problem [28]. Either primary resection of the stenotic pre-saccal portion of the canaliculus is performed endonasally or the stenosis is stented and widened over a period of months by probing and bouginage and insertion of silicone tubing. Recurrences after treatment of intra- and post-saccal stenosis can again be treated endonasally. Recurrences of a pre-saccal stenosis in which reconstruction of the lacrimal passages cannot reliably be achieved are an indication for conjunctivorhinostomy or for insertion of a Heermann-Jones tube [83].

3.2.2 Surgical Technique (See Video Enclosed, See Additionally Training CD-ROM [8, 35, 36, 84], Fig. 3.2a–i)

Surgery is usually performed under general anaesthesia. Procedures under local anaesthesia are feasible

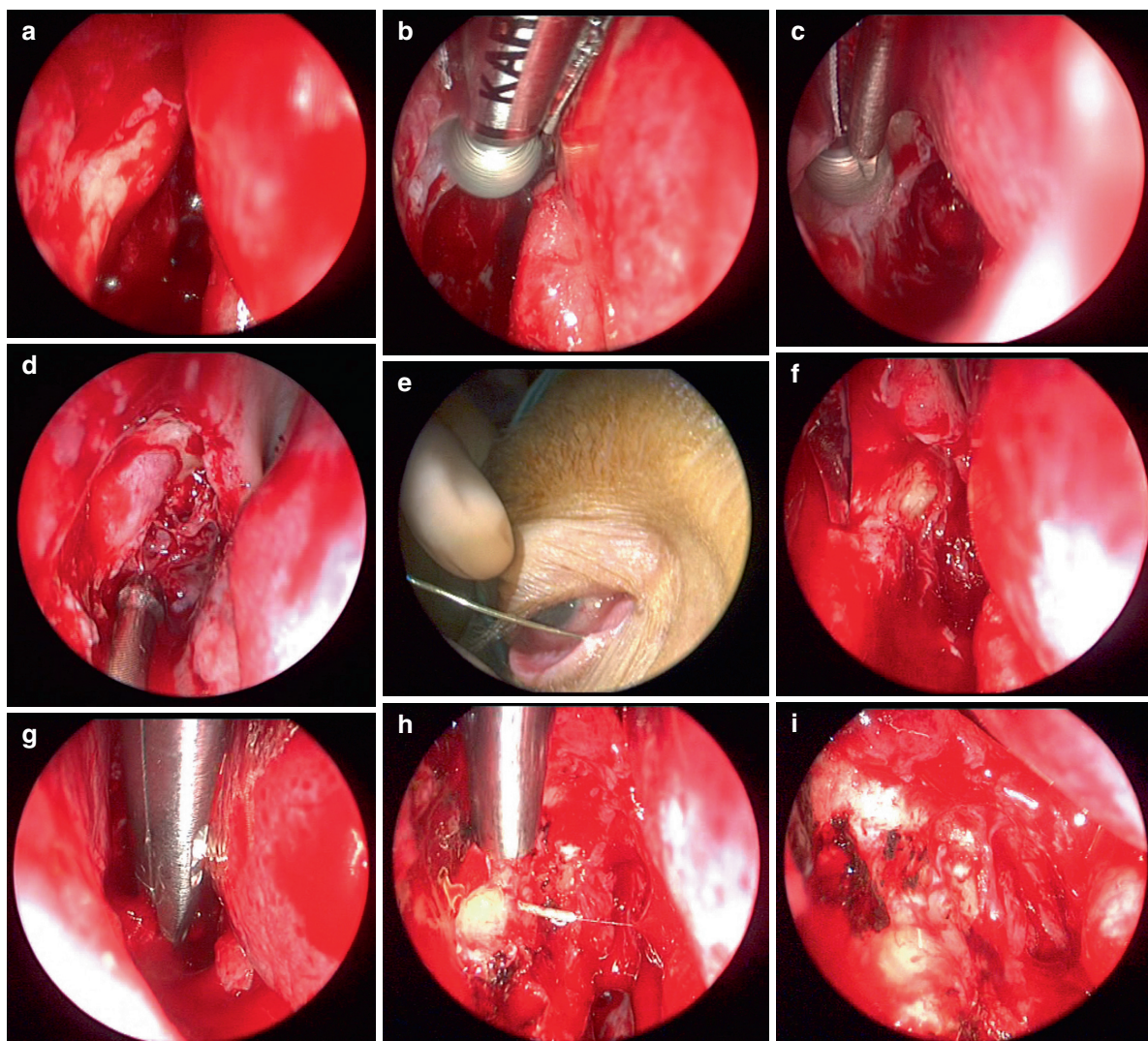


Fig. 3.2 (a–i) Endonasal DCR on the right side (endoscopic view with a 45° endoscope). (a) Exposure of the bone over the lacrimal sac (processus frontalis maxillae). (b) Removal of the bone with a drill (microdebrider, 15° angle, 5 mm diameter, Karl Storz, Tuttlingen, Germany). (c) Stepwise further removal of bone with parts of the lacrimal sac visible. (d) The lacrimal sac

protrudes spontaneously into the nasal cavity. (e) Probing of the lacrimal sac via the inferior canaliculus. (f) Incision of the lacrimal sac with a sickle knife. (g) Removal of the mobilised medial wall of the lacrimal sac. (h) Probing demonstrates the position of the common canalis, which is completely free. (i) Irrigation of the lacrimal system proves an open and unobstructed pathway

when general anaesthesia is not recommended or the patient prefers it. In these cases, infiltration of the supratrochlear and infraorbital nerves is added to the intranasal topical anaesthesia. However, topical anaesthesia of the lacrimal sac may be difficult when an acute infection is present. The nasal cavity is vasoconstricted using cottonoids soaked in topical anaesthesia with epinephrine (1:1,000). The agger nasi is infiltrated with local anaesthesia and epinephrine (1:200,000).

According to the available literature, the manner of visualisation (microscope, endoscope, head lamp) has no influence on the outcome [94], but the author favours the endoscopic approach (45° or 0°, 30°), which is less invasive than the microscopic procedure.

Occasionally, the head of the middle turbinate may need to be trimmed to achieve a proper approach to the lacrimal sac. Septal deviations facing the Agger nasi should be corrected prior to the DCR. If this is the only

deviated septal area, a minimised septoplasty through an “L”-shaped mucosal incision is preferred, followed by circumscribed cartilage resection or correction and reposition of the mucosal flap. Thus, providing a larger space between the septum and lacrimal sac makes it easier to carry out post-operative care.

Some authors recommend the creation of mucosal flaps [8, 50, 75, 79]. The flap measures about 1 cm in height and half a cm in width. At the end of the DCR, the mucosal flap is repositioned to create an anastomosis between the lacrimal sac mucosa and nasal mucosa, partially covering the lateral wall.

In the case of *Agger nasi*, two vertical incisions are made through the mucosa down to the bone, slightly anteriorly and superiorly to the middle turbinate, using the Freer elevator, and the mucosa is removed.

The posterior edge of the ascending part of the maxilla is called the “maxillary line”. It provides a clear anatomic landmark and the bone resection is performed from this edge anteriorly. The bone may be very strong. The true lacrimal bone, located more laterally and posteriorly, is quite thin and more fragile.

Dissection of the lacrimal sac can be achieved by different methods.

- Bone removal with the help of hammer and chisel, the latter directed towards the orbit, implies a strong confidence in the person holding the hammer. Backbiting of the process with Kerrison rongeurs, positioned at the very edge of the “maxillary line” is feasible as long as the bone is not too thick.
- In these cases it is better to employ a diamond or cutting burr under irrigation with saline to drill the ascending process of the maxilla, until a circumscribed exposure of the lacrimal sac surface is achieved.
- Alternatively microdebrider burrs with a 15° bent head are very helpful, particularly in endoscopic DCR.

If there is any doubt about the correct identification of the lacrimal sac, the surgeon can introduce a lacrimal probe through the inferior canaliculus or press against the sac from outside and then push gently. The lacrimal sac may be identified by its bulge (Fig. 3.2). Then, a 90° Kerrison rongeur is used to remove additional bone anteriorly and a 45° Kerrison rongeur to remove the bone superiorly until the entire medial wall and most of the anterior wall of the lacrimal sac are exposed in its superior aspect, where the common canaliculus enters the sac.

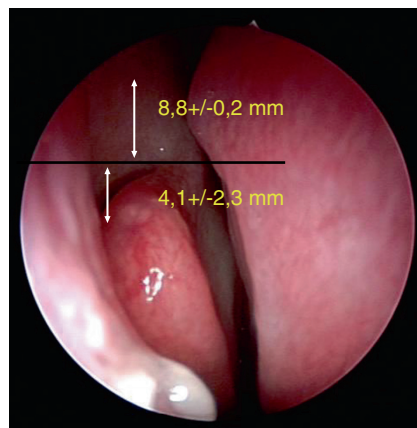


Fig. 3.3 Topographic anatomy of the lacrimal sac using the middle turbinate as landmark (data from 76 CT [96])

A large part of the lacrimal sac lies above the attachment of the middle turbinate and above the orifice of the common canaliculus (Fig. 3.3). Endonasally, adequate exposure is shown by spontaneous tenting of the lacrimal sac into the nasal cavity.

While a helping hand exercises a firm pressure from outside (best: putting a finger on the inner edge of the eye) a vertical incision is then made in the anterior face of the lacrimal sac with the help of a number 11 or a sickle knife. The pressure from outside prevents the sack from the lateral displacement when trying to make the incision. The entire medial wall is removed using straight Blakesley forceps or true cutting forceps. In cases of severe inflammation or infection the medial wall is easily removed by sheer force with the instrument. At this point, pus or mucus usually flows from the sac.

The likelihood of a successful outcome is very high if at the end of the operation practically the entire medial wall of the lacrimal sac has been removed and its lateral wall can heal with the adjacent nasal and paranasal sinus mucosa unhindered by neighbouring structures.

- The bony window must be sufficiently large to allow for shrinking, which is sometimes considerable. For this, the bone should be removed as far as the fornix, i.e. depending on the anatomy, beyond the medial palpebral ligament (in a rostral direction).
- If there is any doubt, the opening of the anterior ethmoid cells or resection of the uncinate process should be performed generously so as to minimise any potential for obstruction dorsally.

- If the middle turbinate comes too close to the opened lacrimal sac it should be medialised (e.g. transseptal suture technique, bolgerisation) or reduced if necessary.

The patency of the DCR is checked by a lacrimal probe passed into the nose via the inferior canaliculus, which is seen in the nasal fossa and by irrigation of the canaliculi with saline.

Depending on the amount of bleeding, additional endonasal packing can be introduced for some hours or days.

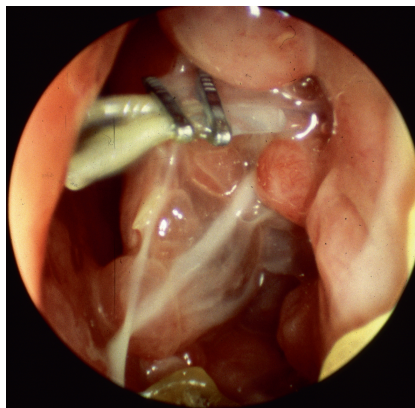


Fig. 3.4 Oedema and granulation around the silicone tubing (endoscopic view, 45° endoscope)

3.2.3 Silicone Stenting for EDCR

In normal cases of post-saccal stenosis and uncomplicated operation, the author uses no silicone stenting.

Whether the use of silicone tubes increases the success rate of lacrimal surgery, particularly when there is no canalicular stenosis, has not been conclusively established [94]. Although some authors report higher success rates with silicone stenting [48], either the results were not statistically significant and/or the studies were retrospective and methodologically flawed so that no reliable conclusions can be drawn in this respect. Other studies found no difference [82].

In a recent prospective study on 46 patients, the overall success rate after primary EN-DCR was 89%: with silicone tubes it was 78%, and without silicone tubes it was 100% [70]. It must be borne in mind that

silicone stenting can be associated with complications such as punctal erosion, slitting of the canaliculi, elongation of the puncta, development of granulomata in the region of the puncta, the lacrimal sac or the lateral nasal wall, dislocation, corneal irritation, difficulties with removal, endonasal crust formation, edema, granulations and secretion [2, 67], (Fig. 3.4).

The author is therefore of the opinion that routine stenting is not indicated with conventional endonasal DCR except in the case of a pre-saccal stenosis or difficult revision cases with fibrosis inside the lacrimal sac.

The stent is fixed using titanium clips and left in situ for 6 months in cases of pre-saccal stenosis or at least 3 months in revision cases (Fig. 3.5).

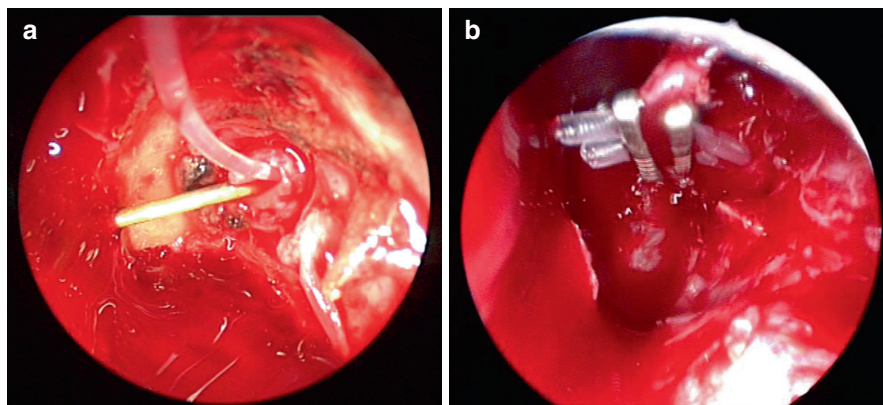


Fig. 3.5 Silicone tubing of the lacrimal system after endonasal DCR. (a) The probe enters the sac via the canalis communis. (b) Fixation using titanium clips (endoscopic view, 45° endoscope)

3.2.2.1 Silicone “Cones” (Lacrimal Duct Stent, Bess, Berlin)

According to Freigang, a similar approach for obtaining a higher success rate by means of stenting is the lacrimal duct stent. After placement of the classical silicone stent (lacrimal duct stent, Bess, Berlin) a silicone cone is introduced via the nasal orifice using a special applicator. In addition to fixing the stent, it prevents the formation of adhesions between the middle turbinate and the lateral nasal wall. This procedure carries the same risks as classical stenting. The tendency to form crusts can be described as slightly greater. Systematic studies of the method have not yet been performed.

3.2.4 Use of Mitomycin C for EDCR

Mitomycin C is an antineoplastic antibiotic, which inhibits collagen synthesis by fibroblasts. Following positive experiences in ophthalmology mitomycin C is increasingly used in ENT surgery in cases where post-operative cicatricial stenosis is a major problem, e.g. in laryngotracheal stenoses, choanal atresia and lacrimal stenosis.

Zilelioglu et al. found success rates (symptom-free + irrigation positive) of 77.3% (17 of 22) with mitomycin C and 77.8% without (14 of 18), 9–27 months after EDCR [101]. They used 0.5 mg/mL for 2.5 min and stented the lacrimal ducts for 4–6 months. The size of the DCR shrank from 35.7 to 1.7 mm² in the mitomycin C group and from 35.3 to 1.5 mm² in the control group. Thus, overall there was no difference.

Camara on the other hand reported in a letter to the editor that he was able to increase the success rate from 90 to 95.4% with the use of mitomycin C (0.5 mg/mL) [13, 14]. He had performed more than 325 endoscopic laser-assisted DCR procedures. In an original paper he then reported on 123 patients who were operated on by Hol:YAG laser using 0.5 mg/mL mitomycin C for 5 min. The silicone stenting was removed after 3 months. Thirty to seventy-two months post-operatively he achieved a success rate of 99.2% measured by symptoms and positive irrigation. For comparison he used a historic control group in which a success rate of 89.6% was achieved. What is remarkable is, by comparison,

the very high success rates obtained with the laser-assisted technique.

Kao et al. examined 14 patients with 15 external operations, who were randomly allocated to mitomycin C (0.2 mg/mL for 30 min) or a control group [34]. Six months post-operatively all mitomycin C patients ($N = 7$) were symptom-free, while in the control group one patient had renewed epiphora and two had adhesions. The surgically created ostium shrank from 66.28 ± 11.06 mm² to 27.10 ± 5.78 mm² (mitomycin C) after 6 months vs. 65.55 ± 8.66 mm² to 10.83 ± 3.37 mm² (control group). The difference was statistically significant.

In a prospective randomised study with 88 external operations, 95.5% of the patients in the mitomycin C group (0.2 mg/mL for 30 min) and 70.5% of the control group were complaint-free, 10 months post-operatively [47]. In the control group a marked improvement was seen in an additional 18%. The difference was significant.

You et al. treated 46 patients with 50 operations in three groups [99]: classical external DCR, additional mitomycin C 0.2 mg/mL, additional mitomycin C 0.5 mg/mL for 5 min.

After 23–42 months (average 35.2 months) 83, 100 and 94% of the lacrimal ducts, respectively, were positive to irrigation (not significant). The size of the intraoperative opening measured endoscopically immediately post-operatively was 53.4 ± 8.4 , 50.6 ± 8.9 and 52.4 ± 8.6 mm² respectively. At the follow-up examination it had shrunk to 13.2 ± 2.7 , 22.2 ± 5.0 and 20.6 ± 4.5 mm² respectively. Application of mitomycin led to a statistically significantly larger opening independent of the concentration.

Altogether there is growing evidence that mitomycin C can successfully reduce stenotic processes resulting from scarring. In lacrimal surgery there are no established standards to date regarding the indications and therapeutic regimens.

As with adequate operative technique, the conventional procedure carries a success rate of more than 90%, it will be difficult to measure any additional benefit. The use of mitomycin C is acceptable for relapses and difficult individual cases. It should on no account be used to compensate for inadequate operative technique. No complications of intranasal use of mitomycin C have been described to date. Histological studies showed thinning of the epithelium with intracytoplasmic vacuoles and loose connective tissue with fewer cells [81].

As the most recent modification, the antineoplastic drug fluorouracil, which also inhibits fibroblast proliferation, was used for the first time by Bakri et al. to reduce the formation of granulation and scar tissue [4]. In a randomised study, the results of laser assisted DCR (holmium laser) was compared with 5-min dabbing of the rhinostomy site with fluorouracil or saline. After a minimum follow-up of 12 months 65 of the 85 cases (76%) in the fluorouracil group and 52 of the 82 cases in the control group (63%) were successful. The difference was not statistically significant.

The author uses mitomycin C not in primary cases of post-saccal stenosis, but in revision cases with scarring of the DCR opening or in the lacrimal sac.

3.2.5 Post-Operative Care After EDCR

Post-operatively, great care must be taken to avoid the development of adhesions between the middle turbinate or septum and lacrimal sac or lateral nasal wall. Significant granulations or fibrin depots should be removed early and any tendency to lateralisation of the turbinate be opposed. Therefore the *follow-up*, with not too frequent but regular and resolute cleaning, i.e. removal of fibrin, crusts and granulations, is important. However, this is not supported by hard evidence in the form of studies. The same applies to all other modalities of follow-up treatment. A theoretical consideration of the principles of action, potential benefits and risks, indicates that the following measures are meaningful. They should be modified in individual cases if necessary.

Endoscopic endonasal removal of the Fibrin clots and crusts is performed first after 7 days after DCR and repeated weekly if necessary. Patients are allowed to rinse their nose with saline once or twice a day from the second week. Patients are not allowed to blow their nose for 1 week after surgery and they are asked to perform regular gentle massages of the external aspect of the lacrimal sac (inner angle of the eye) to facilitate drainage.

- Systemic antibiotics are not routinely necessary. In the case of operation of acute dacryocystitis an antibiotic sufficiently effective against strepto- and staphylococci is given for 7–10 days, depending on how soon the cellulitis subsides. This can easily be monitored clinically.

- The use of topical steroids to obtain a positive influence on wound healing with reduction of the oedema phase and granulations and a hope for reduction in scar formation is established in the follow-up treatment after paranasal sinus surgery. We therefore also follow this practice in endonasal DCR and continue application of the steroids until healing is obtained.
- Almost all therapists prescribe eye drops containing antibiotics and/or corticoids for 2 weeks. This appears meaningful, although proof of their effectiveness is lacking.
- It should be noted that an excessively large DCR can cause increased symptoms in the patient as there is air regurgitation through the lacrimal ducts to the eye when the nose is blown.

3.2.6 Results of EDCR

In spite of all the advantages, the published results are not better, even in some cases slightly worse, than those of the external operation [35, 93, 94]. With the endonasal procedure, the success rates are usually around 80–90% and more, although here too comparison of the studies or summarising several studies is not possible on account of differences between details of the operation techniques, and differences in data collection and evaluation of outcome. There is no doubt that in experienced and self-critical hands, the results of endonasal DCR will reach 95% of the specialised ophthalmological centres (Fig. 3.6 and 3.7).



Fig. 3.6 View into the wide open lacrimal sac on the right side 6 months after endonasal DCR (45° endoscope). The fornix of the sac is nicely visible

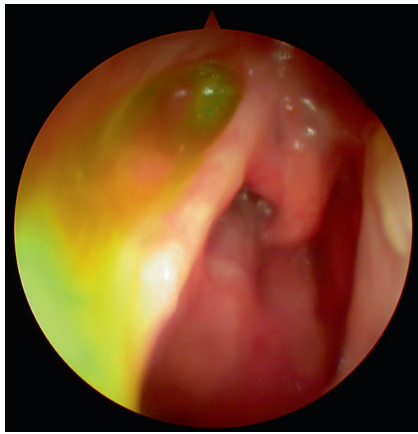


Fig. 3.7 View into the wide open lacrimal sac on the right side 12 months after endonasal DCR (45° endoscope) with proof of function using the fluorescein dye test. The uncinus process has been resected. A small remnant is seen just behind the upper portion of the lacrimal sac

External and endonasal (laser-assisted) lacrimal surgery have been compared in prospective and retrospective studies.

Mirza et al. retrospectively compared 49 patients with external DCR and 76 patients with endonasal laser-assisted DCR [54]. The success rates were 94% for external DCR with an average follow-up of 9 months and 64% for endonasal DCR after 12 months.

Hartikainen et al. compared external and endonasal laser assisted DCR in a prospective study [27]. Thirty two operations (all using silicone stenting) were reviewed 1 year post-operatively. Success was defined as objective demonstration of a patent lacrimal drainage system by irrigation and dacryoscintigraphy. Ninety-one percent of the lacrimal drainage systems operated on externally and 63% of those operated on endonasally were patent. The difference was statistically significant. The average operating time was considerably shorter with the endonasal procedure (23 vs. 78 min).

The problem with the comparison in these two papers is that the authors compared external DCR with laser assisted endonasal DCR which (at least at the moment) produces poorer results than conventional (cold) DCR.

More informative comparisons between the endonasal and external approaches were made by Dolman and Cokkeser et al. [16, 17].

In a retrospective analysis of 153 external and 201 endonasal DCR procedures, Dolman found comparable success rates of 90.2% and 89.1% (“full success”) respectively [17]. The average operating time was

significantly shorter for endonasal DCR (18.5 min vs. 34.3 min). Post-operative epistaxis requiring nasal packing occurred in 4.6% and 5.5% respectively. With external DCR local wound infection occurred in two cases and punctum eversion in six. With endonasal DCR there were periorbital lesions in five cases. Cokkeser et al. performed conventional external lacrimal surgery in 79 patients and an endonasal operation (hammer and chisel technique) in 36 patients (51 sides) [16]. In this prospective study, comparable success rates of 89.8% for the external procedure and 88.2% for the endonasal procedure were obtained after an average of 25 months. Success was defined as the absence of epiphora or other signs of chronic dacryocystitis and positive irrigation of the lacrimal system within the first 6 months. The endonasal procedure was associated with fewer complications, lower morbidity and shorter average operating time (33 vs. 65 min).

Feritis et al. compared the outcome of external (90 patients) vs. endonasal (41 patients) DCR according to the “Glasgow benefit inventory questionnaire” and found no significant differences between the results [25].

In order to establish the value of endonasal DCR, Woog et al. performed a literature search of the years 1968–2000 on behalf of the American Academy of Ophthalmology and evaluated 64 papers [94]. On the basis of the analysis performed, it was difficult to arrive at evidence-based conclusions either on the efficiency of the endonasal and external DCR procedures as a whole or on technical details (e.g. pre-operative work-up, visualisation, surgical instruments, size and location of the neo-ostium, silicone splinting). In the end most questions remained open and further prospective studies were recommended. From the comparisons it was found, that the results of endonasal DCR were poorer than those of the external procedure. However, in most cases, the comparisons were with laser assisted procedures, which had poorer results. Nevertheless, the average success rates after endonasal DCR appear to be slightly lower than those after external DCR [52].

3.3 Endonasal Endoscopic Laser Dacryocystorhinostomy (ELDCR)

Since its introduction in surgical practice, laser technology has improved the operative management of a number of procedures. In an attempt to achieve precise

Table 3.1 The advantages and disadvantages of the endonasal laser DCR over non-laser endonasal DCR

Advantages

Can be performed under local anaesthetic
Can be performed on anticoagulated patients
Shorter operative time
More effective haemostasis and low haemorrhage rates

Disadvantages

Lower success rate
Expensive equipment
Laser precautions required

bone removal with meticulous haemostasis, laser DCR was developed and first described by Massaro et al. [51]. Since then, there have been a number of instances reported using various types of laser for DCR with variable results.

The type of laser appropriate for a DCR would allow delivery via flexible optic fibres, achieve effective bone ablation and provide good haemostasis with a relatively shallow depth of penetration. Therefore the potassium titanyl phosphate (KTP/532), diode and holmium:yttrium aluminium garnet (Ho:YAG) are suitable. The carbon dioxide (CO₂) laser is not ideal because of its poor haemostatic properties, poor bone ablation and cumbersome delivery system. The Argon laser also has relatively poor bone ablation.

The Ho:YAG laser fibres have multiple use specification and this can potentially reduce the cost per procedure. The major disadvantage is the splattering of tissue soiling the lens, requiring frequent cleaning and more collateral damage when compared to the KTP laser.

The KTP/532 with its star pulse mode is most suitable as it vaporises the bone effortlessly and without splattering. The diode laser also has sufficient power to ablate bone. The major disadvantage of the KTP and the Diode laser is that the optical fibre is marketed for single use and therefore the cost per procedure for these lasers is significantly higher.

The endonasal laser DCR (ELDCR) is similar to the cold-instrument EDCR technique with the exception that laser energy is used to vaporise the mucosa and ablate the bone to create a fistula. However, the success rates following non-laser EDCR are somewhat higher with a number of studies quoting success rates of over 90% [9, 85, 100]. The better surgical outcome with conventional surgery is related to a wider bony opening and avoiding the thermal damage caused by

the laser which produces more fibrosis and occlusion at the rhinostomy site. The advantages and disadvantages of the laser technique are given in Table 3.1.

3.3.1 Indications for ELDCR

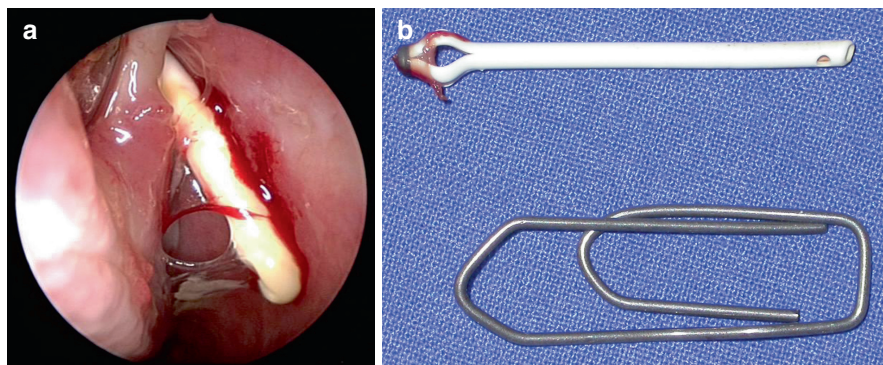
ELDCR is indicated for significant symptoms such as epiphora due to nasolacrimal duct obstruction (NLDO) that is not relieved by simple probing and syringing. It is not indicated for sole obstruction in the puncti, canaliculi, common duct and the lacrimal sac. In many patients there is some proximal obstruction associated with distal blockage. In such cases, gentle probing and dilatation in conjunction with a DCR and insertion of stents can be performed although the results of such an approach are not as favourable as cases of pure distal blockage. ELDCR can also be used in cases of acute dacryocystitis complicated by abscess formation [57]). ELDCR is ideal when a patient is anticoagulated or has a coagulopathy. Not only does it avoid any disruption to their anticoagulant therapy but it can also be done as a day case procedure. It is also more amenable to being performed under local anaesthetic than other techniques, which is useful in those patients unfit for a general anaesthetic. Revision surgery after failed external or endonasal DCR or ELDCR can be performed effectively with the laser, removing the scarred tissue bloodlessly, although the outcome cannot be reliably predicted on account of excessive scarring which may involve the canaliculi and the common canaliculus. It is important that during the procedure the laser power setting is high enough to effect vaporisation rather than charring as the latter will mean that further laser energy and heat may be dissipated to surrounding tissues and produce more scar tissue.

Dacryoliths usually require removal via a wide opening of the lacrimal sac which can be achieved with the cold instrument EDCR (Fig. 3.1) or ELDCR.

3.3.2 Contraindications for ELDCR

The endonasal approach is inappropriate in the presence of malignant lesions of the lacrimal system or the surrounding tissues. In active Wegener's Granulomatosis,

Fig. 3.8 Lacrimal stent which had to be removed surgically. (a) In situ view after medialisation of the inferior turbinate. (b) After removal



any instrumentation induces marked adhesions and stenosis and a DCR by any method is contraindicated. A relative contraindication is a history of trauma as the bone medial to the sac may be thick.

3.3.3 Surgical Technique for ELDCR

One preferred technique is using the KTP/532 laser [55] on star pulse mode with a power setting of 50 W, 10 ms, 10 pulses/s for soft tissue and 70 W, 5 ms, 20 pulses/s for bone.

The patient is placed in the supine position at 15° reverse Trendelenburg. Appropriate laser safety precautions for the patient and operating team are taken to avoid ocular injury. Wet eyepads are placed over the patient's eyes. The operation can be performed under either local or general anaesthesia as per patient and surgeon preference.

The nasal operating site is accessed either with the microscope or the endoscope. When the operating microscope is used, the 300-mm objective is further away from the operating site and thus remains soil-free. It also provides useful magnification. A Killian's speculum is placed in the nostril and the transilluminated site is located. The use of the microscope is however cumbersome and can add significantly to the operating time in inexperienced hands. Endoscopy with video monitoring is much more popular due to its superior visualisation and it is easier to manipulate, though the lens gets soiled due to smoke, blood and debris. Frequent cleaning is required, particularly when using the Holmium:YAG laser. The 0° endoscope is adequate in most cases although the 45° endoscope may afford a better view into the sac. Each

approach has its advantages and the choice would depend on individual training, preferences and the availability of equipment and dedicated instruments.

The upper punctum is dilated and the vitreo retinal light pipe is inserted. The pipe is advanced, initially in a vertical direction through the punctum for a millimetre or so, and then horizontally along the cannaliculus towards the medial canthus. Some resistance is then felt at the common cannaliculus (the soft stop) before it touches the mucosa of the medial wall of the sac (hard stop). From the hard stop, the pipe is withdrawn slightly and advanced in an inferior-medial slanting direction so that it passes into the lacrimal sac. The light is inserted into the upper punctum as it is easier to position the light pipe in the inferior part of the lacrimal sac. This helps to place the rhinostomy in a dependent position, avoiding the formation of lacrimal sump syndrome (a blind pouch with mucus collection of and recurrent dacryocystitis). Cannulating the upper canaliculus also prevents injury to the functionally more important inferior canaliculus. The light is then held in the most dependent position to show the position intranasally. It must be kept in the same position while the rhinostomy is being made to avoid firing the laser in several positions when the light moves.

If the light pipe is accurately positioned in the lacrimal sac, it is usually seen as a bright and sharp spot underneath the tissues, just anterior to the attachment of the bony middle turbinate to the lateral nasal wall. The area of maximal brightness corresponds with the posterior end of the lacrimal sac where the overlying bone is thinnest, and not the centre of the sac. Another landmark for sac location is the maxillary line, a bony eminence which extends from the anterior attachment of the middle turbinate to the root of the inferior turbinate. It overlies the maxillary-lacrimal suture line

within the lacrimal fossa, the light of the endoscope may need to be reduced, to accurately visualise the spot [if there is an agger nasi cell]. The mucosa of the transilluminated area can be infiltrated with 0.25 mL of 1% lignocaine with 1:200,000 adrenaline.

The laser optical fibre is taken to the operation site through a handpiece. Some handpieces contain a second channel that is used to evacuate smoke and debris generated at the operation site. The distal end of the handpiece may be bent by about 25° so that the beam is directed laterally. For the KTP and Ho:YAG lasers, the laser probe is maintained in near contact mode during the procedure and the endoscope tip is positioned approximately 2–3 cm from the target site. The transilluminated area of mucosa covering the medial lacrimal bone is vaporised and the procedure is continued through the bone to make a shallow pit of about 4–5 mm in diameter. The transillumination becomes brighter as the bone is thinned. The process becomes difficult depending on the thickness of the bone formed by the nasofrontal process of the maxilla. Posterior to the anterior lacrimal crest, resection of the paper-thin lacrimal bone is easier. Bleeding can usually be arrested by using the laser in defocused mode. The vaporisation is continued until an opening of around 5–8 mm in diameter is created in the centre of the thinned-out bone. The laser cannot ablate charred tissue and so with continued use on such tissue, heat is dissipated through the surrounding tissues, increasing thermal injury.

The next step is to make an opening into the lacrimal sac. Movement of the light probe will confirm the location of the sac wall. The mucosa of the lacrimal sac is vapourised, again in the direction of transillumination. Alternatively, at this stage, a probe is passed into the lacrimal sac and the mucosa tented medially into the bony opening to confirm the location of the sac. On breaching the lacrimal sac mucosa a fistula (rhinostomy) is created between the nasal cavity and the lacrimal sac. Various measuring devices can be used to assess the size of the rhinostomy to ensure uniformity. The rhinostomy should be at least 5 mm and preferably 10 mm in diameter to reduce the possibility of subsequent closure. Furthermore, the rhinostomy should be located as low as possible as a high rhinostomy results in a sump syndrome, predisposing to recurrent infections of the sac and the duct. The sac can be palpated through the rhinostomy opening to ensure that there is no pocketing of mucus or pus, or fibrous strands, within the sac.

After removal of the light pipe, the lacrimal system is flushed to ensure free flow into the nasal cavity via the fistula. Forcible syringing should be avoided. Unsuccessful syringing indicates an additional proximal obstruction that may have been overlooked at the initial assessment.

A silicone tubed stent is used by a number of surgeons to maintain the patency of the rhinostomy [54, 66, 78, 95]. One end of the tubing is inserted and fed through the upper canaliculus, and the other through the lower canaliculus, so that the ends come out of the new opening into the nasal cavity. The ends are held in situ by a Watzke sleeve or gently tied so that a small loop remains at the inner canthus. It is best to avoid excessive tightening of the loop as this may eventually cause “cheese wiring” at the medial canthus. Stents are removed by cutting the loop at the inner canthus and pulling the sleeve with stents from the nostril.

3.3.4 Potential Problems with ELD CR

- A narrow punctum requires repeated careful dilatation before the light pipe can be passed. Significant trauma to the punctum and the canaliculus will lead to scarring, obstruction and failure with persisting epiphora.
- Intraoperative bleeding is rarely troublesome. Minor bleeding can be controlled with a few laser strikes in defocused mode. Any bleeding that is not easily controlled by a few laser strikes in a defocused mode should be controlled with the application of topical decongestants or vasoconstrictors on pledgets.
- The reflection of the laser aiming beam from the tissues can be strong and this has the potential to be mistaken for the transilluminated light pipe beam with consequent vaporisation undertaken at the incorrect site. It is often helpful to intermittently point the aiming beam away from the operating site and check the position of the light pipe in the sac.
- The transillumination spot is not always easy to locate. Its location may be aided by further manipulation of the light pipe. Even if the light is located, it may be diffuse rather than bright and sharply demarcated, due to a number of factors:
- Hypertrophied anterior end of the middle turbinate

- Thick mucosa covering the anterior lacrimal
- Agger nasi anterior ethmoid cells (8% of cases), uncapping the cell with the laser allows access to the bone that lies medial to the lacrimal sac.
- Thick bone

3.3.5 Post-Operative Care After ELDCR

- Laser DCRs can be performed as an outpatient procedure under local anaesthesia.
- Patients are instructed to douche their nose with saline.
- Antibiotics are not routinely prescribed, except in cases of infection.
- Patients are instructed to avoid heavy lifting, bending or straining, or blowing their noses for some days.
- Slough covers the fistula within 48 h and this clears up within 10 days.
- A first review is recommended after 7 days to inspect the site of the rhinostomy using a nasendoscope and to remove crusts or granulations if necessary.
- The stents are removed transnasally 6 weeks post-operatively by cutting the loop between the canaliculi.
- After 3 months the fistula cannot always be detected as a distinct opening, and the operation site may show a slight dimple, or may appear completely normal.

3.3.6 Results of ELDCR

Most failures occur in the first 18 months due to stenosis at the rhinostomy site although late stenosis can occur up to 3 years after surgery.

The literature reports success rates for the various lasers of around 60–80% [11, 38, 46, 49, 54, 55, 68, 95] with the Holium:YAG laser perhaps having a better success rate with up to 99% in one series [14].

In the prospective comparative study of Moore et al. the results after endonasal conventional DCR were better than those using a holmium laser (but not significantly); however, there was a substantial difference in the size of the bone windows (10 × 10 mm vs. 6 × 6 mm) [56].

In a recent paper by Bakri et al. the authors came to the conclusion that the results of laser assisted DCR are poorer than those of external or conventional endonasal DCR [4].

A recent prospective randomised trial by Ajalloueyan et al. 2007 demonstrated comparable success rates of external DCR and ELDCR (92.4% vs. 94.2%) in 244 eyes [3]. There was less morbidity and shorter operative time in the laser group. The authors used the diode laser creating a 1 × 1 cm wide opening.

Irrespective of the type of laser used the crucial operative parameter is always the creation of a large opening between the lumen of the lacrimal sac and the nasal cavity, because there is a pronounced shrinking tendency.

3.3.7 Post-Operative Complications After ELDCR

In the majority of patients, there are very few post-operative complications, and the procedure is associated with very low morbidity:

- Significant haemorrhage is rare in Laser DCR and only occasionally is nasal packing necessary.
- Rarely, granulations form at the site of the fistula. The most likely cause of granulation formation is a low-grade infection or a foreign body reaction to the stent if it rubs the rhinostomy site. Stent removal usually results in a satisfactory resolution. Antibiotic nasal and eye drops may help reduce the incidence of granulations.
- Synechia usually form between the lateral surface of the middle turbinate and the medial surface of the lateral wall of the nose and may obstruct the rhinostomy, resulting in failure of the procedure. The damage may result from instrumentation or from the spread of laser thermal energy to surrounding non-target structures. If the synechiae are symptomatic then revision surgery may be required.
- An excessively tight stent may cut through the canaliculus as well as the skin in between them. The raw surfaces may heal with a web, which buries the stent. This usually results in scarring and may disrupt the lacrimal drainage pump system. A migrated stent can be retrieved from the nose by cutting one of the tubes that form the loop before the sleeve or

knot. Premature loss of silicone stents may also occur from the knot becoming loose.

3.4 Dacryoendoscopy with Transcanalicular Laserdacryoplasty (TLDP)

In principle, transcanalicular endoscopy with ultrafine endoscopes is no more invasive than a deep probing of the lacrimal system. Endoscopy is mostly carried out before any surgical procedure, whether conventional or endoscopic, which is usually performed with the patient under general anaesthesia.

The puncta have to be dilated. Irrigating softly, the endoscope is inserted via the upper or lower canaliculus. As in normal lacrimal systems the endoscope is pushed forward as far as possible down to the inferior meatus, in other cases up to the point of stenosis. The complete lacrimal passage can be judged by retracting the endoscope with simultaneous irrigation.

In children under the age of 2 years, the small diameter of the lacrimal system, especially of the punctum, increases the risk of injury. Therefore a purely diagnostic endoscopy should only be carried out in exceptional cases.

In normal findings [23], the canalicular mucosa appears white and smooth. The canaliculi have a narrow lumen and a homogeneous structure of the walls. The mucosa of the lacrimal sac is reddish, the lumen is wide and the wall is structured by flat valves. The lumen in the nasolacrimal duct is narrow and shows no valves. The structure of the surface is reddish as in the lacrimal sac. The nasal cavity is noticeable as an intensely red structure with a smooth surface and an enormous space. Membrane surface scars, submucosal scar formations and foreign bodies can be compared with normal findings.

There is no special care after a diagnostic dacryoendoscopy.

Complications may be as follows

- Edema or haematoma of the eye lid because of a *via falsa* occurs in approximately 2%.
- Slitting of the lacrimal punctum or spontaneous dislocation of the silicone intubation (e.g. by blowing the nose) occurs in less than 5%.

First attempts to rechannel a closed lacrimal system by laser have been reported using a Holmium-YAG

laser [19]. The term “canaliculoplasty” was used for this procedure. After the introduction of transcanalicular endoscopes [39], rechannelising of the lacrimal system was possible under endoscopic control and the term “laserdacryoplasty” is used for this procedure [21, 53].

With regard to the diameter of the laser fibre, endoscopically controlled rechanneling by a laser system is possible.

Using a modified miniaturised Erbium-YAG laser developed for glaucoma surgery, a 375- μ m sapphire fibre delivers the laser energy at the top of the probe up to a maximum of 50 mJ and a frequency of 1–3 Hz.

The length of the used laser fibre is 10–11 cm. The Erbium-YAG laser has a wavelength of 2.94 μ m, a wavelength at which the maximum absorption is in water and the laser is operating photoablatively. The mucosal cells of the lacrimal sac have a water content of 80%, so the laser effect can be seen quickly.

The main effect of this laser in the lacrimal passage closed by the stenosis, however, is the resulting cavitation blister and not the ablation [58]. The preparation of bone holes is not possible with the Erbium-YAG laser.

The cavitation blister, which is caused by the laser impulse in the closed system, can extend over several millimetres. Punctal membranous stenosis can be opened by several impulses. The depth of penetration of the laser energy is only a few micrometers and the thermal effect is low.

The necrosis zone is only 10–20 μ m and there is no carbonisation. A modification of the Jünemann probe from two to three working channels allows placement of the laser fibre into the third channel and enables the laser treatment of the stenosis to be performed under endoscopic control. An additional short laser tip with a length of 4 cm has been used for the treatment of canalicular stenosis; this tip is not integrated in an endoscope. The endoscopic examination has to be performed before the laser application.

3.4.1 Indication for TLDP

A laserdacryoplasty is possible in cases of canalicular stenosis and high or deep intrasaccal lesions. The known anatomical valves seem to be the predilection points for adhesion of the valves, causing the closure

in the lacrimal system typically 10–11 mm or 18–20 mm behind the punctum. In addition, membranous occlusions following a failed DCR can be treated successfully by laserdacryoplasty. Today, laserdacryoplasty is mostly performed in cases of canalicular stenosis and saccal stenosis. The mucosa of the lacrimal sac may not be acutely inflamed, with only a slightly enlarged diameter.

3.4.2 Contraindication for TLDP

Laserdacryoplasty is not useful in cases of acute dacryocystitis, mucocoeles, or widespread adhesions following viral infections such as herpes or lacrimal stenosis caused by bone displacement after midface fractures.

3.4.3 Surgical Technique for TLDP

After a diagnostic endoscopy, the laser fibre is brought into an endoscope with a third working channel and the laser is applied. After several laser impulses, free irrigation is noted. Irrigation is now possible without the former resistance and the endoscopic picture confirms the opening. After opening the obstruction, bicanalicular intubation using a silicone tube with a diameter of 0.64 mm is carried out to prevent post-operative adhesions of the mucosa. The tubing remains in place usually for 3 months and is removed transcanalicularly.

If there is no possibility of bicanalicular intubation, a monocanalicular stent is used according to Bernard and Fayet [24]. This Monoka intubation remains in place for at least 6 weeks. The post-operative therapy is the same as that following bicanalicular intubation, which is performed easily in the clinical setting, without general anaesthesia.

3.4.4 Results of TLDP

Using this method, the success rate of LDP related to the indicating symptom at epiphora is about 80% with a post-operative follow-up period of 20.4 months. As

regards canalicular stenosis alone, the success rate is 67% and rises to 86% for isolated common canaliculus stenosis [76]. These LDP results in the treatment of canalicular stenosis are better than those following other microsurgical procedures, even in the hands of experienced surgeons.

Emmerich et al. 1997 reported on 261 dacryoendoscopies following which DCR was performed in 70 patients, lacrimal intubation in 138 patients and laser dacryoplasty in 53 patients [21]. If the endoscopy showed a stenosis at the outlet of the lacrimal sac, punctiform canalicular stenosis or membranous restenosis after DCR, the stenosis was opened with an erbium:YAG laser. On account of the high absorption in the tissue (water) the thermic necrosis zone was only 10–20 µm. Tear duct stenting was performed for 3 months in all cases. After 3 months, 26 patients reported marked improvement, 12 slight improvement, 8 no change and 4 deterioration. Why 3 patients are missing is not mentioned. The paper by Meyer-Rüsenberg gives the same figures [53].

3.4.5 Post-Operative Care and Complications of TLDP

Post-operatively we administer eye drops containing dexamethasone, polymyxin B and neomycin for 3 weeks and vasoconstrictive nose drops for 1 week.

In the case of dacryolithiasis and a concomitant infection with actinomyces or nocardia, we recommend eye drops with erythromycin and colistin for 6 weeks and erythromycin orally for 10 days.

3.5 Microdrill Dacryoplasty (MDP)

Immediately after the introduction of working transcanalicular dacryoplasty with the Erbium-YAG laser, Busse had the idea of introducing another tool into the third channel of the endoscope, namely, a miniaturised drill [20, 22].

The concept was to construct a microdrill for transcanalicular manipulation under endoscopic view. The microdrill consisted of a stainless steel probe 0.3 mm in diameter, driven by a battery-operated motor and a drill shaft. The frequency of the drill was 50 Hz. The

drill was powered by a foot pedal and connected to a Vitroptic T, which is an endoscopic system where the endoscope has already been installed in the probe. In the meantime, we have a much more powerful drill with a frequency up to 3,000 Hz.

3.5.1 Indication for MDP

The drill is not powerful enough to create bone holes to perform a direct anastomosis between the lacrimal system and the nasal cavity. However, in many cases, a clinically completely closed system appears endoscopically not to be completely closed and shows a button-hole like closure with a partial lumen. In such cases a complete opening of the system is possible and can be performed by microdrill dacryoplasty.

Indications for performing a microdrill dacryoplasty are removal of membranes or fragmentation and removal of dacryoliths. The microdrill dacryoplasty is particularly useful in the type of stenosis which was first described by transcanalicular endoscopic findings as the “button-hole stenosis”.

3.5.2 Contraindication for MDP

- Acute infections
- Mucocele
- Stenosis after midfacial fractures

3.5.3 MDP Procedure

The technique of microdrill dacryoplasty is similar to that of laser dacryoplasty. After a diagnostic endoscopy, the microdrill is brought up to the location of the stenosis and pulled forward in front of the endoscope.

A continuous irrigation is required to prevent lacerations and assess the success of the procedure.

After removing all the obstructions, success is again assessed by irrigation under endoscopic control.

It is possible to compare irrigation resistance with a special manometre. The post-operative regimen is the same as after laserdacryoplasty with bicanalicular

intubation when possible, and standard post-operative medical treatment.

Some types of lacrimal obstruction demonstrate a complete obstruction in irrigation and even a complete cessation on X-ray findings. Nevertheless, by performing the endoscopy, a tight lumen at the end of the lacrimal sac located at the region of the Krause valve about 18–20 mm behind the punctum, styled like a buttonhole, can often be seen. In these cases in particular, the obstruction can be removed with the microdrill performing a kind of mucosa curettage and enlarging the tight lumen.

3.5.4 Results of MDP

In a long-term study with a minimal post-operative follow-up period of more than 12 months, the success rate was almost 78% in reducing the symptom of epiphora [23].

3.5.5 Post-Operative Care and Complications of MDP

- Eye drops containing dexamethasone, polymyxin B and neomycin for 3 weeks and vasoconstrictive nose drops for 1 week.
- In the case of dacryolithiasis and a concomitant infection with actinomyces or nocardia, eye drops with erythromycin and colistin for 6 weeks and erythromycin orally for 10 days.

3.6 Balloon Dilatation

Advances in interventional techniques in the lacrimal drainage system have created novel procedures for the easy and safe treatment of epiphora. These methods are simple, safe and cost-effective and can be performed under local anaesthesia on an outpatient basis.

Fluoroscopically and endoscopically guided balloon dacryocystoplasty (balloon dilatation) is a feasible non-surgical therapy in nasolacrimal duct stenosis that may be used as first line therapy. In cases that have initial success, a relatively high long-term success rate can be expected.

Stent placement, which will be described in Sect. 3.7, should be selected with caution as a first-line therapeutic option in patients who refuse surgical procedures or cannot be given general anaesthesia. Although the initial results of stent placement in patients with complete obstructions of the lacrimal drainage system are excellent, long-term results have to be improved.

In 1978, Hanafiee and Dayton first described the use of radiologic technology for interventional application in the lacrimal system [26]. In a small number of patients they dilated native nasolacrimal ducts (NLD) using sialography cannulas under fluoroscopic guidance with a low success rate.

In 1989 Becker and Berry [5], followed by Munk et al. in 1990 [62], reported on the use of radiological instrumentation. Becker and Berry introduced a 3–4-mm coronary angioplasty catheter through the canaliculus in an antegrade approach, whereas Munk et al. introduced a 3–4-mm tibial angioplasty catheter through the inferior opening of the nasolacrimal duct in a retrograde approach. Meanwhile special low-profile dacryocystoplasty catheters have been designed

allowing safe balloon dilation performed antegradely using the transcanalicular access [87, 89]). Therefore no further nasal manipulation is necessary, resulting in greater patient comfort and acceptance of the procedure.

3.6.1 Indications for Balloon Dilatation

Balloon DCR surgery is used in children and adults with partial or incomplete stenoses of the canaliculi and the nasolacrimal duct [32, 41, 44, 74, 88, 92] and in adults with complete stenoses of the nasolacrimal duct.

The Lacricath System (Quest Medical Inc., Allen, Texas, USA; NMP Neuwirth Medical Products GmbH, Obernburg, Germany) is specifically designed for the treatment of the lacrimal system and has different balloons for different clinical situations and is described below:

Two millimetres (Fig. 3.9) – incomplete stenosis in children younger than 30 months (dacryoplasty (DCP))

Three millimetres – incomplete stenosis in children older than 30 months or in adults (dacryoplasty)

Five millimetres (Fig. 3.10 a–c) – complete stenosis, revision DCR

Nine millimetres (Fig. 3.11) – complete stenosis, revision DCR – transnasally

3.6.2 Anaesthesia for Balloon Dilatation

In contrast to most surgical procedures, balloon dilation can be performed as an outpatient procedure under local anaesthesia, except in children who do not cooperate with the procedure.

3.6.3 Surgical Technique with 2 mm or 3 mm Balloon for Incomplete Stenosis

A fine-tipped punctal dilator is selected to perform atraumatic, bloodless superior punctal dilation. After gentle and thorough punctal dilation has been

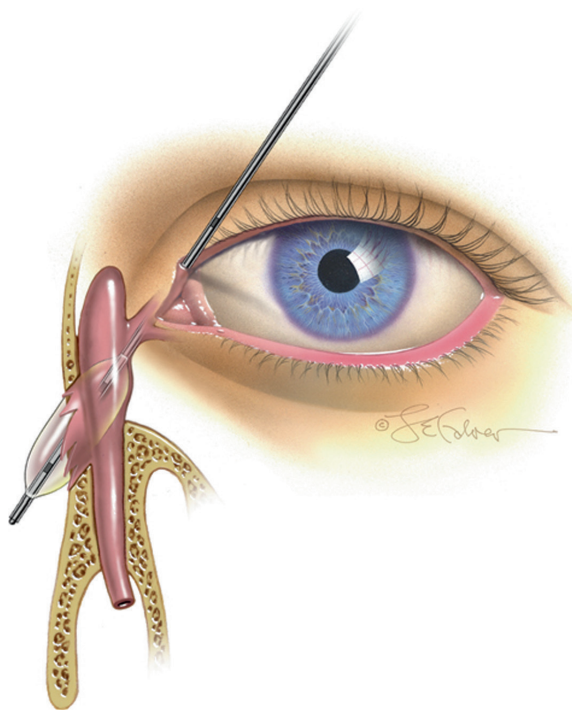


Fig. 3.9 Balloon dilatation with Lacricath® system in complete stenosis of nasolacrimal duct in an adult (5 mm balloon) (schematic drawing). With permission from Quest Medical, Inc., An Atrion Company as well as Bruce Becker, MD

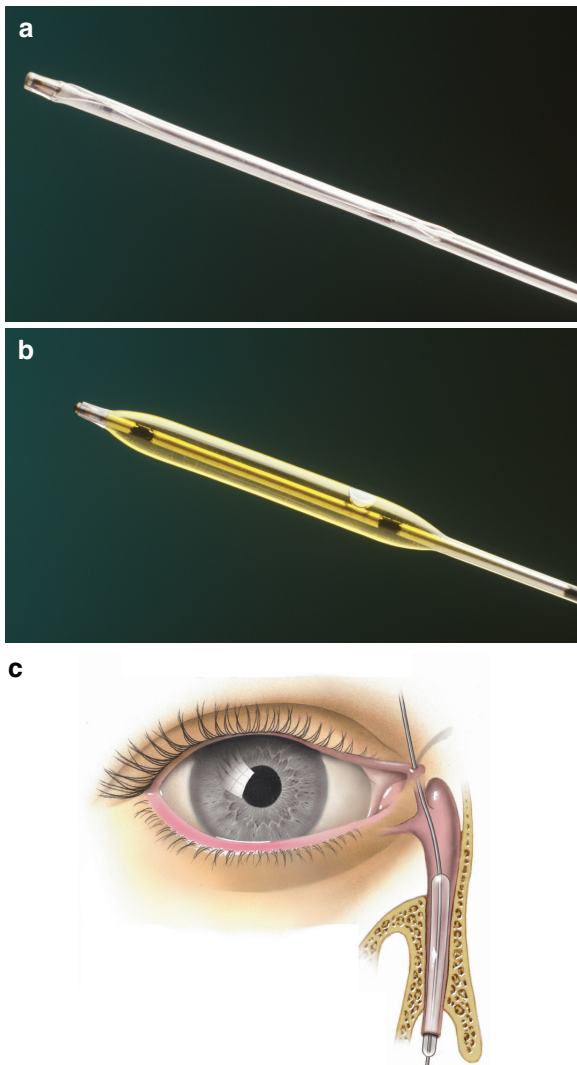


Fig. 3.10 Balloon dilatation with Lacricath® system in incomplete stenosis of nasolacrimal duct (2 mm balloon). (a) Deflated. (b) Inflated. (c) Schematic drawing. With permission from Quest Medical, Inc., An Atrion Company as well as Bruce Becker, MD

completed, lacrimal probes are used to dilate the superior canaliculus carefully and gradually. If the nasal mucosa is adequately decongested, the endoscope should allow a good view of the area beneath the inferior turbinate near the valve of Hasner, thereby confirming a successful probe passage. In some instances, the inferior turbinate must be infrafractured in order to allow adequate visualisation. When necessary, this should be done as atraumatically as possible to avoid

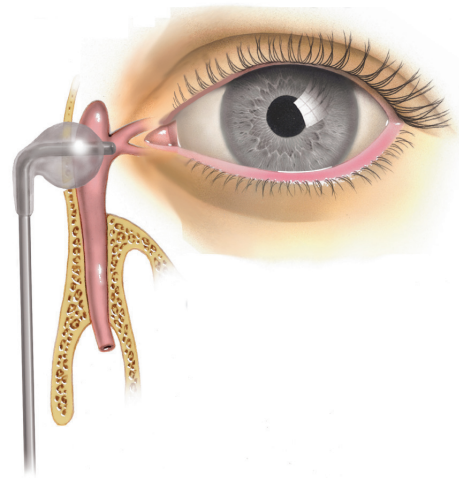


Fig. 3.11 [rechte Seite des Bildes 10C] Transnasal DCR with Lacricath® system in complete stenosis of nasolacrimal duct in an adult (9 mm balloon). With permission from Quest Medical, Inc., An Atrion Company as well as Bruce Becker, MD

bleeding, which can obstruct the view. Suction may be necessary if significant bleeding occurs. If passage of a lacrimal probe is not possible, it is highly unlikely that the balloon catheter will pass successfully.

The balloon catheter is lubricated with ophthalmic antibiotic ointment and passed through the superior canaliculus until it reaches a “hard stop” in the lacrimal sac. As the balloon catheter is slid along the bony medial wall, the tip is directed inferiorly and posteriorly through the NLD. The balloon catheter device is advanced down the NLD until it is visible beneath the inferior turbinate by endoscopy. The tip of the balloon catheter is advanced at least 2 mm beyond the valve of Hasner. Often, this position places the punctum between the two black rings on the anterior working end of the balloon catheter device. If the proximal ring is visible on the catheter, the device is advanced until that ring rests at the superior punctum prior to initial inflation. The inflation device, with dead space evacuated, is attached to the proximal end of the balloon catheter. The balloon is inflated and afterwards gently retracted up the NLD until the distal ring of the catheter rests at the superior punctum. Here, the balloon is again inflated. The dilation is complete at this point, and the balloon is *completely* deflated by vigorous aspiration with a 10-mL Luer-Loc syringe. The catheter is removed through the upper punctum and canaliculus while being aspirated. Irrigation of the lacrimal drainage system may be performed at this point

with a fluorescein-tinted saline solution instilled via a syringe connected to a 23-gauge lacrimal cannula inserted into the canaliculus. Retrieval of fluorescein-tinted fluid in the nose is accomplished with a soft suction catheter and confirms patency of the NLD. Treatment with topical antibiotics is initiated in the operating room or in the recovery room. Silicone tubes can be used, but there is no proof of efficacy.

3.6.3.1 Post-Operative Care

Topical antibiotic or combined antibiotic/steroid drops, such as gentamicin and prednisolone acetate 1% are administered 4 times daily for 10–14 days post-operatively. An age-appropriate nasal decongestant may be administered for 3–4 days after surgery.

3.6.3.2 Complications

Complications following pediatric balloon DCP include failed surgery, creation of false lacrimal passages, canalicular stenosis, and epistaxis.

3.6.3.3 Results

Reported success rates of balloon DCP vary greatly. It is difficult to compare cases that include studies done outside the United States with those done in the United States using the Atrion system, as the balloons and the method of balloon placement are considerably different. Many studies include patients with both incomplete and complete nasolacrimal obstructions. True long-term (more than 5 years) success rates are also unknown, as lacrimal duct balloon technology is new and evolving.

Perry et al. reported a 6-month post-operative success rate of 73% in 15 patients with incomplete NLDO using the LacriCatheter; in this study, success was defined by patency to irrigation [64]. Berkefeld and colleagues reported that in 79% of 47 patients they were able to accomplish the procedure technically using a transnasal approach over a guidewire [7]. Six months following the procedure, 28 of 37 patients (76%) in whom the procedure was technically accomplished were free of epiphora, resulting in an overall success rate of 60% (28 of 47 patients). These researchers

identified several risk factors for reocclusion, including active inflammation, dacryoliths, traumatic stenosis, and long nasolacrimal strictures. Yazici et al. reported a 25% success rate with DCP in patients with complete NLDO and a 50% success rate with the procedure in patients with incomplete obstruction (mean follow-up period of 14 months) [98]. Perry et al. have speculated that post-operative lacrimal intubation may be correlated with their higher long-term success rate [64].

In pediatric patients several authors have reported generally favourable outcomes treated with balloon catheter NLD dilation. Reported success rates for pediatric DCP generally exceed 90% [6, 31, 40].

3.6.4 Surgical Technique with 5 mm Balloon for Complete Stenosis or Revision Cases of DCR According to Ref. [98]

Using the LacriCath 5 × 8-mm balloon, a true DCR ostium between the lacrimal sac and the nasal antrum is created or enlarged.

After punctal dilation, a size 3 or size 4, specially hardened, stainless steel lacrimal probe is passed through the superior punctum and canaliculus until a “hard stop” in the lacrimal sac is reached. The probe is directed inferiorly and posteriorly to a weak and thin point in the bony wall between the lacrimal sac and the nasal cavity. Before pushing the probe through the wall of the lacrimal sac fossa, the nasal packing is removed. The nasal endoscope is then passed and directed toward the anterior tip of the middle turbinate. While viewing the intranasal area around the anterior tip of the middle turbinate, the lacrimal probe, which is already in the lacrimal sac, is slowly advanced. A bulge in the nasal mucosa may be seen as the probe begins to advance. Alternatively, no change in the nasal mucosa may be seen if the probe is entering the nasal cavity beneath the anterior tip on the middle turbinate. In this situation, an attempt is made to change the position of the tip of the lacrimal probe in order to allow the creation of the ostium just anterior and superior to the anterior tip of the middle turbinate. Positioning the ostium here may allow the surgeon to avoid any manipulation of the turbinate. At times, the ostium cannot be placed anywhere but beneath the anterior tip of the middle turbinate. In

this circumstance, the middle turbinate must be medialised or reduced so far as necessary. This can be done with through-cutting nasal forceps or punches or a microdebrider. In some cases resection of the uncinate process is also necessary.

After the initial ostial opening is created by passage of a size 3 or size 4 lacrimal probe and the position of the ostium is optimised, the probe is repeatedly advanced out of a retracted back into the lacrimal sac in different locations to widen the ostium mechanically. The area of the intended ostium is, in effect, “honeycombed” with small holes in preparation for the placement of the balloon catheter device. The perforations in the bone are made contiguously with size 3 or size 4 lacrimal probe. A lubricated, 5 × 8-mm balloon catheter is inserted through the superior punctum and canaliculus, through the common canaliculus and lacrimal sac, and then positioned in the ostium that was previously created with the probe. The endoscope is used to confirm correct positioning of the tip of the balloon catheter at least 2 mm past the nasal mucosa in the nasal cavity. Once the correct position is established, the balloon is attached to the inflation device and is inflated. At times, the balloon device may advance further into the nasal cavity during inflation. It is catheter tip is observed during inflation using the videoendoscope. The balloon is then deflated by releasing the pressure with the manometer. It is again positioned in the ostium using the endoscope. It is reinflated. During the second inflation, mucosal or bone fragments are carefully removed from around the perimeter of the ostium and balloon, using fine ear forceps. It is important to remove any such fragments to minimise the risk of closure of the ostium during the healing process. Some surgeons may prefer to enlarge the ostium transnasally with a nerve hook or rongeurs. Following the second inflation, the balloon is completely deflated and removed. Endoscopic observation of the balloon tip in the nose confirms complete deflation of the balloon prior to withdrawal of the balloon catheter through the upper canaliculus and punctum. Mild resistance may be encountered during the withdrawal of the balloon device. For this reason, some surgeons elect to cut the shaft of the metal portion of the balloon catheter and remove the balloon end of the device through the nostril. This manoeuvre may reduce trauma to the canaliculus.

Secondary balloon DCRs can be performed in the same way as the primary, using the 5-mm diameter

balloon. Some surgeons may elect to additionally apply mitomycin C, 0.4 mg/cc, transnasally to the ostium via a 0.5 × 0.5-in. cottonoid for 5 min, after which the ostium is copiously irrigated transnasally [98]. After removal of the inflation device, a specifically designed lacrimal stent (Stentube, Quest Medical, Allen, Texas, USA; NMP Neuwirth Medical Products GmbH, Obernburg, Germany) can be inserted. The tubing remains in position for 3 or 4 months. Some surgeons may elect to use a traditional lacrimal stent and leave it in place longer, rather than using the Stent tube.

The 9 mm balloon (Fig. 3.11) can be used for transnasal DCR, particularly in revision cases with scarring of the DCR opening. The author has no experiences and insights in the transnasal Lacricath® procedure.

3.6.4.1 Post-Operative Care

Systemic and topical antibiotics are administered for 10–14 days post-operatively. Gentamycin is frequently selected for use as a topical ocular antibiotic and is administered every 2 h while awake for the first 2 days and continued four times daily for an additional 8 days.

Topical ocular and intranasal steroids are administered to reduce inflammation and scarring. Some authors [87] recommend additional systemic steroids for 10 days.

3.6.4.2 Results

Since the initial reports by Becker and Berry [6], several large series have attested to the efficacy of lacrimal balloon dilatation. Technical success rates of 89–95% have been reported. According to the experiences of Lee et al. with 430 eyes of 350 patients, the technical success rate and the overall initial improvement rate were 95 and 57%, respectively [44]. The 2-month, 1-year and 5-year improvement rates were 48, 39 and 37% respectively.

This technique can be successfully used in congenital dacryostenosis [30]. Wilhelm also found a cumulative clinical success rate in 98% after a mean follow-up of 18.4 months in 46 children (mean age 23.5 months) [88].

A 4-year, retrospective, sequential review of endoscopic, balloon-assisted DCR revealed an initial

success rate of 89% [98]. Mean follow-up in this study of 183 patients was 11 months. A second surgery increased the overall success rate to 96%.

3.6.4.3 Complications

The technical failure rate and re-obstruction rate are higher in patients with post-traumatic or post-surgical obstructions than in those with idiopathic obstructions. Nevertheless, no major complications have been reported, and patient compliance and contentment is very high.

3.7 Stent Placement

In 1994 Song et al. first described fluoroscopic guided insertion of plastic stents into the nasolacrimal duct as an alternative to surgical procedures [73]. Initially, so-called mushroom-stents were used in the treatment of complete obstruction of the lacrimal drainage system. The primary result with these techniques seemed promising [63, 71, 92]. Nevertheless, lacrimal stents can be occluded and in contrast to the excellent technical success rates the long time patency rate decreases to 19.2% after follow-up of 5 years [74]. The main problem of the procedure is the tendency toward obstruction of the stent by granulation tissue or mucoid material in the proximal portion of the mushroom stent [69]. To overcome the limitations of the conventional polyurethane stent designed by Song, a new stent type was designed with alterations made in material and stent-design (TearLeader Stent with HYDROFEEL® coating, InterV/PBN Medicals, Denmark). This stent is 6F in diameter and 35 mm in length. It has a slightly S-shaped configuration and a tapered ending without the ballooned portion [90]. Additionally, the surface of the stent is hydrofeel coated.

The TearLeader stent set consists of a dilator, a stent pusher, a 0.47 mm angled atraumatic nitinol guide wire with a 7-cm hydrophilic radiopaque flexible tip and a dacryocystography catheter. For diagnostic purposes and to plan the intervention, dacryocystography is performed in p.a. and lateral views. Digital subtraction dacryocystography is performed before stent implantation to demonstrate the side of obstruction and to exclude anatomical irregularities and variants.

3.7.1 Indications for Stent Placement

It is indicated in patients who suffer from epiphora caused by a complete obstruction of the nasolacrimal drainage system and who refuse surgical procedures or cannot be given general anaesthesia. Stent implantation is done in a retrograde fashion, using special nasolacrimal duct polyurethane stents.

3.7.2 Anaesthesia for Stent Placement

Stent placement can be performed on an outpatient basis under local anaesthesia.

3.7.3 Surgical Technique for Stent Placement

The technique for implanting the conventional mushroom stent is described in detail by Song et al. several times has been [72]: a 0.018-in. ball-tipped guide wire is introduced into the nasolacrimal duct system and gently advanced until reaching the inferior meatus of the nasal cavity. It is pulled out of the external naris with a hook. Then a 6,3-F nasolacrimal sheath with a tapered dilator is passed retrogradely over the guide wire into the upper part of the nasolacrimal system. The dilator is removed and the stent is introduced into the sheath until reaching its tip with the help of a pusher catheter. After this, the sheath has to be withdrawn while holding the pusher catheter in place, thus freeing the stent and allowing the mushroom tip to expand within the dilated lacrimal sac. Finally the guide wire is pulled out superiorly and the pusher catheter inferiorly.

In contrast, the method for implanting the TearLeader stent has been simplified to improve the procedure and to advance patient comfort [88]: the most important difference is that no additional sheath for introducing the stent is necessary, thanks to its well-tapered stent ending. The first step of the procedure is to probe the nasolacrimal duct system with a dacryocystography catheter. Then a flexible angled nitinol guide wire is introduced via the catheter into the nasolacrimal duct system. Under fluoroscopic guidance the guide wire is

gently pushed forward into the inferior meatus of the nasal cavity until protruding from the external naris.

Before stent implantation, the specially designed tapered dacryocystography catheter from the stent set has to be advanced anterogradely over the guide wire until it leaves the nostril. From the distal end the stent is threaded on the guide wire, immediately followed by a stent pusher. In the next step the stent and the stent pusher have to be retrogradely advanced over the guide wire until they come into contact with the dacryocystography catheter. By carefully fixing the anastomosis of the dacryocystography catheter (proximal), the stent and the stent pusher (distal) to the guide wire, the stent is brought into position under fluoroscopic control. After reaching the correct stent position, the guide wire is pulled back while firmly holding in place the stent pusher to avoid dislocation of the stent. Then, the dacryocystography catheter and the stent pusher are retracted leaving the stent in its target position.

Dacryocystography followed by forced irrigation is performed immediately after the procedure to assess correct stent position and stent patency.

3.7.4 Post-Operative Care and Complications After Stent Placement

Post-interventionally, patients are treated with decongestant eyedrops for at least 1 week. Additionally, antibiotic eye drops are used routinely. Prophylactic oral antibiotics prior to stent implantation are not recommended [88].

Clinical follow-up examinations should be performed at intervals of 1 week, and at monthly intervals thereafter. Reasons for stent occlusion are usually granulation of tissue as well as mucoid impactions in the stent. Two months after implantation, the stent should be removed by grasping it transnasally with a hook or forceps. Rarely, it has to be removed endoscopically when it cannot be grasped, or when tight granulation tissue holds it in place (Fig. 3.8).

During stent implantation mild pain sensation might occur, as also blood-tinged nasal discharge after the procedure. Commonly, patients report a foreign body sensation at the medial cantal region for a few days

which spontaneously disappears. Apart from one patient with acute blindness due to an infection after stent implantation [43] no major complications have been reported in the literature and patients' compliance and contentment is very high.

3.7.5 Results of Stent Placement

Many authors agree on the attractiveness of a polyurethane stent used as an alternative to conventional DCR because it offers an easy, effective, safe and reversible way to manage lacrimal drainage problems [33, 42, 65, 69, 90]. However, this method has not yet gained widespread acceptance among ophthalmologists and interventional radiologists. This is due to the long-term results which to date are less than favourable. Even Song et al. decided not to recommend nasolacrimal duct stents as a first-line therapeutic option [37] although having achieved excellent initial clinical results. Yazici et al. came to the same conclusion stating that the success rate of nasolacrimal stent implantation decreases as follow-up lengthens. Lanciego et al. gathered more optimistic results with a mushroom stent designed by Song in a multicentric study recruiting more than 400 patients, showing a primary patency rate of 59% after 5 years [43]. It is highly interesting, however, that despite these rather discouraging results regarding long-term stent patency, many authors express a point of view indicating that they are not prepared to abandon the possibility of polyurethane stenting in tear duct obstructions straight away. The group of Schaudig and Maas [69], for example, admit that the overall success rate is lower than that reported after conventional DCR, yet they draw the conclusion that refinement of the surface and stent design may improve results in the future.

The short-term observation after implantation of the newly designed hydrophilically coated TearLeader stent has already shown a clear tendency toward more favourable results. This also includes good feasibility and greater patient comfort during the implantation procedure as it is shown in our studies [94] and in the first long-term clinical results reported by Ferrer-Puchol et al. 2005 (personal communication). However, longer follow-up periods will be required to define the role of stent implantation finally.

References

1. Anderhuber W, Walch C, Braun H (1997) Die Sarkoidose der Nasennebenhöhlen als Ursache einer therapieresistenten Dacryocystitis. *Laryngo-Rhino-Otol* 76:315–317
2. Anderson RL, Edwards JJ (1979) Indications, complications and results with silicone stents. *Ophthalmology* 86:1474–1487
3. Ajalloueyan M, Fartookzadeh M, Parhizgar H (2007) Use of laser for dacryocystorhinostomy. *Arch Otolaryngol Head Neck Surg* 133:340–343
4. Bakri K, Jones NS, Downes R, Sadiq SA (2003) Intraoperative fluoruracil in endonasal laser dacryocystorhinostomy. *Arch Otolaryngol Head Neck Surg* 129:233–235
5. Becker BB, Berry FD (1989) Balloon catheter dilatation in lacrimal surgery. *Ophthalmic Surg* 20:193–198
6. Becker BB, Berry FD, Koller H (1996) Balloon catheter dilatation for treatment of congenital nasolacrimal duct obstruction. *Am J Ophthalmol* 121(3):304–309
7. Berkefeld J, Kirchner J, Muller HM, Fries U, Kollath J (1997) Balloon dacryoplasty: indications and contraindications. *Radiology* 205:785–790
8. Bernal-Sprekelsen M, Alobid I, Tomas-Barberain M, Della Rocca RC, Schaefer SD (2007) Dacryocystorhinostomy. Surgical technique. In: Weber RK, Keerl R, Schaefer SD, Della Rocca RC (eds) *Atlas of lacrimal surgery*. Springer, Berlin, pp 61–68
9. Bernal Sprekelsen M, Barberan MT (1996) Endoscopic dacryocystorhinostomy: surgical technique and results. *Laryngoscope* 106:187–189
10. Bolger WE, Parsons DS, Mair EA, Kuhn FA (1992) Lacrimal drainage system injury in functional endoscopic sinus surgery. *Arch Otolaryngol Head Neck Surg* 118:1179–1184
11. Boush GA, Lemke BN, Dortzbach RK (1994) Results of endonasal laser-assisted dacryocystorhinostomy. *Ophthalmology* 101:955–959
12. Busse H, Hollwich F (1978) Erkrankungen der ableitenden Tränenwege und ihre Behandlung. *Bücherei des Augenarztes* Heft 74. Enke Stuttgart
13. Camara JG (1999) Success rate of endoscopic laser-assisted dacryocystorhinostomy. *Ophthalmology* 106:441
14. Camara JG, Bengzon AU, Henson RD (2000) The safety and efficacy of mitomycin C in endonasal endoscopic laser-assisted dacryocystorhinostomy. *Ophthalmic Plast Reconstr Surg* 16:114–118
15. Chapmann KL, Bartley GB, Garrity JA, Gonnering RS (1999) Lacrimal bypass surgery in patients with sarcoidosis. *Am J Ophthalmol* 127:443–446
16. Cokkeser Y, Evereklioglu C, Er H (2000) Comparative external versus endoscopic dacryocystorhinostomy: results in 115 patients (130 eyes). *Otolaryngol Head Neck Surg* 123:488–491
17. Dolman PJ (2003) Comparison of external dacryocystorhinostomy with nonlaser endonasal dacryocystorhinostomy. *Ophthalmology* 110:78–84
18. Duffy MT (2000) Advances in lacrimal surgery. *Curr Opin Ophthalmol* 11:352–356
19. Dutton JJ, Holck DE (1996) Holmium laser canaliculoplasty. *Ophthalm Plast Reconstr Surg* 12:211–217
20. Emmerich KH, Meyer-Rüsenberg HW (2001) Endoskopische Tränenwegschirurgie. *Ophthalmo loge* 98:607–612
21. Emmerich KH, Meyer-Rüsenberg HW, Simko P (1997) Endoskopie der Tränenwege. *Ophthalmologie* 94:732–735
22. Emmerich KH, Ungerechts R, Meyer-Rüsenberg HW (2000) Possibilities and limits of minimal invasive lacrimal surgery. *Orbit* 19:67–71
23. Emmerich KH, Ungerechts R, Meyer-Rüsenberg HW (2007) Microsurgery of the lacrimal system: microendoscopic techniques. Minimally invasive diagnostics and therapy in lacrimal surgery. In: Weber RK, Keerl R, Schaefer SD, Della Rocca RC (eds) *Atlas of lacrimal surgery*. Springer, Berlin, pp 105–118
24. Fayet B, Assouline M, Bernard JA (1998) Monocanicular nasolacrimal duct intubation. *Ophthalmology* 105:1795–1796
25. Feretis M, Newton JR, Ram B, Green F (2008) Comparison of external and endonasal dacryocystorhinostomy. *J Laryngol Otol* 20:1–5
26. Hanafee WN, Dayton GO (1978) Dilatation of the nasolacrimal duct under radiographic control. *Radiology* 127:813–815
27. Hartikainen J, Grenman R, Puukka P, Seppä H (1998) Prospective randomized comparison of external dacryocystorhinostomy and endonasal laser dacryocystorhinostomy. *Ophthalmology* 105:1106–1113
28. Heermann J. (1991) Rhinochirurgische Aspekte bei Tränenwegsstenosen. *Otolaryngol Nova* 1:227–232
29. Hoffmann KT, Hosten N, Anders N, Stroszczyński C, Liebig T, Hartmann C, Felix R (1999) High-resolution conjunctival contrastenhanced MRI dacryocystography. *Neuroradiology* 41:208–213
30. Hunerbein R, Grass F, Leber M, Wilhelm K, Kuhn FP (2005) Balloon dacryocystoplasty: interventional radiological therapy of congenital dacryostenosis. *Rofo* 177:1387–1393
31. Hutcheson KA, Drack AV, Lambert SR (1997) Balloon dilatation for treatment of resistant nasolacrimal duct obstruction. *J Am Acad Pediatr Ophthalmol Strabismus* 1:241–244
32. Janssen AG, Mansour K, Rabbe GJ (1994) Dacryocystoplasty: treatment of epiphora by means of balloon dilatation of the obstructed nasolacrimal duct system. *Radiology* 193:453–456
33. Kang SG, Song HY, Lee DH, Choi JY, Ahn HS (2002) Nonsurgically placed nasolacrimal stents for epiphora: long-term results and factors favoring stent patency. *J Vasc Interv Radiol* 13:293–300
34. Kao SC, Liao CL, Tseng JH, Chen MS, Hou PK (1997) Dacryocystorhinostomy with intraoperative use of mitomycin C. *Ophthalmology* 104:86–91
35. Keerl R, Weber R (2004) Dacryocystorhinostomy – state of the art, indications, results. *Laryngorhinootologie* 83:40–50
36. Keerl R, Weber R, Draf W, Gödecke A, Haas JP, Kahle G, Behrendt S, Busse H, Dshambazov K, Emmerich KH, Esser P, Freigang B, Ibing R, Fuchs G, Krüpe H, Michel O, Rochels R, Berkefeld J, Fries U (1999) The interdisciplinary surgery of the lacrimal drainage system. Giebel Verlag, Eiterfeld. ISBN 3-933755-03-4
37. Ko GY, Song HY et al (1993) Obstruction of the lacrimal system: treatment with a covered, retrievable, expandable nitinol stent versus a lacrimal polyurethane stent. *Radiology* 227:270–276

38. Kong YT, Kim TI, Kong BW (1994) A report of 131 cases of endoscopic laser lacrimal surgery. *Ophthalmology* 101: 1793–1800
39. Kuchar A, Novak P, Pieh S, Fink M, Steinkogler FJ (1999) Endoscopic laser recanalisation of presaccular canalicular obstruction. *Br J Ophthalmol* 83:443–447
40. Kushner BJ (1996) Balloon catheter dilatation for treatment of congenital nasolacrimal duct obstruction. *Am J Ophthalmol* 122(4):598–599
41. Lachmund U, Ammann-Rauch D, Forrer A, Petralli C, Remonda L, Roeren T, Vonmoos F, Wilhelm K (2005) Balloon catheter dilatation of common canaliculus stenoses. *Orbit* 24:177–183
42. Lanciego C, De Miguel S, Perea M et al (2001) Nasolacrimal stents in the management of epiphora: medium-term results of a multicenter prospective study. *J Vasc Interv Radiol* 12:701–710
43. Lanciego C, Toledano N et al (2003) Resolution of epiphora with nasolacrimal stents: results of long-term follow-up in a multicenter prospective study. *J Vasc Interv Radiol* 14: 1417–1425
44. Lee JM, Song HY, Han YM, Chung GH, Sohn MH, Kim KS, Choi KC (1994) Balloon dacryocystoplasty. Results in the treatment of complete and partial obstructions of the nasolacrimal system. *Radiology* 192:503–508
45. Lee TS, Woog JJ. (2001) Endonasal dacryocystorhinostomy in the primary treatment of acute dacryocystitis with abscess formation. *Ophthal Plast Reconstr Surg* 17:180–183
46. Lester SE, Robson AK, Bearn M (2008) Endoscopic cold steel versus laser dacryocystorhinostomy: completing the audit cycle. *J Laryngol Otol* 122:924–927
47. Liao SL, Kao SC, Tseng JH, Chen MS, Hou PK. (2000) Results of intraoperative mitomycin C application in dacryocystorhinostomy. *Br J Ophthalmol* 84:903–906
48. Mäntynen J, Yoshitsugu M, Rautanen M (1997) Results of dacryocystorhinostomy in 96 patients. *Acta Otolaryngol Suppl* 529:187–189
49. Maini S, Raghava N, Youngs R, Evans K, Trivedi S, Foy C, Mackintosh G (2007) Endoscopic endonasal laser versus endonasal surgical dacryocystorhinostomy for epiphora due to nasolacrimal duct obstruction: prospective, randomised, controlled trial. *J Laryngol Otol* 121:1170–1176
50. Massegur H, Trias E, Adema JM (2004) Endoscopic dacryocystorhinostomy: modified technique. *Otolaryngol Head Neck Surg* 130(1):39–46
51. Massaro BM, Gonnering RS, Harris GJ (1990) Endonasal laser dacryocystorhinostomy: a new approach to nasolacrimal duct obstruction. *Arch Ophthalmol* 108:1172–1176
52. Metson R, Woog JJ, Puliafito CA (1994) Endoscopic laser dacryocystorhinostomy. *Laryngoscope* 104:269–274
53. Meyer-Rüsenberg HW, Emmerich KH, Lüchtenberg M, Steinhauer J (1999) Endoskopische Laserdakryoplastik. *Ophthalmologie* 96:332–334
54. Mirza S, Al-Barmani A, Douglas SA, Bearn MA, Robson AK (2002) A retrospective comparison of endonasal KTP laser dacryocystorhinostomy versus external dacryocystorhinostomy. *Clin Otolaryngol* 27:347–351
55. Mirza S, Jones NS (2007) Laser-assisted dacryocystorhinostomy. In: Weber RK, Keerl R, Schaefer SD, Della Rocca RC (eds) *Atlas of lacrimal surgery*. Springer, Berlin. pp 73–86
56. Moore WM, Bentley CR, Olver JM (2002) Functional and anatomic results after two types of endoscopic endonasal dacryocystorhinostomy. *Ophthalmology* 109:1575–1582
57. Morgan S, Austin M, Whittet H (2004) The treatment of acute dacryocystitis using laser assisted endonasal dacryocystorhinostomy. *Br J Ophthalmol* 88:139–141
58. Mrochen M, Riedel P, Donitzky C, Seiler T (2001) Zur Entstehung von Kavitationsblasen bei der Erbium-YAG-Laser-Vitrektomie. *Ophthalmologie* 98:163–167
59. Müllner K (1998) Eröffnung von Tränenwegsstenosen mittels Endoskop und Laser. *Ophthalmologie* 95:490–493
60. Müllner K (1997) Tränenwegsendoskopie. *Ophthalmologie* 94:736–738
61. Müllner K, Wolf G. (1999) Endoskopische Behandlung von Tränenwegsstenosen mit Hilfe eines KTP-Lasers – erster Erfahrungsbericht. *Klein Monatsbl Augenheilkd* 215:28–32
62. Munk PL, Lin DTC, Morris DC (1990) Epiphora: treatment by means of dacryocystoplasty with balloon dilatation of the nasolacrimal drainage apparatus. *Radiology* 177:687–690
63. Perena MF, Castillo J, Medrano J, De Gregorio MA, Loras E, Cristobal JA (2001) Nasolacrimal polyurethane stent placement: preliminary results. *Eur J Ophthalmol* 11:25–30
64. Perry JD, Maus M, Nowinski TS, Penne RB (1998) Balloon catheter dilation for treatment of adults with partial nasolacrimal duct obstruction: A preliminary report. *Am J Ophthalmol* 126:811–816
65. Pinto I, Paul L, Grande C, De la Cal MA (2001) Nasolacrimal polyurethane stent placement for epiphora: technical long-term results. *J Vasc Interv Radiol* 12:67–71
66. Reifler DM (1993) Results of endoscopic KTP laser-assisted dacryocystorhinostomy. *Ophthal Plast Reconstr Surg* 9:231–236
67. Rosser PM (1999) There is no crying over spilt tears: the surgical management of primary acquired nasolacrimal duct obstruction. *Aust New Z J Ophthalmol* 27:95–100
68. Sadiq SA, Ohrlich S, Jones NS, Downes RN (1997) Endonasal laser dacryocystorhinostomy – medium term results. *Br J Ophthalmol* 81:1089–1092
69. Schaudig U, Maas R (2000) The polyurethane nasolacrimal duct stent for lower tear duct obstruction: long-term success rate and complications. *Graefes Arch Clin Exp Ophthalmol* 238:733–737
70. Smirnov G, Tuomilehto H, Teräsvirta M, Nuutinen J, Seppä J (2008) Silicone tubing is not necessary after primary endoscopic dacryocystorhinostomy: a prospective randomized study. *Am J Rhinol* 22:214–217
71. Song HY et al (1996) Non-surgical placement of a nasolacrimal polyurethane stent: long-term effectiveness. *Radiology* 200:759–763
72. Song HY, Jin Y-H, Kim J-H, Huh S-J, Kim Y-H, Kom T-H, Sung K-B (1995) Nonsurgical placement of a nasolacrimal polyurethane stent. *Radiology* 194:233–237
73. Song HY, Jin HY, Kim JH, Sung KB, Han YM, Cho NC (1994) Nasolacrimal duct obstruction treated nonsurgically with use of plastic stents. *Radiology* 190:535–539
74. Song, H-Y, Lee DH, Ahn H, Seo T-S, Ko G-Y (2002) Intervention in the lacrimal drainage system. *Cardiovasc Intervent Radiol* 25:165–170
75. Sonkhya N, Mishra P (2008) Endoscopic transnasal dacryocystorhinostomy with nasal mucosal and posterior lacrimal sac flap. *J Laryngol Otol* 28:1–7
76. Steinhauer J, Norda A, Emmerich KH, Meyer-Rüsenberg HW (2000) Laserkanalikuloplastik. *Ophthalmologie* 97: 692–695
77. Struck HG (1999) Zum Stellenwert der externen Dakryocystorhinostomie. *Klin Monatsbl Augenheilkd* 215: 1–3

78. Szubin L, Papageorge A, Sacks E (1999) Endonasal laser-assisted dacryocysto-rhinostomy. *Am J Rhinol* 13: 371–374
79. Tsirbas A, Wormald PJ (2003) Endonasal dacryocystorhinostomy with mucosal flaps. *Am J Ophthalmol* 135: 76–83
80. Tucker N, Chow D, Stockl F, Codere F, Burnier M (1997) Clinically suspected primary acquired nasolacrimal duct obstruction. Clinicopathologic review of 150 patients. *Ophthalmology* 104:1882–1886
81. Ugurbas SH, Zilelioglu G, Sargon MF, Anadolu Y, Akiner M, Aktürk T (1997) Histopathologic effects of mitomycin-C on endoscopic transnasal dacryocystorhinostomy. *Ophthalmic Surg Lasers* 28:300–304
82. Unlu HH, Toprak B, Aslan A, Guler C (2002) Comparison of surgical outcomes in primary endoscopic dacryocystorhinostomy with and without silicone intubation. *Ann Otol Rhinol Laryngol* 111:704–709
83. Weber R, Draf W (1994) Reconstruction of lacrimal drainage after trauma or tumor surgery. *Am J Otolaryngol* 15: 329–335
84. Weber R, Draf W, Kolb P. (1993) Die endonassale mikrochirurgische Behandlung von Tränenwegsstenosen. Indikation, Technik und Ergebnisse *HNO* 41:11–18
85. Weidenbecher M, Hosemann W, Buhr W (1994) Endoscopic endonasal dacryocystorhinostomy: results in 56 patients. *Ann Otol Rhinol Laryngol* 103:363–367
86. Welham RA, Wulc AE (1987) Management of unsuccessful lacrimal surgery. *Br J Ophthalmol* 71:152–157
87. White WL, Popham JK (2004) Balloon-assisted lacrimal surgery. In: Woog JJ (ed) *Endoscopic lacrimal and orbital surgery*. Butterworth & Heinemann, Philadelphia. pp 141–153
88. Wilhelm K (2007) Interventional radiology. In: Weber RK, Keerl R, Schaefer SD, Della Rocca RC (eds) *Atlas of lacrimal surgery*. Springer, Berlin, pp 143–152
89. Wilhelm K, Hofer U, Textor HJ, Böker T, Strunk H, Schild HH (2000) Nonsurgical fluoroscopically guided dacryocystoplasty of common canalicular obstructions. *Cardiovasc Intervent Radiol* 23:1–8
90. Wilhelm K, Loeffler K, Urbach H, Schild H (2002) Complete tear duct obstruction: Treatment with lacrimal polyurethane stent implantation. *Cardiovasc Intervent Radiol* 25:S149
91. Wilhelm K, Loeffler K, Urbach H, Schild H (2003) Behandlung von Tränenwegsverschlüssen mit dem PBN Wilhelm TearLeader Stent – Erste Ergebnisse. *Fortschr Röntgenstr* 175:S1152–153
92. Wilhelm K, Textor J, Hofer U, Böker T, Strunk H, Schild H (1997) Nasolacrimal duct obstructions: Treatment with balloon dilation and stent implantation. *Fortschr Röntgenstr* 167:486–490
93. Woog JJ (2004) Endoscopic dacryocystorhinostomy and conjunctivorhinostomy. In: Woog JJ (ed) *Endoscopic lacrimal and orbital surgery*. Butterworth and Heinemann, Philadelphia. pp 105–121
94. Woog JJ, Kennedy RH, Custer PL, Kaltreider SA, Meyer DR, Camara JG (2001) Endonasal dacryocystorhinostomy: a report by the American Academy of ophthalmology. *Ophthalmology* 108:2369–2377
95. Woog JJ, Metson R, Puliafito CA (1993) Holium:YAG endonasal laser dacryocystorhinostomy. *Am J Ophthalmol* 116: 1–10
96. Wormald PJ, Kew J, Van Hasselt A (2000) Intranasal anatomy of the nasolacrimal sac in endoscopic dacryocystorhinostomy. *Otolaryngol Head Neck Surg* 123: 307–310
97. Yazici B, Hammad AM, Meyer DR (2001) Lacrimal sac dacryoliths. *Ophthalmology* 108:1308–1312
98. Yazici Z, Yazici B, Parlak M, Erturk H, Savci G (1999) Treatment of obstructive epiphora in adults by balloon dacryoplasty. *Br J Ophthalmol* 83:692–696
99. You Y, Fang C (2001) Intraoperative mitomycin C in dacryocystorhinostomy. *Ophthalm Plast Reconstr Surg* 17: 115–119
100. Yung MW, Hardman-Lea S (1998) Endoscopic inferior dacryocystorhinostomy. *Clin Otolaryngol* 23:152–157
101. Zilelioglu G, Ugurbas SH, Anadolu Y, Akner M, Aktürk T (1998) Adjunctive use of mitomycin C on endoscopic lacrimal surgery. *Br J Ophthalmol* 82:63–66

4.1 Penetrating Keratoplasty

4.1.1 Introduction

Cornea transplantation is a fascinating surgical procedure for the many reasons to do it, as well as the many ways to do it. Cornea transplant surgeons now have the option of replacing the posterior cornea for primary and secondary endotheliopathies, as well as the anterior cornea for pathology that does not involve the endothelium. In penetrating keratoplasty (PK), full-thickness host corneal tissue is replaced with full-thickness donor corneal tissue. Erasmus Darwin, the grandfather of Charles Darwin, is given credit for his vision of restoring a scarred cornea to its transparent state [1]. His idea, proposed in 1760, led to our present corneal transplantation procedure [1].

The idea to use living corneal tissue for transplantation was suggested by Franz Reisinger in 1818 [1]. He experimented with the procedure in rabbits and chickens but was unable to achieve clear grafts [1]. Bigger reported a successful homograft procedure on a pet gazelle in 1837, and Von Hippel performed the first successful lamellar cornea transplant in 1886 when he transplanted a rabbit cornea into a human recipient bed [1]. Finally, in 1905, Zirm performed the first successful human cornea transplant [1]. The procedure has continued to evolve since then with successes due to advances in surgical instrumentation, donor tissue preservation, and anti-inflammatory agents. For example,

topical Cyclosporin A (Allergan, Irvine, CA) is now available. According to an eye bank statistical report in 2002, there are approximately 33,000 PKs performed per year in the United States [1].

4.1.2 Indications

Indications for PK are both optical and therapeutic. The most common indications for a cornea transplant, including pseudophakic and aphakic bullous keratopathy, are no longer being treated with PK, but as they are secondary endotheliopathies, they are being treated by endothelial replacement only. Cornea ectasias and thinning, disorders with a previous indication for PK, are being treated by deep anterior lamellar keratoplasty (DALK) now. DALK is replacing PK in the surgical treatment of cornea ectasias that do not show full-thickness scar formation. Briefly, DALK is a procedure whereby the anterior layers of the cornea are removed down to Descemet's membrane and replaced with a donor cornea from which the surgeon has removed the Descemet's membrane. This procedure has the advantage of decreased endothelial graft rejection since the host retains their native endothelium. Other advantages include greater wound stability and less intraoperative complications such as choroidal hemorrhage.

Stromal cornea dystrophies are being treated by this method as well, as are cases of previous viral keratitis with anterior stromal scarring.

While DALK is beginning to become the preferred procedure for some of the mentioned indications in which PK was previously more commonly performed, there are those indications in which PK is still considered the preferred procedure. Full-thickness cornea

H. M. Skeens (✉)
Storm Eye Institute, 167 Ashley Avenue, MSC 676,
Charleston, SC 29425, USA
e-mail: skeens@musc.edu

scars from infectious ulcerative keratitis, mechanical trauma with full thickness scars, advanced cases of ectasia with full thickness scarring, and regrafts related to allograft rejection or related to high amounts of irregular astigmatism with poor visual acuity, are all indications for PK.

4.1.3 Preoperative Evaluation of the Keratoplasty Patient

The main questions to be answered when obtaining a patient's history are related to how the current cornea pathology is affecting the vision and lifestyle, as well as the ability and willingness of the patient to undergo the proposed operative procedure. For patients with a congenital opacity, the best corrected visual acuity (BCVA) that the patient has had in his/her lifetime must be determined so that both the surgeon and the patient have reasonable expectations. Amblyopia may limit the BCVA that the patient may obtain and it is important to discuss this prior to surgery so that the patient may make an informed decision regarding whether or not to undergo the procedure. Many patients do not understand that amblyopia often may be the main reason for their limited visual acuity and falsely believe that the surgeon may be able to restore the eye to a 20/20 visual acuity following the replacement of the abnormal cornea. It cannot be overemphasized that this point must be discussed and made clear prior to surgery.

For patients with a cornea scar related to a history of infection, a history of herpes simplex viral (HSV) keratitis may be elicited. An experienced cornea surgeon can often diagnose a history of HSV keratitis upon clinical examination, but the patient may also be asked certain questions that help elicit this history. For example, the presence of periocular skin lesions at the time that the patient first noticed a decrease in the visual acuity would be associated with a history of HSV infection. It is important to elicit this history from the patient because it is recommended that the patient take an oral antiviral medication following PK for prophylaxis of recurrent HSV infection in the donor graft. HSV following PK will be discussed later in the chapter.

Cornea ectasias represent another primary indication for cornea transplant. Examples of ectasias include

keratoconus (KCN), keratoglobus, and pellucid marginal degeneration (PMD). KCN is a noninflammatory, bilateral cornea dystrophy that causes reduced best-corrected visual acuity and severe astigmatism due to its progressive nature. Management options in the early stages of the disease include spectacles or rigid-gas permeable contact lenses (RGP). If a patient presents with a history of ectasia, it is important to determine if the patient has tried RGP lens wear to improve the visual acuity. The patient must be instructed to try RGP wear prior to further intervention if severe central scarring is not present, and if the patient has not tried this methodology. Reasons for failure with contact lenses include discomfort, a poorly fitting lens, or problems with lens insertion. The patient presenting with contact lens intolerance or advanced disease with cornea scarring may benefit best from cornea transplantation. As mentioned, DALK is now becoming the preferred procedure for cornea ectasia but there are still situations in which full-thickness PK is warranted.

Other treatments are available for cornea ectatic disorders and these include the use of INTACS (Keravision, Inc) and collagen cross-linking. INTACS are intracorneal ring inserts composed of polymethylmethacrylate. Their placement flattens the central cornea. Cornea tissue is not removed in the placement of intracorneal ring segments, and the central optical zone of the cornea is not invaded. INTACS are reported to be an effective method for the treatment of low to moderate KCN (mean K reading ≤ 53) [2]. Shetty et al. performed INTACS implantation in eyes with advanced KCN and good results were noted with respect to visual acuity and corneal topography, without major complications postoperatively [2].

Collagen cross-linking was developed to counteract progressive corneal thinning, and thus the progression of KCN [3]. Collagen cross-linking is carried out via the use of riboflavin (vitamin B2) and UV light on the order of 365–370 nm wavelengths [3]. Riboflavin absorbs UV irradiation and acts as a photosensitizer for the generation of reactive oxygen species [3]. The combination of riboflavin and UV light thus forms radicals that crosslink collagen [3].

The biochemical characteristics of the normal cornea result from the collagen scaffold that has been formed via bonding between the collagen fibrils [3]. The exact configuration of the collagen lamella in the cornea determines the cornea's resistance. The specific cause of KCN is not known, but it is known that there

is a modification of the corneal stromal collagen lamella in KCN. Collagen cross-linking, through the promotion of covalent binding between collagen molecules, stabilizes the collagen scaffold in KCN [3].

In 1998, the first KCN patients underwent collagen cross-linking [3]. Raiskup-Wolf et al. reported on a series of 480 eyes with progressive KCN that underwent collagen cross-linking with UV irradiation and riboflavin, and were followed for a maximum of 6 years [3]. Their results indicated a significant improvement in BCVA and long-term stabilization of the cornea with collagen cross-linking [3]. Further discussion of these techniques is beyond the scope of this chapter.

Other indications for PK that can be elicited during the history taking include mechanical trauma with scar formation, cornea opacification due to limbal stem cell deficiency (LSCD), regrafts for allograft failure and reasons not related to allograft failure. A history of an infectious keratitis not responsive to medical therapy is an indication for a therapeutic keratoplasty.

Besides eliciting the clinical indications for PK and how the patient's lifestyle is affected, the surgeon must determine the ability of the patient to undergo the procedure and to maintain proper follow-up care. For example, in considering the method of anesthesia to be used, the ability of the patient to lie flat for the duration of the procedure is essential. Pulmonary or cardiac abnormalities could interfere with the ability to lie flat as the patient may begin coughing or have difficulty breathing. Severe arthritis could also make it impossible for the patient to remain comfortable in any one position for an extended period of time. These things necessitate general anesthesia.

Preexisting medical problems must be controlled before the surgical procedure. Often the anesthesiologist elicits these conditions and the level of control during the preoperative anesthesia evaluation, but it is helpful if the transplant surgeon, as well, pays attention so as to properly educate the patient prior to the anesthesia exam. Hypertension and diabetes that are not controlled should be stabilized in concert with the primary care physician. Patients should be instructed to take their antihypertensive medications with a small sip of water on the morning before surgery because anxiety is common. It is best to perform surgery on patients with insulin-dependent diabetes early in the day and have the patient take only half of their normal insulin dose before surgery. These patients should eat breakfast promptly postoperatively.

Allergies to medications should be noted in the chart and reviewed prior to surgery to avoid any complications. In particular, an allergic reaction to a preservative in a topical ophthalmic preparation must be identified. Often subconjunctival injections of antibiotic are administered postoperatively and an appropriate list of the patient's allergies is helpful. It is also helpful to elicit any history of allergy to iodine as this is typically used in prepping the patient. Chlorhexidine may be used in patients with an iodine allergy.

Aspirin and nonsteroidal anti-inflammatory drugs, and other medications that interfere with blood coagulability are typically not discontinued if they are necessary for a patient's well-being. The prothrombin times may be checked and if they are in a reasonably good range, some surgeons advocate stopping anticoagulation 48h before keratoplasty and resuming treatment on the first postoperative day [1]. Other surgeons do not stop anticoagulation prior to surgery.

Finally, it is critical to establish the willingness of the patient to maintain follow-up care and to be diligent with the administration of all postoperative medications. If a patient does not live in close proximity to the surgeon and is not willing to travel to all follow-up appointments, the surgery should not be performed. The surgeon should tell the patient prior to scheduling surgery what he or she expects postoperatively. Typically the visits for the first year can be detailed to the patient so that the patient will know if they are able to make these appointments. If, for example, an older teenage patient is considering a cornea transplant procedure for a cornea ectasia, it may be better to schedule the surgery when the patient is not in school, but perhaps on summer break. In this way, the critical initial visits may be kept more easily.

The postoperative medication regimen should be detailed to the patient preoperatively in the same way as the follow-up appointments. The patient should be made aware of the number and frequency of administration of all postoperative medications. An elderly patient who lives alone may need to plan to have additional assistance at home in the immediate postoperative period when the dosing of medication is more frequent than will be necessary later in the postoperative period. It is also a good idea to determine how a patient will obtain their postoperative medications. The surgeon may be able to help an uninsured patient with a drug assistance program in the preoperative period so that there is not an issue following surgery, when having the medication is so critical.

4.1.4 Preparation for Penetrating Keratoplasty

The most common instruments utilized in PK are detailed below.

Basic instrument list

1. Eyelid speculum
2. Scleral fixation rings
3. Large and fine-tipped needle holder
4. Toothed forceps
5. Trephine blades
6. Radial marker
7. Cutting block
8. Corneal punch system
9. Scissors: tenotomy, Westcott, Vannas, cornea transplantation scissors
10. Cannulas and blades

4.1.4.1 Eyelid Speculum

The Kratz-Barraquer wire eye speculum, the Maumenee-Park speculum, and the Lieberman lid speculum (Fig. 4.1) are available choices. The surgeon should have a couple of different speculums available to meet the needs of different anatomic configurations. The speculum must not apply too much pressure onto the globe.

4.1.4.2 Scleral Fixation Rings

The Flieringa rings are our choice (Fig. 4.2). An array of sizes should be available. The most commonly used are the 17 and 18 mm sizes.

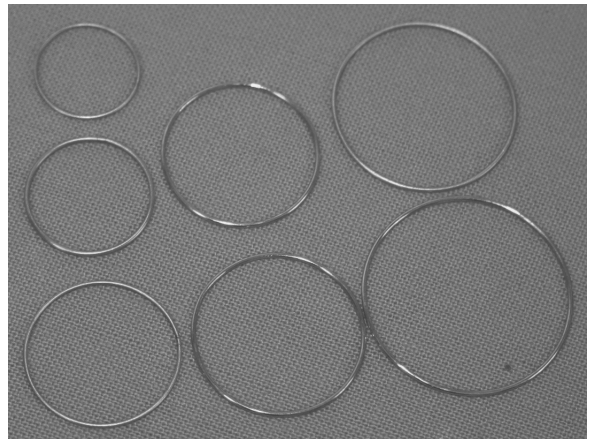


Fig. 4.2 Flieringa scleral fixation rings

4.1.4.3 Large and Fine-Tipped Needle Holder

A curved, nonlocking, round-handled needle holder with standard jaws should be used to place the scleral fixation rings. A Barraquer needle holder with standard jaws is an example. The fine-tipped needle holder should be used to place the corneal sutures (Fig. 4.3). It should be curved, nonlocking, and round-handled as well. A Barraquer needle holder with fine jaws is recommended.

4.1.4.4 Toothed Forceps

Several toothed forceps should be available. Large toothed (0.3 mm) forceps are used to secure the globe during fixation of the scleral rings. Small toothed (0.12) forceps are used to manipulate the donor tissue (Fig. 4.4).

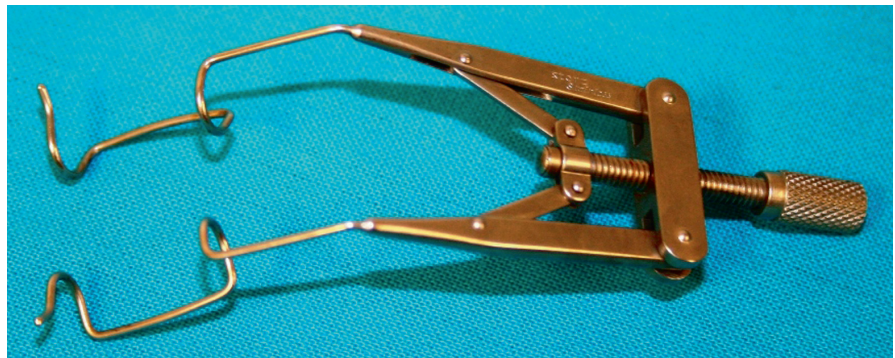


Fig. 4.1 Lieberman lid speculum

Fig. 4.3 Fine-tipped needle holder

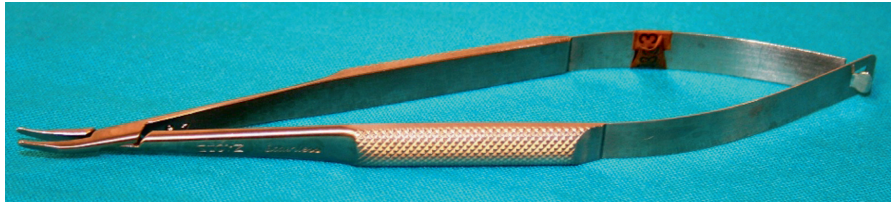


Fig. 4.4 Toothed forceps

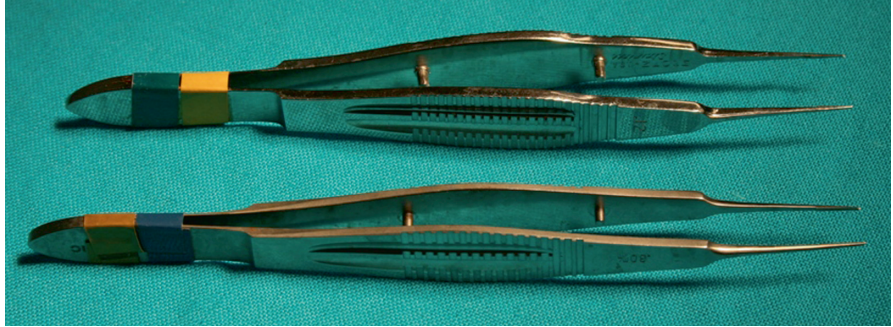


Fig. 4.5 Trephine blade

4.1.4.5 Trephine Blades

We prefer to use hand-held disposable trephine blades (Fig. 4.5). A variety of trephine handles are available if the surgeon prefers. Trephines range in size from 5 to 17 mm. Two of each size should always be available. We maintain a supply of 5–12 mm blades at all times.

4.1.4.6 Radial Marker

Eight and 12 prong radial markers are available (Fig. 4.6).

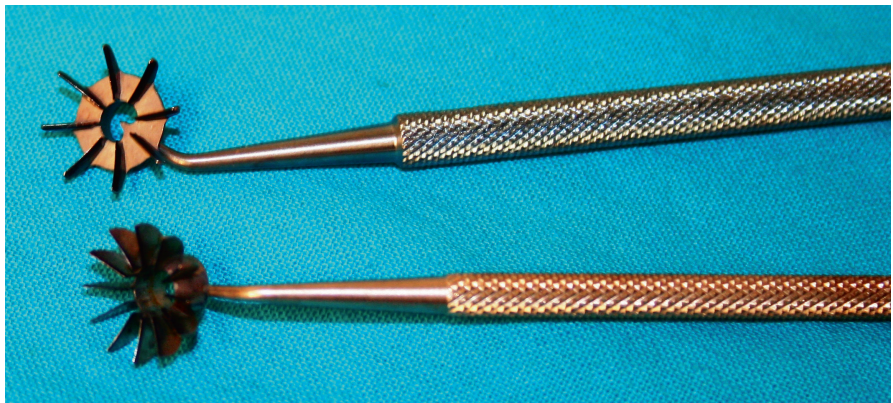


Fig. 4.6 Eight and 12 prong radial markers

4.1.4.7 Cornea Punch

A variety of corneal donor punches are available. These include the Troutman corneal punch, the Iowa punch, the Lieberman gravity-action corneal donor punch, the Rothman-Gilbard corneal punch, and the Barron corneal donor punch. Vacuum-assisted trephination systems are available as well and include the Hessburg-Barron vacuum trephine, the Hanna, the Krumeich, and the Lieberman. We prefer the Iowa punch (Medtronic, Minneapolis, MN) (Fig. 4.7). The Iowa punch incorporates a spring-loaded piston with an expandable retaining edge to accommodate the trephine. The piston is inserted into the carrier guide and advanced with the application of pressure from the surgeon.

4.1.4.8 Cutting Block

Cutting blocks are used with a punch system. They are composed of Teflon, nylon, or polycarbonate. They have a curved, concave well in which to place the



Fig. 4.7 Iowa press



Fig. 4.8 Cutting block

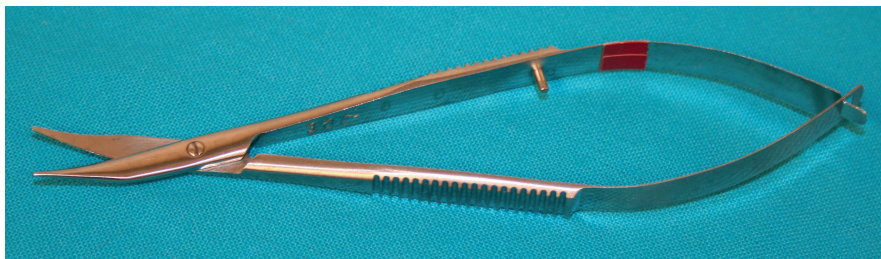
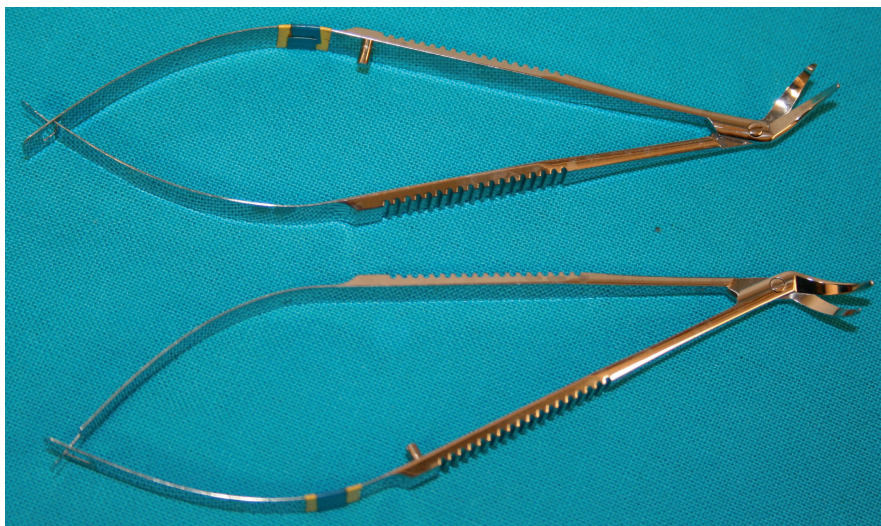
donor tissue endothelial side up. There is a colored centering target in the center of the well to help center the donor tissue properly. The Iowa punch system consists of the Iowa punch and the Iowa punch cutting block (Fig. 4.8). This is our preferred system.

4.1.4.9 Scissors

A variety of scissors are needed. A tenotomy scissors is used to incise the drape. Westcott scissors are usually used to cut suture material, perform conjunctival resection when needed, cut vitreous strands, etc. (Fig. 4.9). Vannas scissors are used to trim sutures, create an iridectomy, and for trimming an uneven posterior corneal ledge. Cornea transplantation scissors are used to remove the host cornea and they have the lower blade inside the upper blade to create a beveled and perpendicular incision (Fig. 4.10).

4.1.4.10 Cannulas and Blades

A cannula is needed to reconstitute the anterior chamber. We like to use a 30-gauge cannula on a 3-mL syringe filled with balanced salt solution (BSS). A 15° disposable blade is used to enter the anterior chamber and to trim sutures.

Fig. 4.9 Westcott scissors**Fig. 4.10** Right and left handed cornea transplantation scissors

4.1.5 Preoperative Medications

Preoperatively we prefer to give our patients i.v. mannitol if there are no systemic contraindications to doing so. Intravenous mannitol helps to dehydrate the vitreous cavity and lower the intraocular pressure (IOP), thus decreasing the incidence of forward prolapse of intraocular contents during the procedure. For younger patients 50 g is typically administered. For older individuals, 25 g may be appropriate. Mannitol is administered over 30 min to 1 h.

Unless a cataract extraction is planned along with PK, pilocarpine 1% ophthalmic drops are administered preoperatively to effect miosis of the pupil and decrease the forward prolapse of intraocular contents during the procedure.

If a cataract extraction is planned concurrent with PK, the pupil is dilated preoperatively in the typical fashion and intraoperative miocchol may be administered following cataract removal to effect miosis.

An antibiotic is administered every 5 min for a total of three doses prior to surgery. Vigamox (Alcon, Fort Worth, TX) or Zymar (Allergan, Irvine, CA) are examples.

A Honan cuff may be used preoperatively to reduce IOP prior to beginning the procedure. A typical setting is 30 mmHg.

4.1.6 Penetrating Keratoplasty Surgical Procedure

The technique of PK is as follows. Patients are taken to the operating room following informed consent and following administration of appropriate medications as detailed above. Anesthesia appropriate to the patient and of the surgeon's preference is undertaken. Most of our patients undergo general anesthesia unless there is a systemic contraindication. General anesthesia with complete paralysis at the time of the removal of the

host cornea ensures that the patient does not undergo a valsalva maneuver and expulse intraocular contents. The eye is prepped and draped in a sterile fashion and a lid speculum is placed. The lid speculum must be properly sized to fit the patient and positioned to minimize pressure against the eye. Any pressure against the eye causes globe distortion that can lead to irregular trephination and resultant astigmatism due to poor suture alignment. Also, pressure against the eye can cause an expulsion of intraocular contents. So it cannot be emphasized enough that the lid speculum must fit properly.

4.1.6.1 Placement of the Scleral Fixation Ring

When the patient has had a previous vitrectomy or when there is a history of prior lens removal, a scleral fixation ring is sutured with four to six interrupted 7-0 vicryl sutures with half-thickness scleral bites, with care not to pass too deeply through the less than 1 mm deep sclera. These sutures are typically placed from the periphery toward the limbus. The fixation ring is sized to measure slightly less than the interpupillary opening as defined by the lid speculum. The ring functions as a potential scaffold to maintain scleral support once the eye is opened if scleral rigidity is insufficient.

Some surgeons have abandoned the use of the fixation rings to avoid any associated globe distortion and astigmatism induced by ring placement. We prefer to suture a Flieringa ring to the episclera with 7-0 vicryl suture. This provides excellent stability.

4.1.6.2 Marking of the Host Cornea

Following placement of the fixation ring if needed, measurement of the host corneal diameter is made in both vertical and horizontal directions with a caliper, and in cases of cornea ectasia, care is taken to measure around the base of the ectatic cornea. The optical axis is marked by the surgeon, using the center of the pupil if possible. Typically the donor graft is centered on the host cornea or over the pupillary axis. An 8- or 12-prong radial cornea marker is used by some surgeons to assist in donor-host suture alignment.

4.1.6.3 Sizing of the Trephine

Sizing of the host trephine is based on several factors that include cornea size and the diameter needed to excise all of the corneal pathology. Traditionally, sizing of the host was also based on minimizing the supposed risk of increased graft rejection and failure by staying as far back from the limbus as possible. But larger diameter grafts have some inherent advantages. These include the excision of the inciting pathology that may be in the cornea periphery as in cases of cornea ectasia, as well as reduced postoperative astigmatism with better corrected and uncorrected visual acuities (UCVA). The authors have presented a group of patients that had large diameter penetrating keratoplasty (LDPK), defined as 8.75 mm or larger, and did not experience an increase in the graft rejection or failure rate. In fact, no patients in our study experienced a graft failure. For this reason, we prefer to use a trephine size of 8.75 mm or larger. Further reasoning and outcome of our study will be discussed later. If an 8.75 mm or larger trephine is chosen, the same size trephine is chosen to cut the donor button. In general, if a smaller trephine is chosen, the donor tissue trephine is routinely sized 0.25 mm larger than the host trephine because donor corneal tissue cut with a trephine from the endothelial surface measures about 0.25 mm smaller in diameter than host corneal tissue cut with the same diameter trephine from the epithelial surface [1].

4.1.6.4 Trephination of the Host Cornea

Host trephination is performed with the hand-held disposable trephine held perpendicular to the cornea. Minimal pressure is exerted against the cornea as the trephine is progressively rotated until it has penetrated approximately 90% depth of the host cornea. It cannot be overemphasized that very little pressure needs to be exerted during this maneuver because the trephines are very sharp and too much exertion could cause an unwanted entry into the anterior chamber with a quick shallowing of the eye and a prolapse forward of intraocular contents. It is the rotation of the trephine that does the cutting, not the use of excessive pressure by the surgeon.

Some surgeons prefer to actually enter the anterior chamber with the initial host trephination and look for

a drop of aqueous to become visualized. Because the cornea is not of absolute uniform thickness, the initial opening using this method will often be only one or a few clock hours.

The authors prefer to trephine to approximately 90% thickness and then enter the anterior chamber with a sharp blade. This allows a more controlled entry. Abrupt entry into the anterior chamber can be associated with a higher risk of suprachoroidal hemorrhage.

4.1.6.5 Trephination of the Donor Cornea

The donor cornea is trephined with the endothelial side facing up using a sharp disposable trephine in a punch block apparatus. The authors prefer to use an Iowa P.K. press and cutting block. Briefly, the cornea tissue is brought to the back table by the circulating nurse and the surgeon uses a toothed forcep to grasp only the donor rim and place the tissue, endothelial side up, on the cutting block. At this time, the tissue is gently lifted by the rim and tilted up, and a Weck cell is used to remove excess fluid from under the donor tissue so that it does not slip during the process of trephination. A red dot in the center of the cutting block helps the surgeon to center the donor cornea appropriately. Centration prior to trephination is essential. The cutting block is placed on the Iowa press which has been assembled with the trephine, and the central donor cornea button is punched. The donor tissue is kept submerged in storage medium and covered while the surgeon is completing preparation of the host stromal bed.

4.1.6.6 Removal of the Host Cornea

Following trephination of the donor cornea, attention is directed again to the patient and a sharp blade is used to enter the anterior chamber for 1 clock hour in the 8 o'clock meridian. A small amount of viscoelastic is placed in the anterior chamber to push the iris back and beveled cornea transplantation scissors are used to remove the host cornea. This maneuver is aided by maintaining host button alignment with toothed forceps. Care is taken not to apply any downward pressure to the globe during this time so as to not expulse the lens. The tips of the scissors should be always be visualized, the scissors should be at an angle of about

10°, and a slight amount of upward pressure against the host cornea should be maintained to avoid iris damage during the cut. Keeping the scissors at an angle of 10° helps create a slight inwardly beveled cut which makes a watertight wound closure easier. Furthermore, the scissors should be advanced around the host cornea in a continuous fashion with very little exit and reentry into the anterior chamber. This ensures that the cut is made uniform, which will help decrease postoperative astigmatism.

If the iris and the lens begin to bulge forward during host trephination, a number of maneuvers can be performed to decrease the positive posterior pressure. First, the surgeon should ensure that pressure is not being exerted while advancing the cornea transplantation scissors. The lid speculum can be loosened and the patient may be placed in reverse trendelenburg positioning. Putting a patient that is overweight in the reverse trendelenburg position can alleviate the positive pressure exerted on the head from the heavy abdomen.

4.1.6.7 Placement of the Donor Cornea Tissue in the Host Stromal Bed

After removal of the host cornea, the donor cornea is brought onto the field and gently grasped with a fine-toothed forcep at the junction of the epithelium and the stroma with great care taken not to touch the endothelium. The donor cornea is transferred onto the host recipient bed and rotated until either the most spherical reflex is obtained with an intraoperative keratometer, or the surgeon is happy with the visualized alignment of the tissues [1]. This may help reduce postoperative astigmatism. If an area of arcus or residual scleral rim is present on the donor tissue, it should be placed superiorly if possible so that, it will be covered by the upper lid.

4.1.6.8 Placement of the Cardinal Sutures

The first 10-0 nylon interrupted suture is placed at the 12 o'clock position. The donor cornea is grasped as mentioned above at the epithelial-stromal junction with a fine-toothed forcep. Some surgeons prefer to use a double-pronged forcep that allows for suture placement between the teeth of the forcep, and then

through the donor and host cornea. The depth of the suture is about 90% on both the donor and host tissues to prevent gapping of the wound. We prefer to use a surgeon's slip knot technique for each of our interrupted sutures so that the tension may be adjusted on each suture and there will be better regulation of postoperative astigmatism. We throw the first two knots in the same direction in order to create the slip and do not secure the knots with two additional passes until the first eight interrupted sutures are passed. The second 10-0 nylon suture is placed 180° away in the 6 o'clock meridian, and is most crucial in terms of tissue alignment and postoperative astigmatism. An equal amount of tissue should be distributed on either side of the 6 and 12 o'clock sutures. The three and 9 o'clock sutures are then passed in the same fashion.

The authors prefer to pass four additional 10-0 nylon sutures between the four cardinal sutures in the same interrupted slip knot fashion. Again, the first two throws are completed to create the slip and the knot is not secured. We then adjust the tension on each slip knot for the first eight sutures passed in order to equalize tension around the cornea. When we have achieved equal tension, we secure each knot starting at the 12 o'clock suture and proceeding in a clockwise direction until all eight knots are secured. An additional two single loops are made with each suture to secure the slip knot. Finally, the anterior chamber is filled with BSS to deepen it and to ensure a watertight wound closure.

4.1.6.9 Completion of Suturing

We prefer to pass an additional 16 radial, interrupted 10-0 nylon sutures to approximate the tissue, but not too tightly as to create unwanted astigmatism. These slipknots are secured after the passage of each suture. Throughout the suturing process, the anterior chamber is reformed with BSS to maintain a prolate shape to the donor cornea and viscoelastic is maintained on the donor cornea to protect the epithelium. A wet cellulose sponge should be kept on the corneal surface as well to avoid light toxicity from the operating microscope.

4.1.6.10 Suture Techniques

A variety of suture techniques exist. These include interrupted sutures only, running suture only, combined interrupted and running suture techniques, and

double running sutures, all of which are valid approaches to wound closure. A study compared the effect of three suturing techniques, including interrupted, single running, and combined interrupted and running, in KCN [4]. Post-keratoplasty astigmatism and final BCVA were evaluated in 103 eyes where patients with a previous diagnosis of KCN underwent PK with one of the three suturing techniques [4]. No difference in the evaluated perimeters was detected among suture techniques [4].

Despite the technique the surgeon chooses, the most common error in any type of suture placement is tying a suture too tight. It is hard to resist tying a suture tightly as the surgeon often believes it will better ensure a watertight closure. But a tight suture is associated with many undesirable effects including cheese wiring, surface healing problems, flat corneal curvature and hyperopia, and severe astigmatism [1]. It is thus essential that the sutures not be tied too tightly.

Another problem encountered in suture placement is that the surgeon does not bury the knots. Young cornea surgeons often leave knots unburied in the rush to complete the procedure and these knots can present a lot of problems. First of all, an exposed knot is a source of irritation and discomfort for the patient. Unburied knots are also associated with giant papillary conjunctivitis and infection. The cornea surgeon should be sure that all knots are rotated and buried at the end of the case. Care also should be taken that the knot is not rotated into the graft-host junction as scarring in this area will make the suture especially difficult to remove in the future.

4.1.6.11 Subconjunctival Medications

Subconjunctival injections of an antibiotic and a steroid are administered at the end of the case. Cefazolin, gentamicin, and dexamethasone are examples. A drop of an antibiotic such as Vigamox (Alcon) or Zymar (Allergan) is placed on the eye. Any remaining viscoelastic is placed on the cornea.

4.1.7 Intraoperative Complications

The most feared complication that can occur during PK is an expulsive choroidal hemorrhage. This will be discussed momentarily. Let's first focus on some of the more common complications that occur and how to

deal with them. We have already mentioned shallowing of the anterior chamber with bulging of the anterior segment contents. This may not really be considered a complication, but it is a common occurrence and the surgeon performing cornea transplantation must know how to deal with it. Oftentimes, a diuretic such as mannitol given preoperatively can help decompress the vitreous cavity and decrease the incidence of anterior chamber shallowing. We see the anterior chamber shallowing most often when the host cornea is being removed with the beveled scissors. The surgeon inadvertently puts pressure on the globe. When shallowing of the anterior chamber occurs, the surgeon should first be sure he/she is not applying any pressure to the eye. As previously mentioned, the patient may be placed in the reverse trephination position and/or the lid speculum may be loosened. Viscoelastics can be used to push back bulging anterior segment contents as well, but care must be taken not to put too much viscoelastic into the anterior chamber as this may cause a rise in the immediate postoperative IOP.

Other intraoperative complications include scleral perforation with fixation sutures, damaged donor buttons, and iris-lens damage [1]. When cataract extraction is combined with PK, the posterior capsule may be torn. Vitreous loss may occur in an eye that has had a previous cataract removal, and finally anterior chamber hemorrhage may occur in an inflamed or perforated eye from iris vessel leakage [1].

4.1.7.1 Scleral Perforation

The surgeon may inadvertently perforate the sclera with passage of the suture to secure the scleral fixation ring. This can result in a retinal hole and subsequent retinal detachment. The ciliary body may also be damaged and hemorrhage may occur in the angle [1]. The surgeon sewing a scleral ring should always use a rounded rather than a cutting needle and keep in mind where the suture is being placed and how thin the sclera is.

4.1.7.2 Damage to the Donor Button

The donor cornea button can be damaged during trephination if an incomplete trephination occurs and the surgeon attempts to trephine again. Endothelial cell damage may also occur if the surgeon inadvertently touches the endothelium or drops the cornea during

transfer, or if the endothelium comes into contact with bulging anterior segment contents during suture placement. The surgeon should always be mindful of the endothelium and perhaps use a drop of viscoelastic on the endothelial surface for protection. The donor cornea should always be prepared prior to removal of the host cornea to ensure tissue is available for replacement, and the host cornea once removed should always be retained in BSS on the operative stand should something unexpected happen to the donor and the surgeon would emergently need to replace the patient's cornea.

4.1.7.3 Damage to the Iris-Lens Diaphragm

Damage to the iris-lens diaphragm usually occurs during trephination or with removal of the host cornea button. A bulging iris can be caught in the tip of the surgeon's scissors and the surgeon must always be mindful of this when removing the host cornea. Viscoelastic is used to push the iris back prior to the initial entry into the anterior chamber and the tip of the scissors is kept pointing up during the removal of the host cornea. Upward pressure is applied as the scissors are advanced around the perimetry of the cornea.

The lens may bulge and in a phakic patient, the anterior lens capsule may be damaged. The surgeon should be prepared to do a cataract extraction if needed and should consider having lens calculations available on phakic patients when going to the OR. Damage to the anterior lens capsule is a rare complication if the surgeon is careful.

4.1.7.4 Posterior Capsule Rupture

A torn posterior capsule may occur during removal of a cataract at the time of PK. The surgeon must be prepared to perform an anterior vitrectomy and place a lens implant in the sulcus or suture it to the iris or sclera. A backup intraocular lens of the correct power should be chosen for each of these locations and made available should they be needed.

4.1.7.5 Vitreous Loss

Vitreous loss may occur in patients with a history of cataract extraction when the posterior capsule was violated, and it may occur in aphakic patients as well. The

surgeon must be prepared to perform a limited anterior vitrectomy. This can be done through the pupil or through an iridectomy and posterior to the intraocular lens. To perform a limited anterior vitrectomy, a phacoemulsification unit (Infiniti, Alcon) with an attached hand-held vitrector is placed on the “vitrectomy” setting with a cut rate of 800 m/s. The vitrector is inserted into the anterior chamber easily as the host cornea has been removed. Any visible vitreous is removed.

4.1.7.6 Anterior Chamber Hemorrhage

Anterior chamber hemorrhage may be encountered in a number of situations. In patients undergoing therapeutic PK for a medically nonresponsive infectious keratitis, intraocular inflammation is associated with engorged iris vasculature that can easily bleed as the host cornea is removed and there is an abrupt drop in the IOP. Previous intraocular inflammation from any number of causes may also have led to scarring of the iris to the host endothelium that when peeled during host cornea excision may bleed. In addition to these things, if the surgeon accidentally cuts the iris as the cornea is being excised, bleeding will be encountered. And, finally, removal of a lens implant that is fibrosed against the iris or in the angle will too be associated with bleeding.

Bleeding that is minor can be ignored. It will most likely stop on its own and often suturing the donor cornea into position will raise the IOP enough to tamponade the bleeding. Profuse bleeding must be stopped and there are a few different ways to do this. The surgeon may apply cautery directly to the bleeding vessel if it can be visualized but care should be taken to not cauterize too much of the iris. A bleeding scleral vessel at the edge of host cornea removal can be cauterized fairly easily. Viscoelastics may be placed in the anterior chamber to tamponade the bleeding and weck cell sponges soaked with epinephrine 1:1000 may be applied as well.

4.1.7.7 Choroidal Hemorrhage

The most dreaded complication of a cornea transplantation procedure is the expulsive choroidal hemorrhage. The incidence of expulsive hemorrhage has been reported from 0.47 to 3.3% [1]. Predisposing factors are advanced age, myopia, glaucoma, inflammation, hypotonia, or previous trauma [1]. When the

cornea surgeon attempts to repair perforated, infected, or severely traumatized eyes, he/she must be prepared to deal with expulsive choroidal hemorrhage [1].

Choroidal detachments or effusions appear as dark shadows or brown masses that can be seen in the red reflex and are often noted during the open-sky phase of the keratoplasty. This is why there should be a quick attempt on the part of the surgeon following host cornea removal to secure the donor cornea with four cardinal sutures and bring the IOP back to the normal range. Expulsive hemorrhages may occur rapidly with a sudden extrusion of intraocular contents, or there may be a more gradual hemorrhage that slowly extrudes the anterior segment structures followed by the vitreous [1]. A valsalva maneuver during the procedure can lead to an expulsive hemorrhage. For this reason, the authors prefer general anesthesia with complete paralysis of the patient when there are no systemic contraindications.

Management of an expulsive choroidal hemorrhage during the open-sky phase of the procedure requires the quick appplanation of a finger or thumb over the wound and perhaps the placement of a posterior sclerotomy large enough for the blood to be expressed. The surgeon should quickly replace either the recipient's cornea or the donor cornea over the wound and secure it with interrupted sutures. These maneuvers will help direct the hemorrhage posteriorly. If the anterior intraocular contents have not been expelled, they can be positioned in their proper places. If they have been expelled, the surgeon should continue closing the wound and plan to have a discussion with the family before an evisceration is undertaken. We prefer not to perform a primary evisceration because having the discussion with the patient and the family first may allow the patient to deal better psychologically with the situation.

4.1.8 Postoperative Management

In general, patients are followed postoperatively at day one, week one, month 1, 2, and 3, and every 3–4 months thereafter. If an epithelial defect is present on day one patients are seen more frequently until the epithelium heals. Visual acuity is measured using a Snellen chart at 20 feet in our clinic. UCVA is recorded at every visit, and BCVA is often attempted at the 1 month postoperative visit. The process of suture removal usually begins after three postoperative months and is guided by

topography. Selective suture removal, the process of removing some sutures while leaving others intact, is one way of managing post-keratoplasty astigmatism. Sutures are removed in the steep topographic or refractive meridian until a desirable visual acuity is obtained. Sutures are removed until the patient obtains a desirable visual acuity. If the patient achieves a good visual acuity with less than 3D of refractive astigmatism, and some sutures remain in the graft, these remaining sutures are not removed. The patient can then be fitted with spectacles or a contact lens.

4.1.8.1 Postoperative Immunosuppressive Regimen

The postoperative topical immunosuppressive regimen will vary among surgeons, but the authors prefer to use a combination of topical prednisolone and topical cyclosporine A (Restasis, Allergan). In general, topical prednisolone is prescribed 4–8 times daily for an average of 2–3 months postoperatively. The prednisolone is tapered by one drop per month until a dose of once daily is obtained. At that time, if the patient is phakic and has experienced no rejection episodes or developed an IOP steroid response, the topical steroid is changed to loteprednol (Lotemax, Bausch & Lomb, Tampa, FL) one to two times per day. The patient is maintained on a minimum of one drop per day for at least 1 year. All patients receive topical cyclosporine A (Restasis, Allergan) twice a day for at least 1 year postoperatively. Many patients remain on topical immunosuppressive medication for an indefinite time period.

4.1.9 Postoperative Complications

The surgeon must be prepared to deal with postoperative complications. Some of the more common complications include wound leaks, epithelial defects, increased IOP, and difficult to control postoperative inflammation.

4.1.9.1 Wound Leaks

A wound leak should be suspected when a patient presents with a shallow or flat anterior chamber, and

has a low IOP. The location of the leak can be identified with the Seidel test. In the Seidel test, fluorescein dye is placed on the surface of the cornea, and the cobalt blue light is used to view a change in color of the dye from black to bright green. Fluorescein dye appears black with a cobalt blue light and an aqueous leak appears green.

Treatment of a wound leak is as follows. If the patient has a flat anterior chamber and the iris is in approximation to the cornea endothelium, the patient should be taken to the operating suite and the anterior chamber deepened as soon as possible. The area of the wound leak should be sutured and a Seidel test is performed under the operating microscope to ensure adequate closure. If the anterior chamber is shallow, but there is no apposition of the iris to the cornea, the surgeon may try a few nonsurgical maneuvers first. A pressure patch may be used to hold the wound together until it has time to self-seal. Alternatively, a bandage contact lens may be used to reappose the wound by tamponading the leak and decreasing trauma from the eyelids to the wound. An antibiotic should be administered with the contact lens as prophylaxis against infection. If these measures fail after 24–48 h, the patient should be taken back to the operating suite and the wound repaired.

4.1.9.2 Epithelial Defects

Postoperative epithelial defects are more commonly encountered than wound leaks. Epithelial defects occur for a couple of different reasons. The donor epithelium may be irregular due to donor preparation factors including the death to preservation time and the preservation to use time. Donor tissue handling is also crucial and the eye bank preparing the donor tissue, as well as the surgeon using the donor tissue, must always be mindful of the epithelium and keep it well lubricated. Use of viscoelastics on the donor cornea throughout the procedure can help to preserve a preoperative intact epithelium.

If the patient has a history of ocular surface disease, this should be treated prior to cornea transplantation. Ocular surface disease includes dry eye syndrome and LSCD due to Stevens Johnson syndrome, ocular cicatricial pemphigoid, severe atopic disease, a history of chemical or thermal burn, and various others. Dry eye syndrome should be treated with anti-inflammatory

agents, and LSCD should be treated with ocular surface stem cell transplantation. These patients may also require permanent or temporary tarsorrhaphy following PK to ensure adequate and prompt epithelial healing.

An epithelial defect that does not heal promptly following PK will lead to persistent inflammation, ulceration, scarring, and graft failure. It is desirable to heal an epithelial defect within 1 week of PK. Methods of doing so include the use of a bandage contact lens with antibiotic coverage, pressure patching, or temporary or permanent tarsorrhaphy. The patient must be made aware of the need for prompt healing of any epithelial defect. Medications may need to be adjusted temporarily to decrease topical toxicity and promote healing. If the dose of topical prednisolone is reduced to aid healing of the epithelium, the surgeon should provide a short oral dose of prednisone if there are no major systemic contraindications. This will help prevent early graft rejection episodes. The possibility of an active herpes viral infection must be kept in mind when the patient has a persistent epithelial defect despite proper treatment. Topical or oral antiviral medication may be needed. The incidence, clinical diagnosis, and treatment of recurrent HSV keratitis in the graft will be discussed below.

4.1.9.3 Suture-Related Problems

Suture exposure postoperatively can be avoided by paying close attention to burying all suture knots at the end of the case. Exposed suture knots and tips are irritating and may cause foreign body sensation, pain, epiphora, excess mucus production, giant papillary conjunctivitis, dellen formation, and cornea erosions and ulcers. They act as a nidus of infection and act as a pathway for microorganisms to travel from the epithelium into the stroma. They also increase the risk of rejection by stimulating inflammation. Exposed suture knots or tails noted on slit-lamp biomicroscopy should be rotated and buried at the slit-lamp if possible. In addition, a broken or loose suture should be removed immediately.

4.1.9.4 Increased Intraocular Pressure

Increased IOP may be noted in the immediate postoperative period. Glaucoma following PK is one of the

most common causes for irreversible visual loss and the second leading cause of graft failure after rejection [5]. Control of an increased IOP is important because studies have shown that an elevated pressure is associated with endothelial cell loss. Svedbergh showed that elevated IOP could cause irreversible damage to monkey endothelial cells in vitro [1]. Bigar reported decreased endothelial cell counts in 5 of 13 eyes following an attack of acute angle closure glaucoma [1].

Post-PK ocular hypertension is defined as an elevated IOP greater than 21 mmHg. If there is an associated visual field loss or optic nerve head change, the patient has glaucoma. It is often hard to assess the optic nerve head or visual field prior to surgery due to cornea opacification. In the 1960s, instruments were developed that allowed routine monitoring of IOP after PK and post-PK glaucoma began to be recognized [5]. It was Irvine and Kaufman in 1969 that first recognized increased IOP after PK and they reported a mean maximum pressure of 40 mmHg in aphakic transplants and 50 mmHg in combined transplants and cataract extraction in the immediate postoperative period [5]. The incidence of glaucoma post-PK varies among reporting authors from 9 to 31% in the early postoperative period to 18–35% in the late postoperative period [5]. In our study of large diameter grafts, glaucoma was noted in 1/35 graft recipients preoperatively. This patient was managed on topical IOP lowering medication preoperatively and remains on topical therapy postoperatively. Three of our remaining 34 patients developed an IOP increase postoperatively that required topical IOP lowering agents to control. This IOP increase was not related to a steroid response. The average time to IOP rise was 11.3 months (range 1–21 months), and all three recipients currently remain on topical therapy. Glaucomatous optic disc damage has not been detected clinically in any of the patients. None of these three patients have required a glaucoma surgery. Seven of 35 patients were steroid responders with a reduction in IOP noted following a dose decrease in the topical prednisolone or following a change to loteprednol. The incidence of glaucoma in our study of large diameter grafts was 8.8%.

Expected preoperative diagnosis that are risk factors for glaucoma in patients undergoing PK include aphakic and pseudophakic bullous keratopathy, irido-corneal-endothelial syndrome, preexisting glaucoma, perforated cornea ulcer, previous PK, posttraumatic cases, combined PK and cataract extraction, and

performance of vitrectomy during PK [5]. As mentioned DSEK is now the procedure of choice for aphakic and pseudophakic bullous keratopathy.

The pathophysiology of increased IOP is multifactorial. Zimmerman et al. proposed that mechanical collapse of the trabecular meshwork in aphakic grafts is the main problem leading to glaucoma [5]. They postulated that the trabeculum needs the posterior support of the lens and the anterior support of Descemet's membrane in order to prevent collapse upon itself [5].

Retained viscoelastic material is another very important cause of elevated IOP in the immediate postoperative period because these agents clog the trabecular meshwork. The initial placement of viscoelastic material into the anterior chamber during host cornea removal to push the iris back prior to inserting the beveled scissors, should be of only the smallest amount necessary. The surgeon should not use viscoelastic agents to deepen the anterior chamber during suture placement but instead should use BSS. Complete removal of these agents must be done at the end of surgery and care should especially be taken when a combined cataract extraction is part of the procedure. If the cornea has permitted adequate visualization and open-sky technique does not need to be employed for cataract removal, the surgeon must be sure to remove all viscoelastic agents from behind the lens implant at the end of the case and prior to beginning the cornea transplantation procedure.

Angle distortion can lead to an increased IOP. Factors that may lead to angle distortion include tight sutures, long suture bites, and larger diameter cornea transplants [5]. However, as mentioned, our study on large diameter cornea transplants had a reported incidence of increased IOP postoperatively within the reported literature incidence of glaucoma in patients with smaller grafts. Furthermore, no patient in our series required a glaucoma surgical procedure for correction of an IOP rise, and no patient had visible optic nerve head changes. Our patients were treated successfully with either a switch to loteprednol or the addition of an IOP lowering agent.

Postoperative inflammation and synechia formation are associated with an elevated IOP as is the use of topical steroid preparations. It is important to control IOP postoperatively and if the surgeon expects a high IOP in the immediate postoperative period, a topical IOP lowering medication or an oral carbonic anhydrase inhibitor should be given as prophylaxis.

An accurate IOP measurement postoperatively is often difficult via Goldmann applanation tonometry because abnormal epithelium and corneal shape will distort the mires. A tono-pen is often most helpful. The surgeon should keep in mind that corneal epithelial and stromal edema will lead to inaccurately low readings.

If a patient has a tarsorrhaphy that does not allow the IOP to be measured with the tono-pen, the IOP may be estimated by digital palpation. New tonometers are available that measure IOP through the lid (Proview Phosphene Tonometer).

Preexisting glaucoma needs to be addressed prior to PK. Reinhard et al. estimated the 3-year graft survival rate in patients with a preoperative history of glaucoma to be 71% in contrast to 89% when such a history is not present [6]. Furthermore, a high incidence of graft failure has been reported if a glaucoma operation is performed following the PK [5]. If a patient is taking more than one medication to treat their glaucoma preoperatively, we suggest discussing surgical options to manage the IOP prior to the PK. The glaucoma specialist and the cornea specialist must work together to ensure the best outcome for the patient postoperatively. A glaucoma drainage device (GDD) placed prior to the PK may be the best management strategy for the IOP postoperatively. A trabeculectomy preoperatively is another choice but we do not believe this is the best choice. Postoperative inflammation following the PK may allow the bleb to fibrose and the surgeon performing a large diameter graft may have difficulty avoiding the bleb when placing sutures. Our patients with pre-existing glaucoma on more than one IOP lowering medication undergo GDD implantation by the glaucoma service in our department prior to PK. The cornea surgeon should wait 6–8 weeks following this procedure to perform the PK in order to allow postoperative inflammation to quiet so as to not put the patient at increased risk for both tube closure and graft rejection.

4.1.9.5 Post-Keratoplasty Astigmatism

Cornea transplantation is now considered a two-stage procedure. The first stage is the actual cornea transplant itself. The second stage involves the correction of any postoperative irregular astigmatism. Postoperative astigmatism is the most common complication of PK.

Multiple factors affect the cylindrical component of the refraction. The tensions of each interrupted suture acts as an independent vector on the central corneal curvature. Interrupted sutures act by causing local flattening and central steepening. The cylindrical spectacle prescription is the vector sum of forces acting on the cornea and describes simple astigmatism, but often the cornea surface is more complex than this and irregular astigmatism is present. Irregular astigmatism is the most common postoperative factor limiting the best achievable spectacle-corrected acuity.

4.1.10 Correction of Post-keratoplasty Astigmatism

Surgical factors that lead to irregular astigmatism include suture tension, suture depth, suture length, suture radiality, and perhaps suture technique [1], although as mentioned above, some studies have not agreed that the suture technique makes much of a difference. It thus makes sense that the removal of a tight or abnormally placed suture would help decrease irregular astigmatism. Selective suture removal is the first method used postoperatively to improve visual acuity. The topography of the donor cornea is not stable until 4–8 weeks after surgery. The surgeon should wait until after this time to begin selective suture removal and we prefer to wait until 12 weeks postoperatively.

Topography helps to guide selective suture removal. Sutures are removed according to the steep topographic axis. The amount of effect from the removal of a single suture in any one meridian cannot be predicted. Typically there are an average of two to three diopters of flattening in the meridian of the removed suture, but this may vary and a much larger change may result [1]. Removal of one suture per postoperative visit allows more predictable adjustment and results in lower postoperative astigmatism when compared to multiple suture removal [1]. The changes usually occur immediately but there may be a continued adjustment in curvature over the ensuing weeks to months [1].

We currently place 24 interrupted 10-0 nylon sutures and begin selective suture removal at 3 months postoperatively according to topography maps.

Once all sutures have been removed and a patient has a residual amount of irregular post-keratoplasty astigmatism, the surgeon has a few options. The first option

is to attempt a RGP lens fit. If a patient is intolerant to the contact lens then the surgeon must find another way to correct the residual astigmatism. Reasons for contact lens intolerance include discomfort of the lens and poor manual dexterity such that the patient has difficulty inserting the lens. Other ways of correcting irregular astigmatism that the surgeon may entertain include wedge resections, relaxing incisions, relaxing incisions with compression sutures, and refractive surgery: laser assisted in situ keratomileusis (LASIK) or photorefractive keratectomy (PRK).

4.1.10.1 Wedge Resections and Compression Sutures

A flat cornea meridian can be steepened with wedge resections or compression sutures. Compression sutures can be placed across the graft–host junction in the flat meridian to cause steepening, but they also cause a compensatory flattening in the steep meridian. They are thus usually used with relaxing incisions. This method is not commonly used because suture materials degrade with time.

Cornea wedge resections can be performed for very high amounts of astigmatism, with the wedge being removed from the donor or the host. Increasing the width of the tissue resection leads to larger amounts of correction. Results can be unpredictable.

4.1.10.2 Relaxing Incisions

Relaxing incisions can be of the arcuate, transverse, or trapezoidal variety. They may be placed at the limbus, in the graft–host junction, or in the donor cornea. These incisions may steepen or flatten the corneal meridian depending on the procedure used [1]. The degree of correction is influenced by the incision depth, length, and proximity to the optical axis [1]. Advantages to relaxing incisions include a rapid return of vision and the procedure can be done at the slit lamp [1]. Results again can be unpredictable.

4.1.10.3 LASIK

LASIK has been successful in reducing post-keratoplasty astigmatism. Donnenfeld et al. have published a

case series of patients effectively treated with LASIK to correct post-keratoplasty astigmatism and myopia [7]. Holland et al. have described the use of post-keratoplasty LASIK to reduce astigmatism and myopia too [8]. Surgical planning for this procedure should not be done until all sutures are removed and most authors advocate waiting at least a year to ensure wound stability. One of the fears in this procedure is that of wound dehiscence during flap creation. For this reason, PRK may be considered the preferred refractive procedure.

4.1.10.4 Photorefractive Keratectomy with Mitomycin C

PRK over a cornea transplant has traditionally been thought of as less predictable than PRK for naturally occurring astigmatism and myopia [1]. Also, it has been associated with cornea haze and regression. Mitomycin C (MMC) is an antibiotic alkylating agent produced by the bacteria *Streptomyces caespitosus*. Its mechanism of action involves the inhibition of DNA synthesis thus affecting rapidly dividing cells and inhibiting the proliferation of fibroblasts and keratocytes [2]. MMC 0.02% has been shown to be effective in the prevention of subepithelial haze following PRK [2].

We have demonstrated that the application of MMC to the cornea for 10s following the refractive procedure eliminates cornea haze and we have not experienced a significant regression amongst our patients we have treated with PRK. A cohort of our patients with post-keratoplasty astigmatism experienced a 42.6% reduction in their spherical equivalent, a 38.8% reduction in manifest cylinder, and a 45.2% reduction in topographic cylinder (Table 4.1). Forty percent of our patients had an improvement in the UCVA and 33.3% had an improvement in the BCVA. All grafts have remained clear postoperatively.

For post-keratoplasty astigmatism, we prefer PRK with MMC as the procedure of choice.

4.1.11 Corneal Allograft Rejection

Corneal allograft rejection is the leading cause of graft failure [3]. A review of the literature shows a decline in the incidence of cornea graft rejection over the years, but the fact that it is still a relatively common occurrence demonstrates that we do not understand it completely [9]. Prompt recognition and treatment are essential in preventing graft failure.

Corneal graft rejection is defined as a complex immune-mediated process that results in decompensation of the transplanted cornea [9]. Billingham and Medawar coined the term “immune privilege” to convey the concept that the anterior segment was exempt from some forms of immune-mediated inflammation [9]. The idea that cornea transplants enjoy immune privilege is supported by the observation that keratoplasty is normally performed without HLA-matching and in the absence of systemically administered immunosuppressive drugs. As a result of these things, there is a common misconception that the immune privilege of the cornea is unconditional. This is very misleading. The immune privilege of corneal allografts is abolished in any condition in which inflammation, neovascularization, or trauma is elicited in the cornea [9]. Most keratoplasty patients, with the exception of those with KCN, have corneal graft beds that have lost their immune privilege due to preceding corneal inflammation, neovascularization, trauma, or infections [9]. Corneal immune privilege in these situations has been revoked and immunologic rejection becomes a major threat to the survival of the cornea transplant. As mentioned, immune rejection is the leading cause of graft failure [9].

Maumenee was the first to establish the immunological basis for corneal allograft rejection [10]. He demonstrated that the application of donor-specific skin grafts to rabbits 2 weeks prior to cornea transplantation resulted in accelerated corneal allograft rejection [10]. He also demonstrated that application of

Table 4.1 PRK with mitomycin C for post-keratoplasty astigmatism: results

	Preoperative	Postoperative	Percentage
Spherical equivalent	2.42D	1.03D	42.6
Manifest cylinder	3.35D	1.30D	38.8
Topographic cylinder	5.98D	2.70D	45.2
UCVA	20/184.7	20/53.2	40
BCVA	20/40.5	20/26.4	33.3
Graft clarity	All clear		
F/U time (month)	9.2 (range 1–34)		

donor-specific skin grafts to rabbits bearing successful cornea allografts induced a rejection in the previously clear grafts [10]. Khodadoust and Silverstein completed a series of studies in the late 1960s and mid-1970s that demonstrated that all three layers of the cornea transplant were independently able to undergo immunologic attack [11].

Since all three layers of the cornea allograft can undergo rejection independent of each other, cornea graft rejection can be classified. Panda et al. classified cornea graft rejection based on a review of the literature [3]. Cornea graft rejection was classified as epithelial rejection, chronic stromal rejection and hyperacute stromal rejection, endothelial rejection, combined stromal and endothelial rejection, and rejection in a repeat graft [3]. As such, corneal graft rejection is characterized by either the development of epithelial and or endothelial rejection lines, unilateral anterior chamber reaction with keratic precipitates, or an increase in cornea thickness in a previously clear graft with aqueous cells [3]. The process occurs at 10 days or more following a successful clear graft [3]. Prior to 10 days the process is termed primary graft failure.

4.1.11.1 Host Risk Factors

A number of factors have been found to increase the risk of immunologic rejection in PK. These include corneal stromal vascularization, prior graft loss, anterior synechiae, previous intraocular surgery, herpes simplex keratitis, ocular surface disease, young age, and a history of anterior segment inflammatory disease [1]. Large diameter grafts have traditionally been associated with an increased risk of graft failure secondary to proximity to the limbal vasculature, but we did not note this complication in our study of large diameter grafts.

4.1.11.2 Vascularized Corneas

The Collaborative Corneal Transplantation Studies (CCTS) defined “high risk” as a cornea with two or more quadrants of deep stromal vascularization [12]. In the CCTS, the risk of rejection was doubled in patients with stromal vascularization in all four quadrants [12]. The degree and depth of preoperative corneal vascularization determines the onset and severity of rejection [12]. The average time of onset to rejection

from time of surgery in one study was 10 months in avascular corneas, 4 months in mildly vascularized corneas, and 2 months in corneas that were heavily vascularized [1]. Polack observed that allograft rejections were more commonly observed in patients with deep stromal vascularization than those with superficial neovascularization [1]. Fine and Stein reported that rejection was reversible in only 50% of patients with vascularized corneas, compared to 66% of patients with avascular corneas [1].

4.1.11.3 Prior Graft Loss

Previous graft loss was defined as an independent risk factor by the CCTS for cornea graft rejection and failure [12]. In the CCTS, the number of previous grafts a patient had was a strong risk factor for graft failure, with each additional graft increasing the risk of graft failure by a factor of 1.2 [12].

4.1.11.4 Graft Diameter

Large-diameter grafts have been avoided by cornea surgeons in the past due to the concern that these grafts have a higher incidence of graft failure. Several studies have commented on an increased risk of graft rejection with large diameter grafts. In the CCTS, the smallest recipient trephine size, 6.5–8.0 mm was used [12]. Mader and Stulting reported corneal graft diameter as a risk factor in PK secondary to proximity to the limbal vasculature where there is more antigenic material [13]. Cowden, Copeland, and Schneider reported the use of LDPK as an eye-saving procedure only and stated that almost all would reject due to their large diameter [14]. They also listed LDPK as a predisposing risk factor for graft failure secondary to limbal proximity [14]. Cherry et al. (1979) found a positive correlation between graft size and allograft rejection [15]. Tuberville et al. [16] found no correlation between allograft reaction incidence and graft size ranging 7.0–8.0 mm [17].

Six patients of 34 in our study of large-diameter grafts experienced graft rejections, but no patient experienced a graft failure. Four of the 6 patients had documented compliance issues and failure to comply with the postoperative regimen led to a graft rejection episode. This stresses the importance of medication compliance and postoperative care following large diameter PK. When

performing LDPKs for any reason, compliance with the postoperative regimen as outlined by the surgeon should be emphasized preoperatively. Interestingly, no patient with a history of previous graft failure experienced a rejection episode in our study.

More recent studies have shown that graft rejection is statistically independent of the graft size [1].

4.1.11.5 Anterior Synechiae

Anterior synechiae may be present from previous anterior segment surgery or from prior chronic inflammation. In the CCTS, the failure rate from any cause doubled if the eye had three or four quadrants of anterior synechiae [12]. Direct contact of the graft with the host vascular system through the peripheral anterior synechiae is believed to put the host at an increased risk of graft failure [1].

4.1.11.6 Previous Intraocular Surgery

Previous intraocular surgery was associated in the CCTS with an increased risk of graft failure [12]. Anterior synechiae, neovascularization, chronic inflammation, and poorly controlled IOP following a previous surgery may be the mechanisms that make previous surgery a risk factor. Specifically, lensectomy, vitrectomy, and glaucoma procedures were the procedures identified as risk factors in this study [12].

4.1.11.7 Herpes Simplex

An increased risk of graft failure may be associated with recurrent HSV keratitis following PK [1]. The herpes simplex virus is endemic throughout the world with some studies estimating a prevalence of about 149/100,000 population [1]. Approximately half a million people in the United States have experienced the disease [1]. Primary infection usually occurs in childhood with seroconversion prevalence increasing with age [1]. Studies of human ganglia have found evidence of HSV infection in as many as 94% of specimens in humans older than 60 years of age [1], and the incidence of ocular HSV has been estimated to be six times higher in patients who have undergone corneal transplant for nonherpetic corneal disease [1]. Given the prevalence of the disease, even without a history of

HSV keratitis, a patient may be at risk for HSV corneal disease after a PK [1].

Cornea scarring is the reason a person would require a PK following HSV keratitis. Recurrent episodes of HSV epithelial keratitis and more commonly recurrent stromal keratitis can cause significant scarring that requires PK for visual rehabilitation [18]. Cornea scarring as a consequence of viral keratitis has declined as an indication for PK over the past five decades [19]. During the 1950s viral keratitis was among the most common indications for corneal transplant [19]. In the 1990s referral centers reported a marked decline in the number of PKs being performed for viral keratitis [19]. The main reason for the decline is probably related to improvements in the medical management and early diagnosis of HSV keratitis [19]. Corneal scarring from HSV keratitis accounts for about three percent of PKs performed [20].

Because the majority of the population carries herpes simplex virus in a latent phase, reactivation of HSV after PK can occur [21]. As mentioned, even without a history of HSV keratitis, a person is at risk for HSV corneal disease after a PK. Recurrent HSV keratitis puts the patient at risk for scar formation in the graft, allograft rejection, and graft failure. The innervation density of the corneal epithelium is 300–600 times that of skin, and cornea nerve disruption during a PK is believed to be a stimulus for HSV reactivation [20]. Indeed, cornea incisions from radial keratotomy (RK) and PK have been shown to induce the shedding of HSV [20]. Corticosteroids may also increase the incidence of reactivation of HSV [20]. The survival rate of cornea grafts performed for HSV keratitis have been cited to range from 60.4 to 80% with the prophylactic use of acyclovir [20].

Viral reactivation can occur in either the early or late postoperative period following PK. Reactivation of a latent HSV infection is the most likely cause for HSV keratitis in patients who had PK without a previous history of HSV but the possibility of transmission of virus through the donor cornea should also be considered [21]. Sometimes the clinical diagnosis of HSV keratitis after a PK may be difficult. The presentation of a HSV epithelial defect may be nondendritic and the HSV keratouveitis and stromal keratitis with edema can be confused with graft rejection. Diagnostic testing for HSV-1 is not very sensitive and a single culture often results in false negatives. The possibility of HSV keratitis must always be considered after PK when an epithelial defect does not respond to standard treatment,

even in patients with no known history of HSV keratitis. One study reported on the common signs and symptoms seen in their patient population with HSV keratitis recurring in the graft [1]. A geographic ulcer or nonhealing epithelial defect was seen in 57% of patients [1]. Forty-three percent of patients had a classic dendrite [1]. Of these patients with epithelial involvement, 36% had involvement of both the host and donor corneas [1]. Seventy-nine percent of patients were symptomatic at the time of diagnosis with 36% reporting pain or discomfort, 29% with visual complaints, and 14% with both discomfort and visual complaints [1].

Herpetic infection can involve not only the epithelium but also the endothelium and stroma as well [22]. Transmission electron microscopy has demonstrated viral particles in the keratocytes and endothelial cells of corneal grafts with postoperative necrotizing stromal keratitis [1].

The diagnosis of ocular HSV is usually clinical and the classification should be based on the one proposed by Holland and Schwartz [22]. Briefly, epithelial disease is infectious and related to active viral replication. Epithelial disease presents as grouped vesicles, geographic ulcers, or a classic HSV dendrite. Stromal disease can be infectious as in necrotizing stromal keratitis, or noninfectious as in immune stromal keratitis which is solely inflammatory and not related to active viral replication. Endothelial disease, or endotheliitis, is usually inflammatory as well. The diagnosis of recurrent ocular HSV after a PK must always be kept in mind because of the difficulty in distinguishing recurrent HSV from a graft rejection episode.

Prophylactic antiviral therapy has been used to prevent the recurrence and relapse of herpetic keratitis after corneal transplantation. Systemic or topical acyclovir therapy used prophylactically over a period of 1 year has been found to effectively decrease the recurrence rate of HSV keratitis and improve the graft survival rate [23]. The dose of 400 mg given twice daily is typically prescribed. The efficacy of systemic and topical acyclovir as a prophylactic agent was first studied for herpetic genital and labial infections where it was found to reduce the frequency and severity of recurrences of HSV infections [23]. Although acyclovir cannot prevent recurrent episodes completely, it does prolong the recurrence-free interval and reduces the duration of herpetic disease [23]. A recurrence rate of 15% has been reported in a cohort of patients taking systemic acyclovir [23]. A study compared oral acyclovir to oral valacyclovir in the prevention of recurrent

HSV keratitis and found them comparable [23]. Oral valacyclovir has a more comfortable dosing regimen.

The cornea surgeon performing cornea transplantation must be vigilant regarding the diagnosis of a possible herpetic keratitis in patients with a history of HSV keratitis as well as patients without a remarkable history of it. In patients that have a history of HSV disease, prophylactic antiviral therapy in the form of acyclovir or valacyclovir should be used for a minimum of 1 year post-PK and possibly for the patient's lifetime. We prefer systemic agents to topical ones in order to limit medication toxicity on the donor epithelium. Patients with a history of viral keratitis should not undergo cornea transplantation until the eye has been recurrence free for a minimum of 6 months to 1 year.

4.1.12 Treatment of Allograft Rejection

For an endothelial rejection, the patient is placed on topical prednisolone every 1 h while awake along with oral prednisone (1 mg/kg/day). This dosing regimen is maintained for 1 week and if the rejection episode has been treated successfully, the topical steroid dose is tapered very slowly to four times per day and then maintained at this dosage over a 3–4-month period before tapering it down to a maintenance dose of one more drop per day than what the patient had been using when the rejection episode occurred. If the patient had been on topical loteprednol (Lotemax, Bausch and Lomb) at the time of the rejection episode, a switch is made to topical prednisolone and dosed as outlined above. When the patient has demonstrated adequate resolution of the rejection episode, and following the slow taper of prednisolone, the surgeon may choose to switch the patient back to loteprednol at a higher dosing frequency than was being used prior to development of the rejection episode. Topical loteprednol has advantages over prednisolone in a phakic patient in that it has not been cited in the literature to cause cataract. Loteprednol also has an associated lower incidence of an IOP rise. Holland has demonstrated an 8% risk of an IOP increase in known steroid responders using prednisolone following cornea transplantation compared to a less than 1% increase in those known steroid responders using loteprednol [24].

For stromal involvement, treatment is the same as outlined for endothelial rejection. If an epithelial rejection line is present, without stromal or endothelial

involvement, the patient is placed on topical prednisolone every 1 h without the oral agent.

4.1.13 Large Diameter Penetrating Keratoplasty

As mentioned above, the authors prefer a large diameter technique. LDPKs have been avoided by other cornea surgeons due to the concern that these grafts have a higher incidence of graft failure. Our study did not find this to be true. The potential advantages of

LDPK include the excision of the inciting pathology that may be located in the periphery, and reduced postoperative astigmatism.

In cases of corneal ectasia (PMD and some cases of KCN), the pathology extends in the far peripheral cornea. Smaller central grafts fail to excise the peripheral pathology and result in poor outcomes. Therefore in these cases, LDPKs may be the preferred procedure.

Retrospective chart reviews of our patients that have undergone LDPK have demonstrated superior astigmatism results with improved best corrected (BCVA) and UCVA postoperatively. The preoperative average BCVA was 20/100 (range 20/25 – HM, Table 4.2), and

Table 4.2 Results of LDPKs in 35 Patients

Eye	Age	Indication for PK	Prep BCVA	Postoperative refraction	Final BCVA	F/U (months)	Donor size	Suture in/out	Graft status
1	83	KCN	20/200	-1.50 + 2.75 × 180	20/70	14	8.75/8.75	In	Clear
2	55	KCN	20/400	None	20/50	20	9.5/9.5	In	Clear
3	83	Failed PK	20/400	-1.00 + 0.75 × 14	20/60	20	10.0/9.5	In	Clear
4	56	KCN/PMD	20/160	-4.00 + 1.25 × 157	20/20	21	9.5/9.5	Out	Clear
5	34	KCN	20/200	Plano	20/20	51	10.0/10.0	–	Lost to F/U
6	81	Failed PK	HM	+1.25 + 4.75 × 23	20/125 ^a	22	9.5/9.5	–	Clear
7	39	KCN/PMD	20/40	+0.50 + 1.75 × 43	20/25	14	10.0/10.0	–	Clear
8	56	RK	20/40	+0.25 + 2.50 × 60	20/30	32	9.5/9.5	–	Clear
9	52	KCN	20/200	-3.25 + 100 × 125	20/30	18	10.0/10.0	In	Clear
10	27	KCN	20/80	-1.75 + 2.75 × 155	20/30	23	8.75/8.75	In	Clear
11	37	PMD	20/200	-1.50 + 4.25 × 007	20/125	20	9.5/9.5	In	Clear
12	49	FUCHS	20/40	-0.50 + 2.00 × 30	20/25	20	9.0/9.0	In	Clear
13	44	Failed PK	20/70	-0.50 + 2.25 × 75	20/25	40	8.75/8.75	In	Clear
14	45	KCN	20/200	+4.25 + 1.25 × 140	20/25	37	9.0/9.0	Out	Clear
15	64	KCN	20/400	-0.50 + 2.75 × 69	20/40	13	9.25/9.25	In	Clear
16	25	KCN	20/200	-1.25 sphere	20/25	33	9.0/9.0	In	Clear
17	64	KCN	20/200	-1.50 + 0.75 × 32	20/25	91	8.75/8.75	Out	Clear
18	64	KCN	20/250	None	20/30	81	8.75/8.75	In	Clear
19	29	KCN/PMD	20/60	-1.50 + 3.50 × 165	20/20	50	10.0/10.0	Out	Clear
20	29	KCN/PMD	20/50	-4.00 sphere	20/20	75	10.0/10.0	Out	Clear
21	41	KCN	20/100	None	20/40	14	–	In	Clear
22	38	KCN	20/25	None	20/25	16	9.0/9.0	In	Clear
23	36	KCN	20/60	-2.50 + 3.75 × 100	20/25	22	9.0/9.0	In	Clear
24	42	PMD	20/300	-1.75 + 2.00 × 58	20/30	51	9.5/9.5	In	Clear
25	50	Failed PK	20/60	Pl + 5.00 × 165	20/25	12	9.5/9.5	In	Clear
26	40	KCN	20/30	+4.75 + 0.75 × 70	20/20	19	9.0/9.0	In	Clear
27	52	KCN/PMD	20/200	-3.25 + 1.00 × 125	20/20	18	10.0/10.0	In	Clear
28	33	KCN	20/30	-0.50 + 2.75 × 155	20/25	14	9.0/9.0	In	Clear
29	39	RK	20/40	-1.25 + 2.00 × 44	20/70	12	9.0/9.0	In	Clear
30	37	KCN	20/40	-1.25 + 1.50 × 175	20/25	38	9.5/9.5	In	Clear
31	44	KCN	20/30	+1.75 + 1.25 × 43	20/20	45	8.75/8.75	In	Clear
32	49	Failed PK	20/200	+0.50 + 4.00 × 100	20/30	17	9.5/9.5	In	Clear
33	62	KCN	20/80	-0.75 + 2.00 × 92	20/40	22	8.75/8.75	Out	Clear
34	56	KCN	20/30	-2.00 + 2.00 × 139	20/30	24	9.0/9.0	In	Clear
35	62	SCAR	20/160	+1.00 + 3.50 × 150	20/40	23	8.75/8.75	In	Clear

KCN keratoconus; PMD pellucid marginal degeneration; RK radial keratotomy; PK penetrating keratoplasty

^aOptic nerve pallor

the postoperative BCVA was 20/32 (range 20/20 to 20/125, Fig. 4.11). Postoperatively, 43% of patients had 20/40 or better UCVA (Fig. 4.12). Average postoperative manifest cylinder was +2.19D (range 0 to +4.75D, Fig. 4.13) with 77% of patients having less than +3.00D of cylinder. Our results did not indicate a higher rate of graft failure (Fig. 4.14)

4.1.14 Summary

Proper patient education and follow through pre- and postoperatively is important to maintaining a healthy transplant. Patients must be instructed to call with any of the warning signs of a graft rejection. These include redness, irritation or pain, decreased vision, and

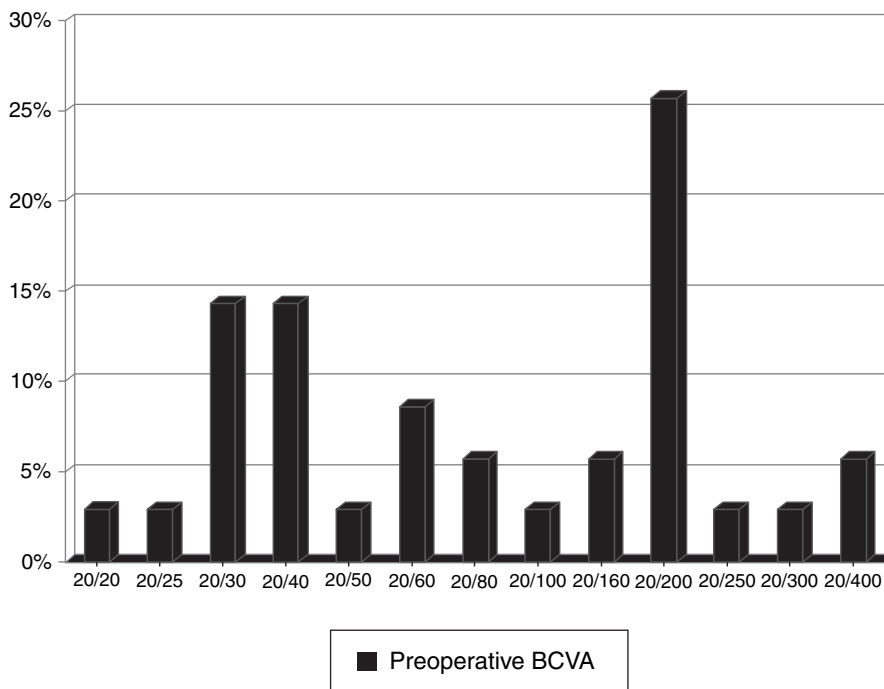


Fig. 4.11 Preoperative best corrected visual acuities of patients that underwent LDPK

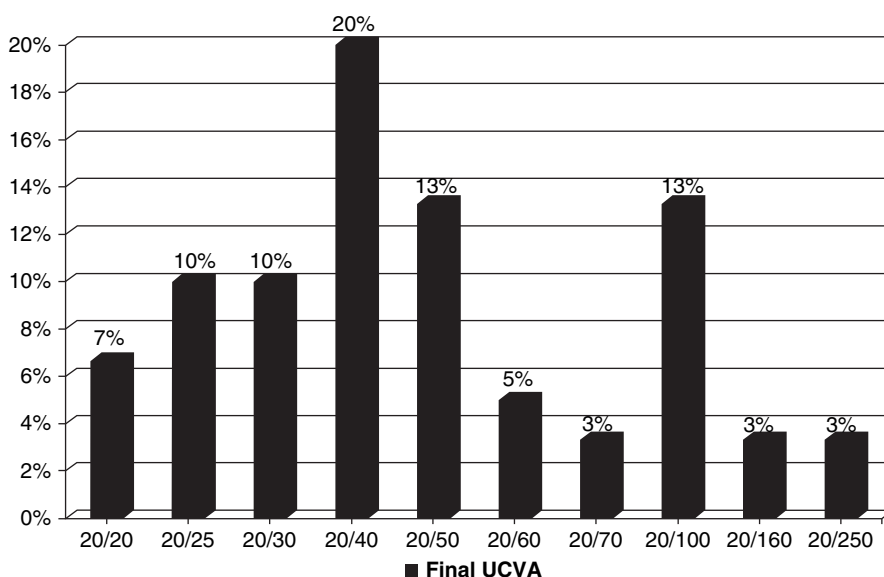


Fig. 4.12 Postoperative UCVA following LDPK

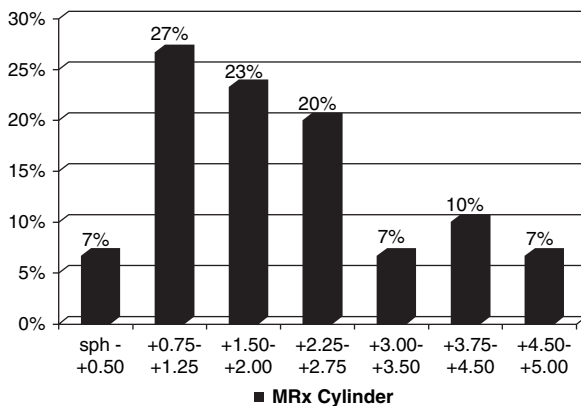


Fig. 4.13 Postoperative manifest cylinder following LDPK

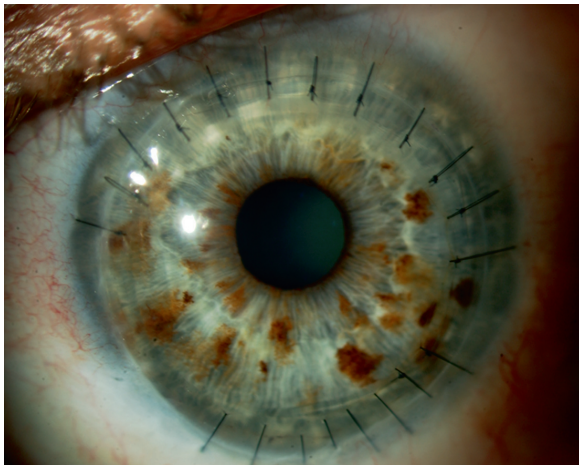


Fig. 4.14 LDPK with partial suture removal. Photo courtesy of Edward J. Holland

sensitivity to light. Patients must also be informed of the importance in medication use as prescribed and in keeping all follow-up visits. As mentioned, these discussions should be made preoperatively so that proper decision can be made by both the surgeon and the patient on whether to proceed with cornea transplantation. Cornea transplantation can be a very rewarding procedure if the surgeon and the patient are meticulous with respect to follow-up care and medication use. With practice, a good cornea transplant surgeon can obtain great visual results improving the quality of their patient's vision, as well as the quality of their lives [25].

References

1. Krachmer JH, Mannis MJ, Holland EJ (2005) Cornea. Elsevier Mosby, Philadelphia
2. Carones F, Vigo L, Scandola E et al (2002) Evaluation of the prophylactic use of mitomycin-C to inhibit haze formation after photorefractive keratectomy. *J Cataract Refract Surg* 28:2088–2095
3. Panda A, Vanathi M, Kumar A et al (2007) Corneal graft rejection. *Surv of Ophthalmol* 52:375–396
4. Javadi M, Naderi M, Zare M et al (2006) Comparison of the effect of three suturing techniques on postkeratoplasty astigmatism in keratoconus. *Cornea* 25:1029–1033
5. Dada T, Aggarwal A, Vanathi M et al (2008) Post-penetrating keratoplasty glaucoma. *Indian J Ophthalmol* 56:269–277
6. Raiskup-Wolf F, Hoyer A, Spoerl E et al (2008) Collagen cross-linking with riboflavin and ultraviolet-A light in keratoconus: long-term results. *J Cataract Refract Surg* 34: 796–801
7. Donnenfeld E, Kornstein H, Amin A et al (1999) Laser in situ keratomileusis for correction of myopia and astigmatism after penetrating keratoplasty. *Ophthalmology* 106: 1966–1974
8. Malecha MA, Holland EJ (2002) Correction of myopia and astigmatism after penetrating keratoplasty with laser in situ keratomileusis. *Cornea* 21:564–569
9. Niederkorn JY (2007) Immune mechanisms of corneal allograft rejection. *Current Eye Res* 32:1005–1016
10. Maumenee A (1951) The influence of donor-recipient sensitization on corneal grafts. *Am J Ophthalmol* 34:142–152
11. Khodadoust AA, Silverstein AM (1969) Transplantation and rejection of individual cell layers of the cornea. *Invest Ophthalmol* 8:180–195
12. CCTS Research Group (1992) The collaborative corneal transplantation studies. *Arch Ophthalmol* 110:1392–1403
13. Mader T, Stulting D (1991) The high-risk penetrating keratoplasty. *Ophthalmol Clin North Am* 4:411–422
14. Cowden J, Copeland R, Schneider M (1989) Large diameter therapeutic penetrating keratoplasties. *J Refract Corneal Surg* 5:244–248
15. Cherry PMH, Pashby RC, Tadros ML et al (1979) An analysis of corneal transplantation. *Ann Ophthalmol* 11:461–469
16. Tuberville AW, Foster CS, Wood TO (1983) The effect of donor cornea epithelium removal on the incidence of allograft rejection reactions. *Ophthalmology* 90:1351–1356
17. Settee R, Korean M, Anand D et al (2008) Intakes in advanced keratoconus. *Cornea* 27:1022–1029
18. Ghosh S, Jhanji E, Taylor H et al (2008) Acyclovir therapy in prevention of recurrent herpetic keratitis following penetrating keratoplasty. *Am J Ophthalmol* 145:198–202
19. Branco B, Gaudio P, Margolis T (2004) Epidemiology and molecular analysis of herpes simplex keratitis requiring primary penetrating keratoplasty. *Br J Ophthalmol* 88: 1285–1288
20. Reinhardt T, Kalgan C, Cetin A (1997) The influence of glaucoma history on graft survival after penetrating keratoplasty. *Greases Arch Clin Exp Ophthalmol* 235:553–557
21. Borderie V, Meritet J, Chaumeil C et al (2004) Culture-proven herpetic keratitis after penetrating keratoplasty in patients with no previous history of herpes disease. *Cornea* 23:118–124

22. Holland EJ, Schwartz GS (1999) Herpes simplex virus keratitis classification and treatment. *Clinical Signs Ophthalmol* 14:1–19
23. Goldblum D, Bachmann C, Tappeiner C et al (2008) Comparison of oral antiviral therapy with valacyclovir or acyclovir after penetrating keratoplasty for herpetic keratitis. *Br J Ophthalmol* 92:1201–1205
24. Holland EJ (2003) In post-keratoplasty patients: a safer alternative to prednisolone? Data on file, Bausch & Lomb pharmaceuticals

4.2 Descemet's Stripping Endothelial Keratoplasty

4.2.1 Introduction

Endothelial cornea dysfunction has previously been treated with full thickness cornea transplantation. Fuchs endothelial dystrophy, pseudophakic bullous and aphakic bullous keratopathy are conditions that are the results of endothelial dysfunction.

Pseudophakic bullous keratopathy remains the leading indication for keratoplasty [1, 2]. Fuchs endothelial dystrophy is a very common indication for cornea transplant as well, with an incidence falling just behind regrant and keratoconus [1]. Fuchs endothelial dystrophy demonstrates clinical signs that range from asymptomatic cornea guttata to a decompensated cornea with stromal edema, subepithelial fibrosis, and epithelial bullae. Onset of the condition is typically after the age of 50 and there is a female preponderance. Some cases may be sporadic but others demonstrate autosomal dominant transmission [3].

Histopathological analysis of excised corneal buttons of patients with clinically diagnosed Fuchs dystrophy demonstrates thickening of Descemet's membrane, multiple guttata of varying size and shape, and attenuation of the corneal endothelium [4]. Guttata are focal excrescences of altered basement membrane material synthesized by abnormal endothelial cells [5]. The histopathological changes are noted in the central cornea and underlay areas of clinical edema. The peripheral cornea is usually clear clinically and shows little histologic change [4].

Clinically, Fuchs dystrophy progresses slowly over a period of 20 or more years with the patient first developing asymptomatic cornea guttata and later developing corneal edema with decreased vision and pain [6]. Symptoms usually do not appear until middle age but some pathologic studies have suggested abnormalities in endothelial function occurring early in life [6].

Traditionally, PK was the only surgical procedure available for the correction of endothelial dysfunction. Full-thickness keratoplasty for endothelial dysfunction is complicated by the same issues that complicate PK. High astigmatism, suture-related problems, and ineffective wound healing are some of these [7]. When only the posterior layers of the cornea are diseased, it

no longer makes sense to replace the entire thickness of the cornea. Melles first described a technique of posterior lamellar keratoplasty in 1999 in which he advocated the transplantation of posterior corneal tissue for endothelial dysfunction [7]. In his technique, the recipient and donor corneas were manually dissected at 80–90% stromal depth, excising the posterior recipient stroma and endothelium with a trephine and scissors, and inserting a donor button through a scleral incision [7]. He advocated the procedure in cases of endothelial dysfunction, citing that “less surgical time, less risk of intraoperative complications, less risk of high astigmatism, faster visual recovery, less frequent follow-up visits for selective suture removal, elimination of suture-induced vascularization toward the graft, and less risk of wound dehiscence” [7]. He later described a technique in 2004 for excision of only the Descemet membrane and the endothelial cell layer without incisions being made in the posterior corneal stroma [8]. This technique would enable a quicker and less traumatic preparation of the recipient stromal bed [8]. The stroma is usually not affected in cornea endothelial dysfunction and thus it is not necessary to involve the stroma in the dissection. Melles thus described the technique of Descemet’s stripping [8]. Descemet’s stripping endothelial keratoplasty has replaced full thickness cornea transplantation as the procedure of choice for cornea endothelial dysfunction. The indications for DSEK have expanded to include those listed above as well as corneal edema associated with iridocorneal endothelial syndrome (ICE) and to restore clarity to a failed prior penetrating graft [9].

In 2005, 4.5% of the donor corneas transplanted in the US were used for endothelial keratoplasty [9]. In 2006, this number jumped to 45% of tissue requests [9]. DSEK patients regain vision sooner, have minimal to

no refractive shift postoperatively, and have an eye that is structurally more sound [9]. It is for these reasons that cornea transplant surgeons are now performing DSEK as opposed to full-thickness keratoplasty.

4.2.2 Descemet’s Stripping Endothelial Keratoplasty Surgical Technique

Instrument list

1. Trephines 8.0, 8.5, 9.0 mm
2. Moria CB microkeratome (if not using pre-cut tissue)
3. 300 and 350 micrometer heads for microkeratome
4. Artificial anterior chamber (if performing manual donor dissection)
5. DORC dissection blades (three curved blades)
6. Paracentesis blade
7. 2.75 Millimeter keratome (for clear cornea incision)
8. Crescent blade (for scleral tunnel incision)
9. Reverse Sinskey hook
10. Descemet’s stripping instrument (Fig. 4.15)
11. Irrigation/Aspiration handpiece and Phaco unit
12. Inserting forceps (Kelman-McPherson, Goosey, Charlie)
13. Tuberculin syringes (one with air + cannula, one with BSS + cannula, one with air + 27- or 30-gauge needle)
14. Needle holder
15. Tying forceps

The donor cornea is prepared first, followed by surgery on the recipient. It is the author’s preference to use pre-cut tissue from an eyebank. This eliminates the step of donor preparation.



Fig. 4.15 Descemet’s scraper

4.2.2.1 Donor Cornea Preparation

The technique of donor cornea preparation has been described by Price and Price [10]. In manual donor dissection, a corneoscleral rim is mounted on an artificial anterior chamber (AC) and the chamber is inflated with air or BSS. The tissue is dissected at about 90% stromal depth using a series of three curved blades (DORC International, Zuidland, The Netherlands) [10]. Automated dissection is performed using a Moria CB microkeratome (Moria, Doyleston, PA) and either a 300- or a 350- μm head depending on central corneal pachymetry less than or greater than 570- μm [10]. After dissection, the donor is transferred to a cutting block and placed endothelial side up. An 8-, 8.5-, or 9-mm-diameter trephine is used to punch a central corneal button. The button is maintained on the cutting block and covered until ready for use.

4.2.2.2 Host Cornea Preparation

The patient is brought to the operating suite after informed consent has been obtained. Anesthesia is a retrobulbar block (RBB) in most cases. The surgery may be performed under topical monitored anesthesia as well [9]. Attention is directed temporally on the patient and an 8-, 8.5-, or 9 mm trephine is used to mark the recipient corneal epithelium to outline the area from which Descemet's membrane is to be removed. Typically the same trephine needed for donor preparation is used. A paracentesis site is made temporally on the recipient with a paracentesis blade. Additional paracenteses are placed around the limbus at locations that will permit the entry of instruments to allow adjustment of the donor graft following placement. The gentian violet marker is used to mark the paracentesis blade so as to make identification of the paracenteses easy. The anterior chamber is filled with viscoelastic (Healon, Advanced Medical Optics, Irvine, CA) to deepen and maintain it. A 5-mm clear corneal temporal incision is made, or a scleral tunnel of the same length is created to minimize induced astigmatism. Descemet's membrane is scored along the previously marked epithelial tract using a modified Sinskey hook. Descemet's membrane and endothelium are removed from within the scored area using a Descemet's stripping instrument to loosen the membrane in the 3 o'clock position and pull it toward the incision at the 9 o'clock position. The peeled Descemet's membrane is removed from the eye and

laid out across the cornea to ensure it was removed in entirety. The irrigation/aspiration handpiece is then used to remove the remaining viscoelastic from the anterior chamber so that the graft will adhere well.

4.2.2.3 Insertion of the Donor Cornea

The donor cornea is brought onto the operative field on the cutting block and a small amount of Healon is placed on the endothelial surface to protect the endothelium during the folding process. The donor tissue is folded using a forceps (Kelman-McPherson [Katena], Goosey [Moria], or Charlie [Bausch & Lomb]), or any of the surgeon's choice into a taco or a burrito shaped configuration. The cornea cap is discarded. The edge of the 5 mm cornea or scleral incision is grasped and lifted with a toothed forcep to aid insertion of the tissue. The tissue is inserted into the AC stromal side up and air is injected through the paracentesis to unfold the donor tissue and press it up against the recipient cornea. The cornea/scleral incision is sutured with 10-0 nylon suture, and the knots are buried. If needed, a 27- or 30-gauge needle with the tip bent with the needle holder and on a tuberculin syringe, can be inserted into the AC to aid proper positioning of the donor tissue. Care is taken to only grasp the stromal edge of the tissue so as to not damage any endothelial cells. When the surgeon is happy with the placement of the graft, the AC is filled with air for 10 min, followed by an exchange of air for BSS. Enough air is maintained in the AC so as to clear the inferior pupil when the patient is in an upright position. A drop of Vigamox (Alcon, Fort Worth, TX) is instilled in the eye. The patient is taken to the recovery room and will lay face up in the recovery room for 30 min to 2 h in order to allow the air to be in contact with the donor cornea and further promote adhesion. We prefer 2 h.

4.2.3 Postoperative Medications

Postoperatively, the authors prefer a combination of topical steroid and cyclosporin A as described earlier for PK. In general, topical prednisolone is prescribed 4–8 times daily for an average of 2–3 months postoperatively. The prednisolone is tapered by one drop per month until a dose of once daily is obtained. At that time, if the patient is phakic and has experienced no

rejection episodes or developed an IOP steroid response, the topical steroid is changed to loteprednol (Lotemax, Bausch & Lomb, Tampa, FL) one to two times per day. The patient is maintained on a minimum of one drop per day for at least 1 year. All patients receive topical cyclosporine A (Restasis, Allergan, Irvine, CA) twice a day for at least 1 year postoperatively. Many patients may remain on topical immunosuppressive medication for an indefinite time period.

4.2.4 Donor Dislocation Risks

Graft dislocation is a complication of DSEK. It is known as the most common postoperative challenge [11]. The incidence of donor detachment of the graft typically is higher when the surgeon performs his or her first DSEK cases. Price and Price described their experience with donor dislocation in the first 200 eyes in which they performed DSEK [11]. The rate of donor dislocation decreased inversely with the number of cases performed [11]. Others have cited similar results with dislocation rates in the literature ranging anywhere from 1 to 25% and higher [11–13]. Risk factors for graft dislocation include the entrapment of fluid between the donor and recipient corneas and rubbing the eye [9]. Techniques to reduce interface fluid have been described by Price and Terry and include the placement of fenestrations in the mid-peripheral recipient cornea to provide a pathway for fluid to exit, the use of a LASIK roller to massage the corneal surface to facilitate removal of entrapped fluid, and scraping the peripheral recipient cornea bed to allow for donor edge adhesion [9]. O'Brien et al. reported that donor dislocation after DSEK is more common in eyes without an intact lens/iris diaphragm, and/or that underwent extensive tissue manipulation during surgery [12].

4.2.5 Repositioning Donor Tissue

When a clear space can be detected on postoperative slit lamp exam between the donor and recipient tissue, the donor graft has become detached from the recipient. Most donor dislocations are noted within the first week to several weeks following surgery [11, 13]. Stromal edema is visualized over the area of dislocation and the patient's vision is often decreased from expected. It is

necessary at this point to reattach the donor tissue. This may be performed in a minor surgery room. The patient is taken to the minor surgery room and laid flat under the operating microscope. Using sterile technique and a 30-gauge needle on a tuberculin syringe, the AC is filled again with air in exchange for anterior chamber fluid. The donor graft is pressed into approximation with the host stroma. The AC is maintained again at a 100% air fill for 10 min. The air is then exchanged for BSS as described in the surgical technique above so that the air bubble in the AC will clear the inferior pupil border when the patient sits upright so as to prevent pupillary block. The patient is maintained in the face up position as described previously for 30 min to 2 h to allow good donor–host apposition.

4.2.6 Treatment of Rejection Episodes

Endothelial graft rejection is a concern with DSEK. Signs of immunologic rejection at the initial diagnosis include keratic precipitates, diffuse corneal edema, and a combination of both [14]. Epithelial and anterior stromal immunologic reactions are not a concern because these are not transplanted in DSEK [14]. If a rejection episode is confirmed or suspected, the patient is placed on topical prednisolone every 1 h while awake along with oral prednisone (1 mg/kg/day). This dosing regimen is maintained for 1 week and if the rejection episode has been treated successfully, the topical steroid dose is tapered very slowly to four times per day and then maintained at this dosage over a 3–4-month period before tapering it down to a maintenance dose of one more drop per day than what the patient had been using when the rejection episode occurred. If the patient had been on topical loteprednol (Lotemax, Bausch & Lomb) at the time of the rejection episode, a switch is made to topical prednisolone and dosed as outlined above. When the patient has demonstrated adequate resolution of the rejection episode, and following the slow taper of prednisolone, the surgeon may choose to switch the patient back to loteprednol at a higher dosing frequency than was being used prior to development of the rejection episode. Topical loteprednol has advantages over prednisolone in a phakic patient in that it has not been cited in the literature to cause cataract. Loteprednol also has an associated lower incidence of an IOP rise. Holland showed an 8% risk of an IOP

increase in known steroid responders using prednisolone following cornea transplantation compared to a less than 1% increase in those known steroid responders using loteprednol.

Most cases of endothelial graft rejection clear. One study cited a 7% graft failure rate following a graft rejection episode. The patient can be successfully regrafted with DSEK [14].

4.2.7 Visual and Refractive Outcomes

The recovery of useful vision following DSEK occurs usually within weeks [15]. This is in contrast to traditional PK where it may take up to 12 months or longer to achieve a satisfactory visual acuity when large diameter PK is not used. As described in “PK,” post-PK astigmatism is the most common complication of the full-thickness transplant. As mentioned, PK is considered to be a two step procedure with the first step being the actual cornea transplant itself, followed by a second step that involves correction of the resultant astigmatism. DSEK has been shown to be a “refractive neutral” cornea transplant [15]. Visual and refractive outcomes of the first 50 cases of a single surgeon were analyzed and mean manifest cylinder as well as mean manifest spherical equivalent were unchanged from preoperative values [15]. Furthermore, at 6 months post DSEK, 62% of patients had $\geq 20/40$ BCVA and 76% had $\geq 20/50$ BCVA [15]. Koenig et al. reported a 6-month postoperative BCVA of 20/40 or better in 61.8% of their patients [16].

A hyperopic shift of less than 0.50D has been reported by Price and Price [11], while Koenig et al. reported a hyperopic shift of 1.19 ± 1.32 D [16]. Our patients have experienced a hyperopic shift similar to that reported by Koenig. For this reason, when implanting an IOL for a concurrent cataract removal at the time of DSEK, the surgeon should consider implanting an IOL with a refractive error of -1 D.

4.2.8 Other Complications

Pupillary block is a potential complication of DSEK. A large amount of air in the anterior chamber can block the flow of aqueous through the pupil and out

the trabecular meshwork. Air that fills the anterior chamber can block the pupil when the patient is in the supine position, but if the air bubble is such that it fills less than 50% of the chamber at the end of the procedure, when the patient sits up to eat or go to the bathroom, the air will be in mid-pupil position such that any supine position pupillary block will resolve. Taking care to leave only a 50% air fill at the end of the case, and having the patient sit upright after 2 h and prior to going home, to ensure that the inferior border of the air bubble clears the inferior pupillary margin, can help prevent pupillary block. Air may also become trapped behind the pupil, shallowing the anterior chamber, and pressing the iris against the endothelium leading to pupillary block. Dilation of the pupil postoperatively with phenylephrine and cyclogyl can add additional protection against pupillary block. If a patient presents with pupillary block due to trapped air, dilating drops should be administered and the patient should be laid back to allow the air to float into the anterior chamber. If this does not work, BSS can be injected into the anterior chamber at the slit lamp to deepen it and force the air from behind the iris. A Yag laser can also be used to make an iridotomy thus providing a channel for aqueous flow and relieving pupillary block. If the iris has been opposed to the endothelium for an extended period, adhesions may begin to form and the patient may need to be taken back to the operating suite to break the adhesions and deepen the anterior chamber. This should be done immediately to lower the IOP and to preserve endothelial cells.

Central retinal artery occlusion is a rare complication of DSEK. Compression of the retinal vasculature from the high IOP produced during the initial adhesion of the graft with the air bubble is the cause.

As mentioned, graft failure rates reported in the literature range from 0 to 29% with those cases requiring surgical reattachment of a dislocated donor disc having a higher rate of endothelial failure [12].

Endothelial cell loss following DSEK has been reported at 34% at the 6-month postoperative exam and remains stable for the first year [17].

4.2.9 Summary

It has been well established that DSEK surgery can preserve and restore the normal recipient cornea, while providing excellent visual acuity within an acceptable

time frame. The avoidance of full-thickness cornea incisions and sutures is a great advantage. Wound dehiscence with expulsion of intraocular contents is not a risk following DSEK. DSEK is associated with its' own complications however, and the cornea surgeon performing this procedure must be aware of how to deal with these potential complications. Full-thickness penetrating keratoplasty is no longer indicated for endothelial dysfunction. DSEK patients regain vision sooner, have minimal to no refractive shift postoperatively, and have an eye that is structurally more sound [9]. As with PK, the long-term success of DSEK will depend on an adequate number of viable endothelial cells in the donor corneal tissue. The most common cause of late PK graft failures is due to low endothelial cell counts [16]. The rapid visual recovery, low morbidity, and minimal effect on the anterior corneal curvature make DSEK the procedure of choice for endothelial dysfunction (Fig. 4.16a, b)

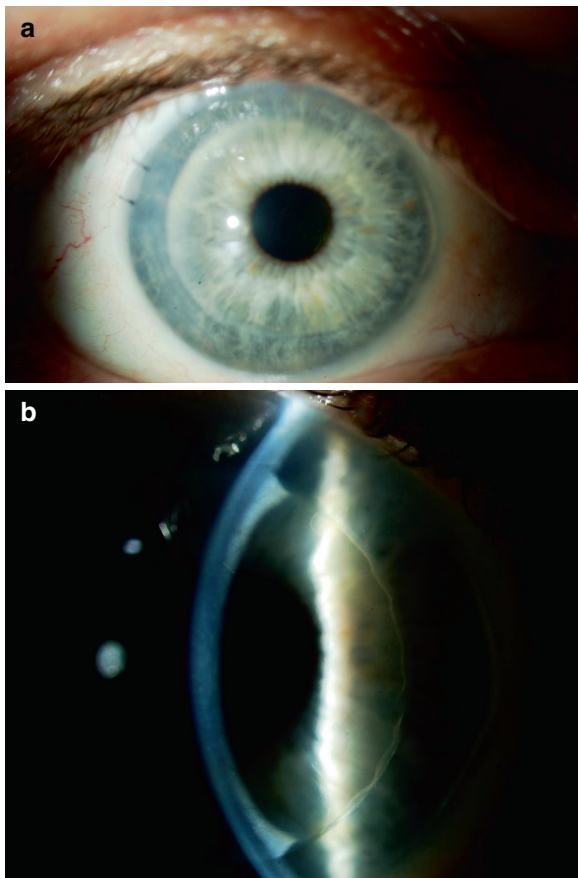


Fig. 4.16 (a, b) Postoperative photo of a DSEK patient. Courtesy of Edward J. Holland

References

1. Cosar C, Banu M, Sridhar M et al (2002) Indications for penetrating keratoplasty and associated procedures, 1996–2000. *Cornea* 21:148–151
2. Pahor D, Gracner B, Falez M et al (2007) Changing indications for penetrating keratoplasty over a 20-year period, 1985–2004. *Klin Monatsbl Augenheilkd* 224:110–114
3. Magovern M, Beauchamp G, McTigue J et al (1979) Inheritance of Fuchs combined dystrophy. *Ophthalmology* 86:1897–1923
4. Rodrigues M, Krachmer J, Hackett J et al (1986) Fuchs corneal dystrophy. A clinicopathologic study of the variation in corneal edema. *Ophthalmology* 93:789–796
5. Adamis A, Filatov V, Tripathi B et al (1993) Fuchs endothelial dystrophy of the cornea. *Surv Ophthalmol* 38:149–168
6. Wilson S, Bourne W (1988) Fuchs dystrophy. *Cornea* 7: 2–18
7. Melles G, Lander F, Beekhuis W et al (1999) Posterior lamellar keratoplasty for a case of pseudophakic bullous keratopathy. *Am J Ophthalmol* 127:340–341
8. Melles G, Wijdh R, Nieuwendaal C (2004) A technique to excise the descemet membrane from a recipient cornea. *Cornea* 23:286–288
9. Price M, Price F (2007) Descemet's stripping endothelial keratoplasty. *Curr Opin Ophthalmol* 18:290–294
10. Price M, Price F (2006) Descemet's stripping with endothelial keratoplasty. Comparative outcomes with microkeratome-dissected and manually dissected donor tissue. *Ophthalmology* 113:1936–1942
11. Price F, Price M (2006) Descemet's stripping with endothelial keratoplasty in 200 eyes. *J Cataract Refract Surg* 32: 411–418
12. O'Brien P, Lake D, Saw V et al (2008) Endothelial keratoplasty: case selection in the learning curve. *Cornea* 27: 1114–1118
13. Terry M, Shamie N, Chen E et al (2008) A simplified technique to minimize graft dislocation, iatrogenic graft failure, and pupillary block. *Ophthalmology* 115:1179–1186
14. Jordan C, Price M, Trespalacios R et al (2008) Graft rejection episodes after Descemet's stripping with endothelial keratoplasty: part one: clinical signs and symptoms. *Br J Ophthalmol* 93:387–390. doi:10.1136/bjo.2008.140020
15. Price F, Price M (2005) Descemet's stripping with endothelial keratoplasty in 50 eyes: a refractive neutral corneal transplant. *J Refract Surg* 21:339–345
16. Koenig S, Covert D, Dupps W et al (2007) Visual acuity, refractive error, and endothelial cell density six months after Descemet stripping and automated endothelial keratoplasty. *Cornea* 26:670–674
17. Terry M, Chen E, Shamie N et al (2008) Endothelial cell loss after Descemet's stripping endothelial keratoplasty in a large prospective series. *Ophthalmology* 115:488–496

4.3 Pterygium

4.3.1 Introduction

A pterygium has been defined as a triangular-shaped, elastotic degeneration of the conjunctiva, consisting of bulbar conjunctival epithelium and hypertrophied subconjunctival connective tissue, occurring medially and laterally in the palpebral fissure, and encroaching onto the cornea [1]. Epidemiological studies suggest an association with chronic exposure to sunlight, with an increased geographical prevalence in a “peri-equatorial pterygium belt” of latitudes 37° north and south of the equator [2]. The examination of more than 64,000 Aborigines and 40,000 non-Aborigines throughout rural Australia in the early 1980s demonstrated an increased prevalence of pterygium in Aborigines [3]. Furthermore, the pattern of pterygium prevalence was tested against UV zones with the lowest prevalence of pterygia seen in the lowest UV intensity zone and vice versa [3]. Aborigines live most of their lives outdoors with most of their communities having makeshift housing in surroundings of bare ground [3]. These findings help to demonstrate a strong correlation between UV irradiation and the prevalence of pterygium. Indeed, the UV type B light in solar radiation has been found to be the most significant environmental factor in pterygium pathogenesis [2].

Studies have recently demonstrated that a pterygium could possibly not be just a degenerative lesion, but the result of an uncontrolled cell proliferation [2]. The p53 tumor suppressor gene has been implicated and may be damaged by UV radiation-induced mutations, resulting in abnormal expression in pterygial epithelium [2]. Some have postulated that the human papillomavirus may be involved as well. Tseng et al. have speculated that a pterygium may in fact represent an area of localized limbal stem cell deficiency [2]. As will be discussed in surgical technique, a conjunctival autograft is a safe and effective means of reducing pterygium recurrence. One type of conjunctival autograft is the limbal-conjunctival autograft in which 0.5 mm of the limbus and peripheral cornea are transplanted with the conjunctival graft and aligned limbus to limbus over the scleral defect [4]. Some authors have cited a lower recurrence rate with this technique [4], furthering the idea that a pterygium may be the

result of a limbal dysfunction. Youngson noted in 1972 that loss of limbal integrity following the removal of a pterygium was one of the principal elements in the pathology of the recurrent condition [5]. At a time when the location and function of the limbal stem cells was not elicited, Youngson noted the importance of limbal integrity in the pathology of pterygium recurrence. He postulated that loss of limbal integrity leads to the inability to determine the demarcating change in epithelial type between the cornea and conjunctiva, and that without a limbal barrier, the corneal and conjunctival epithelial cells meet on the sclera remote from the limbus and begin to form an extracorneal pterygium that then grows toward the limbus [5]. While his concept of the pathogenesis of a recurrent pterygium may not be entirely accurate, it is important to note his realization of the involvement of the limbus.

In many parts of the developing world, where ophthalmic care is not so readily accessible, severe pterygium remains a cause of corneal blindness. Patients presenting with pterygia often complain that the pterygia are cosmetically unacceptable and/or that they have a constant foreign body sensation, a gritty sensation, or a chronically red, irritated eye. All of these are acceptable reasons for excision. Sometimes patients need to be ensured that pterygia are not cancerous growths. Indeed, there are case reports of carcinoma in situ and squamous cell carcinomas that mimic the appearance of pterygia, and the surgeon must always keep this in mind and remove any suspicious lesions to send to pathology for histopathologic diagnosis.

4.3.2 Treatment of Pterygium

The definitive treatment for a pterygium is surgical removal. While removal of a pterygium can seem relatively simple, the procedure can be very deceiving and recurrence rates can be high if the lesion is not removed properly. There are a variety of techniques available for surgical removal that may be employed, but each is associated with different recurrence rates and complications. Bare sclera technique, in which the pterygium is removed without associated adjunctive therapy, has a 30–80% recurrence rate [6]. Other procedures

performed include bare excision combined with adjunctive beta-irradiation, intraoperative or postoperative use of MMC, conjunctival autografting, and excision with amniotic membrane. The main goals of pterygium removal are to completely excise the pterygium and prevent its recurrence. Complications from the removal must be minimized as well, and thus there are numerous reports in the literature citing varying surgical techniques and their rates of associated recurrence and complications. We believe the technique of pterygium removal with conjunctival autograft over the bared sclera is the procedure that is associated with the lowest recurrence rate and has the least amount of complication. Recently, the use of a fibrin adhesive to secure the graft, as opposed to sutures, has decreased operating time and minimized pain and foreign body sensation postoperatively [7–9].

Instrument list

1. Lidocaine (2%) with epinephrine on 27- or 30-gauge syringe
2. Violet marking pen
3. Westcott scissor
4. Beaver blade
5. Toothed and non-toothed forceps
6. Fine-tipped needle holder
7. Tissell fibrin glue kit
8. Lieberman lid speculum

4.3.3 Surgical Technique

The patient is brought to the operating suite following informed consent. Anesthesia may be subconjunctival only or a RBB may be administered. We prefer a RBB when removing large pterygia so as to minimize ocular motility and make the patient most comfortable. When a pterygium is extensive and the rectus muscles are involved, the muscles will need to be manipulated with a muscle hook during the case, and this can be uncomfortable for the patient. A RBB is most helpful.

Following the administration of RBB, the patient is prepped and draped in a sterile fashion, often with a solution of 5% povidone-iodine if there are no allergies. A Lieberman lid speculum, or any of the surgeon's preference, is inserted to retract the lids from the surgical field. The surgeon usually sits superior for the duration of the case.

4.3.3.1 Removal of the Pterygium

The area of the pterygium is marked with a gentian violet marking pen. Two percent lidocaine with epinephrine in a 3-mL syringe with a 27- or 30-gauge needle is injected under the pterygium to elevate it. The tips of the Westcott scissor are placed under the body of the pterygium and between the pterygium and underlying sclera in order to dissect and lift the pterygium away from the sclera. Care is taken not to involve the rectus muscle. A peripheral to central dissection of the pterygium is then carried out by first making an incision across the body of the pterygium with the Westcott scissor and then reflecting the pterygium across the limbus. Often the pterygium can be peeled off the cornea with a toothed forcep as there is a plane above Bowman's layer that can be identified. A blade of the surgeon's preference may be used to remove the remaining fibrous tissue from the cornea that is atop Bowman's layer. The pterygium should be laid out flat on a glove paper and placed in formalin and sent for histopathologic confirmation of the diagnosis. We then perform an extensive removal of tenon's layer superiorly, medially or laterally, and inferiorly, by grasping the excessive tenon's tissue with a toothed forcep and pulling the redundant tissue out from underneath uninvolved conjunctiva and excising it with a Westcott scissor. If the pterygium covers the medial or lateral rectus muscles, the muscle is identified on a muscle hook and the pterygium dissected off the muscle using a wooden cotton-tip applicator and a rolling motion in the direction of the muscle fibers to effect the dissection bluntly. Sometimes the semilunar fold must be extracted as well.

4.3.3.2 Harvesting the Conjunctival Autograft

The most successful step to successful autograft surgery is the careful harvesting of a thin, Tenon-free conjunctival graft of a large enough size to cover the defect following pterygium removal.

The globe is rotated inferiorly to expose the superior bulbar conjunctiva. An area of appropriate size conjunctiva is marked with the caliper and outlined with the gentian violet marker. It should be noted that some degree of graft retraction will occur and so the area marked should be 1 mm oversized in each diameter. The area chosen should be as far away from the

excised pterygium as possible. A 27- or 30-gauge needle on a 3-mL syringe is used to inject 2% lidocaine with epinephrine between the conjunctival epithelium and Tenon's layer in order to aid separation. Care is taken not to place the needle into the area that will be the future conjunctival autograft, but to place the needle outside the gentian violet marks. A blunt-tipped Westcott scissor is used to incise the epithelium along the previously marked tracts and blunt and sharp dissections are used to dissect the epithelium away from Tenon's layer. Non-toothed forceps should be used only when handling the conjunctiva. Careful lifting of the conjunctival epithelium allows Tenon's layer to be put on stretch, and Tenon's fibers are cut close to the epithelium, with care taken not to buttonhole the conjunctiva. Dissection of the graft is carried forward to the limbus.

4.3.3.3 Securing the Conjunctival Autograft

It is important that the conjunctival epithelium remains uppermost and to ensure this position, inversion of the graft must not occur. The conjunctival graft should be slid over the cornea towards the bare sclera to maintain the epithelium up. We orient the graft limbus to limbus although we are likely not transferring any limbal stem cells with our autograft harvesting technique. The graft should be spread to cover the entire area of bare sclera. We previously placed 10-0 nylon sutures in the graft to adhere it to the episclera. In this technique, 10-0 nylon sutures are used to secure the graft first at the superior and inferior limbus, followed by the superior and inferior edges of the posterior most aspect of the graft. A surgeon's slip-knot technique, or any other tying technique the surgeon is familiar with, may be used (Fig. 4.17).

We now use fibrin glue as an alternative to suturing. In this technique, the conjunctival graft, epithelial side up, is spread to cover the entire area of the bare sclera. Two tying forceps are used to grasp the pointed superior and inferior ends of the graft nearest the limbus first. The anterior half of the graft is laid back onto itself to mid graft position, and the glue is applied in two parts. The fibrinogen is applied to the back of the graft and the thrombin is applied to the bare sclera. The ends of the graft are again grasped with the tying forceps and the anterior half of the graft is laid back onto the sclera and pressed into position with the tying forceps. The thrombin activates the fibrinogen,

forming the fibrin glue. The graft is held pressed to the bare sclera for 30 s. The superior and inferior ends of the posterior aspect of the graft are grasped with the tying forceps and the posterior half of the graft is laid back onto itself and the glue is applied as prior. The graft is laid back down onto the bare sclera and pressed into position and held for 30 s. It is smoothed out gently with the tying forceps. Any excess glue is removed.

4.3.3.4 Fibrin Glue vs. Nylon Sutures

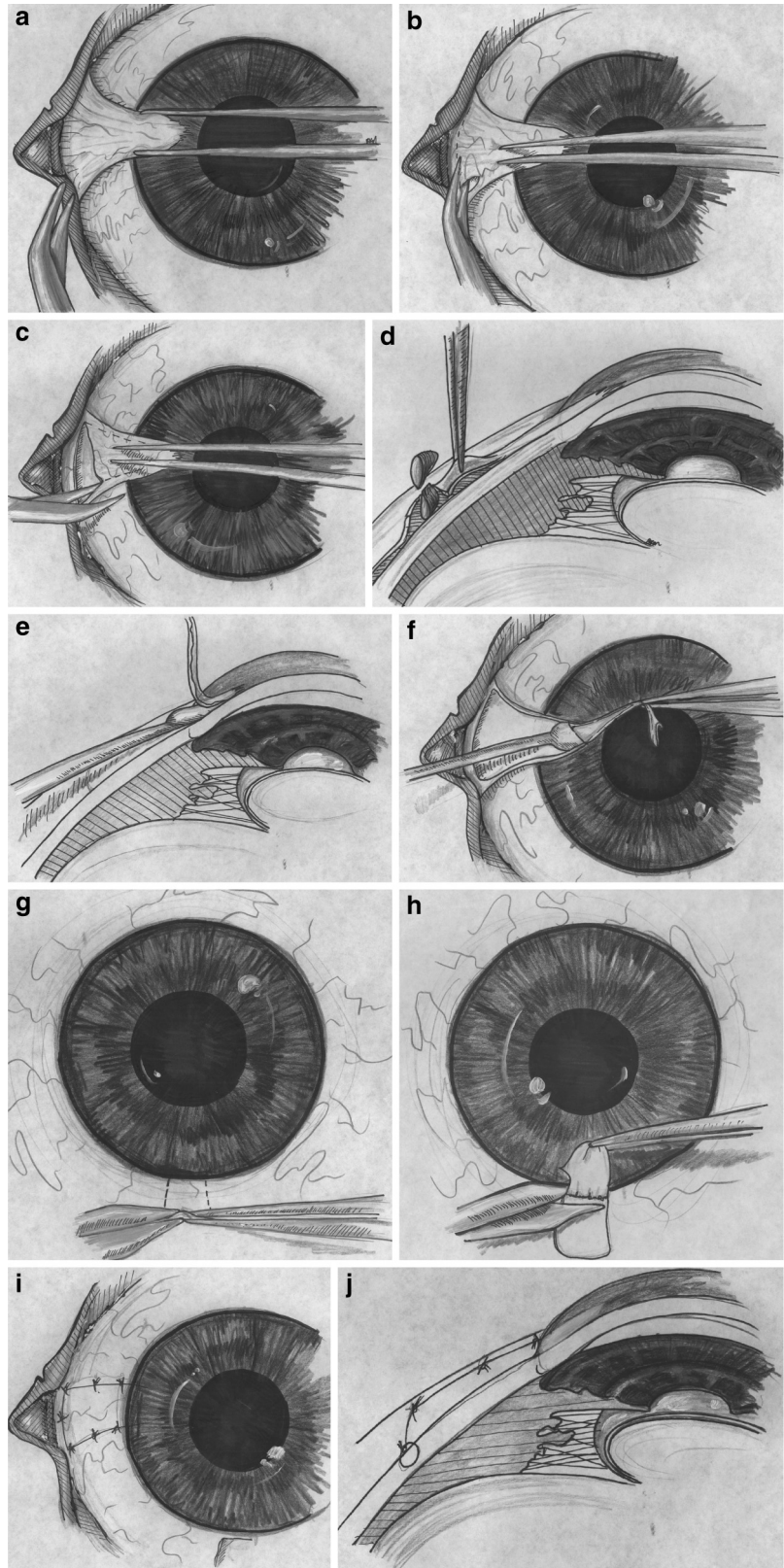
Currently, many surgeons are attaching their conjunctival autografts by means of suturing. The use of sutures can be associated with several disadvantages that include a prolonged operating time, postoperative irritation and pain, and suture-related complications such as granuloma formation and others. Sutures can present a nidus for infection as well.

Tissue adhesives are an alternative means for attaching a conjunctival autograft and may avoid the complications just mentioned with suture use. Several studies have reported on their efficacy in securing a conjunctival autograft following pterygium removal and in decreasing the postoperative complications of suture use [7, 8, 10]. Tisseel is a two component tissue adhesive that mimics natural fibrin formation [8]. The glue has two components. One component consists of fibrinogen mixed with factor XIII and aprotinin, and the other component is a thrombin-calcium chloride solution. All components are prepared from human blood that has been extensively screened. When the two components are mixed, the thrombin activates the fibrinogen and forms the fibrin glue. The two components can be administered sequentially as described in our technique above, or can be placed in a double syringe applicator (Duploject) that comes in the operative kit.

4.3.4 Postoperative Management

Postoperatively, prednisolone drops are administered four times daily along with topical Vigamox (Alcon, Fort Worth, TX). If a large epithelial defect is present from removal of the apex of the pterygium off the cornea, a bandage contact lens is placed for comfort until the defect heals. Topical preservative-free artificial tears

Fig. 4.17 (a–j) Pterygium removal with conjunctival autograft. Dissection usually begins at the base of the pterygia and proceeds towards the cornea. See text for details. The conjunctival autograft is usually harvested superiorly and secured limbus to limbus over the bare scleral defect. Notice in these drawings, the autograft is secured with sutures as opposed to fibrin glue. Also note that the autograft is much smaller in the drawing than is usually the case intraoperatively. Drawings by Katie Moser



are used several times daily for excessive irritation. Patients are examined at 1 day postoperatively, 1 week postoperatively, 1 month postoperatively, and every 1–2 months thereafter for the first year. If a large epithelial defect is present, patients may need to be seen more frequently following the 1 day postoperative visit to ensure adequate healing without cornea ulceration.

Patients are maintained on a topical steroid medication for a minimum of 1 year following surgery. Initially, topical prednisolone is used four times daily and the drop is decreased by one drop per month until a drop of once daily is being used. At this point, if the eye is quiet, a switch is made to topical loteprednol due to the associated lower side effect profile. If at any point the patient develops an increase in intraocular pressure while on topical prednisolone, a switch is made to topical loteprednol.

If during the follow-up period we note an early recurrence of the pterygium, 0.1 mL of dexamethasone 4 mg/mL is administered subconjunctivally with the hope of halting the fibrovascular response.

4.3.5 Recurrent Pterygium

A pterygium recurrence is defined as a regrowth of pterygium onto the surgical limbus. Tan et al. developed a grading scale that can be employed at the slit lamp to help the surgeon predict recurrence rates for a pterygium [1]. It is based on the relative translucency of the body of the pterygium [1]. A T1 grade pterygium is thin and atrophic and has the lowest rate of recurrence [1]. A T3 grade pterygium is thick and fleshy and has a higher rate of recurrence [1]. A T2 grade pterygium falls in between these. While surgical technique is related to recurrence rate, recurrence after pterygium removal is also believed to be more common in patients with thick, fleshy pterygia, usually young adults, compared to the more atrophic lesions that are seen in elderly adults [1].

Surgical technique is highly related to pterygium recurrence. Fifty percent of pterygium recurrences occur within the first 120 days post removal, and 97% occur within the first year [4]. Tan et al. noted that 86% of recurrences occurred by 6 months after surgery and 93% occurred by 12 months [11]. Conjunctival autografts have been associated with a recurrence rate in the range of 2–39% [2, 4, 12]. Tan et al. have

demonstrated that surgeon experience is a factor in the rate of recurrent pterygium formation following conjunctival autografting [11]. Surgeons performing ten or more procedures have less recurrence than those performing four to five procedures and those performing this number of procedures have less recurrence than surgeons who have performed none [11]. Recurrences usually arise around the superior and inferior borders of the conjunctival autograft indicating that the graft may not have been large enough. Techniques other than conjunctival autografting have typically been associated with higher rates of recurrence.

4.3.6 Other Techniques in Pterygium Removal

4.3.6.1 Bare Scleral Technique

In this technique, the pterygium is removed and the sclera is left bare. This technique has been associated with a recurrence rate ranging from 24% to as high as 89% [11, 12]. This technique is associated with the highest rate of recurrence and is not recommended.

4.3.6.2 Adjunctive Agents

Mitomycin C

MMC is an antibiotic alkylating agent produced by the bacteria *Streptomyces caespitosus*. Its mechanism of action involves the inhibition of DNA synthesis, resulting in long-term inhibition of Tenon's fibroblast proliferation [13]. Its use in pterygium surgery as an adjunctive agent was first reported in Japan in 1963 [13]. It use was first reported in the United States in 1988 [13].

The concentration of intraoperative MMC typically used ranges from 0.01 to 0.04%, with 0.02% being the most common concentration used [2]. Some surgeons prefer to use MMC eyedrops postoperatively. Again, 0.02% is the concentration most commonly used and the drops are applied four times a day for 5–14 days with a mean duration of application of 10 days [2].

In addition to pterygium surgery, MMC has been successfully used in the treatment of ocular surface neoplasia, symblepharon repair, glaucoma filtration surgery, and others [13]. Numerous studies have reported

on its effectiveness in the prevention of pterygium recurrence [2, 14–16]. Recurrence rates have been reported to a range of less than 10% in some cases [15].

Despite its effectiveness in the prevention of pterygium recurrence, we do not advocate the use of MMC in routine cases of pterygium removal. MMC has been associated with significant sight-threatening complications including scleral necrosis, infectious scleritis, perforation, and endophthalmitis [2]. Avisar et al. reported a significant effect on endothelial cell density with a 21% decrease in endothelial cell counts following application to the bare sclera after pterygium removal [17]. We have noted several cases of limbal stem cell deficiency in patients referred to our clinic as a result of the use of MMC following pterygium removal.

If a patient has undergone previous multiple pterygium removals for recurrences associated with severe subconjunctival fibrosis, MMC may be used with success [18]. MMC should only be used when the patient has failed a combination of amniotic membrane transplantation (AMT) and conjunctival autograft placement [18]. The same aforementioned complications with MMC and should be detailed to the patient prior to surgery.

Beta-Irradiation

Beta-irradiation is another adjunct to pterygium removal that may help prevent recurrence. There are not many studies available on beta-irradiation following pterygium removal. Beta-irradiation is administered postoperatively as several applications, given over several days to 2 weeks. Chayakul showed that beta-irradiation is associated with higher recurrence rates than postoperative MMC drops [2]. Beta-irradiation is also associated with some of same sight-threatening complications as MMC use such as scleral necrosis, infectious scleritis, corneal perforation, and endophthalmitis. We do not recommend the use of beta-irradiation following pterygium removal.

4.3.6.3 Amniotic Membrane Transplantation

AMT has been used for a variety of ocular surface diseases since Kim and Tseng reintroduced the procedure in 1998 [18]. AMT has been shown to suppress fibrosis when used for pterygium removal [4, 18]. Transforming growth factor betas are potent fibrinogenic growth

factors. Suppression of this signaling pathway has an antifibrosis effect [18]. Tseng et al. demonstrated that the transforming growth factor beta pathway in fibroblasts is suppressed when in contact with the stromal side of the amniotic membrane [4, 18]. It is through this mechanism that the amniotic membrane may help reduce scarring and fibrosis following pterygium removal. The amniotic membrane has an anti-inflammatory effect as well, so this may help contribute to postoperative wound healing [4, 18].

Despite the theoretical advantages, clinical results of AMT for pterygium removal have been variable. Prabhasawat et al. reported a recurrence rate of 37.5% in recurrent pterygia treated by AMT [4]. The rate was significantly higher than those treated by conjunctival autograft. Tananuvat et al. found that the recurrence rate was significantly higher in a group of patients that underwent AMT as compared to a group that had conjunctival autograft (40 vs. 4.8%) [4]. Ma et al. compared the recurrence rates after excision of primary pterygium combined with amniotic membrane graft, conjunctival autograft, and topical MMC and found that the recurrence rates were low and comparable among all three groups [4].

The reasons for such high variability in reported recurrence rates are unclear, but variation in surgical technique, demographic differences, and different definitions of recurrence may be factors [4].

When very large pterygia require extensive removal of fibrovascular tissue such that there is a large bare scleral defect, a large enough conjunctival autograft may not be available. In these instances, AMT may be combined with the conjunctival autograft to ensure coverage of the entire bare sclera defect. The AMT is secured stromal side down first with fibrin glue or 10-0 nylon suture depending on the surgeon's preference, and the conjunctival autograft is laid on top, epithelial side up and secured in the same fashion. Shimazaki et al. demonstrated this to be a safe and effective method for recurrent pterygium that are often associated with symblepharon and ocular motility restriction and thus require large area of excision [18].

4.3.6.4 Various Techniques in Conjunctival Autografting

Variations in conjunctival autograft surgery include the use of limbal-conjunctival autografts, conjunctival

flaps, conjunctival rotation autografting, and as mentioned conjunctival grafts combined with amniotic membrane grafts.

It has been suggested that including limbal stem cells in the conjunctival autograft may act as a barrier to conjunctival cells migrating across the limbus and onto the cornea and help prevent pterygium recurrence. Harvesting of the limbal-conjunctival autograft is similar to harvesting the conjunctival autograft except the dissection is continued 0.5 mm beyond the limbus. The donor is oriented in the recipient bed limbus to limbus. No conclusive evidence exists to date regarding the superiority of limbal-conjunctival autografts over conventional conjunctival autografts [2].

A sliding conjunctival flap may be harvested from the superior or inferior bulbar conjunctiva to close the bare sclera defect. Reported recurrence rates are one to 5%, but there are only a few reports in the literature where this method has been reviewed [12].

4.3.7 Complications in Pterygium Removal

Recurrence is the main complication of pterygium removal and has been reviewed. A more serious, sight-threatening condition is surgically induced necrotizing scleritis. This is a local autoimmune reaction and has been described to occur in the vicinity of previous surgical wounds. The overall incidence of surgically induced necrotizing scleritis (noninfectious and infectious) following pterygium removal has been reported to be 0.2–4.5% [19]. Higher rates of scleral necrosis are associated with the adjunctive use of MMC or beta-irradiation, especially if higher concentrations are used [19]. Because the clinical appearance of progressive scleral melting at the site of pterygium removal may mimic necrotizing scleritis due to autoimmune disease, systemic autoimmune disease must be ruled out in such patients [19].

Scleral necrosis after pterygium removal can manifest as a quiet scleral melt that is discovered on clinical exam, as noninfectious necrotizing scleritis that presents with no anterior chamber reaction, good visual acuity, and mild tenderness with visible scleral melting, and as infectious necrotizing scleritis that presents with severe pain, decreased vision, and perhaps a scleral abscess [19, 20]. A diagnosis of scleral necrosis always necessitates a systemic autoimmune work-up even though the patient

may have a history of a pterygium removal. The work-up includes a complete blood count, erythrocyte sedimentation rate and C-reactive protein, antinuclear antibodies, anti-DNA antibodies, rheumatoid factor, cytoplasmic and neutrophilic antibodies, urinalysis, serum uric acid, syphilis serology, and chest X-ray [20]. Wegener's granulomatosis is a systemic, life-threatening disorder that must always be kept in mind when a patient in the correct age group presents with necrotizing scleritis. This is a true ophthalmic emergency that requires immediate hospitalization and consult with an internist for intravenous immunosuppression.

Scleral melting not related to active autoimmune disease and as a result of pterygium removal, should be treated medically initially. A combination of oral NSAIDs and topical corticosteroids, as well as topical cyclosporine A (Allergan, Irvine CA) may be effective. If the necrosis worsens on this treatment, the addition of oral corticosteroids may quiet the eye and halt the process. If oral corticosteroids control the necrosis and an improvement is seen, the patient may need to be maintained on oral immunosuppression for up to a year or longer. In this case, the ophthalmologist should work in conjunction with a rheumatologist or transplant immunologist to coordinate an immunosuppressive agent that may be safer for long term use like methotrexate.

If medical management fails and perforation seems likely, surgical management is required to reconstitute the sclera. For this, a variety of materials are available that include conjunctival autografting, amniotic membrane placement, and lamellar patch graft with cornea or scleral tissue. Seng-Ei Ti and Donald Tan reported on the successful use of corneal lamellar grafting to preserve globe integrity in cases of severe scleral melting [19]. Corneal tissue, as opposed to scleral tissue, has some significant advantages. Because it is thicker and the lamellae are more tightly packed, cornea tissue provides more support to a thinning area of sclera and may reduce the risk of remelting [19].

4.3.8 Summary

Pterygia can be uncomfortable and cosmetically undesirable for our patients. In addition, if they encroach a great deal on the cornea, they can severely affect the visual acuity by producing high amount of irregular astigmatism. We have found that the best technique for

removal is that of conjunctival autografting. It has the lowest recurrence rate in our hands. It does however take practice and young surgeons should pay the closest attention to harvesting a thin graft large enough to cover the entire scleral defect. It is in this way that the recurrence rate will be the lowest, and the procedure will be most successful (Fig. 4.18a–c).

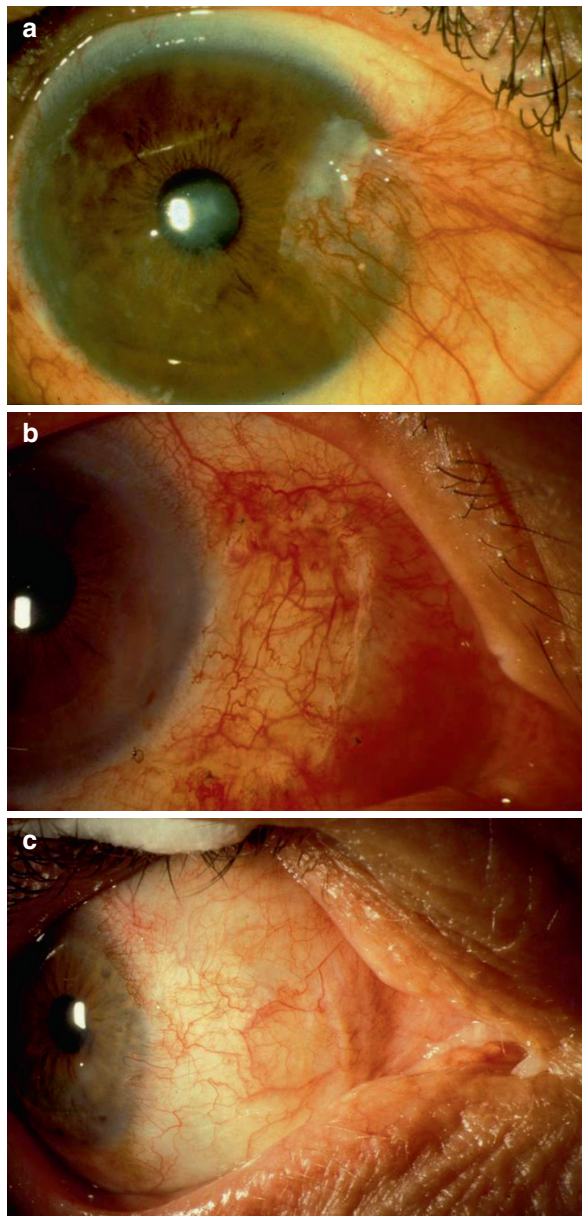


Fig. 4.18 (a) Preoperative pterygium. (b) One month postoperative pterygium removal with conjunctival autograft. (c) Postoperative photo of the same patient 3 months postoperatively. Photo courtesy of Edward J. Holland

References

- Holland EJ, Mannis MJ (2002) Ocular surface disease. Springer, New York
- Ang L, Chua J, Tan D (2007) Current concepts and techniques in pterygium treatment. *Curr Opin Ophthalmol* 18:308–313
- Moran D, Hollands F (1984) Pterygium and ultraviolet radiation: a positive correlation. *Br J Ophthalmol* 68:343–346
- Tananuvat N, Martin T (2004) The results of amniotic membrane transplantation for primary pterygium compared with conjunctival autograft. *Cornea* 23:458–463
- Youngson RM (1972) Recurrence of pterygium after excision. *Br J Ophthalmol* 56:120
- Norliza W, Raihan I, Azwa J, Ibrahim M (2006) Scleral melting 16 years after pterygium excision with topical mitomycin c adjuvant therapy. *Cont Lens Anterior Eye* 29: 165–167
- Bahar I, Weinberger D, Gatton D (2006) Pterygium surgery: fibrin glue versus vicryl sutures for conjunctival closure. *Cornea* 25:1168–1172
- Koranyi G, Seregard S, Kopp E (2004) Cut and paste: a no suture, small incision approach to pterygium surgery. *Br J Ophthalmol* 88:911–914
- Marticornea J, Rodriguez A, Maria T et al (2006) Pterygium surgery: conjunctival autograft using a fibrin adhesive. *Cornea* 25:34–36
- Uy H, Reyes J, Flores J et al (2005) Comparison of fibrin glue and sutures for attaching conjunctival autografts after pterygium excision. *Ophthalmology* 112:667–671
- Ti S, Chee S, Dear K et al (2000) Analysis of variation in success rates in conjunctival autografting for primary and recurrent pterygium. *Br J Ophthalmol* 84:385–389
- Fernandes M, Sangwan V, Bansal A et al (2005) Outcome of pterygium surgery: analysis over 14 years. *Eye* 19: 1182–1190
- Solomon A, Kaiserman I, Raiskup F et al (2004) Long-term effects of mitomycin C in pterygium surgery on scleral thickness and the conjunctival epithelium. *Ophthalmology* 111: 1522–1527
- Hui-Kang Ma D, See L, Liao S et al (2000) *Br J Ophthalmol* 84:973–978
- Raiskup F, Solomon A, Landau D et al (2004) Mitomycin C for pterygium: long term evaluation. *Br J Ophthalmol* 88: 1425–1428
- Walkow T, Daniel J, Meyer C et al (2005) Long-term results after bare scleral pterygium resection with excimer smoothing and local applications of mitomycin C. *Cornea* 24: 378–381
- Avisar R, Avisar I, Bahar I (2008) Effect of mitomycin C in pterygium surgery on corneal endothelium. *Cornea* 27:559–561
- Shimazaki J, Kosaka K, Shimmura S et al (2003) Amniotic membrane transplantation with conjunctival autograft for recurrent pterygium. *Ophthalmology* 110:119–124
- Ti S, Tan D (2003) Tectonic corneal lamellar grafting for severe scleral melting after pterygium surgery. *Ophthalmology* 110:1126–1136
- Esquenazi S (2007) Autogenous lamellar scleral graft in the treatment of scleral melt after pterygium surgery. *Arch Clin Exp Ophthalmol* 245:1869–1871

5.1 Trends in Refractive Surgery

1. Laser vision correction
 - (a) Decreasing the amount of tissue ablation per dioptré treated
 - (b) Increasing the predictability of LASIK
 - (c) Reducing the incidence of complications associated with LASIK
 - (d) Decreasing the time required for the procedure
 - (e) Increasing the optical quality post-operatively
2. Phakic intraocular lens surgery
 - (a) Minimising incision size
 - With newer lens design
 - With newer materials
 - (b) Advances in diagnostic anatomy and PIOL sizing technology
 - (c) Decrease in complication rates
 - (d) Improving outcomes of phakic intraocular lens surgery
 - (e) Ability to treat all types of refractive errors
3. Presbyopic lens surgery
 - (a) Decreasing the incision size required
 - (b) Improved performance of lenses
 - Aspheric designs
 - Toric designs

5.2 Introduction

Refractive surgery is the newest subspecialty in ophthalmology, gaining popularity after the introduction

of photorefractive keratectomy (PRK) and laser in situ keratomileusis (LASIK) in the 1980s and 1990s respectively. Whilst LASIK is the most popular refractive surgery technique today, it is by no means the only refractive surgery technique available. Rapid development in technology and surgical techniques in the field of refractive surgery has led to a wide range of surgical techniques available to the refractive surgeon today.

Refractive surgery techniques today can be broadly classified into corneal refractive surgery techniques, intraocular refractive surgery techniques and presbyopic correction techniques. Corneal refractive surgery techniques include techniques which correct refractive errors by reshaping the cornea either by surgery or by laser treatment. Corneal refractive surgery techniques include refractive keratotomy, astigmatic keratotomy and laser treatments like Advanced Surface Ablation techniques (including PRK and epi-LASIK) and LASIK. Intraocular refractive surgery includes techniques which involve intraocular surgery, for example phakic intraocular lens implantation. Presbyopic correction techniques include any technique which aims to correct presbyopia. These techniques include laser treatment, conductive keratoplasty, corneal inlays and the use of multi-focal intraocular lenses.

In all the types of refractive surgery techniques, the trend is towards minimising surgical incisions and invasiveness. Newer technology aims to improve the results of surgery while at the same time reducing the amount of tissue damage or manipulation required. However, unlike conventional ophthalmic surgeries where minimal invasive surgeries are measured by the size of the incisions, in refractive surgery techniques, minimal invasive surgeries are achieved by various other technological methods which will be discussed in the subsequent sections.

J. L. Alio (✉)
Vissum, Instituto Oftalmológico de Alicante, Adva de Denia
s/n, Edificio Vissum, 03016 Alicante, Spain
e-mail: jlalio@vissum.com

5.3 Cornea Refractive Surgery

5.3.1 Laser In Situ Keratomileusis (LASIK)

LASIK is currently the most popular refractive surgery technique. Since the introduction of LASIK in 1992, the goal of all refractive surgeons performing LASIK is to achieve predictable and accurate results while at the same time minimising the amount of tissue ablation and improving safety of the procedure. The LASIK procedure consists of two key parts, corneal flap creation and laser ablation of the stromal bed. Hence, the above-mentioned goals of refractive surgeons can be accomplished by technological advancements in microkeratome/flap creation technology and improvements in LASIK delivery systems. The trends in LASIK are:

1. Decreasing the amount of tissue ablation per dioptre treated
2. Increasing the predictability of LASIK
3. Reducing the incidence of complications associated with LASIK
4. Decreasing the time required for the procedure
5. Increasing the optical quality post-operatively

5.3.1.1 Advances in Flap Creation Technology

The creation of a corneal flap prior to excimer laser ablation of the stromal bed is a key feature of LASIK. This is also perhaps the riskiest step during LASIK as complications during flap creation like buttonholes, partial or free flaps can be devastating. The thickness of the flap is also an important factor. A thinner corneal flap will result in a thicker stromal bed prior to excimer laser ablation. This means that more corneal tissue can be ablated while at the same time maintaining a safe residual stromal bed after ablation. Hence, higher degrees of refractive error may be treated. Furthermore, the risk of corneal ectasia may be reduced with a thicker residual stromal bed.

Currently, corneal flaps can be created by using a microkeratome or by femtosecond laser. Microkeratomes use blades to cut the corneal stroma while femtosecond laser utilises laser to create bubbles which are delivered in a raster pattern across the cornea to create an interface cut and then a side cut. The flap is

then lifted with blunt dissection using a spatula or similar instrument. In both methods, technologies have been developed with the goals of creating safer, thinner and more precise corneal flaps.

Microkeratomes

The first commercially available microkeratome was the Automated Corneal Shaper (ACS), manufactured by Bausch & Lomb. It was a good unit in the hands of an experienced surgeon but had inherent problems that increased the risk of complications. The ACS has different parts which must be taken apart during the sterilisation process and subsequently reassembled. Errors in reassembly may result in major complications during flap creation. Second-generation microkeratomes include Draeger Lamellar Keratome (Storz Instrument GmbH, Heidelberg, Germany) and Microprecision test model (Microprecision Instrument Company, Inc, Phoenix, Az). Hoffman et al. compared the three second-generation microkeratomes and showed that the three systems produced irregular surfaces with chatter lines and the variability in flap thickness was over 20 μm in all three systems [25].

Third-generation microkeratomes include the Hansatome microkeratome (Bausch and Lomb Surgical) which was commercially available in 1997. The Hansatome microkeratome incorporated many design and functional improvements over the ACS microkeratome which aims to improve the safety of the instrument to minimise intraoperative flap complications. Studies by Walker et al. and Jacobs et al. confirmed that intraoperative flap complications are less likely to occur with the Hansatome microkeratome than with the ACS microkeratome [29, 64]. The Hansatome microkeratome is available with the 200, 180 or 160 μm head. Hence, theoretically, the minimum flap thickness possible with the Hansatome microkeratome was 160 μm . But in one study, the mean flap thickness created with the Hansatome microkeratome using a 160 μm head resulted in a mean flap thickness of $97 \mu\text{m} \pm 18$ (SD) (range 65–163 μm). Thus, while the third-generation microkeratomes afford greater safety compared to the earlier microkeratomes, the flaps created are not as precise as is demanded by refractive surgeons today.

Today, a wide range of new microkeratomes are available to the refractive surgeons, each promising safer

and more precise corneal flap creation. These newer microkeratomes include the Amadeus II microkeratome (Advanced Medical Optics), Zyoptix XP microkeratome (Bausch & Lomb), Moria's One Use-Plus and M2 microkeratomes, BD K-4000 microkeratome (Becton Dickinson), Nidek's MK-2000 microkeratome and the Carriazo-Pendular microkeratome (SCHWIND eye-tech solutions). Most of these microkeratomes are available with heads designed to create either 120 or 130 μm flaps. Some of the microkeratomes, for example the Carriazo-Pendular microkeratome, is available with a 90- μm cutting head (Fig. 5.1). Comparison of the Hansatome and Zyoptix XP microkeratome in one study showed that although the two microkeratomes produced flaps of similar mean thickness, the Zyoptix



Fig. 5.1 The Carriazo-Pendular microkeratome

XP showed significantly less variation in flap thickness than the Hansatome. The Zyoptix XP microkeratome was less affected by measurable pre-operative variables such as pre-operative spherical equivalent of the eye and was closer to nominal labelling [52]. While current available microkeratomes produce corneal flaps which are more precise than third-generation microkeratomes, variations in flap thickness are still present [59].

Recently, Moria has launched its One Use-Plus SBK (Sub Bowman's Keratomileusis) microkeratome (Fig. 5.2) which is designed to create ultra thin flaps which are comparable to flaps created by femtosecond laser. While conventional LASIK flap has a thickness of 120–180 μm , the One Use-Plus SBK is designed to create thinner flaps of between 90 and 110 μm . The cutting of thinner flaps will preserve more of the integrity of the cornea, thereby lowering the risk of ectasia while at the same time provide greater comfort to the patient post-LASIK. This microkeratome is also extremely fast compared to existing microkeratomes, thereby reducing suction time. The microkeratome is also reported by the company to produce smoother stromal beds (Fig. 5.3). This may lead to a reduction in the induction of post-operative corneal aberrations. But more studies will be needed to assess its performance.

Femtosecond Laser

The introduction of the femtosecond laser to create a corneal flap, the first and most popular being the Intralase® femtosecond laser (Advanced Medical Optics), was a significant advancement in LASIK technology. This “bladeless” procedure involves the creation of cavitation bubbles by laser in a raster pattern across the cornea to create an interface which can then be lifted by a blunt dissection instrument. While



Fig. 5.2 The Moria One Use-Plus SBK microkeratome

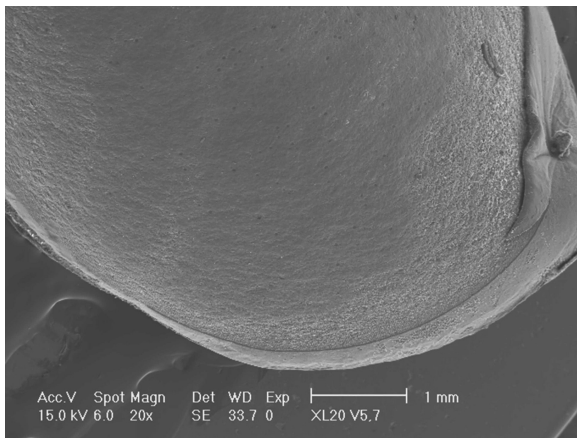


Fig. 5.3 Scanning electron microscope image of a stromal bed after creation of a flap by the Moria One Use-Plus SBK microkeratome

the femtosecond laser is a relatively new technology, improvements in technology can be observed over this short time period. The trends in femtosecond laser technology include:

1. Ability to create thinner flaps
2. Decreasing the amount of energy delivered to the cornea
3. Decreasing the time required for the procedure with increased precision
4. Decreasing the biomechanical impact of the flap creation
5. Reducing trauma (including changes in intraocular pressures during surgery)

The main advantage of using a femtosecond laser for flap creation is the greater degree of control and monitoring before and during flap creation compared to microkeratomes. The size, position of the flap and position of the hinge can be determined pre-operatively. Furthermore, since the corneal flap is only created after the flap is mechanically lifted, should a complication occur during the raster pattern delivery, the process can technically be “reversed” by waiting a few weeks before performing the procedure again. This affords greater safety and almost eliminates the risk of flap complications like partial flaps or buttonholes, especially for high-risk eyes, e.g. eyes with steep corneas.

Intralase® is also able to create thinner flaps of up to 90 µm compared to conventional microkeratomes. Several studies have showed that the flaps created by

Intralase® are more precise and predictable compared to conventional microkeratomes [13, 31]. The precision and predictability of the Intralase® machine allows the refractive surgeon to better plan and individualise the LASIK surgery for their patients, especially patients with borderline corneal thickness. At the same time, ability to create thinner flaps will also help preserve the structural integrity of the cornea and lower the risk of corneal ectasia.

We compared the flaps created by the Intralase® FS laser, the Moria M2 microkeratome (Moria, Antony, France) and the Carriazo-Pendular microkeratome (Schwind eye-tech solutions, Kleinostheim, Germany). Several mechanical microkeratomes create flaps that are thinner at the centre than the periphery (meniscus-shaped configuration). Analysis of the flaps created by the Moria M2 microkeratome, which is an applanation microkeratome, using the very high-frequency (VHF) eye scanner, Artemis 2 (Ultralink LLC, St Petersburg, Fla) with a 50-MHz probe confirmed this. This is because the plate induces an excessive compression of the peripheral tissue of the cornea with posterior indentation of the central area (Fig. 5.4a). The Carriazo-Pendular microkeratome, an indentation microkeratome, produced an almost planar configuration with slight thickening in the inferior area (Fig. 5.4b). The flaps created by the Intralase® FS laser were also more homogeneous, showing a planar or almost-planar thickness flap profile in most cases, compared to the M2 microkeratome (Fig. 5.4c). A meniscus-shaped flap behaves as an additional optical element of the ocular system, introducing new higher-order aberrations and modifying the predictability of the second-order corrections. In our study, the corneal spherical-like RMS was higher in the M2 group compared to the other two groups.

Studies have also compared the visual quality and amount of corneal aberrations after LASIK with Intralase® and conventional microkeratomes. Durrie et al. compared eyes which have undergone LASIK with Intralase® and the Hansatome microkeratome. His study showed statistically better UCVA and manifest refractive outcomes after LASIK with the IntraLase femtosecond laser may be the result of reduced post-operative astigmatism and trefoil induced by the machine [22]. Studies have also demonstrated that the Intralase® induces less post-operative aberrations compared to conventional microkeratomes [39, 61].

The main disadvantage of the femtosecond laser is the longer time required to create the raster pattern.

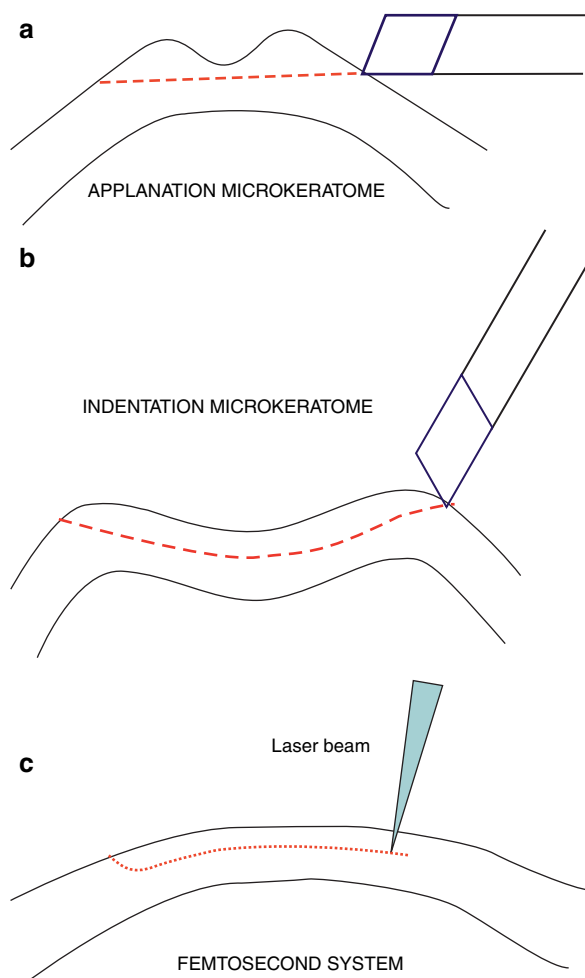


Fig. 5.4 Schematics showing the lamellar cut procedure using different devices for lamellar keratotomy. (a) Lamellar cut with an applanation microkeratome (Moria M2). (b) Lamellar cut with an indentation microkeratome (Carriazo-Pendular). (c) Lamellar photodisruption of the interface by the femtosecond laser (Intralase)

However, with newer versions, the process is much quicker, albeit still slower than conventional microkeratomers. For example, the fourth-generation Intralase® machine has a frequency of 150kHz. This is 15 times faster than the original Intralase machine which has a frequency of 10kHz.

Newer systems have higher repetition rates and use lower energy levels to enable faster flap creation and to reduce the amount of thermal energy delivered to the cornea, thereby reducing the incidence of Transient Light Sensitivity Syndrome. For example, the Zeiss VisuMax® has a repetition rate of 200kHz and a typical pulse energy of less than 300nJ per laser spot. Innovations in the optics used in the Zeiss VisuMax® enables increased focusing precision of the laser spots delivered (Fig. 5.5) to the cornea.

Other technological advances can be seen in femto-second laser platforms. The trend in these new innovations is in line with the overall aim of minimal invasive surgery. For example, the Zeiss VisuMax® uses spherically curved contact glass to applanate the eye during the docking procedure (Fig. 5.6). By this method, the VisuMax® creates a spherical contact interface only with the corneal surface and limbus, the cornea is minimally applanated during this step and the intraocular pressure rise is reduced. Hence, patient discomfort during this step is markedly reduced. Furthermore, suction is only applied during the laser procedure, thereby minimising the time the eye is under suction. As the sclera is not touched during this procedure, complications related to conjunctival trauma, e.g. conjunctival oedema, conjunctival haemorrhage, are avoided. Another advantage of this method is that the flap is created while the eye is in a “relaxed” compared to an eye with a flattened cornea. Hence, the flap diameter

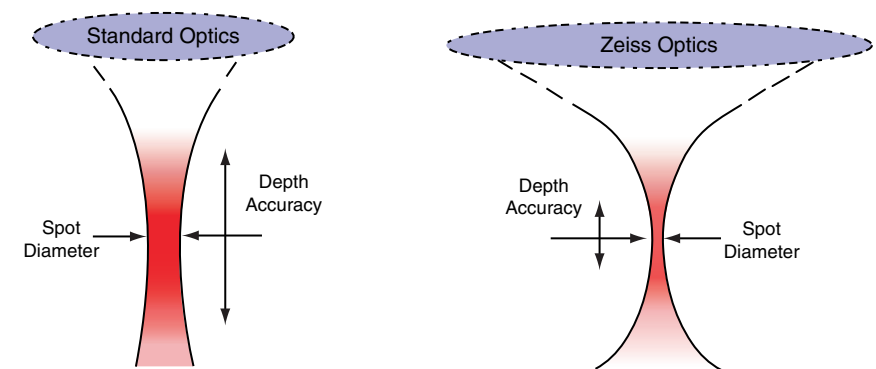


Fig. 5.5 Diagram showing how the optics used in the Zeiss VisuMax® increases the precision of each laser spot by increasing the depth accuracy and reducing the spot diameter of each laser spot

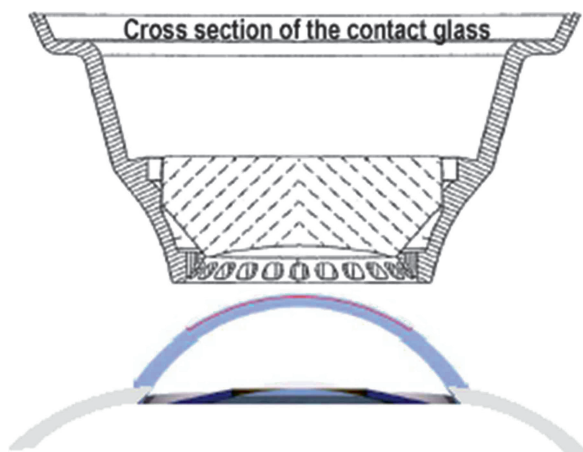


Fig. 5.6 Diagram showing the spherically curved contact glass used in the Zeiss VisuMax®

created is larger compared to a fully applanated eye. For example, an 8.8 mm VisuMax® flap bed diameter equals a 9.4-mm “Intralase® applanated bed diameter” (7.7 mm corneal curvature radius).

Currently, four femtosecond laser machines are available commercially, the Ziemer LDV system, Zeiss VisuMax®, IntraLase® FS laser, and 20/10 Perfect Vision (Femtec), with the IntraLase® FS laser having the most clinical experience. All four systems are based on the same principle of photodisruption in corneal tissue, but differences exist regarding the concept of these devices. Further evaluation will be useful to compare the results of the flaps created by these four devices.

5.3.1.2 Technological Advances in Laser Delivery Platforms

LASIK uses excimer laser systems to deliver laser on the corneal stromal bed to ablate the cornea, thereby altering the refractive power of the cornea. There is a wide range of excimer laser delivery systems available to the refractive surgeons today. Continuous improvements in laser delivery systems have improved the outcomes of LASIK.

Over the last 15–20 years, excimer laser platforms have evolved to become highly sophisticated instruments. First-generation excimer laser platforms used broad beam lasers with small optical zones and were only able to correct myopia. Second-generation

excimer laser platforms have a larger optical zone and were able to perform myopic and hyperopic corrections. Some second-generation excimer laser platforms also incorporated a passive eye tracker. The Schwind Keratom F, a third-generation excimer laser platform, used a broad beam laser with fractal mask capabilities and has aspheric ablation profiles. The fourth-generation systems incorporated fractal rotating mask and scanning slit capabilities and are capable of some customised corrections. These systems also have active eye-tracking capabilities. Fifth-generation systems, like the Schwind Esiris (Schwind eye-tech solutions, Kleinostheim, Germany), uses a high-speed, flying-spot laser with high-speed active tracking system (340 Hz) and is capable of customised wavefront driven corrections. The latest, sixth generation excimer laser available today is the Schwind Amaris (Schwind eye-tech solutions, Kleinostheim, Germany). This system incorporates high-speed (500 Hz), flying-spot laser with a high-speed (1,050 Hz), 5-dimensional, active eye tracker amongst other new innovations.

The following advancements in technology of the excimer laser delivery system allow refractive surgeons today to achieve predictable and accurate results while at the same time reduce the amount of time and tissue ablated, which is the goal of minimal invasive surgery in LASIK.

1. Faster excimer lasers
2. Reduction of collateral thermal tissue damage
3. Advanced eye trackers
4. Newer ablation profiles

5.3.1.3 Faster Excimer Lasers

The repetition rate of the excimer laser system determines the number of laser pulses applied to the cornea per second and this frequency is expressed in terms of Hertz (Hz). Naturally, an excimer laser system which can delivery more laser spots per second will be able to ablate more corneal tissue in a given time, and thus result in a faster treatment time. The speed of existing laser platforms varies from 15 to 500 Hz. However, the trend towards faster laser platforms is evident. The speeds of the newer laser platforms are faster than the older platforms and are reaching 400 Hz (Eye-Q, Wavelight) and 500 Hz (Amaris, Schwind Eye-tech and Concerto, Wavelight). Laser platforms with speeds

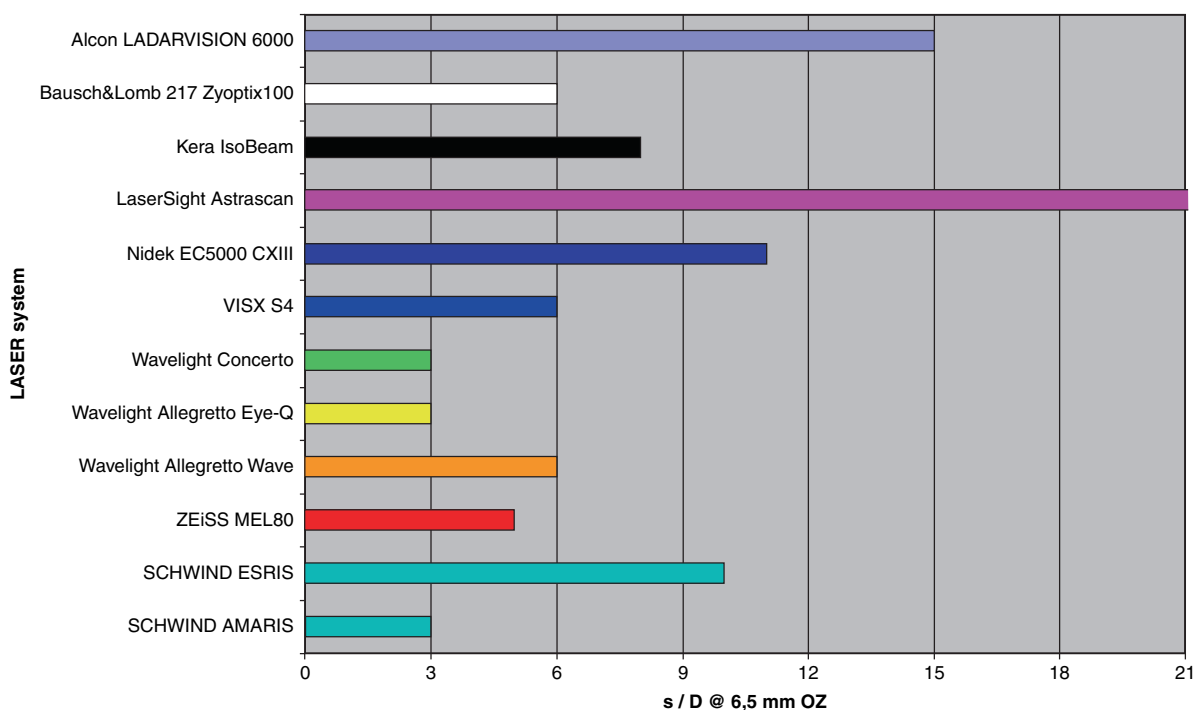


Fig. 5.7 Graph comparing speeds of the various excimer lasers

of 500Hz require less than 4 seconds per dioptre to ablate a 6.5-mm optical zone compared to 7–10s per dioptre using conventional laser platforms (Fig. 5.7).

The Amaris (Schwind Eye-tech) laser platform is among the newest and fastest laser platform commercially available today. It has a repetition rate of 500Hz, making it one of the fastest laser platforms around. Ensuring accuracy in laser spot placement is a key consideration in such a fast laser platform. The Amaris laser platform is able to achieve this by incorporating two fluence levels into its system. A high fluence level is used to speed up the treatment while a low fluence level is used to ensure higher accuracy. High fluence level is used for the initial treatment and low fluence level is used for the last 1–2 dioptres of corneal ablation. On average, for each treatment, 80% of the treatment procedure uses high fluence and low fluence is used for the remaining 20%. Figure 5.8 shows the difference in spot profiles for high and low fluence levels. The high fluence spot profile has a larger spot diameter and ablates more cornea tissue with each spot, which allows faster ablation in a given time, whereas the low fluence spot profile has a smaller spot diameter enabling more precise ablations. This concept results

in minimised ablation time while at the same time, ensuring maximal ablation smoothness.

5.3.1.4 Reduction of Collateral Thermal Tissue Damage

Another key consideration in excimer laser technology is the reduction of thermal damage to the cornea. This is especially important in newer, high-speed laser delivery systems as a high repetition rate may result in shorter intervals between laser pulses on the same area on the cornea. This may increase the thermal load on the cornea and result in thermal damage. Conventional laser platforms randomise the laser spot position during treatment to reduce successive overlapping. However, this system does not completely avoid successive overlapping.

The Schwind Amaris laser platform uses an Intelligent Thermal Effect Control to reduce the heating of the cornea significantly. This system ensures that the area around an applied laser spot is blocked for a certain time to let the cornea cool down and this area becomes dynamically smaller as the peripheral areas

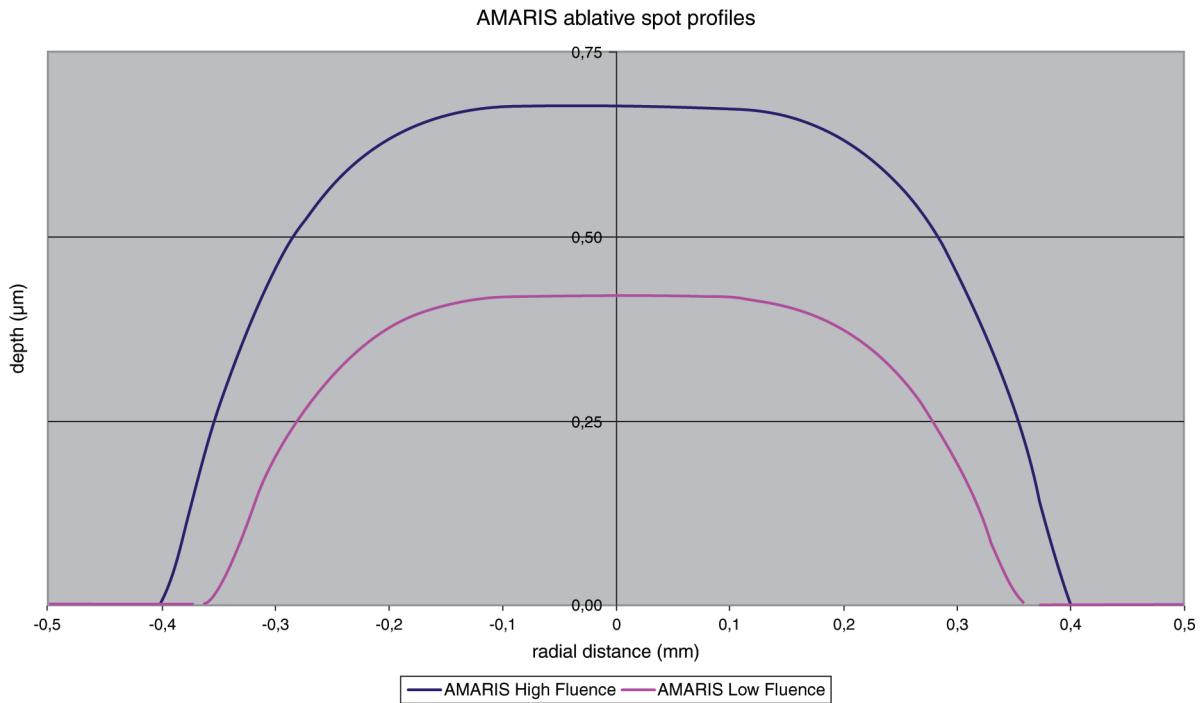


Fig. 5.8 Graph showing the difference in the AMARIS high and low fluence ablative spot profiles

cool down. The cooling-down time for the cornea is different during high fluence and low fluence treatments. This system ensures that there is no overlapping of successive laser spots and minimal thermal load on the cornea, hence reducing the risk of thermal damage.

5.3.1.5 Advanced Eye Trackers

The introduction of eye trackers in excimer laser platforms have greatly improved the accuracy of the placement of the laser spots and minimised the risk of decentred ablations. However, improvements in eye-tracker technology of conventional excimer laser platforms are necessary to meet the demands of laser refractive surgery today. High-speed laser platforms and customised treatment ablation require extremely accurate laser spot placement to ensure accuracy of the treatment. The demands on the eye tracker are high and multi-fold.

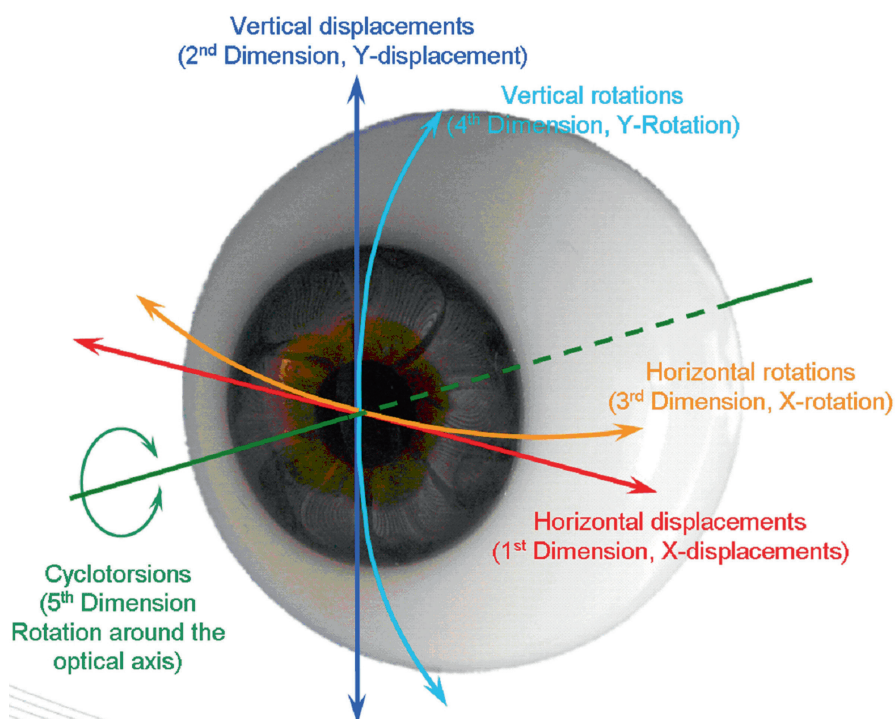
Faster laser platforms correspondingly require faster eye trackers. Without ultrafast eye trackers, even the slight movement of the patient's eye will result in a spot placement far from the intended area on the

cornea. In general, the eye tracker should be at least twice as fast as the speed of the laser in order to ensure accurate laser spot placement. Most eye trackers in conventional laser platforms have capturing rates of between 60 and 330 Hz or are able to detect the pupil position at 4,000 Hz. This results in a response time of up to 36 ms. Clearly, this will not be sufficient for high-speed laser platforms of 500 Hz or more.

The Schwind Amaris incorporates a high-speed eye tracker with an acquisition speed of 1,050 Hz. This eye tracker has a response rate of less than 3 ms and tracks both the limbus and pupil. Most existing eye trackers also only detect pupil position and do not compensate for pupil size and pupil centre shifts during treatment. As the pupil centre may shift during treatment as the pupil constricts or dilates, the centre of the pupil may change during the treatment process. Hence, the importance of eye trackers that are able to track both the pupil and the limbus simultaneously to ensure that the laser spot placement is accurate with respect to the pre-operative pupil position or the corneal vertex.

It is evident that eye movements are possible in more than two dimensions (Fig. 5.9). In fact, a total of five dimensions of eye movements can be recognised.

Fig. 5.9 The five dimensions of movement of an eye which is possible during excimer laser refractive surgery



Horizontal and vertical displacements of the eye (X and Y displacements) occur when the patient's head is moved laterally or vertically. However, the eye may also rotate vertically or horizontally around the centre of the eye ball (X and Y rotation). Lastly, cyclotorsions or rotation around the optical axis may also occur. Cyclotorsion of the eye may occur when the patient is placed in a supine position from a standing position before treatment. Cyclotorsion of the eye may also occur during the treatment procedure. While all laser platforms incorporate an eye tracker, most eye trackers only track horizontal or vertical displacements of the eye and only a few eye trackers are able to track cyclotorsional rotations of the eye. The ability to track all movements of the eye is crucial to enable accurate placement of the laser spots with respect to the cornea vertex, especially for customised laser ablations.

Rotational movement of the eye around the centre of the eye ball (X and Y rotation) will result in a shift in the placement of the laser spot with respect to the vertex if the eye tracker is tracking only the horizontal or vertical displacement of the eye (Fig. 5.10). Advanced eye tracker will need to take this into consideration in order to ensure more precise placement of laser spots. The Schwind Amaris incorporates a

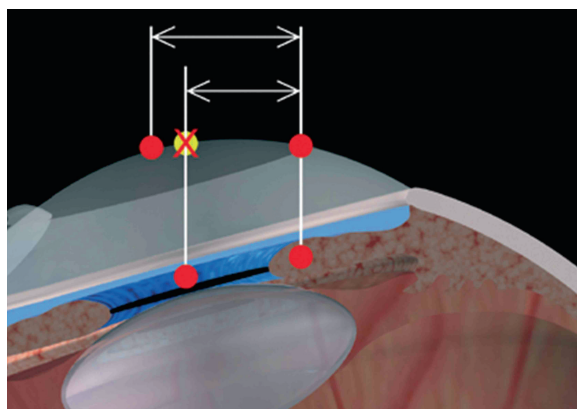


Fig. 5.10 Diagram showing the effect of rotational movement of the eye around the centre of the eye ball (X and Y rotation) on the placement of the laser spot with respect to the vertex

rolling compensation by using a Rotation Balance Algorithm to compensate for such rotational movements of the eye.

Cyclotorsion movements of the eye can be classified as either static cyclotorsion movement or dynamic cyclotorsion movements. Static cyclotorsion movement occurs when the patient is moved from an upright to a supine position while dynamic cyclotorsion

movement occurs during the treatment procedure. Advanced eye trackers must be able to detect both types of cyclotorsion movements.

Static cyclotorsion detection is performed by comparing pre-operative topography or limbal features when the patient is upright with the topography, iris or limbal features when the patient is supine. Dynamic cyclotorsion tracking is performed by tracking the iris or limbal features during the treatment process. Advanced eye trackers, for example in the Amaris laser platform (Schwind Eye-tech), are able to perform both static and dynamic cyclotorsion tracking.

5.3.1.6 Newer Ablation Profiles

Standard excimer laser ablations of the cornea are known to result in a more oblate cornea after myopic correction and a more prolate cornea after hyperopic correction. Hence, myopic laser refractive surgery induces a positive spherical aberration while hyperopic corrections induce a negative spherical aberration [33, 65, 69]. LASIK is also reported to induce more higher-order aberrations after surgery. Most excimer laser delivery systems today come with ablation profiles designed to reduce the induction of such aberrations. For example, aspheric ablation profiles in the Bausch and Lomb 217 Zyoptix 100 and the Zeiss MEL 80 are designed to maintain the prolate shape of the cornea after myopic laser treatment and reduce the induction of spherical aberrations. Customised or wavefront-guided ablation profiles are also available and the aim of these profiles is to correct pre-existing individual optical aberrations while correcting the refractive error during excimer laser refractive surgery.

Customised or wavefront-guided LASIK have been shown to be as safe and efficacious as conventional LASIK [1, 8, 17, 49]. Wavefront-guided LASIK has also been shown to reduce the amount of induced higher-order aberrations compared to conventional LASIK [24]. But other studies have shown that wavefront-guided LASIK only reduced higher-order aberrations in less than 50% of eyes [32]. Furthermore, the clinical benefits of performing wavefront-guided LASIK compared to conventional LASIK in a normal eye may not be apparent [53]. Some of the factors which may affect the results of customised or wavefront-guided LASIK include variables in the LASIK procedure, which includes accurate centration of the laser spot, creation and replacement of the corneal flap

and wound healing. Cyclotorsion in the supine position may also influence the spot position as related to the aberrometer data. The size of the laser spot diameter is also an important factor for the success of advanced ablation profile. The smaller the spot size the more precise is the ablation.

The design of the excimer laser platform is crucial to enable accurate corneal ablation based on the pre-operative topography or aberrometry investigations. Advanced eye-tracker systems, for example in the Schwind Amaris, will allow accurate placement of the laser post, despite movements of the patient's eye. A smaller laser spot size will also allow precise etching of the cornea stromal bed. Most conventional excimer lasers have a spot size of 0.8mm or more. The new Schwind Amaris has a spot size of only 0.54mm, allowing more precise ablations. Thus, we can observe that for successful results of newer laser ablations profiles, they must be accompanied by improvements in the design of the excimer laser platform.

5.3.2 PRK and Advanced Surface Ablations (ASA)

There is a recent resurgence in the prevalence of photorefractive keratectomy (PRK) and other ASA techniques like Epi-LASIK which are performed due to increasing awareness of complications, in particular, corneal ectasia after LASIK and flap-related complications. However, haze formation in these techniques remains a concern and various methods of reducing the risk of haze can be observed in recent years. The following trends can be observed in PRK and ASA techniques:

1. Decrease thermal load on the cornea
2. Use of wound-healing modulators
3. Trend towards Epi-LASIK

5.3.2.1 Decrease Thermal Load on the Cornea

Haze is an important complication related to PRK and to a lesser extent, ASA techniques. Haze results in a reduction in transparency of the cornea and its exact aetiology is unknown. There is a higher incidence of haze after PRK in eyes with higher degrees of myopia [4, 5]. Studies have also shown that there is a greater

intensity of keratocyte proliferation and myofibroblast generation after PRK for high corrections, in contrast to PRK for low corrections [40, 66]. Another study showed that corneas undergoing PRK for higher corrections were subject to greater rises in temperature for longer periods of time [38]. Thus, the thermal load on the cornea during PRK may be a risk factor for haze formation. The magnitude of corneal wound repair and the development and duration of corneal haze also increased proportionally with increasing stromal photablation depth (i.e. the volume of stromal tissue removal) [41]. It is possible that lasers which remove less stromal tissue will induce less haze for the same amount of refractive correction. Hence, newer excimer laser platforms like the SCHWIND Amaris which has a smaller spot size, dual fluence levels and a special thermal effect control may help to reduce the thermal load on the cornea during PRK and also during ASA techniques. This may help to reduce the incidence of haze in these procedures.

5.3.2.2 Use of Wound-Healing Modulators

Corneal wound healing is a complex cascading sequence of events. Multiple cytokines and growth factors, such as interleukin (IL)-1, tumour necrosis factor (TNF) α , bone morphogenic proteins 2 and 4 (BMP), epidermal growth factor (EGF) and platelet-derived growth factor (PDGF), are released from the corneal epithelium and epithelial basement membrane after epithelial injury [47, 67]. In the event of impaired epithelial mechanical barrier function associated with this injury, for example in PRK, these mediators of cellular responses are able to reach the stroma and bind to their respective receptors to the keratocyte cells, where they trigger a variety of biological responses. One of the biological responses includes the generation of myofibroblasts, presumably derived from keratocytes, under the influence of transforming growth factor (TGF)- β [70]. An important characteristic of myofibroblasts is reduced corneal transparency relative to keratocytes. Studies have showed greater intensity of myofibroblast generation after PRK corrections, in contrast to PRK for low myopia. However, the exact role of myofibroblast generation in haze formation remains unclear. But modulating the wound response may help to reduce the risk of haze formation.

Mitomycin C (MMC) has been showed to reduce scar formation in rabbits after PRK [58, 68]. Mitomycin

C induces apoptosis of keratocytes and myofibroblasts, but the predominant effect in inhibiting or treating haze appears to be at the level of blocked replication of keratocytes or other progenitor cells of myofibroblasts [48]. In a study by Bedei et al., the application of MMC 0.02% solution immediately after PRK produced lower haze rates and had better predictability and improved efficacy 1 year after treatment [10]. Other studies also showed reduced incidence and severity of haze after PRK with the application of MMC intraoperatively [36, 46]. In our centre, we routinely use MMC 0.02% for PRK with ablations of greater than 50 μm .

Other wound modulators are also hypothesised to reduce haze formation. Several wound modulators have been studied and have shown promise in reducing haze formation. Anti-TGF- β was shown to reduce keratocyte activation and transformation and inhibited stromal fibrosis, leading to a reduction in early light reflectivity as well as to a more rapid decline in rabbits after PRK. Anti-TGF- β treatment may be useful in reducing post-PRK corneal haze development in patients by inhibiting the recruitment of highly reflective, activated keratocytes, inhibiting myofibroblast transformation and reducing stromal fibrosis [42]. Urokinase-type plasminogen activator has been shown to prevent haze after photorefractive keratectomy in rabbits in one study [19]. Another study showed that cytochrome c peroxidase significantly accelerates epithelial healing after PRK [56]. However, further studies are needed to confirm if cytochrome c peroxidase is able to prevent corneal haze.

While many of these new wound modulators have been shown to be effective in reducing haze after PRK in animals. More studies will be needed to confirm if they will be effective in humans.

5.3.2.3 Trend Towards EPI-LASIK

The theoretical advantage of advanced surface ablation procedures such as laser epithelial keratomileusis (LASEK) and Epi-LASIK is that these procedures preserve the epithelial button which is repositioned over the laser-ablated corneal surface. This epithelial sheet is thought to act as a natural contact lens that decreases post-operative pain and haze formation. The intact corneal epithelium may play an important part curbing sub-epithelial haze and differentiation of myofibroblasts in corneal wound healing [45]. Epi-LASIK uses specific microkeratome with a blunt oscillating blade

to perform the epithelial separation. Comparison of the effect of mechanical (Epi-LASIK) and alcohol-assisted excision (LASEK) on the histological ultrastructure of epithelial disks from human corneas showed that EpiLASIK technique is less invasive to epithelial integrity than LASEK [51].

Comparison of PRK, LASEK and epi-LASIK patients showed that epi-LASIK patients had the best day 1 visual acuity and had comparable visual and refractive results to other surface ablation techniques with lower levels of post-operative pain for the first 2 h. However, there was a high rate of flap failure and conversion to PRK [50]. One year results of 234 eyes of 138 patients underwent epi-LASIK for the correction of low to moderate myopia showed good refractive outcomes with only 14% of eyes have clinically insignificant (trace) haze [30]. Further long-term studies will be necessary to compare the effectiveness of Epi-LASIK compared to other excimer laser refractive surgery techniques.

5.3.3 Summary

We can see that currently the technology is available for refractive surgeons to achieve the aims of minimal invasive surgery in LASIK, that is, to perform accurate and predictable LASIK while at the same time minimise tissue damage and time required. In our centre, we use the Intralase® FS laser to create the cornea flaps for most of our LASIK patients and we use the Schwind Amaris excimer laser system in order to achieve our goals of minimal invasive surgery in LASIK.

5.4 Intraocular Refractive Surgery

5.4.1 Phakic Intraocular Lens Surgery

Trends in Phakic Intraocular Lens Surgery

1. Minimising incision size
 - (a) With newer lens design
 - (b) With newer materials
2. Advances in diagnostic anatomy and PIOL sizing technology
3. Decrease in complication rates

4. Improving outcomes of phakic intraocular lens surgery
5. Ability to treat all types of refractive errors

Phakic intraocular lenses (PIOLs) are an important part of a refractive surgeon's armamentarium. PIOLs are used in the correction of eyes with high refractive errors, especially if the cornea is thin. PIOLs are also used in cases where the corneal topography is abnormal or suspicious. As in the case of LASIK, refractive surgeons are continuously searching for new methods and technology to perform minimal invasive surgery for PIOL implantation. As implantation of PIOL requires incisions in the eye, the advantages of minimal invasive surgery are clear. A smaller incision will enable a more rapid patient rehabilitation, induce much less astigmatism, especially if no sutures are required, and cause less patient discomfort. In addition, advances in lens designs and diagnostic equipment have led to a reduction in the risk of complications related to PIOLs.

Development of PIOL began in the 1950s. But early lens models were plagued with poor outcomes and complications associated with poor quality lenses and surgical techniques. Jan Worst introduced an innovative lens design whereby the lens is attached to the mid-peripheral iris in 1978. The Baikoff ZB (Domilens, Lyon, France) angle-supported intraocular lens was introduced in 1986. Since then, phakic intraocular lens technology has advanced greatly.

The Baikoff ZB PIOL was made of polymethylmethacrylate with a Z-flex design and an optic diameter of 4.5 mm. This rigid PIOL required a limbal incision of at least 6 mm and the patient required regional anaesthesia for the surgery. With such a large incision, surgically induced astigmatism is unavoidable in many cases. Hence, it may be difficult to predict the final refractive outcome. This is ironic, considering that this is a refractive procedure. Such a large incision is also associated with a higher incidence of pupil ovalisation. Thus, a PIOL which can be implanted with a sutureless incision of 3 mm or less is one of the most important considerations in minimal invasive surgery for PIOLs.

The Baikoff ZB angle-supported intraocular lens has a 25° anterior haptic angle. Vaulting of PIOLs, especially angle-supported PIOLs, has been postulated to be a major cause of endothelial cell loss, a common problem associated with PIOLs. Newer designs of

angle-supported PIOLs, for example the ZB5M (Domilens), have incorporated design changes such as a smaller vaulting angle and thinner optics to reduce the risk of long-term endothelial cell loss. However, long-term endothelial cell loss in eyes with angle-supported PIOLs is observed in some studies.

Newer PIOL designs include different methods of securing the PIOLs in the anterior chamber. Iris-supported models include the iris-fixated Artisan PIOL (Ophtec BV, Groningen, The Netherlands; marketed in the USA as Verisyse, Advanced Medical Optics, Santa Ana, CA) and the posterior chamber lens-supported PIOL include the Visian Implantable Collamer Lenses (ICL; Staar Surgical Company, Monrovia, CA). Chief consideration in the design of the iris-supported and posterior-chamber-supported models was to increase the distance between the PIOL and the endothelium, thereby reducing the risk of long-term endothelial cell loss.

The Verisyse/Artisan PIOL incorporates specially designed iris claws in its haptics to secure the PIOL to the iris. With this iris claw, this PIOL should not cause problems like anterior vaulting or instability in the anterior chamber [9]. However, implantation of the Verisyse/Artisan PIOL requires at least a 5.5-mm limbal incision which must be closed by sutures. Studies on a foldable version of the Verisyse/Artisan PIOL, the Artiflex PIOL, are still underway in Europe [14]. This foldable version will require a smaller incision and hopefully, achieve the aims of minimal incision surgery for PIOLs.

The posterior-chamber-supported PIOLs are implanted in the sulcus, between the natural crystalline lens and the iris. Long-term endothelial cell loss is less of a problem in such lenses. However, the close proximity of these lenses to the natural lens increases the risk of cataract formation. One of the more commonly used posterior-chamber-supported PIOLs today is the Visian ICL. The older version of the Visian ICL, the V3 ICLs, which has been discontinued, was associated with a higher incidence of anterior subcapsular cataract formation compared to the newer V4 ICLs [54].

Conventional PIOLs also do not correct astigmatism. However, recently, newer PIOLs with toric designs have been introduced to correct astigmatism at the same time. Hence, more invasive procedures like limbal relaxing incisions or combining PIOL implantation with excimer laser treatment to correct astigmatism are no longer necessary with these new toric PIOLs. Currently, toric models of the Artisan

[21] and Visian ICL are available. However, as discussed above, the Artisan PIOL requires a larger incision which may result in a surgically induced astigmatism.

5.4.1.1 Advances in Diagnostic Equipment

Choosing the appropriate model and size of PIOLs is essential to avoid potential complications. Inserting an oversized angle-supported PIOL in an eye with an anterior chamber depth of less than 3 mm will result in a high risk of long-term endothelial cell loss. Traditionally, the sizing of PIOLs was based on measurements of the white-to-white distance of the cornea. However, it is well known that the white-to-white distance is a poor indicator of the internal dimensions of the anterior or posterior chamber and does not accurately measure the distance between the irido-corneal angles [28]. Anterior segment anatomy also differs significantly from myopes to hyperopes and this will affect the choice of PIOL. Specialised surgical devices such as intraocular calipers are still inaccurate and have not been able to solve the problem of precise PIOL sizing. The advent of the Visante anterior segment optical coherence tomography (AS-OCT; Carl Zeiss Meditec Inc, Dublin, CA) has revolutionised the way refractive surgeons evaluate the anterior segment and perform PIOL sizing. The Visante AS-OCT uses a 1,320 nm wavelength to obtain images of the anterior chamber similar to A and B scanning (Fig. 5.11). Of importance to the refractive surgeon are the measurements for anterior chamber depth, angle-to-angle measurements and calculations of the anterior chamber angle. These values will assist the refractive surgeon in deciding the choice of PIOL and to size the appropriate PIOL for the patient.

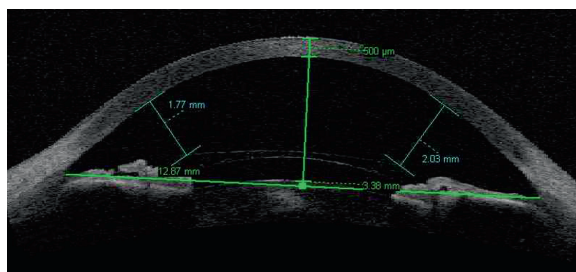


Fig. 5.11 OCT image of a phakic intraocular lens in the eye

5.4.1.2 Types of Phakic Intraocular Lens

We will discuss two PIOLs which require sutureless incisions of less than 3 mm and, therefore, more closely achieve the goals of minimal incision surgery for PIOL.

5.4.1.3 Kelman-Duet Phakic Intraocular Lens

The Kelman-Duet PIOL (TEKIA, Irvine, CA, USA) is an angle-supported PIOL. What makes it different from other angle-supported PIOL is that it has an independent haptic and a separate optic frame of 6 mm (Fig. 5.12). The main advantage is the ability to implant this lens through a sub-2.5 mm sutureless incision. This allows the refractive surgeon to perform this surgery under topical anaesthesia. Another advantage of this lens is the exchangeability of both the lens haptic and optic. It is known that the human myopic eye may experience optical and refractive changes such as progressive myopia, presbyopia or changes in lens asphericity throughout the lifespan. Exchangeability of the optic is an option that allows the implant to be adapted for these future refractive changes. Another important advantage of this lens is the possibility of selecting the appropriate size of the haptic depending on the anatomic characteristics of the anterior segment. This

enables a specific complication of angle-supported PIOLs (i.e. pupil ovalisation due to inappropriate selection of the size of lens) to be solved.

Lens Design

The Kelman-Duet lens is a two-piece, angle-supported PIOL, consisting of the haptic and optic. Both parts are independent and implantable through a sub-2.5 mm incision. The polymethylmethacrylate haptic has three points of support and harbours a central area with two anchors to engage the optic of the lens. The total length of the haptic is from 12 to 13.5 mm. The haptic supporting tips are rounded and oval to ensure smooth contact with the angle structures. The angulations of the haptic are 11.1° for the 12.0 mm haptic, 10.5° for the 12.5 mm haptic and 9.6° for the 13.0 mm haptic.

The mono-focal optic is made of silicon and has a total diameter of 6 mm, with two eyelets to be attached to the haptic frame. It can be injected through a sub-2.0 mm incision. The periphery area of the optic has a glare-preventing shield to avoid light reflexes in dim-light conditions. The optic is available in 1-diopter increments in optic power from -6.0 to -20.0 D.

Surgical Technique

Pre-Operative Preparation

It is recommended that all patients undergoing Kelman-Duet implantation should have had a Visante AS-OCT scan of the eyes. The anterior chamber depth (as measured from the endothelium to the anterior lens surface), cornea-iris angle measurement and sulcus-to-sulcus measurements are important in deciding whether the patient's eye is suitable for the Kelman-Duet PIOL. Pre-operative endothelial cell counts are also essential. Eyes undergoing the Kelman-Duet PIOL implantation should fulfil the following criteria:

1. Mean endothelial cell density of more than 2,500 cell/cm²
2. Anterior chamber depth of more than 3.0 mm
3. Cornea-iris angle of more than 35°
4. Sulcus-to-sulcus measurement of more than 11.0 mm

Implantation of the Kelman-Duet PIOL can be performed under topical anaesthesia. In our centre, preservative-free lidocaine 2% is used with mild sedation



Fig. 5.12 The Kelman-Duet two-piece phakic intraocular lens

with midazolam (Roche, Madrid, Spain). One drop of 1% pilocarpine (Isoptocarpine, Alcon Cusi, Barcelona, Spain) is instilled into the eye 30 min before surgery.

The size of the haptic required depends on the sulcus-to-sulcus measurement. One millimetre is added to the sulcus-to-sulcus measurement and the nearest largest haptic size is chosen (12.0, 12.5, 13.0 and 13.5 mm). For example, an eye with a sulcus-to-sulcus measurement of 11.3 mm will require a 12.5 mm haptic.

Operative Procedure

A 1 mm paracentesis is performed inferiorly corresponding to the steepest meridian. Then, a 2.5-mm or 2.0-mm corneal incision is made with a carbon knife (Accutome, Malvern, PA, USA). Preservative-free lidocaine (0.2 ml of 1%) is then used to irrigate the anterior chamber. Healon (Pharmacia, Upsala, Sweden) is injected until the anterior chamber is completely filled.

A peripheral iridotomy is performed in the superior quadrant using a surgical vitrectomy cutter. Subsequently, the haptic of the lens is then introduced, placing it in an oblique meridian. The optic part of the lens is prepared in the cartridge of a Medport injector (Bausch & Lomb, Irvine, CA, USA), with its surface curved down and eyelets perpendicular to the main axis of the cartridge. The cartridge was previously lined with 2% hydroxypropyl methylcellulose (Celoftal, Alcon Cusi, Barcelona, Spain). A small piece of silicone sponge is used to prevent damage to the optic when the metal piston of the injector is pushing the lens into the eye. After the optic is injected into the anterior chamber, the eyelets of the optic is fixed to the hooks of the haptic using either two Lester or Sinsky hooks.

Healon is then removed from the anterior chamber by irrigation with balanced salt solution (BSS, Alcon Cusi, Barcelona, Spain). The corneal incision is hydrated and 0.1 ml of 1% Cefuroxime injected in the anterior chamber before the end of surgery (Fig. 5.13).

Post-Operative Care

Post-operative treatment consists of Maxidex (Alcon Cusi, Barcelona, Spain) one drop three times daily for 2 weeks and Oftacilox (Alcon Cusi, Barcelona, Spain) one drop every 12 h for 3 days.

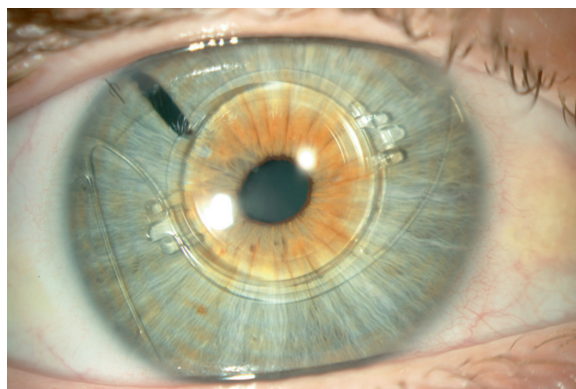


Fig. 5.13 Kelman-Duet PIOL in the eye

Results

We examined 169 eyes of 110 patients with moderate or high myopia 1 year after implantation with the Kelman-Duet PIOL at our centre (VISSUM/Instituto Oftalmológico de Alicante, Alicante, Spain).

Refractive Outcomes

Mean pre-operative spherical equivalent refraction was -15.01 ± 4.53 D (range: -8.75 to -26.00 D). At 12 months, spherical equivalent refraction was within ± 0.50 D in 57.72% of eyes (71) and within ± 1.00 D in 81.30% of eyes (100). (Spherical equivalent refraction was recorded in only 123 eyes at 12 months.) At 12 months, the refraction of plano was reached in 20.54% of cases. The predictability is summarised in Fig. 5.14.

At the last post-operative visit, UCVA was 20/40 or better in 108 (83.72%) eyes and 20/20 or better in 37 (28.68%) eyes (Fig. 5.15). Best spectacle-corrected visual acuity improved by two or more Snellen lines in 68 (56.20%) eyes (Fig. 5.16). No eye lost two or more Snellen lines of BSCVA. The efficacy index was 1.18 ± 0.43 at 6 months and 1.19 ± 0.40 at 12 months.

Corneal Endothelium

Endothelial morphometric data are shown in Table 5.1. There was a decrease in pre-operative endothelial cell density and 3-month post-operative measurements, and between 3-month and 6-month post-operative measurements. However, the difference was not statistically significant for either time period. But, when pre-operative and 12-month post-operative measurements

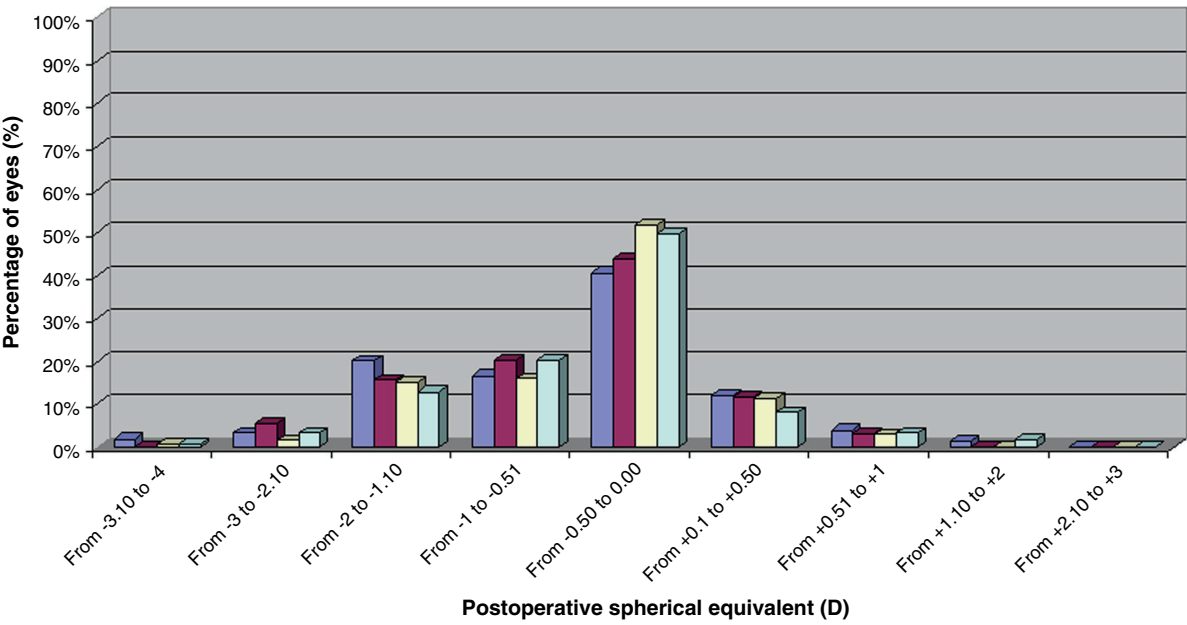


Fig. 5.14 Predictability results at 12 months after implantation with the Kelman-Duet phakic intraocular lens. All parameters were recorded for all eyes only at the pre-operative visit. Data for some of the post-operative visits are missing because the patient did not follow up. Total number of eyes: pre-operative = 146, 1 month = 146, 3 months = 128, 6 months = 131, and 12 months = 123

Fig. 5.15 Cumulative post-operative uncorrected visual acuity (UCVA) at 12 months after implantation with the Kelman-Duet phakic intraocular lens vs. cumulative pre-operative best spectacle-corrected visual acuity (BCVA)

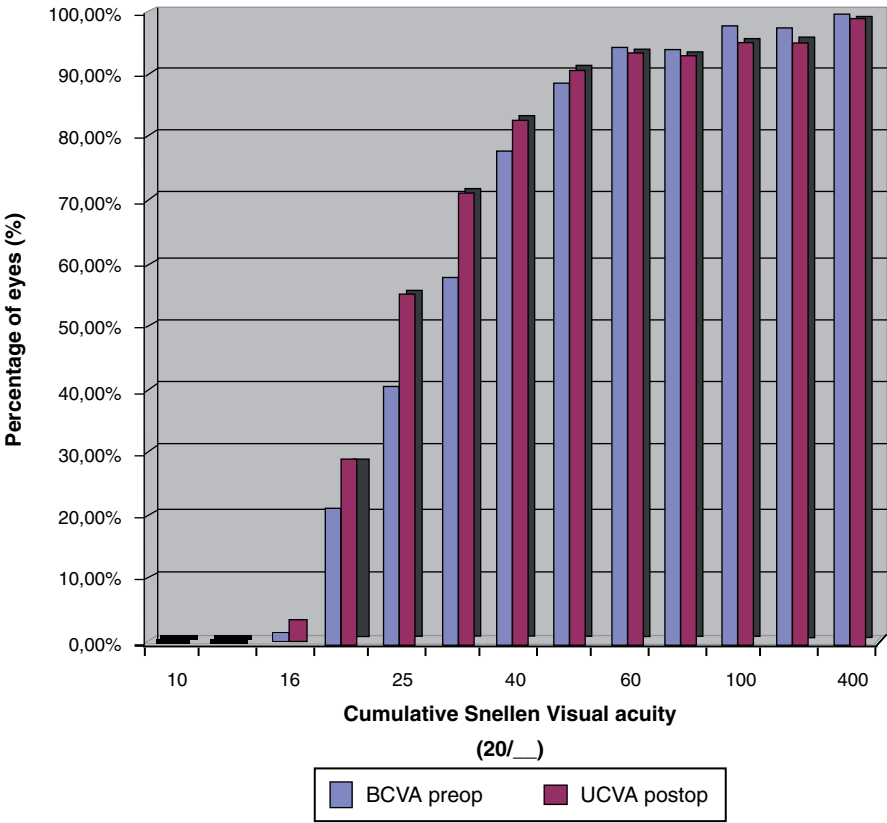


Fig. 5.16 Change in best spectacle-corrected visual acuity (BCVA) at 12 months after implantation with the Kelman-Duet phakic intraocular lens

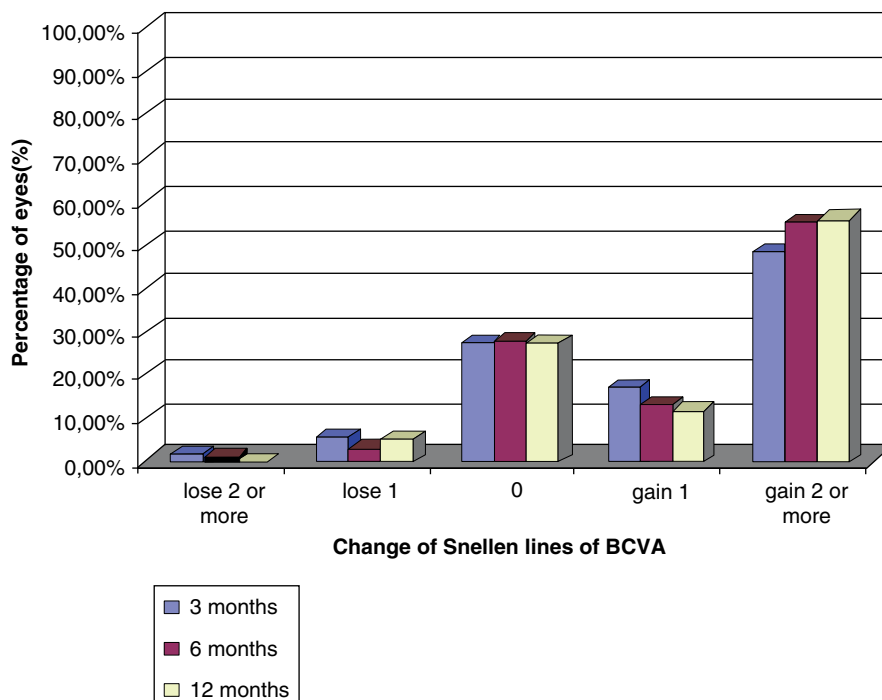


Table 5.1 Endothelial morphometric findings in 110 eyes that underwent implantation with the Kelman-Duet phakic intraocular lens^a

	Pre-operative	Mean \pm SD	
		3 Months	12 Months
Cell density (cells/mm ²)	2726.12 \pm 376.47	2683.21 \pm 380.32	2579.14 \pm 320.86
Percentage of loss (%)		2.73 \pm 9.67	5.43 \pm 11.19
Coefficient of variation	46.44 \pm 1957	35.82 \pm 10.94	38.83 \pm 9.48

^aBecause different protocols were used at each centre to determine corneal endothelial changes, only endothelial data for 110 eyes from the coordinating centre were included in the analysis

were compared, the total decrease in cell density is statistically significant. As in any study concerning the endothelial cell loss in PIOLs, longer follow-up is necessary to confirm this observation.

Loss of endothelial cell density was more than 15% in 19 (17.27%) eyes. Of these cases, pupil ovalisation occurred in 8 (42.11%) eyes and the lens appeared decentred at the anterior segment in 6 (31.58%) eyes. In 4 (50.0%) of the eyes with pupil ovalisation, the haptic was exchanged to improve the situation.

Complications

Surgery was completed successfully in all eyes with no intraoperative complications. Post-operatively, no lens

opacification, chronic increased IOP, or pupillary block occurred, and none of the lenses had to be explanted during the follow-up period.

In the early post-operative period, one (0.59%) eye experienced synechiae between the iris and the optic of the lens. This was resolved by widening the iridotomy. Endothelial cell density loss was >20% in this eye. Additionally, significant flare reaction occurred in 1 (0.59%) eye at 1 month post-operatively but was resolved with injection of intracameral triamcinolone acetonide. Mild and severe levels of pupil ovalisation were present in 17 (10.06%) eyes. Normally, this phenomenon is produced by inadequate adjustment of the total length of the haptic to the internal intertrabecular distance of the eye. For this reason, haptic exchange

was performed in 9 (5.33%) eyes and haptic repositioning was performed in 3 (1.78%) eyes. Mild decentration of the lens could be appreciated by slit-lamp microscopy in 9 (5.33%) eyes. Night vision disturbances such as halos or glare were a significant complaint in 11.24% of eyes (19) at 1 month, but this frequency decreased to 4.73% of eyes (8) at 3 months post-operatively.

At 12 months post-operatively, no severe complications were present. The percentage of cases with pupil ovalisation was similar to that at 3 months post-operatively. Haptic exchange was performed through the sub-2.5-mm incisions in all cases that required exchange. Lens decentration was apparent in 11 (6.51%) eyes at 12 months post-operatively. Halos and glare were disturbing phenomena in 2 (1.18%) eyes. No retinal complications were noted.

5.4.1.4 Visian Implantable Collamer Lens

The Visian Implantable Collamer Lens (ICL; Staar® Surgical Company, USA) is a one-piece foldable phakic intraocular lens which is implanted in the posterior chamber, just anterior to the natural crystalline lens. The main advantages of this PIOL is that it can be inserted through a sub-3 mm corneal or limbal incision and the position of the PIOL ensures a greater distance from the PIOL to the corneal endothelium, thereby reducing the risk of long-term endothelial cell loss [20]. Toric models of this PIOL are also available.

Lens Design

The Visian ICL is a one-piece PIOL which is made from Collamer, a proprietary, biocompatible, UV-absorbing, hydrophilic porcine collagen/Polyhydroxyethyl methacrylate (HEMA) copolymer. The biological composition of the Visian ICL has excellent biocompatibility with the eye. The Visian ICL incorporates a forward vault into its plate-haptic design with a central convex/concave optical zone and is designed to have minimal contact with the natural crystalline lens.

The optic and the overall diameters of the Visian ICL vary with refractive power, ranging from 4.9 mm (optic)/12.1 mm (overall) to 5.8 mm (optic)/13.7 mm (overall). The Visian ICL is able to correct myopia of -3.0 D to -20.0 D (US approval).

The toric version of the Visian ICL (TICL) is available and is currently undergoing trials [57]. The TICL is identical (identical haptic design) to the current V4 Staar Visian ICL except that it has an anterior toric surface. The TICLs are manufactured to minimise rotation and require the refractive surgeon to rotate the ICL no more than 22.5° from the horizontal meridian.

Surgical Technique

Pre-Operative Preparation

It is recommended that all patients undergoing ICL implantation should have had a Visante AS-OCT scan of the eyes. Pre-operative endothelial cell counts are also essential. Eyes undergoing the ICL implantation should fulfil the following criteria:

1. Mean endothelial cell density of more than 2,500 cell/cm²
2. Anterior chamber depth of more than 3.0 mm

In our centre, ICL implantation is performed under topical anaesthesia. Two drops of preservative-free lidocaine 2% is used. In the case of TICL implantation, corneal marking of the horizontal axis is performed at the slit-lamp while the patient is sitting upright.

Operative Procedure

A 1-mm paracentesis is performed inferiorly corresponding to the steepest meridian. Then, a 3.0-mm corneal incision is made with a carbon knife (Accutome, Malvern, PA, USA). Visthesia (Carl Zeiss Meditec), a combination of Sodium Hyaluronate and Lidocaine, is subsequently injected in the anterior chamber followed by 2% hydroxypropyl methylcellulose (Celoftal, Alcon Cusi, Barcelona, Spain). A peripheral iridotomy is then performed in the superior quadrant using a surgical vitrectomy cutter. Subsequently, the pupil is dilated using intracameral mydriasis using 1 mL of a vial containing (G. cyclopentolate 1% 1 mL, G. Phenylephrine 10% 1.5 mL, lignocaine 2% 5 mL, solution BSS, C.S.P 10 mL, each vial contains 2 mL).

The ICL is loaded into the injector and injected into the eye in a smooth motion and allowed to slowly unfold. The footplates of the ICL are tucked under the iris using the Vukich ICL manipulator (ASICO LLC,

Westmont, IL, USA), taking care to ensure that the optic does not cross the optic during this manoeuvre.

In the case of the TICL implantation, corneal marking of the intended axis of placement of the TICL is performed at the start of the surgery. This axis is determined by the manufacturer and the refractive surgeon will have to mark the axis according to the instructions provided by the manufacturer. After the TICL is inserted in the eye, the TICL is rotated to the intended axis prior to the tucking of the footplates.

Viscoelastic is then removed from the anterior chamber by irrigation with balanced salt solution (BSS, Alcon Cusi, Barcelona, Spain) and the pupil miosed with intracameral Acetylcholine 1% (Acetilcolina 1%, Alcon Cusi, Barcelona, Spain). The corneal incision is hydrated and 0.1 ml of 1% Cefuroxime injected in the anterior chamber before the end of surgery.

Post-Operative Care

Post-operative treatment consists of Maxidex (Dexamethasone 0.1%, Alcon Cusi, Barcelona, Spain) one drop, three times daily for 2 weeks, Oftacilox (Ciprofloxacin 0.3%, Alcon Cusi, Barcelona, Spain) three times daily for 7 days and Votaren eye drops (Diclofenac Sodium 28 µg in 0.3 mL, Novartis Pharmaceuticals, Barcelona, Spain) every 12h for 6 weeks.

5.4.1.5 Results

Lackner et al. evaluate long-term results after insertion of implantable contact lenses (ICLs) in 75 phakic eyes (65 myopic, 10 hyperopic eyes) of 45 patients aged 21.7–60.6 years [35]. Their study showed that the ICL was effective in correcting myopia and hyperopia. After ICL implantation, mean UCVA up to the end of individual observation time was Snellen 0.36 ± 0.36 for myopic patients and Snellen 0.58 ± 0.28 for hyperopic patients. Improvement in BCVA was also observed in myopic eyes. Mean post-operative BCVA was 0.73 ± 0.26 in these eyes compared to the mean pre-operative BCVA of 0.49 ± 0.23 . However, the main complication was the development of subcapsular anterior opacifications of the crystalline lens which was noted in 25 eyes (33.3%).

Uusitalo et al. also showed that the ICL was effective in the treatment of myopia in 38 eyes of 22 patients [63]. All but three patients (5 eyes) are able to manage

most activities without spectacles. The mean spherical equivalent refraction at the last examination ± 1.00 D of the targeted refraction in 31 eyes (81.6%) and within ± 0.50 D in 27 eyes (71.1%) and the refraction remained stable with a statistically insignificant change ($p > 0.05$) at each interval during the follow-up.

Schallhorn et al. compared the Visian Toric Implantable Collamer Lens (TICL) and photorefractive keratectomy (PRK) in the correction of moderate-to-high myopic astigmatism [57]. Their prospective, randomised study evaluated 43 eyes implanted with the TICL (20 bilateral cases) and 45 eyes receiving PRK with mitomycin C (22 bilateral cases) with moderate-to-high myopia (−6.00 to −20.00 diopters (D) sphere) measured at the spectacle plane and 1.00–4.00 D of astigmatism. This study showed that after 6 months, the TICL performed better than PRK in terms of safety (BSCVA), efficacy (UCVA), predictability and stability. Contrast sensitivity was also noted to be better in the TICL group.

5.4.2 Summary

We can see that we have the lens and the technology to perform minimal invasive surgery for phakic intraocular lens implantation today. Currently, we are able to insert these PIOLs through a sub-3 mm sutureless incision and advances in PIOL technology and diagnostic equipments have improved the safety profile of PIOLs in general. In our centre, our first choice PIOL is the Kelman-Duet PIOL as it is safe and requires a smaller incision. The Visian ICL is preferred in eyes with smaller cornea–iris angles or if significant astigmatism is present.

5.5 Lens and Cataract Surgery

Cataract surgery is one of the most common surgeries in ophthalmology and presbyopia is the most common refractive problem affecting all adults above the age of 45 years. The expectations of cataract patients have increased with time. Most patients now expect a swift recovery after surgery and expect to be able to see both far and near without the use of spectacles. Cataract

surgery and intraocular lens technology have evolved substantially. The trends we see are:

1. Minimising incisions during cataract surgeries
2. Increasing popularity of multi-focal intraocular lenses
3. Improved performance of pseudophakic intraocular lenses
 - (a) Aspheric intraocular lenses
 - (b) Toric intraocular lenses

Today, the technology is available to achieve excellent refractive outcomes in post-cataract patients and to meet their expectations of being spectacle-free post-operatively. Micro-incisional cataract surgery allows cataract surgery to be performed through incisions smaller than 2.0 mm. Many types of multi-focal lenses are available in the market and some can be inserted through incisions smaller than 2.0 mm. Newer intraocular lenses also afford improved visual performance by incorporating aspheric designs. Toric lenses also now allow astigmatism to be corrected without additional surgical procedure like limbal-relaxing incisions.

5.5.1 Surgery: Micro-Incisional Cataract Surgery (MICS)

Micro-incisional cataract surgery (MICS) is defined as surgery performed through incisions of less than 2.0 mm. Current techniques and intraocular lens technology allow cataract removal through a 1.7 mm incision. The advantages of smaller incisions are:

1. Reduced surgical trauma
2. Reduced surgically induced astigmatism
3. More rapid visual rehabilitation

We conducted a randomised study comparing the outcomes of MICS vs. coaxial phacoemulsification in 100 eyes of 50 patients with nuclear or corticonuclear cataract grades of 2+ to 4 (Lens Opacities Classification System III) in our centre [3]. The final incision size was 1.7 ± 0.21 mm in the MICS group and 3.1 ± 0.25 mm in the coaxial group. Vectorial analysis of surgically induced astigmatism in the MICS group showed that in 35% of the eyes, a change of less than 0.25 D was induced by the surgery; in 50%, the change was between 0.25 and 0.5 D; and in 15%, it was between 0.5 and 1.0 D. None of the eyes in the MICS group showed a vectorial change of more than 1.0 D. While in the coaxial phacoemulsification group, 20% of eyes showed a vectorial change of 0.25–0.5 D; 30% showed a change of 0.5–1.0 D; and 50% showed changes of more than 1.0 D (Fig. 5.17). Surgically induced astigmatism calculated by vectorial analysis showed that in the MICS group, a mean vectorial astigmatic change of 0.36 ± 0.23 D was induced compared with 1.20 ± 0.74 D in the coaxial phacoemulsification group ($p < 0.01$). There was no statistical difference in the 3 months UCVA ($p = 0.74$), BCVA ($p = 0.85$) and mean percentage of endothelial-cell loss between the two groups ($p = 0.33$). No intraoperative complications were reported in either group. This study showed that MICS allows cataract surgery through a smaller incision and causes minimal surgically induced astigmatism. The latter point is of great importance for refractive surgeons and the implantation of multi-focal intraocular lenses.

We also assessed the visual outcomes of 45 eyes which underwent MICS surgery with the Acri.Smart 48S (Carl Zeiss Meditec AG, Jena, Germany) intraocular lenses in our centre [6]. The mean corneal incision size was 1.46 ± 0.19 mm (range 1.4–1.9 mm) for all the eyes. Six months after surgery, 71.3% of the patients

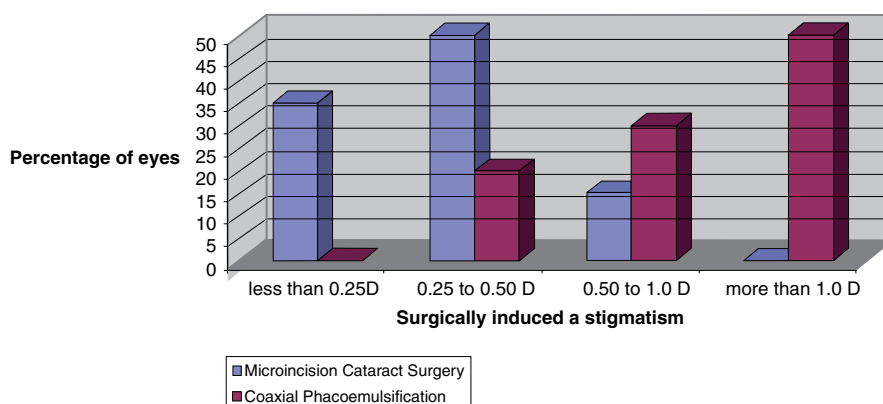


Fig. 5.17 Graph comparing surgically induced astigmatism in MICS vs. coaxial phacoemulsification

had uncorrected distance acuity of 20/32 or better and 98.9% had best corrected distance acuity of 20/25 or better. The safety index and efficacy index for distance vision of the procedure was 2.5 and 1.8 respectively. Another study also showed MICS does not degrade the optical quality of the cornea or induce a modification in corneal astigmatism [23].

Thus, we can see that MICS is able to achieve the aims of minimal incision surgery for cataract surgery and is a key factor in achieving optimal refractive outcomes in presbyopic patients with cataracts.

5.5.2 The Ideal MICS Intraocular Lens

Pseudophakic intraocular lenses (IOLs) have evolved in tandem with cataract surgery. In order to take advantage of the sub-2.0 mm incision possible with MICS, refractive surgeons must be able to implant the pseudophakic IOLs through these small incisions. In addition, the IOLs should be multi-focal IOLs to correct both ametropia and presbyopia at the same time. Evolution of aspheric and toric lenses has also taken place which may further improve the outcomes of cataract surgery.

The criteria for the ideal MICS IOL is very stringent. The ideal MICS IOL will have to fulfil the following criteria:

1. Able to be implanted through a sub-2 mm incision
2. Able to correct presbyopia
3. Have an aspheric design
4. Have a toric model available

5.5.2.1 Aspheric Intraocular Lenses

The cornea has a prolate surface with positive sphericity while the natural crystalline lens has a negative sphericity. Conventional pseudophakic IOLs have positive sphericity and these result in an increase in total optical aberrations, especially spherical aberrations, post-cataract surgery [26]. These aberrations play a substantial role in degrading visual performance when the pupil is large, i.e. scotopic night conditions [37]; hence, the development of aspheric IOLs. These aspheric designs are intended to reduce or eliminate the spherical aberration of the eye and improve functional vision as compared with a spherical pseudophakic implant.

Studies have demonstrated reduction or elimination of spherical aberration with the Tecnis IOL (AMO, Santa Ana, CA, USA) when compared with conventional spherical IOLs [11, 12, 18, 34, 44]. Eyes with the Tecnis Z9001 IOL with a modified anterior aspheric surface induced significantly less higher-order aberration and spherical aberration compared to the spherical Clariflex IOL (AMO, Santa Ana, CA, USA). Contrast sensitivity also revealed better values under photopic and mesopic conditions with the Tecnis Z9001 IOL [62]. Recent studies also supported reduction of spherical aberration and showed superior functional vision with the AcrySof IQ IOL (Alcon, Fort Worth, TX, USA) compared to spherical IOLs [7, 55].

Caporossi et al. compared patients who were randomly assigned to receive either IOLs with a spherical biconvex optic (Acrysof SN6OAT [Alcon] or Sensar AR40e [Advanced Medical Optics, AMO]) or IOLs with an aspheric optic (Acrysof IQ SN6OWF [Alcon], Tecnis Z9000 [AMO] or Sofport L161AO [Bausch & Lomb]) [15]. Their study showed that aspheric IOLs showed better contrast sensitivity compared to spherical IOLs at spatial frequencies of 6, 12, and 18 cycles per degree (cpd) under photopic conditions and at all spatial frequencies under mesopic conditions. Mean total spherical aberration was statistically lower in dominant eyes with aspheric IOLs (0.05 ± 0.06 , 0.11 ± 0.1 , and $0.19 \pm 0.08 \mu\text{m}$ for the Tecnis Z9000, Acrysof IQ SN6OWF and Sofport L161AO, respectively) compared with eyes with spherical IOLs (0.62 ± 0.24 and $0.46 \pm 0.19 \mu\text{m}$ for the Acrysof SN6OAT and Sensar AR40e, respectively) for a 5-mm pupil diameter. This showed that the aspheric IOLs had less wavefront aberrations and performed better under both photopic and mesopic contrast sensitivity compared to the spherical IOLs.

Thus, we can see that the visual performance, especially in scotopic conditions, is improved with aspheric IOLs.

5.5.2.2 Toric Intraocular Lenses

Correcting post-cataract surgery astigmatism, either due to pre-existing astigmatism or surgically induced astigmatism, has always been a challenge for refractive surgeons. As discussed earlier, surgically induced astigmatism can be reduced by MICS. However, correction of pre-existing astigmatism remains. Moderate

amounts of corneal astigmatism have traditionally been addressed through peripheral corneal relaxing incisions or by judicious selection of incision site [16, 43]. However, these methods can be unpredictable, and in the case of corneal relaxing incision, involve additional incisions with the associated side effects and risks. Excimer laser surgery after cataract surgery has also been advocated to correct the astigmatism. However, this again involves an additional procedure with its associated potential side effects and risks.

The introduction of the toric intraocular lens is an obvious solution to this problem. The pre-existing astigmatism can be corrected at the time of IOL implantation with an appropriate toric IOL. This means that the patient will not have to undergo additional procedures and be exposed to the risks of the procedures. Furthermore, toric IOLs will be able to correct higher degrees of astigmatism compared to peripheral corneal relaxing incisions [27, 60]. This will enable refractive surgeon to achieve the aims of minimal invasive surgery in correcting astigmatism during cataract surgery.

5.5.2.3 ACRI.LISA 366D and ACRI.LISA TORIC 466TD

Lens Design

The ACRI.LISA 366D IOL (Carl Zeiss Meditec AG, Jena, Germany) was specifically designed for MICS and can be implanted through an incision of less than 1.7 mm. It incorporates a new concept, refractive–diffractive optics, into its design to provide simultaneous good distance and near vision and to improve intermediate vision over previous designs.

The ACRI.LISA 366D is a bifocal, biconvex, optimised aspheric single piece IOL with a square-edged optic and haptic (Fig. 5.18). It is made of foldable acrylate with 25% water content which is able to absorb ultraviolet light (Acri.Lyc material) and has a hydrophobic surface. The aspheric profile of the IOL is aimed to correct the positive spherical aberration of the cornea. The sharp square edges of the IOL are designed to reduce the incidence of posterior opacification. It has an optic diameter of 6.0 mm, with an overall size of 11.0 mm.

The refractive–diffractive optics splits incident light into refractive distance focus with 65% light intensity and a diffractive near focus with 35% light intensity. The

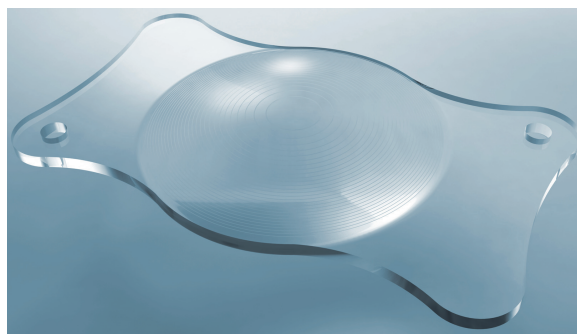


Fig. 5.18 The ACRI.LISA 366D intraocular lens

IOL power varies from 0.00 D to +32.00 D (0.00 D to +10.0 D in 1.0 increment and +10.0 D to +32.0 D in 0.5 D increment) and incorporates a +3.75 D near addition which corresponds to +3.75 D in the spectacle plane.

The ACRI.LISA TORIC 466TD (Carl Zeiss Meditec AG, Jena, Germany) has a similar design and is composed of the same material as the ACRI.LISA 366D. However, it has an aspheric, toric anterior surface in addition to its bifocal, diffractive, aspheric posterior surface. The IOL power available is able to provide −10.0 D to +32.0 D of spherical correction and +1.0 D to +12.0 D of cylindrical correction.

5.5.2.4 Surgical Technique

Operative Procedure

Topical anaesthesia (preservative-free lidocaine 2%) and mild sedation with midazolam is used in our centre.

The clear cornea incision is placed on the axis of the positive corneal meridian, which was previously marked at the slit lamp to prevent cyclorotation, using an Alio MICS diamond blade (Katena, Denville, NJ). A second similar clear corneal incision is made 90° apart and dilation is obtained with intracameral mydriatics using 1 mL of a vial containing cyclopentolate 1% (1 mL), phenylephrine 10% (1.5 mL), lignocaine 2% (5 mL), and balanced salt solution (BSS) (10 mL). A dispersive ophthalmic viscoelastic (Viscoat, AlconCusi) is injected to fill the anterior chamber and to protect the anterior chamber structures and the corneal endothelium. Subsequently, a cohesive ophthalmic viscoelastic (Celoftal, Alcon Cusi) is injected in the anterior chamber. Capsulorrhexis is performed with an Alio MICS

capsulorrhexis forcep (Katena). After that, hydrodissection is performed with BSS using a flat blunt 25-gauge cannula.

Pre-chopping (counter chopping technique) is performed to divide the nucleus into four quadrants before applying ultrasound energy. Pre-chopping is performed using two pre-choppers (Alio MICS, Katena) which are introduced through the two incisions and aligned on the same axis. They are then advanced beneath the anterior capsulorrhexis edge and around the equator. After the nucleus is cracked into two fragments, it is rotated and the same manoeuvre is repeated on the other axis to crack the nucleus into four quadrants.

An Infiniti phacoemulsification platform (Alcon) was used for MICS. A 45° microphacoemulsification tip and an Alio hydromanipulator fingernail (Katena) are introduced through the two incisions to manipulate and emulsify the fragments. After the elimination of the first quadrant, the epinuclear rim was trimmed in the different quadrants to remove all the cortical material remaining in the capsular bag.

The Acri.LISA 366D IOL is loaded in a cartridge and inserted into a hydraulic injector (Acri.Glide, Acri.Tec). The incision is enlarged laterally at its internal side to approximately 1.5 mm with a diamond blade. The tip of the cartridge is introduced partially into the external part of the incision, after which the IOL is injected into the capsular bag. The proximal IOL is placed in the bag, guided by a second instrument (Alio intraocular manipulator, Katena). After the ophthalmic viscoelastic is removed, the incisions are hydrated using a 30-gauge cannula (Alcon). Intraocular preservative-free cefuroxime 1% (0.1 ml) is injected into the anterior chamber. No sutures are used normally.

Post-Operative Care

Post-operative topical therapy included a combination of topical antibiotics (ofloxacin 0.3% [Exocin]) and a steroid (dexamethasone 0.1% [Maxidex]).

5.5.2.5 Results

Alfonso et al. conducted a prospective study of the ACRI.LISA 366D IOL in 81 patients who had bilateral implantation of these IOLs [2]. This study showed that the lens was tolerated with no complications noted after 3 months. After 3 months, the mean uncorrected

binocular distance acuity (at 6 m) was logMAR 0.13 ± 0.20 and the mean uncorrected binocular near acuity (at 33 cm) was 0.01 ± 0.05 . 95.1% of patients achieved uncorrected binocular distance acuity of 20/40 or better and 100% of patients achieved uncorrected near acuity of 20/40 or better. This study showed good visual outcomes for both distance and near visual acuity. However, more studies with longer follow-up and comparison with other multi-focal IOLs will have to be conducted. To the best of our knowledge to date, there is no study which has reported the results of the ACRI.LISA 466TD toric, bifocal IOL.

5.5.3 Summary

Currently, we are able to perform cataract surgery through a sub-2.0 mm corneal incision by using MICS and the lens technology is able to correct refractive errors including presbyopia as well as astigmatism. In our centre, we routinely perform MICS for cataract surgery and the ACRI.LISA 336D lens is the preferred choice for appropriate patients who require presbyopia correction. The ACRI.LISA 466TD is used if the patient has pre-existing astigmatism.

5.6 The Future: Beyond the Horizon of Refractive Surgery Today

We have already seen the state of the art of refractive surgery techniques and technology available today. We can only dream of what the future holds for refractive surgery. However, looking at the existing trends today, perhaps the following may not be too far away.

1. Punctural Surgeries

We have witnessed the gradual decrease in incision size for cataract surgery and phakic intraocular lens implantations. This is due to both technological advances in surgical techniques and intraocular lens technology. Perhaps in the future, these surgeries can be performed through puncture incisions in the cornea.

2. Advanced laser systems

While we have seen that the excimer and femtosecond laser systems have evolved into highly advanced and

sophisticated systems, the possibility of further improvement is inevitable. Perhaps nanosecond lasers and “cooler” lasers may be used in the future. Femtosecond lasers with automatic tracking, centration and docking process may help to improve the centration of corneal flaps created by femtosecond lasers.

3. Fully customised intraocular lenses

In the future, all phakic and pseudophakic intraocular lenses will be customised to each individual. They should be able to correct all types of refractive error, including high astigmatism to enable the patient to achieve excellent unaided vision. In addition, these lenses will take into account each individual's existing corneal asphericity and aberrations and be customised to ensure optimal visual quality. These lenses will also be implantable through minute puncture incisions to complement the surgical techniques described above.

4. True accommodative presbyopic intraocular lenses

The ideal presbyopic intraocular lens should be a truly accommodative intraocular lens which can mimic the changes in power of a natural lens. This will eliminate problems related to current multi-focal intraocular lenses, e.g. pupil dependency and night vision problems. Another possibility can be the injection of a polymer into the capsular bag which can function as a normal lens. However, the problem of capsular fibrosis and the lack of control over the amount of refractive error which can be corrected will have to be overcome.

Reference

1. Aizawa D, Shimizu K, Komatsu M et al (2003) Clinical outcomes of wavefront-guided laser in situ keratomileusis: 6-month follow-up. *J Cataract Refract Surg* 29:1507–1513
2. Alfonso JF, Fernandez-Vega L, Senaris A, Montes-Mico R (2007) Prospective study of the Acri.LISA bifocal intraocular lens. *J Cataract Refract Surg* 33:1930–1935
3. Alio J, Rodriguez-Prats JL, Galal A, Ramzy M (2005) Outcomes of microincision cataract surgery versus coaxial phacoemulsification. *Ophthalmology* 112:1997–2003
4. Alio JL, Muftuoglu O, Ortiz D et al (2008) Ten-year follow-up of photorefractive keratectomy for myopia of less than -6 diopters. *Am J Ophthalmol* 145:29–36
5. Alio JL, Muftuoglu O, Ortiz D et al (2008) Ten-year follow-up of photorefractive keratectomy for myopia of more than -6 diopters. *Am J Ophthalmol* 145:37–45
6. Alio JL, Rodriguez-Prats JL, Vianello A, Galal A (2005) Visual outcome of microincision cataract surgery with implantation of an Acri.Smart lens. *J Cataract Refract Surg* 31:1549–1556
7. Awwad ST, Lehmann JD, McCulley JP, Bowman RW (2007) A comparison of higher order aberrations in eyes implanted with AcrySof IQ SN60WF and AcrySof SN60AT intraocular lenses. *Eur J Ophthalmol* 17:320–326
8. Bahar I, Levinger S, Kremer I (2007) Wavefront-guided LASIK for myopia with the Technolas 217z: results at 3 years. *J Refract Surg* 23:586–590; discussion
9. Baumeister M, Bühren J, Kohnen T (2004) Position of angle-supported, iris-fixated, and ciliary sulcus-implanted myopic phakic intraocular lenses evaluated by Scheimpflug photography. *Am J Ophthalmol* 138:723–731
10. Bedei A, Marabotti A, Giannecchini I et al (2006) Photorefractive keratectomy in high myopic defects with or without intraoperative mitomycin C: 1-year results. *Eur J Ophthalmol* 16:229–234
11. Bellucci R, Morselli S, Pucci V (2007) Spherical aberration and coma with an aspherical and a spherical intraocular lens in normal age-matched eyes. *J Cataract Refract Surg* 33:203–209
12. Bellucci R, Scialdone A, Buratto L et al (2005) Visual acuity and contrast sensitivity comparison between Tecnis and AcrySof SA60AT intraocular lenses: a multicenter randomized study. *J Cataract Refract Surg* 31:712–717
13. Binder PS (2006) One thousand consecutive IntraLase laser in situ keratomileusis flaps. *J Cataract Refract Surg* 32:962–969
14. Budo C, Hessloehl JC, Izak M et al (2000) Multicenter study of the Artisan phakic intraocular lens. *J Cataract Refract Surg* 26:1163–1171
15. Caporossi A, Martone G, Casprini F, Rapisarda L (2007) Prospective randomized study of clinical performance of 3 aspheric and 2 spherical intraocular lenses in 250 eyes. *J Refract Surg* 23:639–648
16. Carvalho MJ, Suzuki SH, Freitas LL et al (2007) Limbal relaxing incisions to correct corneal astigmatism during phacoemulsification. *J Refract Surg* 23:499–504
17. Caster AI, Hoff JL, Ruiz R (2005) Conventional vs wavefront-guided LASIK using the LADARVision4000 excimer laser. *J Refract Surg* 21:S786–S791
18. Chen WR, Ye HH, Qian YY et al (2006) Comparison of higher-order aberrations and contrast sensitivity between Tecnis Z9001 and CeeOn 911A intraocular lenses: a prospective randomized study. *Chin Med J (Engl)* 119:1779–1784
19. Csutak A, Silver DM, Tozser J et al (2004) Urokinase-type plasminogen activator to prevent haze after photorefractive keratectomy, and pregnancy as a risk factor for haze in rabbits. *Invest Ophthalmol Vis Sci* 45:1329–1333
20. Dejaco-Ruhswurm I, Scholz U, Pieh S et al (2002) Long-term endothelial changes in phakic eyes with posterior chamber intraocular lenses. *J Cataract Refract Surg* 28:1589–1593
21. Dick HB, Alio J, Bianchetti M et al (2003) Toric phakic intraocular lens: European multicenter study. *Ophthalmology* 110:150–162
22. Durrie DS, Kezirian GM (2005) Femtosecond laser versus mechanical keratome flaps in wavefront-guided laser in situ keratomileusis: prospective contralateral eye study. *J Cataract Refract Surg* 31:120–126

23. Elkady B, Alio JL, Ortiz D, Montalban R (2008) Corneal aberrations after microincision cataract surgery. *J Cataract Refract Surg* 34:40–45
24. He R, Qu M, Yu S (2005) Comparison of NIDEK CATz wavefront-guided LASIK to traditional LASIK with the NIDEK CXII excimer laser in myopia. *J Refract Surg* 21: S646–S649
25. Hofmann RF, Bechara SJ (1992) An independent evaluation of second generation suction microkeratomes. *Refract Corneal Surg* 8:348–354
26. Holladay JT, Piers PA, Koranyi G et al (2002) A new intraocular lens design to reduce spherical aberration of pseudophakic eyes. *J Refract Surg* 18:683–691
27. Horn JD (2007) Status of toric intraocular lenses. *Curr Opin Ophthalmol* 18:58–61
28. Hosny M, Alio JL, Claramonte P et al (2000) Relationship between anterior chamber depth, refractive state, corneal diameter, and axial length. *J Refract Surg* 16:336–340
29. Jacobs JM, Taravella MJ (2002) Incidence of intraoperative flap complications in laser in situ keratomileusis. *J Cataract Refract Surg* 28:23–28
30. Katsanevaki VJ, Kalyvianaki MI, Kavroulaki DS, Pallikaris IG (2007) One-year clinical results after epi-LASIK for myopia. *Ophthalmology* 114:1111–1117
31. Kezirian GM, Stonecipher KG (2004) Comparison of the IntraLase femtosecond laser and mechanical keratomes for laser in situ keratomileusis. *J Cataract Refract Surg* 30: 804–811
32. Kohnen T, Bühren J, Kuhne C, Mirshahi A (2004) Wavefront-guided LASIK with the Zyoptix 3.1 system for the correction of myopia and compound myopic astigmatism with 1-year follow-up: clinical outcome and change in higher order aberrations. *Ophthalmology* 111:2175–2185
33. Kohnen T, Mahmoud K, Bühren J (2005) Comparison of corneal higher-order aberrations induced by myopic and hyperopic LASIK. *Ophthalmology* 112:1692
34. Kurz S, Krummenauer F, Thieme H, Dick HB (2007) Contrast sensitivity after implantation of a spherical versus an aspherical intraocular lens in biaxial microincision cataract surgery. *J Cataract Refract Surg* 33:393–400
35. Lackner B, Pieh S, Schmidinger G et al (2003) Outcome after treatment of ametropia with implantable contact lenses. *Ophthalmology* 110:2153–2161
36. Lee DH, Chung HS, Jeon YC et al (2005) Photorefractive keratectomy with intraoperative mitomycin-C application. *J Cataract Refract Surg* 31:2293–2298
37. Liang J, Williams DR (1997) Aberrations and retinal image quality of the normal human eye. *J Opt Soc Am A Opt Image Sci Vis* 14:2873–2883
38. Maldonado-Codina C, Morgan PB, Efron N (2001) Thermal consequences of photorefractive keratectomy. *Cornea* 20: 509–515
39. Medeiros FW, Stapleton WM, Hammel J et al (2007) Wavefront analysis comparison of LASIK outcomes with the femtosecond laser and mechanical microkeratomes. *J Refract Surg* 23:880–887
40. Mohan RR, Hutcheon AE, Choi R et al (2003) Apoptosis, necrosis, proliferation, and myofibroblast generation in the stroma following LASIK and PRK. *Exp Eye Res* 76:71–87
41. Moller-Pedersen T, Cavanagh HD, Petroll WM, Jester JV (1998) Corneal haze development after PRK is regulated by volume of stromal tissue removal. *Cornea* 17:627–639
42. Moller-Pedersen T, Cavanagh HD, Petroll WM, Jester JV (1998) Neutralizing antibody to TGFbeta modulates stromal fibrosis but not regression of photoablative effect following PRK. *Curr Eye Res* 17:736–747
43. Muller-Jensen K, Fischer P, Siepe U (1999) Limbal relaxing incisions to correct astigmatism in clear corneal cataract surgery. *J Refract Surg* 15:586–589
44. Munoz G, Albarran-Diego C, Montes-Mico R et al (2006) Spherical aberration and contrast sensitivity after cataract surgery with the Tecnis Z9000 intraocular lens. *J Cataract Refract Surg* 32:1320–1327
45. Nakamura K, Kurosaka D, Bissen-Miyajima H, Tsubota K (2001) Intact corneal epithelium is essential for the prevention of stromal haze after laser assisted in situ keratomileusis. *Br J Ophthalmol* 85:209–213
46. Nassaralla BA, McLeod SD, Nassaralla JJ Jr (2007) Prophylactic mitomycin C to inhibit corneal haze after photorefractive keratectomy for residual myopia following radial keratotomy. *J Refract Surg* 23:226–232
47. Netto MV, Mohan RR, Ambrosio R Jr et al (2005) Wound healing in the cornea: a review of refractive surgery complications and new prospects for therapy. *Cornea* 24: 509–522
48. Netto MV, Mohan RR, Sinha S et al (2006) Effect of prophylactic and therapeutic mitomycin C on corneal apoptosis, cellular proliferation, haze, and long-term keratocyte density in rabbits. *J Refract Surg* 22:562–574
49. Nuijts RM, Nabar VA, Hament WJ, Eggink FA (2002) Wavefront-guided versus standard laser in situ keratomileusis to correct low to moderate myopia. *J Cataract Refract Surg* 28:1907–1913
50. O'Doherty M, Kirwan C, O'Keeffe M, O'Doherty J (2007) Postoperative pain following epi-LASIK, LASEK, and PRK for myopia. *J Refract Surg* 23:133–138
51. Pallikaris IG, Naoumide II, Kalyvianaki MI, Katsanevaki VJ (2003) Epi-LASIK: comparative histological evaluation of mechanical and alcohol-assisted epithelial separation. *J Cataract Refract Surg* 29:1496–1501
52. Pepose JS, Feigenbaum SK, Qazi MA, Merchea M (2007) Comparative performance of the Zyoptix XP and Hansatome zero-compression microkeratomes. *J Cataract Refract Surg* 33:1386–1391
53. Phusitphoykai N, Tungsiripat T, Siriboonkoom J, Vongthongsri A (2003) Comparison of conventional versus wavefront-guided laser in situ keratomileusis in the same patient. *J Refract Surg* 19:S217–S220
54. Sanders DR, Vukich JA (2002) Incidence of lens opacities and clinically significant cataracts with the implantable contact lens: comparison of two lens designs. *J Refract Surg* 18:673–682
55. Sandoval HP, Fernandez de Castro LE, Vroman DT, Solomon KD (2008) Comparison of visual outcomes, photopic contrast sensitivity, wavefront analysis, and patient satisfaction following cataract extraction and IOL implantation: aspheric vs spherical acrylic lenses. *Eye* 22:1469–1475
56. Scalinci SZ, Scorolli L, De Martino L et al (2005) Effect of cytochrome c peroxidase on corneal epithelial healing process after photorefractive keratectomy. *J Cataract Refract Surg* 31:1928–1931
57. Schallhorn S, Tanzer D, Sanders DR, Sanders ML (2007) Randomized prospective comparison of visian toric

- implantable collamer lens and conventional photorefractive keratectomy for moderate to high myopic astigmatism. *J Refract Surg* 23:853–867
58. Schipper I, Suppelt C, Gebbers JO (1997) Mitomycin C reduces scar formation after excimer laser (193 nm) photorefractive keratectomy in rabbits. *Eye* 11(Pt 5):649–655
59. Solomon KD, Donnenfeld E, Sandoval HP et al (2004) Flap thickness accuracy: comparison of 6 microkeratome models. *J Cataract Refract Surg* 30:964–977
60. Sun XY, Vicary D, Montgomery P, Griffiths M (2000) Toric intraocular lenses for correcting astigmatism in 130 eyes. *Ophthalmology* 107:1776–1781
61. Tran DB, Sarayba MA, Bor Z et al (2005) Randomized prospective clinical study comparing induced aberrations with IntraLase and Hansatome flap creation in fellow eyes: potential impact on wavefront-guided laser in situ keratomileusis. *J Cataract Refract Surg* 31:97–105
62. Tzelikis PF, Akaishi L, Trindade FC, Boteon JE (2008) Spherical aberration and contrast sensitivity in eyes implanted with aspheric and spherical intraocular lenses: A comparative study. *Am J Ophthalmol* 145:827–833
63. Uusitalo RJ, Aine E, Sen NH, Laatikainen L (2002) Implantable contact lens for high myopia. *J Cataract Refract Surg* 28:29–36
64. Walker MB, Wilson SE (2000) Lower intraoperative flap complication rate with the Hansatome microkeratome compared to the Automated Corneal Shaper. *J Refract Surg* 16:79–82
65. Wang L, Koch DD (2003) Anterior corneal optical aberrations induced by laser in situ keratomileusis for hyperopia. *J Cataract Refract Surg* 29:1702–1708
66. Williams DK (1997) Multizone photorefractive keratectomy for high and very high myopia: long-term results. *J Cataract Refract Surg* 23:1034–1041
67. Wilson SE, Mohan RR, Mohan RR et al (2001) The corneal wound healing response: cytokine-mediated interaction of the epithelium, stroma, and inflammatory cells. *Prog Retin Eye Res* 20:625–637
68. Xu H, Liu S, Xia X et al (2001) Mitomycin C reduces haze formation in rabbits after excimer laser photorefractive keratectomy. *J Refract Surg* 17:342–349
69. Yoon G, MacRae S, Williams DR, Cox IG (2005) Causes of spherical aberration induced by laser refractive surgery. *J Cataract Refract Surg* 31:127–135
70. Zhong Y, Cheng F, Zhou Y et al (2000) The changes of TGF- α , TGF- β 1 and basic FGF messenger RNA expression in rabbit cornea after photorefractive keratectomy. *Yan Ke Xue Bao* 16:176–180

Daniel S. Mojon¹

6.1 Introduction

In October 1839, only a few days apart, two surgeons independently performed the first documented successful myotomy to improve strabismus. In Berlin, Johann Friedrich Dieffenbach myotomized one medial rectus muscle in an esotropic boy while Florent Cunier of Brussels myotomized one lateral rectus muscle to cure an exodeviation [29]. Probably, already in 1818, William Gibson of Baltimore had myotomized several patients. However, because of the disappointing results, he failed to report it until 1841. Since these early beginnings of strabismus surgery, many different operating techniques for rectus and oblique eye muscles have been described, making surgical outcome more predictable. This chapter is devoted to minimally invasive approaches to strabismus surgery. All techniques being reviewed aim to reduce tissue traumatism, postoperative patient discomfort, hospital stay and working disability. For such techniques it is advisable to use the operating microscope which will allow higher magnifications than magnifying spectacles. A better view of the operating site allows a less traumatic tissue dissection and a better control of bleeding. Chemodenervation therapy, which can also be considered a minimally

invasive procedure, will not be appraised since excellent literature on that topic already exists [1, 18–20].

6.2 Nonsurgical Treatment

A nonsurgical treatment remains less invasive than minimally invasive surgery. Even if this seems obvious, strabismus surgery is indicated only if all nonsurgical options have been considered and potential alternatives have been tried. As nonsurgical treatments are beyond the scope of this book, only some key points that have to be tried before considering surgery will be mentioned. First, patients with visible strabismus, with no chance of postoperative binocular vision, should try to wear glasses. This may suffice to distract. However, glasses must be carefully selected. Exodeviations are accentuated by horizontally narrow glasses and esodeviations by horizontally wide glasses. Thus, horizontally narrow glasses should be tried for esotropia and horizontally wide glasses for exotropia. This is the only option for patients with disturbing pseudostrabismus, apart from lid surgery to change the amount of visible sclera. Second, a preoperative automatism should be developed to look for symptoms and signs of ocular myasthenia gravis and endocrine orbitopathy. In ocular myasthenia gravis patients, strabismus surgery is indicated only if medical treatments fail. In patients with endocrine orbitopathy, orbital decompression has to be considered, because usually strabismus surgery is advisable only afterwards. For both diseases, squint angles should be stable before strabismus surgery can be performed. Third, in all phakic patients a cycloplegic refraction is needed, regardless of their age. Patients with dark iris require the use of atropine. A prescription of the correct glasses or contact lenses may eliminate

¹ The author has no financial interests in any of the products mentioned in this chapter.

D. S. Mojon
Department of Ophthalmology, Kantonsspital St. Gallen,
Rorschacherstrasse, 9007 St. Gallen, Switzerland
e-mail: daniel.mojon@kssg.ch

asthenopia or improve a squint. In purely accommodative strabismus, bifocals or progressive lenses must be considered. Fourth, for smaller, not too incomitant squint angles, the option of definitive prismatic correction should be discussed before suggesting surgery. Fifth, when there is a high risk for anesthesia, strabismus surgery may not be indicated. For example, permanent occlusion of one eye should be considered for diplopia, which can only be treated surgically. For occlusion with glasses, the best cosmetic solution is obtained using Bangerter graded foils. The least strong foil to eliminate diplopia should be chosen, as it allows the best possible view of the occluded eye. In younger patients, usually foils are not accepted and, therefore, occlusive contact lenses should be tried. Sometimes high myopic or hyperopic contact lenses induce enough blur to eliminate diplopia. The blurring contact lens solution is better compared to total occlusion as peripheral vision is preserved. Sixth, the surgical procedures that are going to be used should be read critically, especially regarding the time point when it is indicated. Is there evidence that very early surgery, for example for intermittent exotropia, has a better outcome than waiting for progression? Could it be that some patients operated on very early would never have required surgery? Unfortunately, many questions about strabismus surgery remain unanswered because of lack of randomized prospective studies and of long follow-up times. Sometimes good history taking will disclose that strabismus surgery is indicated, although the patient claims to be treated adequately, for example, with prisms. Only if asked specifically about dangerous situations, an old patient wearing prisms may admit that he has already fallen several times from the stairs because of diplopia on downgaze when looking outside the glasses. If all nonsurgical options have been considered, strabismus surgery should be recommended, as this will prevent serious injuries.

6.3 Types and Classification of Conjunctival Openings

The type of conjunctival incision will greatly influence the postoperative quality of life, cosmesis and, later, the function of the operated muscle. It will also influence the ease with which revision surgery. A certain type of conjunctival opening can be classified by the

shape, orientation, size, and placement. Surgery may require one or several identical incisions or several different cuts. The shape is best described using capital letters, if necessary a combination of several. Single shapes used for strabismus surgery include C-shaped, I-shaped, and L-shaped openings (Fig. 6.1a). Combined shapes are CI-shaped and ICI-shaped cuts (Fig. 6.1b). The main orientations can be described as limbus-parallel, radial, or oblique (Fig. 6.1c). The size can be given in millimeters or for a limbal peritomy in the quadrants involved or, alternatively, in clock hours. Placements may be limbal, paralimbal, or in the fornix. Usually, a fornix opening is well anterior to the true anatomical fornix. Additional placement information such as clock position or between or over which structures (muscle, muscle insertion) is necessary (Fig. 6.1d).

6.4 Rectus Muscle Procedures

Many strabismologists use Harms' limbal approach [4], popularized by von Noorden [27, 28]. It is an ICI-shaped limbal opening over a quadrant allowing good performance of a muscle recession, resection or plication (Fig. 6.1e). The opening can be started either radially or perilimbally. For small muscle displacements, especially in younger patients with elastic conjunctiva, it is possible to reduce the total opening size by performing only one radial incision (Fig. 6.1f). Unfortunately, perilimbal openings may predispose a patient to anterior segment ischemia [8] and induce considerable postoperative discomfort, and are prone to complications like corneal dellen formation [25] and Tenon's tissue prolapse [20]. Therefore, if possible, this approach should be avoided. For the rectus muscle, Swan suggested an I-shaped limbus-parallel incision close to the fornix, followed by a radial incision of the Tenon's capsule over the bulk of the muscle (Fig. 6.1g) [24]. After muscle surgery, the Tenon's capsule and conjunctiva have to be closed separately. This opening does not have the disadvantages of Harms' limbal approach. However, today, it is rarely used because inadvertent injury to the muscle belly and ciliary vessels may occur [21]. This may induce copious bleeding. Postoperatively, it may induce visible scarring in the palpebral fissure. Excessive scarring around the muscle often renders reoperations more difficult [1]. Parks advocated a nearly limbus-parallel I-shaped

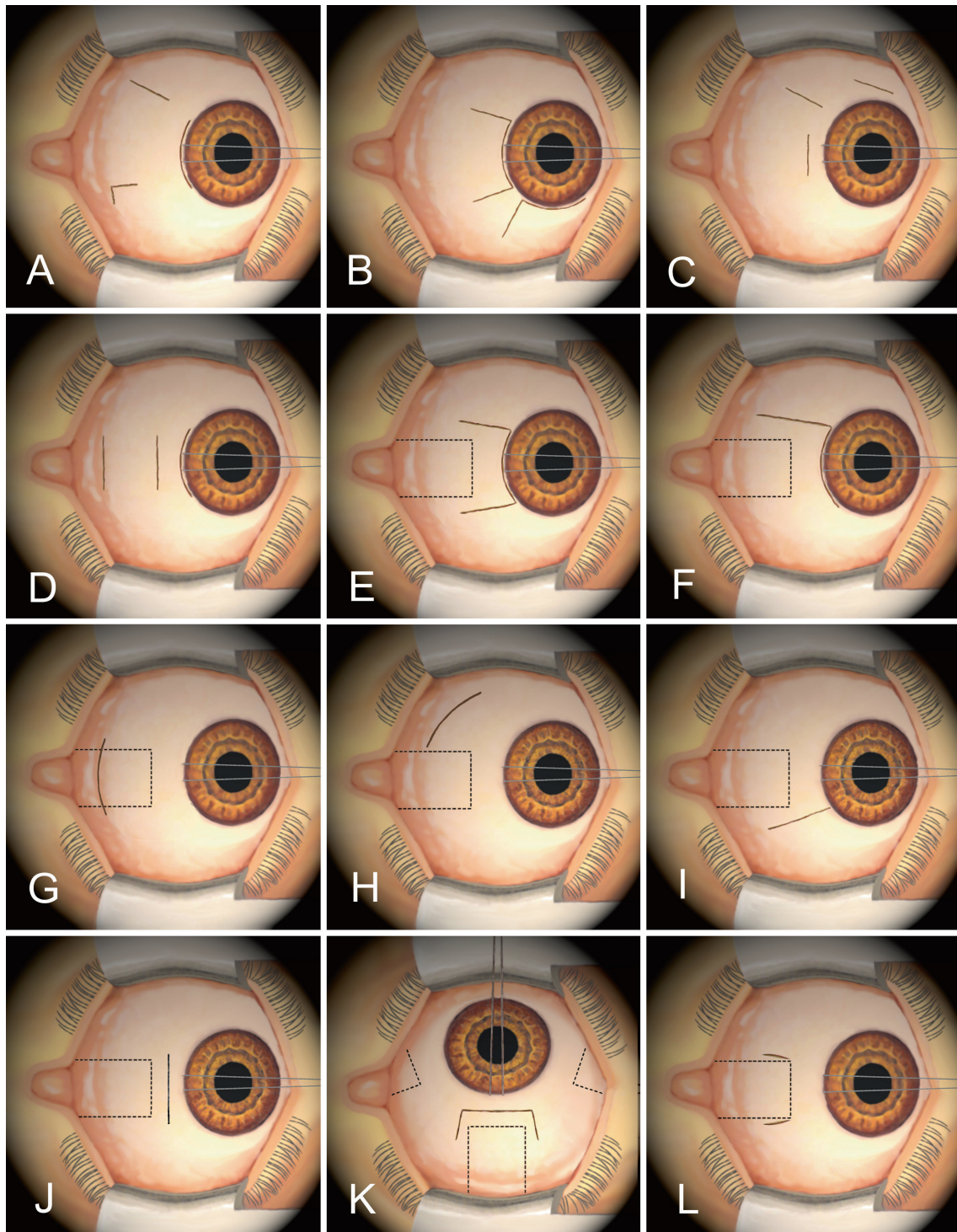


Fig. 6.1 Classification of conjunctival openings for strabismus surgery: (a) Single shapes used for strabismus surgery, (b) combined shapes, (c) main orientations, (d) placement information. Most important types of conjunctival openings for strabismus surgery:

(e) Harms limbal approach, (f) Harms' limbal opening with only one radial incision, (g) Swan's opening, (h) Parks' opening, (i) Velez's opening, (j) Santiago's opening, (k) same opening with two relaxing cuts over a vertical rectus muscle, (l) Gobin's openings

fornix incision for the conjunctiva and Tenon's capsule between two adjacent rectus muscles [16]. For horizontal rectus muscles, the lower fornix is selected, unless the muscle has to be supraplaced (Fig. 6.1h). For muscle surgery, the opening is moved over the muscle adjacent to the one that has to be displaced. This technique is very elegant as it does not have the disadvantages of the two previous techniques. If two adjacent rectus muscles need surgery, one opening will suffice. Unfortunately, it cannot be used in older patients with inelastic conjunctiva since full visualization of the surgical procedure will induce a tear. Velez suggested a radial incision covered by the upper lid. For medial rectus surgery, the incision is made in the nasal superior quadrant, and for lateral rectus surgery in the temporal superior quadrant (Fig. 6.1i) [26]. The disadvantages are that the cut reaches the limbus and that an already slightly decreased conjunctival elasticity will not allow displacing the cut without tearing. Santiago tried a paralimbal approach with an opening placed halfway between the limbus and the muscle insertion (Fig. 6.1j) [22]. For horizontal muscles, the disadvantages include visible scarring in the palpebral fissure and difficult muscle access in inelastic conjunctiva, especially if larger muscle displacements are necessary. The technique is more valuable for vertical rectus muscle surgery as the openings are covered by the lids. For vertical rectus muscles, two additional relaxing cuts will improve visualization of the operating site (Fig. 6.1k). For strabismus surgeries reducing tissue disruption, the term MISS (minimally invasive strabismus surgery) has been proposed [9, 11–14]. For rectus muscle loop recession, Gobin described the principle of access through two small radial openings, one along the superior and the other along the inferior margin of the rectus muscles (Fig. 6.1l) [3, 10]. These openings allow recessions and plications (tucks) to be performed even in older patients with inelastic conjunctiva, as all surgical steps can be done without moving the cuts. Postoperatively, such cuts will remain covered by the lids except from during upgaze and excessive lateral gaze. This access technique minimizes anatomical disruption. If necessary, the cuts can be joined at the limbus, which will help to perform surgery using the usual limbal approach. Focusing on minimally invasive techniques, Parks' fornix and MISS parainsertional access techniques are presented in detail. Plications are preferable to recessions because they are less disruptive and can be easily revised in the first couple of days.

Additionally, Priglinger's Y-split recession is described as an alternative to posterior fixation suture because this approach avoids retroequatorial suturing. Adjustable sutures may be valuable for unpredictable situations. In such patients, I personally prefer an intraoperative adjustment, which is feasible if surgery is performed with topical anesthesia. Clearly, this technique cannot be used for children. The disadvantages if a postoperative adjustment has to be performed are (1) the need for general anesthesia in younger children, (2) possible discomfort or pain if performed with topical anesthesia, (3) difficulties in predicting final alignment in the early postoperative course, and (4) possible increased scarring of the conjunctiva and perimuscular tissue, which may leave visible conjunctival scars and make repeat surgery more difficult.

6.4.1 MISS Rectus Muscle Recession

The technique and results of MISS rectus muscle recessions have been published in a case control study [9]. It can be performed without assistance. Use of the operating microscope is advisable. After applying a limbal traction suture, the eyeball is rotated away from the field of surgery (Fig. 6.2a). Direct contact of the traction suture, with the cornea must be avoided because of the risk of corneal erosion. Two small radial keyhole openings are performed, one along the superior and the other along the inferior rectus muscle margin (Fig. 6.2a). The anterior margin of the opening is at the level of the tendon insertion. The total size of the openings depend on the amount of muscle recession that has to be achieved. As a rule of thumb, the opening size should be 1 mm less than the amount of muscle displacement to be achieved. The minimal opening size is 2.5 mm. For example, a recession or plication of 4 mm can be performed through two 3-mm openings. Usually, for recessions of more than 5 mm, an opening of 2 mm less than the amount is sufficient. Patients with reduced elasticity of the conjunctival tissue require slightly larger cuts. With blunt Westcott scissors and using the two cuts for access, the episcleral tissue is separated from the muscle sheath and the sclera (Fig. 6.2b). After identifying the borders of the muscle, it is hooked. Next, a meticulous dissection of the check ligaments

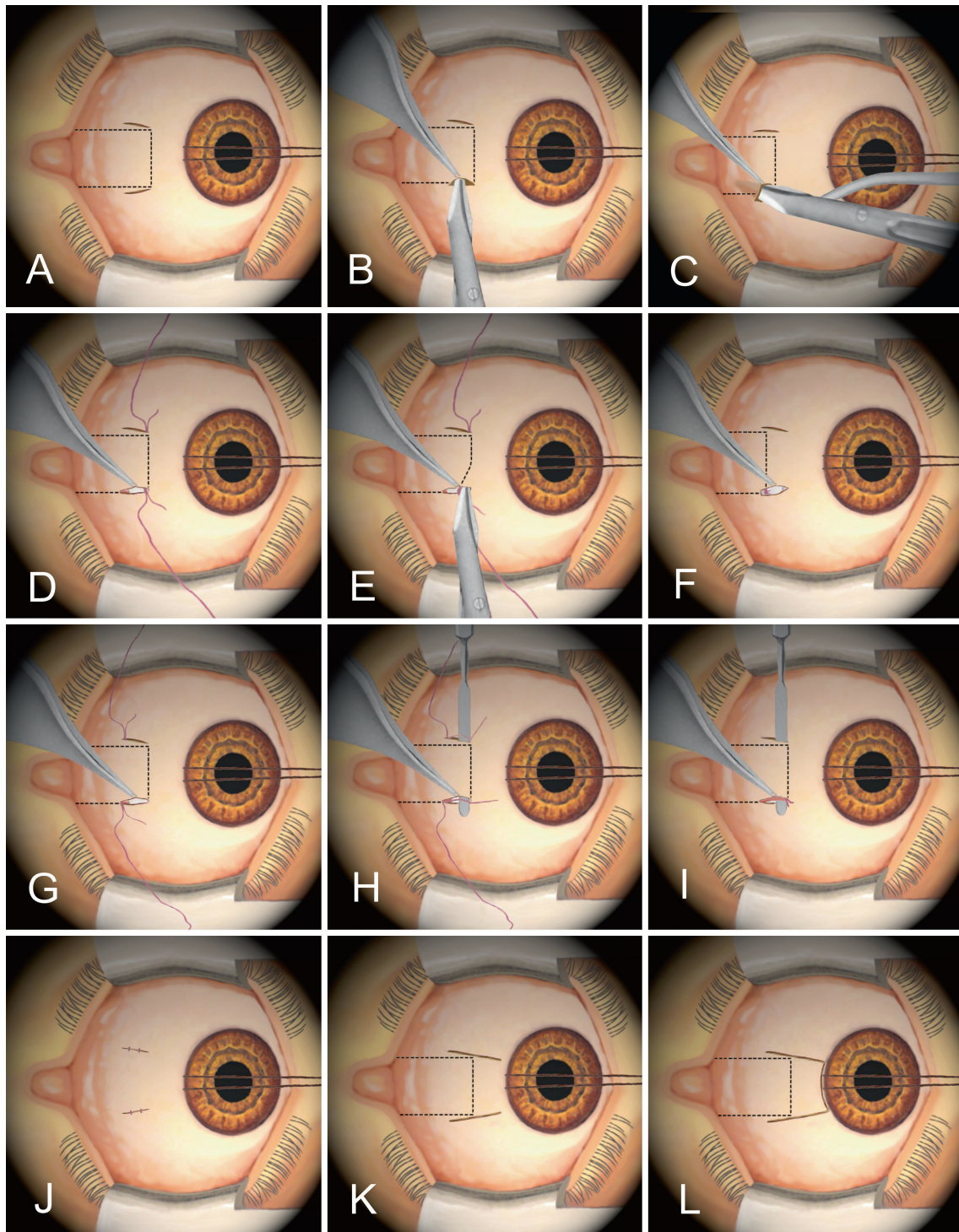


Fig. 6.2 Schematic representation of the surgical steps for MISS rectus muscle recession and plication [9]: (a) Paraincisional cuts, (b) separation of episcleral tissue from the muscle sheath and the sclera, (c) after hooking the muscle, dissection of the check ligaments and intermuscular membrane, (d) for a recession two sutures are applied to the superior and inferior borders of the muscle tendon, (e) detachment of the tendon, (f) reattachment

after measurement of amount of recession, (g) for a plication two sutures are applied to the upper and lower borders of the muscle at a distance corresponding to the plication amount, (h) insertion of iris spatula, (i) plication, (j) after performing the recession or plication, two sutures are applied to each of the small cuts, (k) if a better visualization is necessary, the cuts can be prolonged anteriorly, or (l) be joined at the limbus.

and intermuscular membrane is performed (Fig. 6.2c). This dissection is performed 6–7 mm behind the insertion. The resulting tunnel allows the surgeon to perform rectus muscle displacements easily. To perform a recession, two sutures are applied to the superior and inferior borders of the muscle tendon, as close to the insertion as possible (Fig. 6.2d). Then, the tendon is detached using Wescott scissors (Fig. 6.2e). Usually, hemostasis is necessary afterwards. If prominent vessels are visible at the insertion site, it is advisable to cauterize them before detaching the tendon. After measuring the amount of recession, the tendon is reattached with two sutures to the sclera (Fig. 6.2f). The tendon has to be stretched to avoid the middle part of the muscle bowing backwards. The surgical procedure is ended by applying two sutures to

each of the two small cuts (Fig. 6.2j) and retrieving the traction suture. The eye is not patched. Figure 6.3 shows photographs on the first postoperative day in a 10-year-old patient after 4.5 mm lateral rectus recession. At the same time the ipsilateral medial rectus muscle was plicated. In the primary position, only a minimal redness of the conjunctiva is visible (Fig. 6.3a). In adduction upgaze (Fig. 6.3b) and adduction downgaze (Fig. 6.3c) the keyhole openings become visible. This type of MISS openings minimize post-operative visibility of surgery and patient discomfort. At any time during surgery, the cuts can be prolonged anteriorly (Fig. 6.2k), and, if necessary, joined with a limbal cut (Fig. 6.2l). This can become necessary if excessive bleeding occurs, and cannot be stopped with cauterizing the small cuts.

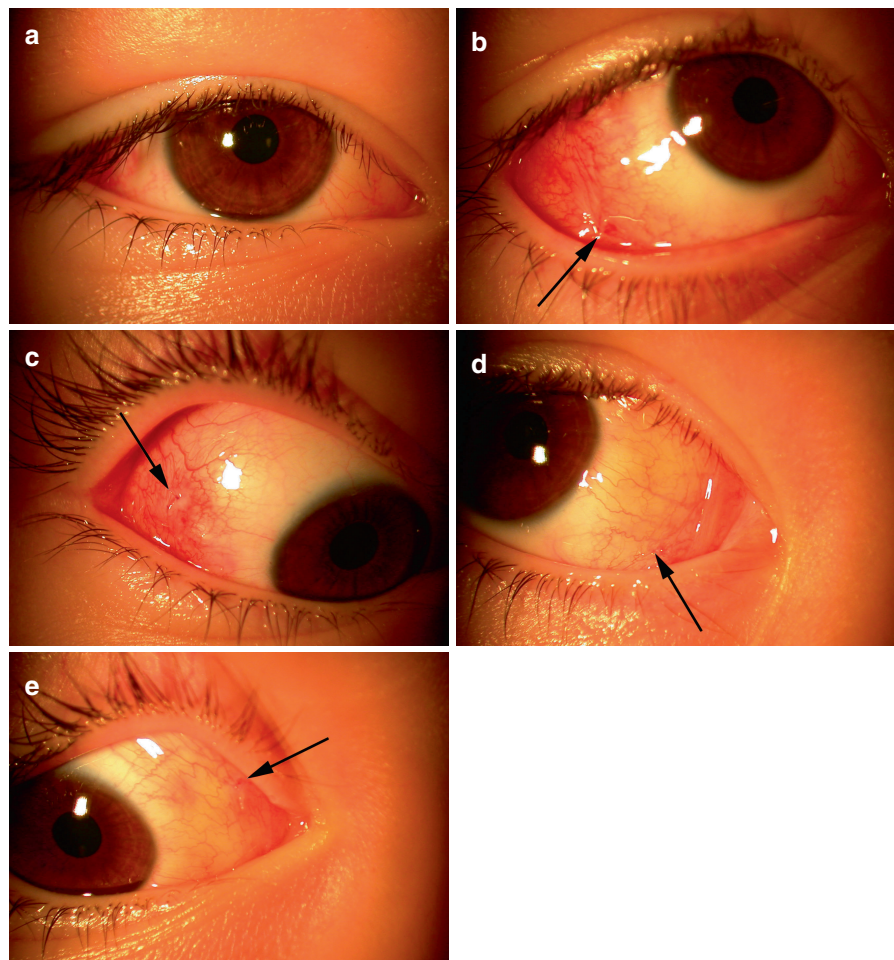


Fig. 6.3 Photographs on the first postoperative day after a 4.5-mm lateral rectus recession and 5.5 mm medial rectus plication in a 10-year-old patient: (a) In primary position, all cuts are covered by the eyelids, (b) In adduction upgaze and (c) in adduction downgaze, the keyhole openings for recession become visible, (d) in abduction upgaze and (e) in abduction downgaze, the small cuts for plication become visible

6.4.2 MISS Rectus Muscle Plication

The MISS rectus muscle plication method has been reported in detail in the same publication that describes MISS rectus muscle recessions [9]. MISS rectus muscle plications are best performed under the operating microscope. There is no need for an assistant. A limbal traction suture is applied and the eyeball is rotated away from the field of surgery (Fig. 6.2a). Two small radial conjunctival openings are performed, one along the superior and the other along the inferior rectus muscle margin (Fig. 6.2a). The anterior margin of the opening is at the level of the tendon insertion. The total size of the openings depend on the amount of muscle plication. As a rule of thumb, the opening size will be at least 2.5 mm. For larger plication the opening should be 2 mm less than the amount of muscle displacement that has to be achieved. For example, a plication of 6 mm can be performed through two 4-mm openings. The openings for plications can be kept smaller compared to the ones for recessions of the same amount. The reason for this is that using forceps the location where the muscle has to be sutured can be advanced until it becomes visible through the keyhole opening. With blunt Wescott scissors the episcleral tissue is separated from the muscle sheath and the sclera (Fig. 6.2b). After identifying the borders of the muscle, it is hooked. Next, a meticulous dissection of the check ligaments and intermuscular membrane is performed (Fig. 6.2c). This dissection is performed 6–7 mm behind to the insertion. The resulting tunnel allows the surgeon to perform a rectus muscle plication easily. If prominent vessels are visible at the insertion site or where the muscle suture will be applied, they should be cauterized before suturing. Two sutures are applied to the upper and lower borders of the muscle at the distance from the tendon insertion site corresponding to the plication amount (Fig. 6.2g). Next, the sutures are passed at the superior and inferior tendon insertions. An iris spatula is inserted between the tendon and the sutures (Fig. 6.2h) and the muscle is plicated as for open strabismus surgery (Fig. 6.2i). After removal of the spatulum, the surgical procedure is completed by applying two sutures to each of the two keyhole cuts (Fig. 6.2j). The eye is not patched. Figure 6.3 shows a 10-year-old patient on the first postoperative day after 4 mm medial rectus plication. The patient had at the same time an ipsilateral lateral rectus muscle recession. In the primary position, only a minimal redness of the conjunctiva is visible (Fig. 6.3a). In abduction upgaze (Fig. 6.3d) and

abduction downgaze (Fig. 6.3e) the keyhole opening becomes visible. MISS openings lying far away from the limbus reduce postoperative visibility of surgery and increase the quality of life in the immediate postoperative period. If necessary, the paraincisional cuts can be prolonged anteriorly (Fig. 6.2k), or joined with a limbal cut (Fig. 6.2l), which will allow better visualization of the operating site.

6.4.3 Parks' Rectus Muscle Recession

Parks popularized a fornix-based conjunctival incision, which is covered by the lids postoperatively [16]. The opening is placed between two adjacent rectus muscles and can be made in any of the oblique quadrants. The cut direction is parallel to the limbus (Fig. 6.4a) or more oblique (Fig. 6.4b). The term fornix is misleading as such openings lie much more anterior than the anatomical fornix. The opening lies about 8–10 mm behind the limbus. For larger surgical amounts, it will be necessary to use a cut lying closer to the rectus muscle and more posterior. Incisions in the lower quadrants are preferable as they will minimize visible postoperative redness. After applying a traction suture and incising the conjunctiva and Tenon's capsule over a length of approximately 9 mm (Fig. 6.4a or b), the rectus muscle is hooked using a small muscle hook (Fig. 6.4c). After ensuring that the muscle insertion has been found, the small hook is replaced by a larger one (Fig. 6.4d). If the end of the hook is visible through the conjunctiva, the complete insertion has been hooked. With a small hook the conjunctiva is retracted over the insertion (Fig. 6.4e). Using scissors the bare sclera is exposed (Fig. 6.4f). After applying two sutures to the muscle insertion (Fig. 6.4g), the muscle is desinserted, recessed and reattached to the sclera using two sutures. Some surgeons omit conjunctival closure in younger patients if at the end of surgery the conjunctival borders are closely approximated. Others prefer to apply sutures in all cases (Fig. 6.4l) [1].

6.4.4 Parks' Rectus Muscle Plication

The incision is performed in the same way as described in the previous paragraph for rectus muscle recessions (Fig. 6.4a–f). After exposing the muscle, two sutures are applied at a distance from the tendon insertion site

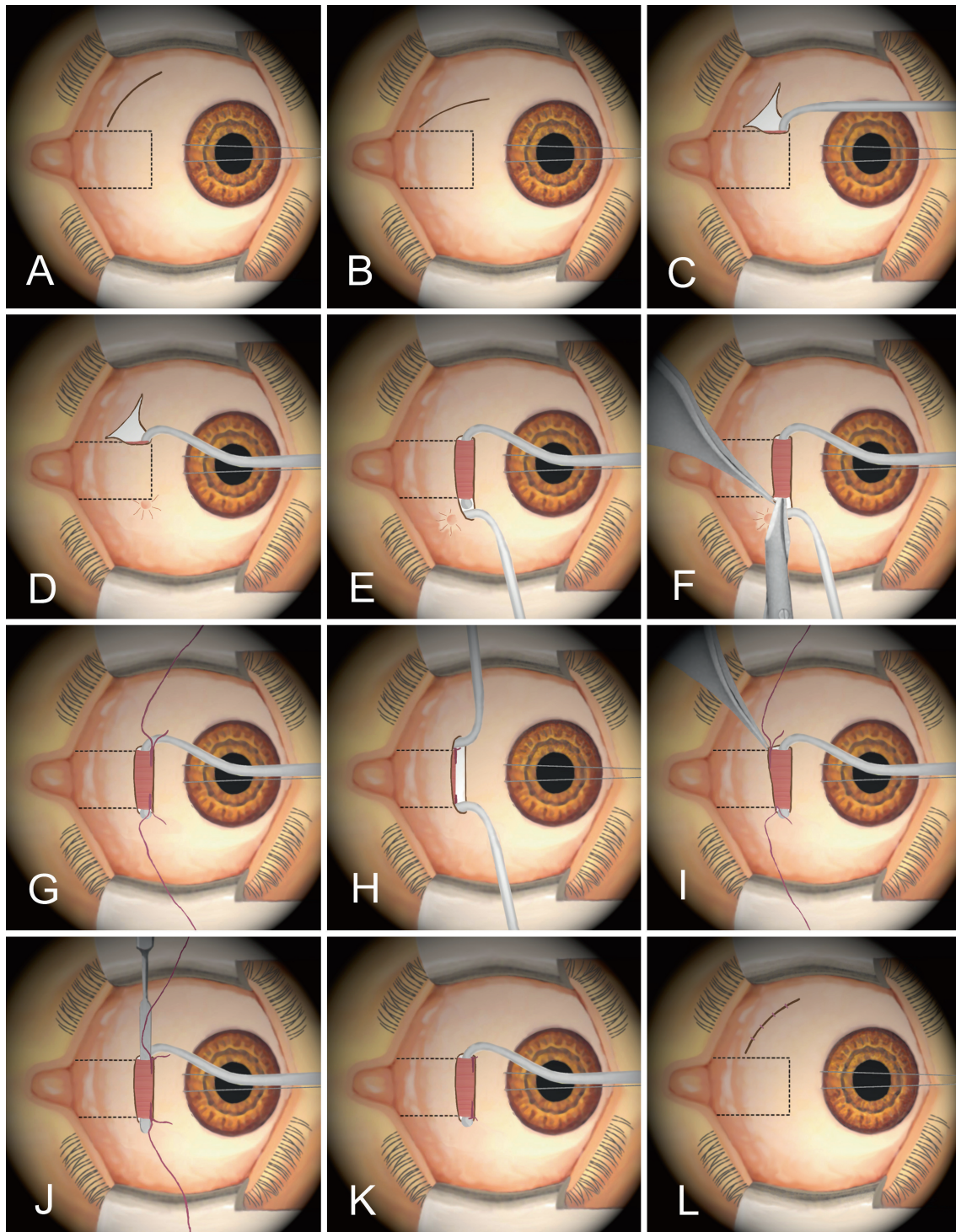


Fig. 6.4 Schematic representation of the surgical steps for Parks' rectus muscle recession and plication : (a, b) Fornix-based conjunctival incisions with slightly different orientations, (c) hooking of the rectus muscle with a small hook, (d) replacement of the small hook by a larger one, (e) retraction of the conjunctiva over the insertion, (f) exposure of bare sclera, (g) for a recession, two

sutures are applied to the muscle insertion, (h) muscle desinsertion and reattachment at the new location, (i) for a plication, two sutures are applied at a distance from the tendon insertion site corresponding to the plication amount, (k) after anchoring the suture at the original insertion site, an iris spatula is inserted, and (l) the muscle is plicated, (l) closure of the conjunctival incision

corresponding to the plication amount (Fig. 6.4i). Then, the two sutures are anchored to the sclera at the original insertion site. An iris spatula is inserted between the tendon and the sutures (Fig. 6.4j) and the muscle is plicated (Fig. 6.4k). Some surgeons do not suture the conjunctiva in younger patients if a spontaneous close approximation is visible. Others always apply sutures (Fig. 6.4l) [1].

6.4.5 MISS Rectus Muscle Posterior Fixation Suture

Posterior anchoring of a rectus muscle is indicated for incomitant strabismus to reduce the force in the agonist contralateral to the weak muscle, to correct near/distance incomitance, to reduce dissociated vertical deviation, or to decrease the amplitude of nystagmus. The MISS technique and its results of a case series have been published previously [14]. The surgical procedure is easier if done with the operating microscope and can be performed by oneself without the need

for an assistant. A limbal traction suture is applied to expose the rectus muscles, which have to be weakened. Contact of the traction suture with the cornea has to be avoided. For access, two small L-shaped cuts are performed slightly anterior to the location where the scleromuscular sutures will be placed (Fig. 6.5a). The size of the radial cuts is 4 mm and the relaxing cuts 2 mm. In patients with reduced elasticity of the conjunctival tissue, larger openings will be necessary to avoid conjunctival tearing. Anterior prolongation of the cuts will allow combining retroequatorial suturing with a MISS recession or plication. Here, isolated posterior fixation suturing is shown. With blunt Westcott scissors the episcleral tissue is separated from the muscle sheath and the sclera. Then, a measure caliper is used to determine the exact placement of the scleromuscular sutures (Fig. 6.5a). The posterior fixation is done by first passing a nonresorbable suture through the sclera (Fig. 6.5b), followed by the muscle suture, which will include one third of the muscle (Fig. 6.5c). Tightening is performed by a three-throw adaptation suture followed

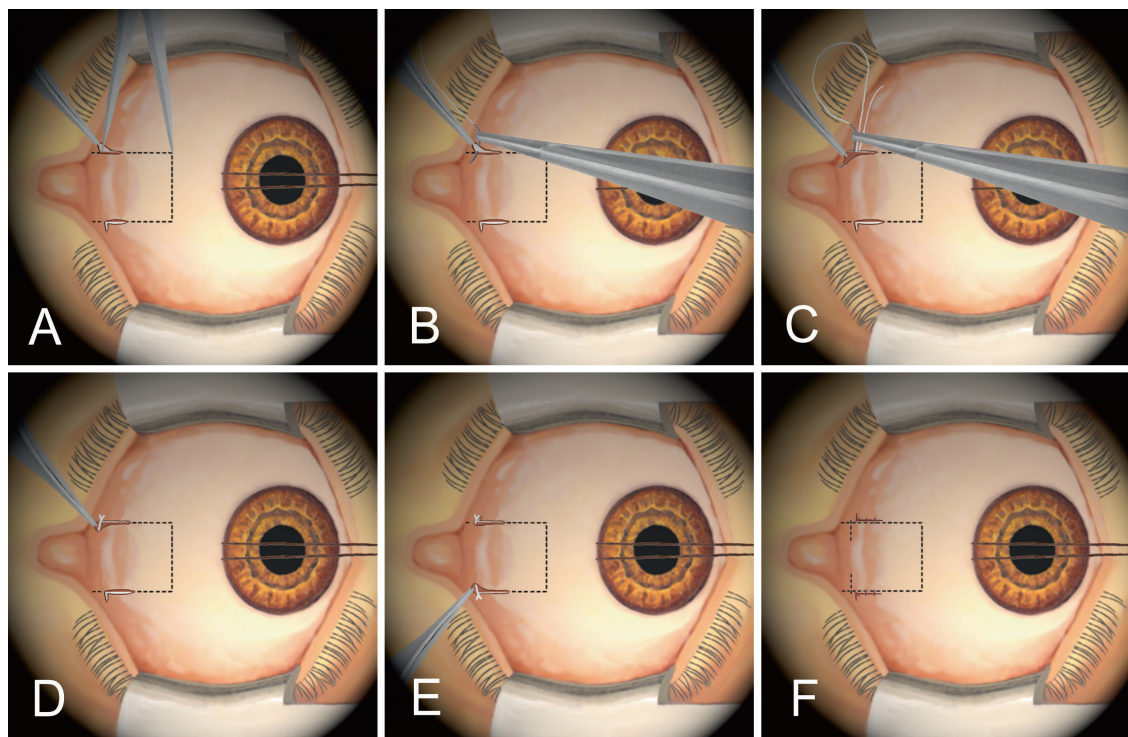


Fig. 6.5 Schematic representation of the surgical steps for MISS rectus muscle posterior fixation suture [14] : (a) After two small L-shaped cuts are performed slightly anterior to the location where the scleromuscular sutures will be placed, a measure caliper is used to determine the exact placement of the scleromuscular sutures, (b)

a nonresorbable suture is passed through the sclera, (c) the muscle suture, which will include one third of the muscle, is performed (d) tightening is done by a three-throw adaptation suture followed by two securing loops, (e) afterwards, a posterior fixation suture is placed at the other border of the muscle, (f) conjunctival closure

by two securing loops (Fig. 6.5d). Afterwards, using the identical technique, a posterior fixation suture is placed at the other border of the muscle (Fig. 6.5e). If necessary, hemostasis is performed. The surgical procedure is ended by applying single sutures (Fig. 6.5f). As both cuts lie far away from the limbus, eye patching is not necessary. If needed, anterior prolongation of the radial openings and/or the relaxing cuts will help to better visualize the operating site. This may become necessary in patients with excessive scarring from previous surgery, if a stronger hemorrhage occurs, or if the rectus muscle needs additionally to be recessed or plicated. Joining of the two cuts at the limbus will help to achieve full visualization of the operating site. Figure 6.6 shows the postoperative photographs at 24h of a 27-year-old patient necessitating inferior rectus posterior fixation surgery 14mm behind the muscle insertion. In primary position, the cuts were fully covered by the lids and the perilimbal conjunctiva showed only a minimal redness. On upgaze, the keyhole openings became visible (Fig. 6.6, black arrow).

6.4.6 Priglinger's Rectus Muscle Y-Split Recession

Based on simplified mechanical considerations, Priglinger et al. developed a new surgical procedure named Y-split recession allowing the reduction of the torque of rectus muscles [5, 6]. Surgery is usually performed on both rectus muscles. As there is no need for

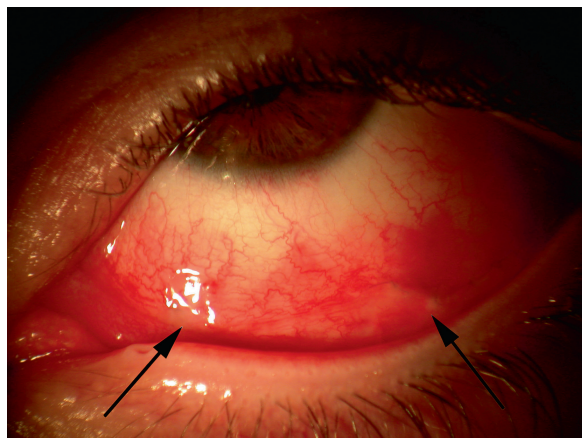


Fig. 6.6 Photograph on the first postoperative day after MISS inferior rectus posterior fixation surgery 14mm behind the muscle insertion in a 27-year-old patient

retroequatorial suturing, the risk of retinal detachment is minimized and, probably, postoperative swelling and discomfort are also reduced. Torque reduction is achieved by splitting the rectus muscle over a length of 15–17 mm (Fig. 6.7a), desinsertion of the two halves after applying a suture to each muscle half (Fig. 6.7b), and Y-reinsertion (Fig. 6.7c). The splitting reduces the lever arm for all eye positions, which allows reducing the variability of the strabismus angle. The recession influences the minimum strabismus angle and allows controlling the position of the eye in primary position. Compared to retroequatorial myopexia, undesired radial forces will be minimal, and possibly proprioceptive inputs are preserved better. Force reduction in the direction of the operated rectus muscle is less pronounced compared to retroequatorial fixation surgery. An increase in force reduction can be achieved by splitting the muscle up to 20 mm behind the insertion and/or by increasing the Y-angle. Two different points have to be marked to determine the new insertion site of the two split muscle halves (Fig. 6.7d). The distances have been determined for a globe length of 21.2 mm and a splitting distance of 15 mm. Point A is located in the middle of the physiologic insertion of the muscle while point B is 6 mm backwards. The reinsertion site lies x mm away from point B and y mm from point A. The distance z , the shortest distance between the new insertion and the cornea, will ensure that reinsertion is performed at the correct position. Therefore, this distance has also been named “control distance.” The different distances in function of the squint angle are as follows. For minimal angles up to 17 pdpt. $x = 8.5$ mm, $y = 8.0$ mm, and $z = 10.3$ mm, for minimal angles between 18 and 26 pdpt. $x = 9.0$ mm, $y = 8.0$ mm, and $z = 10.7$ mm, and for minimal angles above 27 pdpt. $x = 10.0$ mm, $y = 8.0$ mm, and $z = 10.8$ mm. Y-split recession has to be combined with ipsilateral rectus muscle reinforcement (resection or plication) for minimal strabismus angles of more than 23° . Y-split recession can also be performed with the MISS technique using two paraincisional cuts. It usually induces more subconjunctival hemorrhage than a MISS recession alone and, therefore, mild perilimbal redness may be seen after surgery (Fig. 6.8).

6.4.7 MISS Rectus Muscle Repeat Surgery

The principle of MISS surgery can also be applied to repeat rectus muscle surgery [11]. In repeat surgery,

Fig. 6.7 Schematic representation of the surgical steps for Priglinger's Y-split rectus muscle recession: (a) Splitting of the rectus muscle over a length of 15–17 mm, (b) desinsertion of the two halves after applying a suture to each muscle half, (c) Y-reinsertion, (d) points used to determine the new insertion site of the two muscle halves

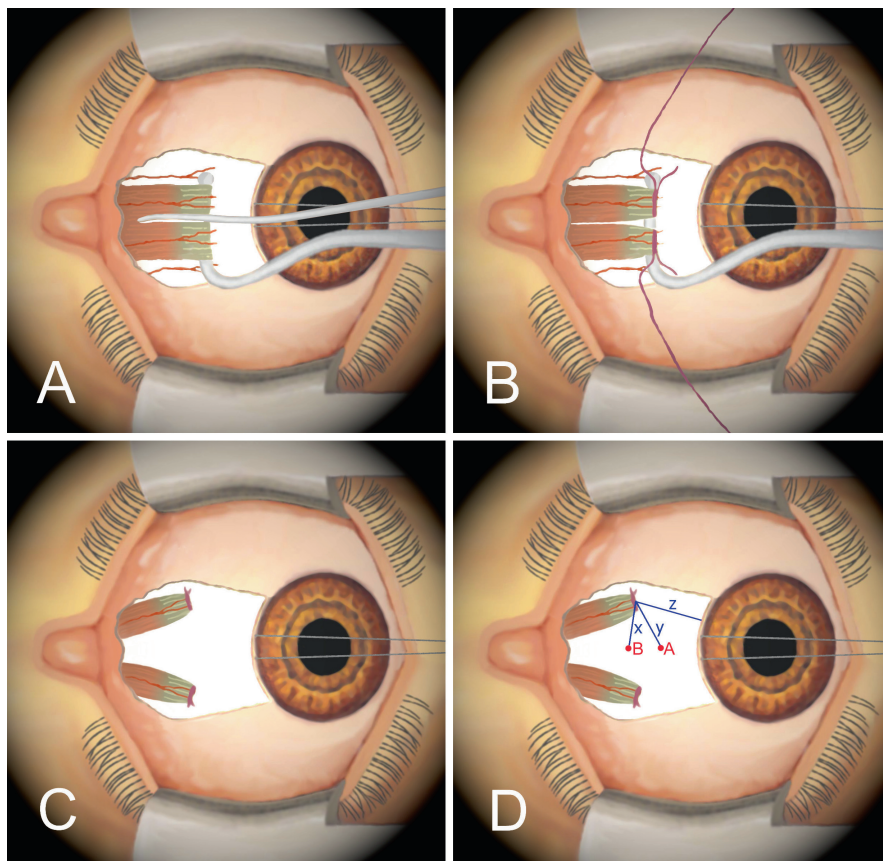
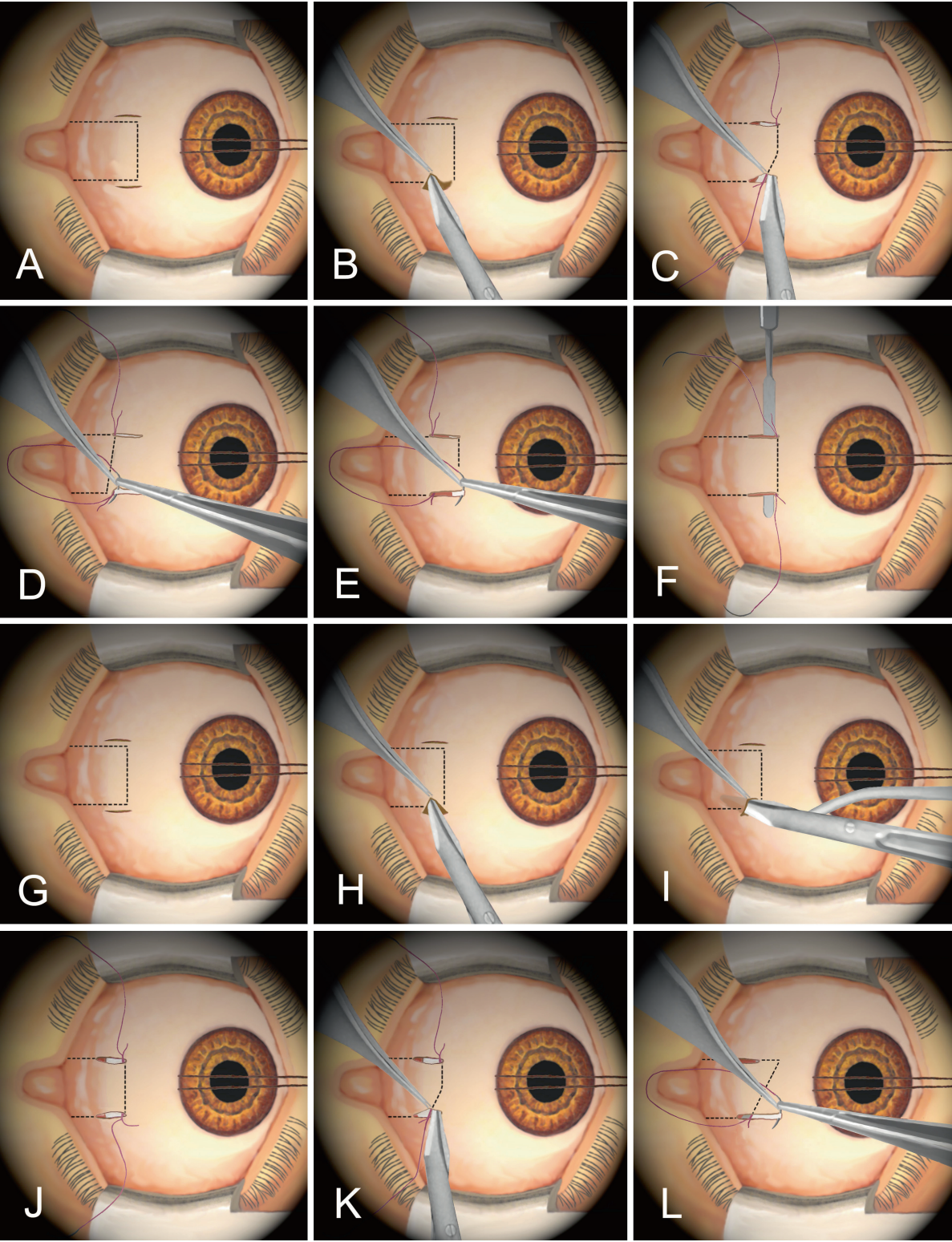


Fig. 6.8 20 Twenty-year-old patient on the first postoperative day after MISS Y-split recession of the medial rectus muscle

the location of the rectus muscle insertion may differ from the physiologic position. Preoperative knowledge of where the exact insertion lies is less important for surgery using Harms' limbal opening or Parks' fornix

incision, as the insertion position will not influence the location of the conjunctival cuts. However, this knowledge will allow minimizing of the MISS keyhole opening by placing it exactly where surgery will be done (Fig. 6.9a). Preoperatively, the planned intraoperative opening placement can be determined using information about the type and amount of previous surgery. If not available, the site can be established either preoperatively by location of the muscle insertion using the slit-lamp or intraoperatively by moving the eye, using the traction suture. Apart from eyes with excessive scarring or with abundant Tenon's tissue, a movement of the eye frequently helps to distinguish the vessels that are conjunctival and those which belong to the muscle, thus helping to determine the actual insertion site. The big advantage of this approach is that the surgeon will not have to reopen an already traumatized perilimbal conjunctiva and, thus, can avoid the risk of a permanent increase of conjunctival redness and scarring. Probably, the risk of anterior segment ischemia is also decreased [8]. If previous surgery has been performed very carefully, the cuts will have to be



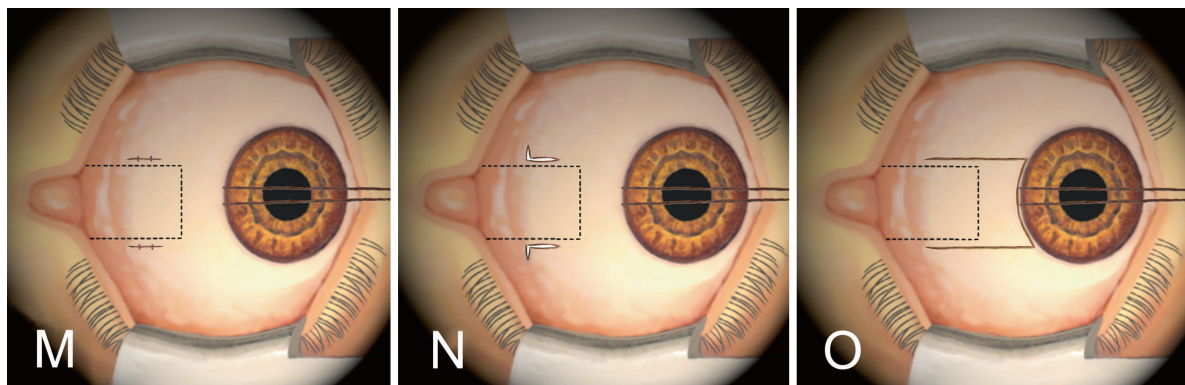


Fig. 6.9 Schematic representation of the surgical steps for MISS rectus muscle repeat surgery [11]: (a) For a repeat recession, two small paraincisional cuts are performed, (b) meticulous dissection of the check ligaments, the intermuscular membrane, and previous scars 6–7 mm backward from the insertion, (c) two sutures are applied to the superior and inferior borders of the muscle tendon, (d) after measurement of the amount of recession, the tendon is reattached with the two sutures to the sclera, (e) for a repeat plication, two sutures are applied to the upper and lower borders of the muscle at a distance from the tendon insertion site corresponding to the plication amount, and the sutures are passed at the superior and inferior tendon insertions respectively, (f) an

iris spatula is inserted between the tendon and the sutures, and the muscle is plicated, (g) for an advancement after previous muscle recession, two small radial cuts are performed, one each along the actual superior and inferior muscle margins, (h) the episcleral tissue is separated from the muscle sheath and the sclera, (i) the muscle is hooked and a meticulous dissection of the check ligaments and intramuscular membrane is performed 6–7 mm backward from the insertion, (j) two sutures are applied to the superior and inferior borders of the muscle insertion, (k) muscle desinsertion, (l) muscle anchoring after advancement, (m) conjunctival closure, (n) a better visualization is achieved by performing two L-shaped cuts; or (o) by joining the two cuts at the limbus

slightly larger compared to the eyes in which the rectus muscle had no prior surgery. For excessively scarred rectus muscles, for example, after retroequatorial fixation sutures, adjustable sutures, or after several previous operations, an L-shaped keyhole opening will be necessary to adequately separate the muscle from the surrounding tissue (Fig. 6.9n). All surgical steps of repeat surgery can be performed without an assistant. *MISS rectus muscle recession*: The principle of repeat rectus muscle recessions through keyhole openings does not differ from the previously described MISS rectus muscle recession techniques (see Sect. 6.4.1). Briefly, a limbal traction suture is applied to rotate the eyeball away from the field of surgery and two small radial cuts are performed, one along the superior and one along the inferior muscle margin (Fig. 6.9a). As already mentioned, sometimes L-shaped openings will become necessary (Fig. 6.9n). With blunt Wescott scissors and using the two cuts for access, the episcleral tissue and previous scars are separated from the muscle sheath and the sclera. When the borders of the muscle have been identified, the muscle is hooked. Now, a meticulous dissection of the check ligaments, the intermuscular membrane, and previous scars is performed 6–7 mm behind the insertion (Fig. 6.9b). Through the resulting tunnel, two sutures are applied to the superior

and inferior borders of the muscle tendon as close as possible to the insertion. After cauterization of visible vessels at the insertion, the tendon is detached using Wescott scissors (Fig. 6.9c). If necessary, additional hemostasis is performed. After measurement of the amount of recession, the tendon is reattached with two sutures to the sclera (Fig. 6.9d). The surgical procedure is finished by applying two sutures to each of the two small cuts (Fig. 6.9m). *MISS rectus muscle plication*: This technique is also comparable to the technique described for plications in eyes with no prior surgery (see Sect. 6.4.2). After moving the eye opposite to the field of surgery using a limbal traction suture and performing two small cuts and a tunnel between the cuts, two sutures are applied to the upper and lower borders of the muscle at the distance from the tendon insertion site corresponding to the plication amount. Then, the sutures are passed at the superior and inferior tendon insertions respectively (Fig. 6.9e). Excessive scarring will make it necessary to prolong the openings more than usual. Compared to revision recession surgery, only rarely will an L-shaped opening become necessary (Fig. 6.9n). An iris spatula is inserted between the tendon and the sutures and the muscle is plicated (Fig. 6.9f). The surgical procedure ends with two sutures to both small cuts (Fig. 6.9m).

MISS rectus muscle advancement: This technique is different from all other MISS rectus muscle procedures and will, therefore, be described in more detail. After rotation of the eye using a limbal traction suture, two small radial cuts are performed, one along the superior and one along the inferior muscle margin (Fig. 6.9g). The anterior margin of the cut is at the level of the actual tendon insertion. With blunt Wescott scissors and using the two cuts for access, the episcleral tissue is separated from the muscle sheath and the sclera (Fig. 6.9h). When the borders of the muscle have been identified, the muscle is hooked. Now, a meticulous dissection of the check ligaments and intermuscular membrane is performed 6–7 mm behind the insertion (Fig. 6.9i). The resulting tunnel allows the advancement to be performed. Two sutures are applied to the superior and inferior borders of the muscle tendon as close as possible to the insertion (Fig. 6.9j). Then the tendon is detached using Wescott scissors (Fig. 6.9k). If necessary, hemostasis is performed. After measuring

the amount of advancement, the tendon is reattached with two sutures to the sclera (Fig. 6.9l). To perform the reattachment without enlarging the opening, the cut has to be displaced anterior, using a forceps. The surgical procedure is completed by applying two sutures to each of the two small cuts (Fig. 6.9m). If a better visualization of the operating site is necessary, the two cuts can be prolonged anterior or posterior. In cases of excessive scarring, it is preferable to perform an additional perpendicular relaxing cut at the posterior border (Fig. 6.9n). If normal visibility is needed, e.g., if the muscle cannot be found, the two cuts can be joined at the limbus (Fig. 6.9o). Frequently, about 10 days after MISS repeat rectus muscle surgery, the eye will appear normal in primary position (Fig. 6.10a). In this 13-year-old patient, the medial rectus muscle was advanced by 5 mm and the lateral rectus muscle plicated by 5 mm because of consecutive esotropia. On eccentric gaze while retracting the eyelids, the keyhole openings will become apparent (Fig. 6.10b–e).

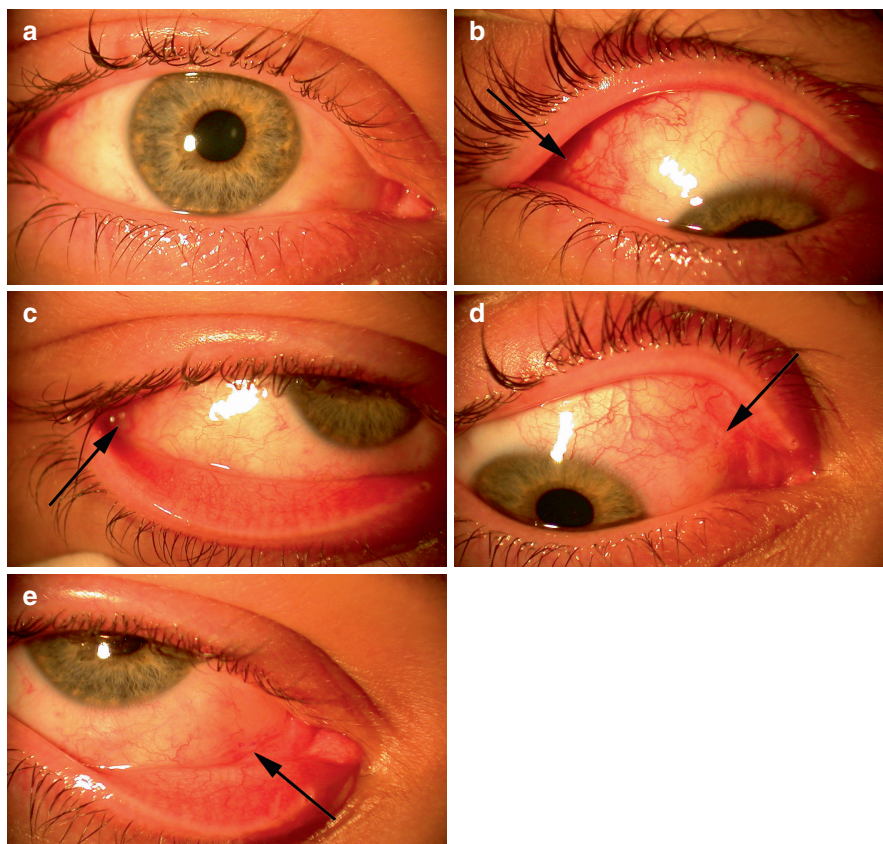
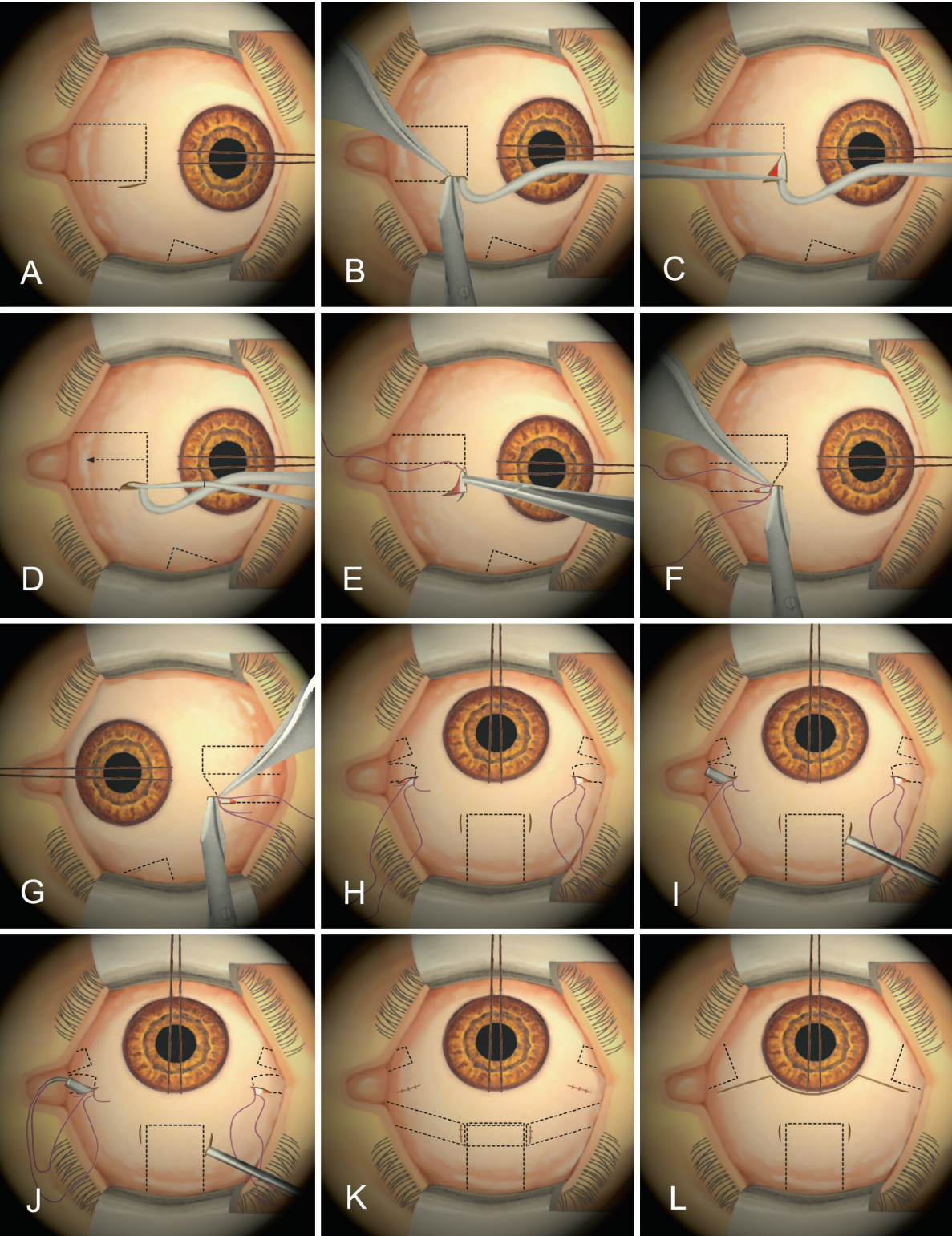


Fig. 6.10 Photographs on the tenth postoperative day after MISS medial and lateral rectus muscle revision surgery in a 13-year-old child: (a) Primary gaze position, (b–e) in eccentric gaze position, the keyhole openings become visible

6.4.8 *MISS Rectus Muscle Transposition Surgery*

Rectus muscle transpositions are indicated for strabismus associated with compete paralysis. They generate new force vectors that can replace the paralysed muscle. So far, partial or full rectus muscle transpositions are usually performed through large limbal openings. As an alternative, surgery can be performed through two radial cuts placed between the paralysed muscle and the two adjacent muscles, which will be transposed. As with Parks' fornix incision, such openings must be displaced over the muscle insertion to allow performing all surgical steps. In older patients the conjunctiva will tear and so radial cuts cannot be used for older patients. Unfortunately, transposition surgery using limbal openings often induces considerable conjunctival and lid swelling during the direct postoperative period and may even lead to corneal surface problems. To avoid these complications, a MISS transposition technique, which can also be used in inelastic conjunctiva, has been developed [13]. Several small keyhole openings are to be placed exactly where the surgical steps are to be performed. For a partial muscle transposition of both adjacent muscles, four openings will suffice; for complete transposition six openings are necessary. A blunt 20G sub-Tenon's anesthesia cannula is used to safely displace the needles and later the muscle to the paralysed muscle. The rest of the conjunctiva remains untouched. The cannula is introduced through the cut where the transposed muscle is anchored. Then, it is advanced until it comes out from the opening lying next to the muscle which is to be transposed. The needles are inserted in the cannula. Next, the cannula is retracted, allowing the needles to be safely displaced. It is important to take into account the anatomy of the oblique muscles to correctly undercross or overcross the transposed muscles. This access and tissue dissection technique minimizes anatomical disruption and, postoperatively, allows all openings to remain covered by the lids except during excessive gaze positions. The muscle transposition technique explained here in detail is Kaufmann's modified Hummelsheim procedure [7]. As in the Hummelsheim technique, half of both rectus muscles next to the weak rectus muscles are transposed. The modification consists in an undercrossing of the weak muscle by the transposed half-muscles. For large squint angles in primary position,

surgery has to be combined with ipsilateral rectus muscle recession or botulinum toxin injection. For smaller squint angles, both a combined rectus muscle recession and plication, transposition without undercrossing, or transposition of less than 50% of the fibers should be considered. All surgical steps can be performed without the help of an assistant. An operating microscope will enhance visibility of all surgical steps. A limbal traction suture will allow optimal exposure of the first of the two rectus muscles, which will be split and transposed. Then, a small paraincisional radial cut is performed at the muscle part which is to be transposed (Fig. 6.11a). The anterior margin of the cut is at the level of the tendon insertion. The size of this opening is approximately 4 mm. In patients with reduced elasticity of the conjunctival tissue, slightly larger openings will be necessary to split the muscle without tearing the conjunctiva. With blunt Wescott scissors the episcleral tissue is separated from the muscle sheath and the sclera. Then the muscle is hooked. Now, on the side of the opening, a meticulous dissection of the check ligaments and intermuscular membrane is performed (Fig. 6.11b). This dissection is performed 7 mm behind the insertion. The resulting tunnel will help to split the muscle easily. A curved ruler is used to measure the muscle insertion width and to determine its midpoint (Fig. 6.11c). Starting at the midpoint, the muscle is gently split using a small muscle hook with a mark 15 mm away from the hook (Fig. 6.11d). Splitting is stopped as soon as the mark reaches the insertion, which will ensure that exactly 15 mm of the muscle has been split. Two single sutures are applied to the muscle tendon which is to be transposed. These sutures are placed as close as possible to the insertion (Fig. 6.11e). Then, the split half-muscle is detached from the insertion using a Wescott scissor (Fig. 6.11f). If necessary, hemostasis is performed. After applying a new limbal traction suture, the same technique is used to split the other rectus muscle (Fig. 6.11g). After desinsertion of the second split half-muscle, the minimally invasive transposition can be performed. Therefore, a new limbal traction suture is applied, which will help to expose the weak rectus muscle. Now, two small paraincisional keyhole cuts are performed along the muscle margin (Fig. 6.11h). The size of these openings is 3 mm. Afterwards, a blunt 20G sub-Tenon's anesthesia cannula is inserted through one of these openings and advanced under the weak rectus muscle to come out through the



contralateral cut used to split the contralateral half-muscle (Fig. 6.11i). Both needles of the half-muscle are gently inserted in the cannula until they are fixed (Fig. 6.11j). Now, the cannula is retracted, and allowed to safely pass through tunnel. After withdrawal of the needles from the cannula, the scleral fixations are prepared next to the insertion of the weak rectus muscle. By slow traction on both sutures, the contralateral half-muscle will undercross the weak muscle. As soon as they become visible, they can be anchored by two single knots. Then, the same procedure is performed for the second half-muscle. Now, care has to be taken that the cannula will not injure the already transposed half-tendon. The surgical procedure is completed by applying single sutures to each of the four small cuts (Fig. 6.11k). If the operating site needs to be better visualized, e.g., if excessive bleeding occurs, which cannot be stopped with cautery through the small cuts, or in patients with previous surgery with excessive scarring, during surgery the corresponding cut has to be enlarged or the two larger cuts joined at the limbus (Fig. 6.11l). Usually, on the first postoperative day after MISS rectus muscle transpositions, the paralimbal conjunctiva have a normal appearance or are only minimally swollen (Fig. 6.12). This 7-year-old girl had a transposition of half medial and lateral rectus muscles to the superior rectus muscle.

6.5 Oblique Muscle Procedures

Unless oblique muscle surgery is performed together with surgery of an adjacent rectus muscle or excessive scarring is expected from previous trauma or surgery, most surgeons prefer to avoid a perilimbal opening. Nonlimbal cuts remain covered by the eyelids, even during excessive up- and downgaze. This

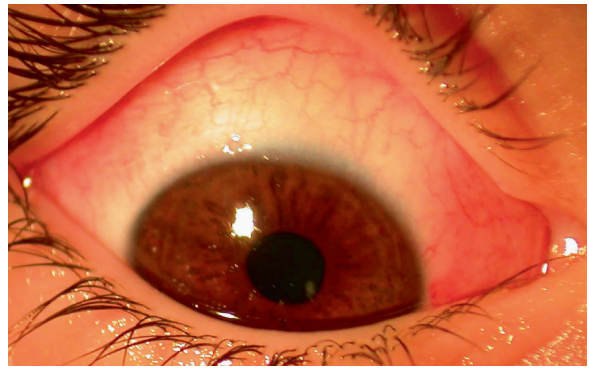
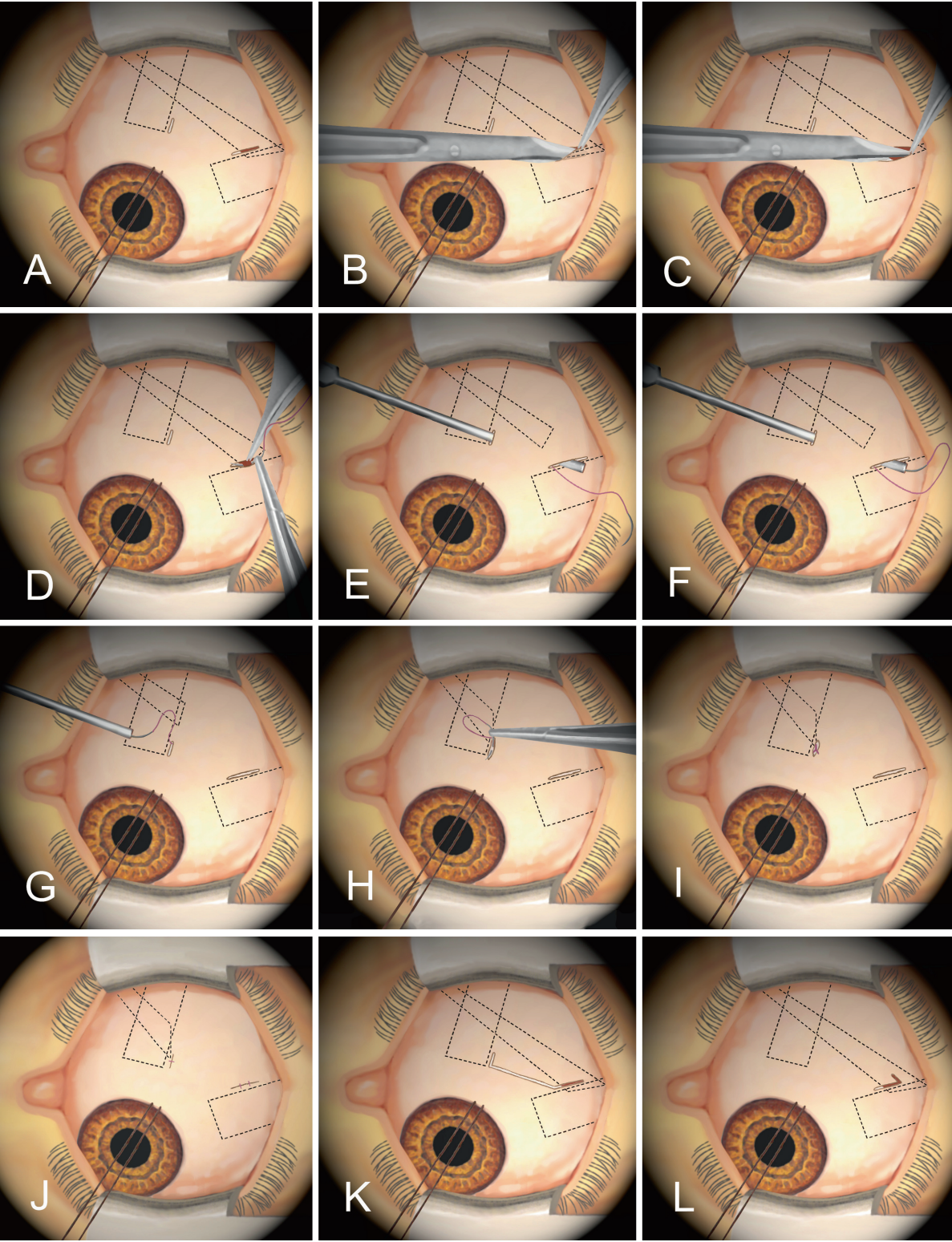


Fig. 6.12 Photograph on the first postoperative day after MISS partial horizontal rectus muscle transposition to the superior rectus muscle in a 7-year-old patient

will minimize postoperative discomfort and visibility of surgery, avoid complications like corneal deltan formation [25] and Tenon's tissue prolapse, and reduce the risk for anterior segment ischemia [8]. Most oblique inferior procedures are designed to weaken the muscle. Unless the muscle is transposed, for example to achieve an additional depressive function, anchoring of the anterior muscle border will suffice. It is believed that leaving the posterior border free will allow a reattachment at the best functional position [20]. Additionally, posterior border anchoring is technically demanding and dangerous because of the proximity to the macula. In the following text, a minimally invasive inferior oblique recession with reattachment of only the anterior border is shown, as this surgical technique will help to control most situations in which a weakening is necessary. Usually, to achieve a graded recession along the physiologic muscle course, for each 3 mm of recession the anterior border has to be anterialized by 1 mm. Greater anteroposition of the anterior border will allow overproportionally weakening elevation,

Fig. 6.11 Schematic representation of the surgical steps for MISS rectus muscle transposition surgery [13]: (a) a small radial cut is performed along the border of the medial muscle that will be transposed (b) the episcleral tissue is separated from the muscle sheath and the sclera, the muscle is hooked, and the check ligaments and intermuscular membrane are dissected, (c) with a ruler the midpoint of the muscle insertion is determined, (d) the muscle is split using a small muscle hook, (e) two single sutures are applied to the half muscle tendon that will be transposed, (f) the half-muscle is detached from the insertion, (g) the same procedure is applied to the other half rectus muscle that will be transposed, (h) the weak

rectus muscle is exposed, and two small radial cuts are performed along the muscle insertion, (i) a blunt cannula is inserted through one of these openings and advanced under the weak rectus muscle in order to exit at the contralateral half-muscle, (j) both needles are fixed into the cannula, (k) after retraction of the cannula, a slow traction on both sutures will transpose the contralateral half-muscle to the weak muscle, which can then be anchored by two single knots at the sclera; the same procedure is performed for the second half-muscle, and all conjunctival cuts are closed, (l) if the operating site needs to be better visualized, the corresponding cut can be enlarged, or the two larger cuts can be joined at the limbus



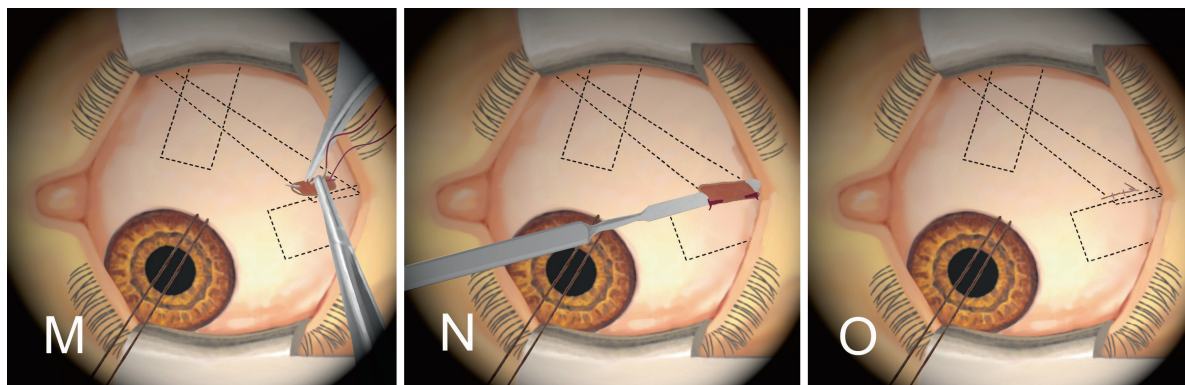


Fig. 6.13 Schematic representation of the surgical steps for MISS inferior oblique recession [12]: (a) A radial cut is performed over the insertion of the inferior oblique muscle, (b) a second cut is applied where the reinsertion will be performed later, (c) with blunt Wescott scissors, the inferior oblique insertion is separated from the surrounding tissue, (d) the insertion is completely detached, (e) one single suture is applied to the anterior third of the detached muscle insertion, (f) a blunt cannula is passed through the second cut, the reinsertion site opening, and advanced in order to be get out through the first cut, (g) the needle is gently inserted in the cannula until it is fixed, (h) the cannula is retracted, (i) the scleral fixation is performed, (j)

conjunctival closure, (k) if a better visualization is needed, the two small cuts can be joined to form one large opening. Schematic representation of the surgical steps for MISS inferior oblique plication: (l) an L-shaped cut is placed over the insertion of the inferior oblique muscle, (m) the inferior oblique insertion is separated from the surrounding tissue, and after measuring the amount of plication, a single suture is passed at that location through the anterior and another through the posterior third of the muscle, and both sutures are passed through the insertion of the muscle, (n) after placing a spatulum over the most distal part of the muscle, the plication is performed by tying both sutures, (o) conjunctival closure

and lesser anteroposition will overproportionally weaken exocyclotorsion. Rarely, enhancement of the function of an inferior oblique is required. Probably, a plication, which is described here, is less dangerous and demanding than muscle advancement if scleral anchoring of the sutures is avoided. Plication of only the anterior border mainly increases exocyclotorsion while an isolated plication of the posterior border mainly increases the elevatory effect of the inferior oblique. Minimally invasive superior oblique recession is performed similar to the recession of the inferior oblique. Again usually, it is not necessary to reattach the posterior border of the tendon. An overproportional anteroposition of the anterior border will weaken the depressive action more and underproportional anteroposition helps to mainly reduce incyclotorsion. Plication of the superior oblique is probably best performed using a temporal approach, as with the nasal approach neighboring structures may be damaged [20].

Additionally, two other minimal invasive techniques for superior oblique surgery are described, namely Boergen's modified Harada-Ito operation and Mühlendyck's partial posterior tenectomy for Brown's syndrome.

6.5.1 MISS Inferior Oblique Muscle Recession

The main indications for inferior oblique recession, sometimes combined with a tuck of the superior oblique, are inferior oblique overaction and superior oblique palsy. Ungraded recessions should not be used anymore, mainly because of the lack of the possibility of reversion. In contrast to the rectus muscle, the inferior oblique is often recessed over a large distance. If the principle of MISS is applied, conjunctival openings have to be placed only where absolutely necessary. For smaller inferior oblique recessions, the whole surgery can be performed through one single opening. Larger recessions can be handled by detaching and suturing the muscle using a keyhole cut and reanchoring the muscle through a second keyhole opening [12]. All surgical steps can be done without an assistant. First, a limbal traction suture is applied to expose the temporal inferior quadrant of the eye globe. A 4-mm radial cut is performed over the insertion of the inferior oblique muscle (Fig. 6.13a). The anterior margin of the cut is 1 mm anterior to the tendon insertion. For patients with inelasticity of the conjunctival tissue, slightly larger cuts are necessary. A second cut is applied where

later the reinsertion will be performed (Fig. 6.13a). If the reattachment is next to the lateral border of the inferior rectus muscle, the muscle itself will help as a landmark. If a graded recession of a certain amount is planned, the place is marked using a measure caliper. With blunt Wescott scissors the inferior oblique insertion is separated from the surrounding tissue (Fig. 6.13b). Then, using the same scissors, the insertion is completely detached (Fig. 6.13c). Now, a single suture is applied to the anterior third of the detached muscle insertion (Fig. 6.13d). Usually there is no need for suturing the posterior part of the insertion. If necessary, a second suture is applied. Afterwards, a blunt 20G sub-Tenon's anesthesia cannula is passed through the reinsertion opening and advanced to come out through the opening next to the physiologic insertion (Fig. 6.13e). The needle is gently inserted in the cannula until it is fixed (Fig. 6.13f). Now, the cannula is retracted (Fig. 6.13g), the needles retracted from the cannula, and the scleral fixation is performed (Figs. 6.13h, i). After having checked that all posterior fibers of the inferior oblique insertion have been properly cut, the surgical procedure is finished by closing the two keyhole cuts (Fig. 6.13j and 6.14). If during minimally invasive surgery, visibility of the operating site is insufficient, e.g., after excessive bleeding, which cannot be stopped with cautery through the small cuts, the two openings can be joined, which will allow a better view (Fig. 6.13k). MISS inferior oblique recession can be combined with MISS ipsilateral, lateral or inferior rectus muscle surgery. Enlargement of the corresponding cut and performing an additional paraincisional keyhole opening on the opposite side of the adjacent rectus muscle will allow MISS rectus muscle surgery as described earlier (Sect. 6.4). MISS graded oblique muscle recessions will only induce minimal scarring. Usually, the conjunctiva is closed with two single sutures at the original insertion site and with one single suture where the muscle has been reattached to the sclera (Fig. 6.14).

6.5.2 MISS Inferior Oblique Muscle Plication

Inferior oblique muscle plications are rarely performed because, when indicated, most surgeons prefer performing superior oblique muscle recessions. For large

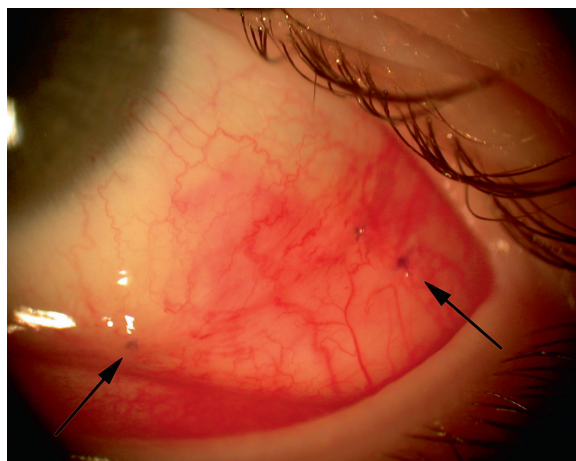


Fig. 6.14 Photograph on the first postoperative day after a 13 mm inferior oblique recession in a 15-years-old patient

incyclotorsions, strong overaction of the superior oblique muscle, or if excessive scarring of the superior oblique tendon is expected, strengthening procedures of the inferior oblique muscles may be indicated. All surgical steps can be performed without an assistant. A microscope will help perform the surgery more easily. A limbal traction suture is applied to expose the temporal inferior quadrant of the eye globe. During surgery, direct contact of the traction suture with the cornea has to be avoided. An L-shaped cut is placed over the insertion of the inferior oblique muscle (Fig. 6.13l). With blunt Wescott scissors the inferior oblique insertion is separated from the surrounding tissue. Then, after measuring the amount of plication, a single suture is passed at that location through the anterior third of the muscle. The same procedure is performed at the posterior muscle border (Fig. 6.13m). Both sutures are passed through the insertion of the muscle. After placing a spatulum, the plication is performed by tying both sutures. (Fig. 6.13n). The surgical procedure is completed by applying single sutures to the small cut (Fig. 6.13o).

6.5.3 MISS Superior Oblique Muscle Recession

Superior oblique recessions will reduce muscle overaction, ipsilateral hypotropia, which is most pronounced in adduction, and incyclotorsion, usually seen on abduction. Surgery can be performed without an assistant.

For a smaller recessions, under the superior rectus muscle, the usual approach with one big opening is used. If larger recessions are indicated, the total opening size can be drastically reduced by using two cuts, one at the site where the tendon has to be desinserted and one where it will be reinserted. A limbal traction suture is applied to expose the superior quadrant of the eye globe. A 4 mm radial cut is performed over the insertion of the superior oblique muscle and a smaller radial cut of approximately 2 mm where the muscle will be reattached (Fig. 6.15a). The reinsertion place is found using a measure caliper. With blunt Wescott scissors, the superior oblique insertion is separated from the surrounding tissue. Now, a single, nonresorbable suture is applied to the anterior third of the muscle tendon close to the insertion (Fig. 6.15b). Usually, it is only necessary to reinsert the anterior border to the sclera, and, therefore, no second posterior suture is needed. Afterwards, a blunt 20G sub-Tenon's anesthesia cannula is passed through the reinsertion site opening and advanced under the superior rectus muscle to come out through the second opening. The needle is gently inserted in the cannula until it is fixed (Fig. 6.15c). Now, the cannula is retracted and the tendon is completely detached at its insertion (Fig. 6.15d). Then, the scleral fixation is performed (Fig. 6.15e). After having checked that all posterior fibers of the superior oblique insertion have been properly cut, the surgical procedure is completed by applying single sutures to each of the two small cuts (Fig. 6.15f). This approach allows, a MISS superior rectus muscle recession or plication using the same two cuts to be performed.

6.5.4 MISS Superior Oblique Muscle Plication

Superior oblique muscle plications are indicated for superior oblique palsies. The use of a microscope is recommended. A limbal traction suture is applied to expose the superior quadrant of the eye globe. Direct contact of the traction suture with the cornea has to be avoided. An L-shaped cut is placed over the insertion of the superior oblique muscle (Fig. 6.15g). The tendon is hooked while another hook pulls the lateral rectus muscle border medially (Fig. 6.15h). After measuring the amount of plication, a single, non-resorbable suture is passed at that location through the anterior third of the tendon

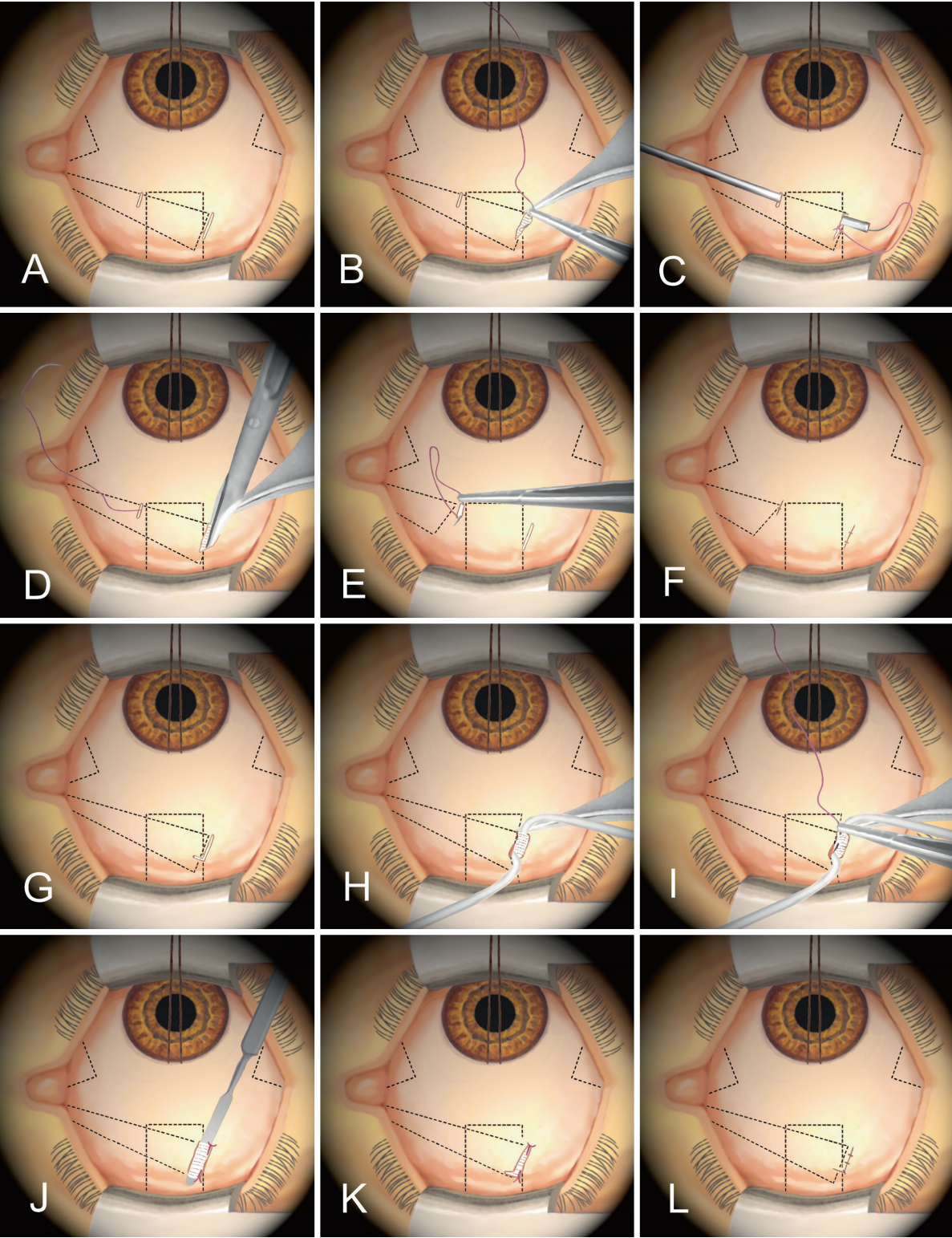
(Fig. 6.15i). The same procedure is performed at the posterior tendon border. Both sutures are passed through the insertion of the muscle. After placing a spatulum, the plication is performed by tying both sutures (Fig. 6.15j). The spatulum is retracted (Fig. 6.15k). The surgical procedure is completed by applying single sutures to the small cut (Fig. 6.15l).

6.5.5 Boergen's Modified Harada-Ito Operation

Acquired fourth nerve palsy is characterized by horizontal V-pattern, vertical, and cyclotorsional deviation. Boergen described a modification of the Harada-Ito procedure for excyclotropia correction, which is less invasive and seems to induce less postoperative Brown's syndrome [2]. After applying a traction suture and the superior oblique tendon has been visualized through a temporal approach (Fig. 6.16a), the tendon is split over a distance of 8–10 mm starting at the insertion (Fig. 6.16b). This can be performed through a small keyhole opening. Without detaching the insertion, the anterior part is displaced 3–6 mm temporal to the lateral insertion of the superior rectus muscle using a nonresorbable suture (Fig. 6.16c). Thus, the anterior half of the tendon will form a loop. The procedure corrects excyclotorsion. However, as the anterior and posterior parts of the tendon are still joined, this will also decrease the V-pattern incomitance and vertical deviation to a certain degree. For unilateral cases with more than 5° of vertical deviation, it will be necessary to also tuck the posterior half of the tendon. This will require a larger conjunctival opening.

6.5.6 Mühendyck's Partial Posterior Superior Oblique Tenectomy for Congenital Brown's Syndrome

Many cases of congenital Brown's syndrome are caused by an inelastic thickening of the posterior part of the superior oblique tendon [15]. Mühendyck described this anomaly in a large case series and proposed a minimally invasive approach to treat the condition. After applying a traction suture, a temporal approach to the superior oblique is chosen. By elevating the tendon at



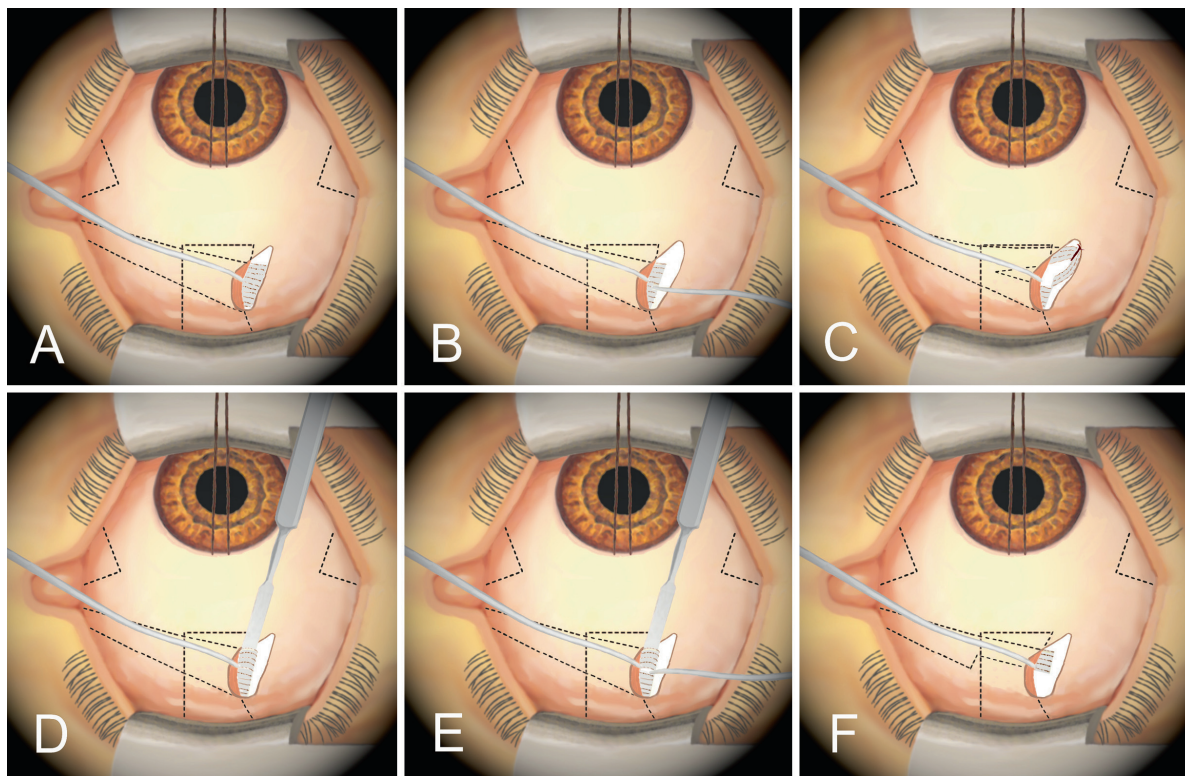


Fig. 6.16 Schematic representation of the surgical steps for Boergen's modified Harada-Ito operation. (a) The superior oblique tendon is visualized through a temporal approach, (b) the tendon is split over a distance of 8-10mm, (c) the anterior part is displaced in order to form a loop. Schematic representation of the surgical steps for Mühlendyck's partial posterior

superior oblique tenectomy for congenital Brown's syndrome. (d) After choosing a temporal approach, the posterior inelastic part of the tendon is exposed, with a spatula (e) the anterior, normal part is separated from the posterior, inelastic part, (f) as much of the posterior part as possible is resected

the insertion site using a small spatula while a hook is displacing the lateral border of the rectus muscle medially, the posterior inelastic part can be easily visualized (Fig. 6.15d). The anterior, normal part and the posterior scar are separated using a second, small hook (Fig. 6.15e). The enlarged, inelastic posterior part of the

tendon is resected as far as possible medially, starting at the insertion site (Fig. 6.15f). Now, forced elevation in adduction of the eye should again be possible. During the first postoperative days, it is important that scarring between the remaining tendon and sclera is prevented. This can be achieved by occluding the opposite eye and

Fig. 6.15 Schematic representation of the surgical steps for MISS superior oblique recession: (a) A radial cut is performed over the insertion of the superior oblique muscle and where the muscle will be reattached, (b) with blunt Wescott scissors, the superior oblique insertion is separated from the surrounding tissue, and a single, nonresorbable suture is applied to the anterior third of the muscle tendon, (c) afterwards, a cannula is passed through the reinsertion site opening and advanced till it reappears at the second opening, and the needle is gently inserted in the cannula until it is fixed, (d) now, the cannula is retracted, and the tendon is completely detached at its insertion, (e) the scleral fixation is performed, (f) after having checked that all posterior

fibers of the superior oblique insertion have been properly cut, the conjunctival cuts are sutured. Schematic representation of the surgical steps for MISS superior oblique plication: (g) L-shaped opening over the insertion of the superior oblique insertion, (h) the tendon is hooked while another hook pulls the lateral rectus muscle border medially, (i) after measuring the amount of plication, a single, non-resorbable suture is passed at that location through the anterior and another suture through the posterior-third of the tendon, (j) the sutures are passed through the insertion of the muscle and after placing a spatulum, the plication is performed, (k) the spatulum is retracted, (l) conjunctival closure

applying a sector occlusion on the operated eye, which will force it to look in elevation-adduction. Alternatively, a transpalpebral stay suture can be applied to fix the eye in adduction-elevation. The latter will allow using the opposite eye normally and ensure that even during the night, the operated eye remains in this position. In contrast to a tenotomy, a consecutive superior oblique palsy is only rarely seen, as the anterior tendon part remains untouched. In cases showing no or insufficient postoperative improvement of Brown's syndrome repeat surgery will often disclose that not all fibers of the abnormal posterior part of the tendon have been resected [15]. Recently, Saxena suggested visualizing the superior oblique tendon with trypan blue [23]. This could allow identifying and delineating the posterior, enlarged, inelastic part of the tendon more easily.

6.6 Postoperative Handling

Core points:

- After surgery TobraDex® ointment (Alcon) is applied; the eye is not patched.
- For 2 weeks TobraDex® suspension (Alcon) thrice daily and TobraDex® ointment (Alcon) in the evening are applied.
- Strenuous physical activities are not allowed during the first two postoperative days
- A direct contact of the eye and the periocular region with non sterile fluids is not allowed for 1 week
- Irritating fluids, fumes and dust should be avoided for about 4 weeks

Usually, at the end of surgery, TobraDex® ointment (Alcon, 1 mg dexamethasone and 3 mg tobramycin per gram of 0.5% chlorobutanol) is applied. No eye patch is used. For the first 2 weeks after surgery, TobraDex® suspension (Alcon, 1 mg dexamethasone and 3 mg tobramycin per mL of 0.01% benzalkonium chloride) thrice daily and TobraDex® ointment (Alcon) in the evening are administered. In repeat surgery with excessive scarring, treatment should be prolonged until the conjunctival redness has disappeared completely. In the first two postoperative days, strenuous physical activities are not allowed because of the risk of secondary hemorrhages. During the first week, a direct contact of the eye and the periocular region with non-sterile fluids is not allowed. Irritating fluids (e.g.,

chlorate water in swimming pools) and irritating fumes and dust (e.g., heavily smoking environment) should be avoided for about four weeks.

6.7 Specific Complications of MISS

The intraoperative and postoperative complications of strabismus surgery are numerous. Fortunately, severe ones are rare. This chapter focuses on specific complications related to minimally invasive strabismus surgery.

6.7.1 Intraoperative Complications

Traction suture: If the limbal traction suture is too superficial, it may pull out during surgery. A new traction suture should be applied slightly more posterior. This will usually remain unaffected. However, sometimes, such patients might experience an increased discomfort while moving the eyes on the first postoperative day. A traction suture that is not limbal but slightly posterior, might induce a tear in inelastic conjunctiva of older patients while the keyhole openings are excessively displaced. A too deep limbal traction suture might penetrate the eye. The surgeon will notice a loss of anterior chamber depth and, sometimes, see aqueous humor leaking at the suture entrance or exit. The traction suture should be immediately removed and reapplied more posteriorly. Postoperatively, a filtering bleb and hypotonia may develop. Probably, a prescription of a local topical carboanhydrase inhibitor will speed up the regression of the filtering bleb. The traction suture should never touch the cornea because of the risk of corneal erosion. Traction sutures at the inferior, lateral, and superior limbus will usually not rub on the cornea. Traction sutures applied to the medial limbus will touch the cornea. Therefore, a hypomochlion has to be created (see 6.8.1). In exophthalmic eyes, it may be impossible to avoid corneal rubbing if only one traction suture is placed in the quadrant where surgery is planned. For such cases, two limbal traction sutures in the adjacent quadrants should be used, for example, for medial rectus surgery one at the inferior and another at the superior limbus. A disadvantage of such sutures is that they will expose the surgical site less well since

they allow only a restricted rotation of the eye. *Keyhole openings:* Bleeding should be stopped immediately as otherwise visibility of the anatomical structures through the small cut will be considerably reduced. Openings placed over the insertion should be avoided because of the high risk of injuring larger muscle vessels, which may result in an excessive subconjunctival hemorrhage with severely reduced visibility of the surgical site. Sometimes it is inevitable that the cuts have to be or joined at the limbus. The cuts need also to be enlarged if they have been placed at the wrong site, especially in patients with inelastic conjunctiva. Openings in repeat surgery or cuts lying near the fornix bear the risk of herniation of orbital fat. As soon as fat becomes visible, the surgeon should avoid further prolonging of the cut in the corresponding direction. Sometimes, cauterization will be necessary to stop bleeding and to retract the orbital fat. In such cases, closure of the conjunctival cuts at the end of surgery should be preceded by a separate adaptation of the Tenon's capsule. In young children, the Tenon's tissue might hinder good visualization of the operating site. However, usually, it is not advisable to resect the excessive Tenon's tissue prolapsing through the keyhole openings because of the risk of a hemorrhage, which might be hard to control. Cuts with visible Tenon's tissue should be closed by first adapting Tenon's tissue, followed by a conjunctival suture. Probably, this will enhance ease of repeat surgery using the same or other access techniques. Suturing through the small cuts has to be performed always under optimal conditions of visualization. If visibility is not full, the cuts have to be enlarged. In case of penetration or suspected penetration of the globe, the pupil has to be dilated to examine the retina at the end of surgery. If a retinal break is seen, cryocoagulation or laser coagulation should be performed. The necessity for a systemic antibiotic treatment after globe penetration remains unclear. The more experienced a surgeon gets with MISS, the smaller the conjunctival openings will be. However, this will increase the risk of conjunctival tears. Elderly patients with inelastic conjunctiva are particularly at highest risk. If a tear is purely conjunctival as it does not involve the underlying Tenon's tissue, exact readaptation will not result in a visible scar and repeat surgery will not be negatively affected. Also the other tears will usually remain invisible and not hinder repeat surgery, unless the tear is over the muscle insertion. *Desinsertion:* The tendon at

the muscle insertion might tear longitudinally when the muscle is detached. This does not allow proper reinsertion of the muscle with only two sutures, as the tear would allow a posterior bowing of the middle part of the insertion. To avoid tearing, either the tension of the traction suture should be diminished before muscle desinsertion or, alternatively, the whole tendon should be stabilized with a forceps just distally from the insertion while it is desinserted. Care has to be taken to ensure that the muscle sutures are not cut. Usually, for recessions, it is preferable to pass the sutures through the sclera at the reinsertion site before desinsertion. This will help to pull the sutures away from the insertion and thus avoid inadvertently being cut during desinsertion. If the middle part of the muscle bows back at the reinsertion site, a central suture avoiding the long ciliary vessel should be performed through the tunnel. If a suture is inadvertently cut during the desinsertion, the corresponding part of the tendon is pulled back through the cut, which will allow reapplying the suture. While usually oblique muscle desinsertion is not followed by a hemorrhage, mostly rectus muscles will. Therefore, it is advisable to cauterize all larger vessels starting about 2 mm behind the insertion and ending about 2 mm anterior to it. Bipolar diathermy with a coaxial tip is the best option to cauterize vessels through conjunctival keyhole openings while performing MISS. This type of cauter will minimize the risk of inadvertent cauterization of the conjunctiva next to the bleeding vessels. Another advantage of this type of cautery is the possibility of regulating the energy level, which will permit minimizing the risk for tissue burns. Always start with the minimal setting and hold the tip still for one or two seconds over the vessel before you decide that the settings are too low. In lateral and medial rectus recessions, never cauterize the vessels directly at the desinsertion site after tendon desinsertion as the sclera may retract, which might result in permanent visibility of the thinned sclera, usually a bluish line. If cosmetically disturbing, this may require scleral patching. To safely stop bleeding at the insertion after tendon detachment, cauterize the corresponding vessels 2 mm anterior to the desinsertion. Sometimes, after desinsertion, some fibers remain attached. This will result in significant undercorrection. In oblique muscles the most posterior fibers are at risk of being cut, in rectus muscles using the two keyhole openings, usually such fibers lie in the middle of the tunnel. Thus, after muscle reattachment, always

search for such fibers. They are best found after muscle reattachment as they will be stretched. Sometimes an anterior bowing of a part of the new insertion might indirectly point to remaining fibers. In addition to that, inspection of the reinsertion site will ensure that none of the scleral sutures had loosened while being tied and will disclose posterior bowing of the middle part of the new insertion, both of which would result in an overcorrection. If during desinsertion a buttonhole occurs in the overlying conjunctiva, try to find and excise the conjunctiva that has been cut. Otherwise, a serous conjunctival cyst may grow. *Plication:* In patients with abundant Tenon's tissue, the inexperienced surgeon might grasp the tissue surrounding the muscle instead of the muscle itself. This can be avoided by liberating the muscle from the surrounding tissue at the site where the suture has to be placed. This needs to be done with caution, because often larger vessels will accompany the lateral borders of the muscle. The part of the muscle where the posterior plication suture will be applied is at risk of gliding through the grasping forceps, when pulled forward. For short plication distances, there is no need to pull the muscle anterior to apply the suture. However, for larger amounts of plication, this becomes necessary, to visualize the distal plication site through the keyhole cuts. The more the muscle has to be pulled forward, the higher the risk of gliding, which would result in an undercorrection. Check that the forceps still grasp the muscle firmly and avoid additionally grasping Tenon's tissue. The proximal plication suture at the original insertion will sometimes require a dissection to get bare sclera. If the proximal plication suture is anchored to the Tenon's tissue instead of the sclera, a significant undercorrection will result. Before trying to approximate the distal plication suture to the insertion site, the tension of the traction suture should be reduced. This is crucial for larger plication distances as otherwise the suture may rupture due to very high tension. If this happens, the corresponding plication suture has to be redone. When performing a plication of the lateral and superior rectus muscle, avoid grasping the tendon of the adjacent oblique muscle tendon. *Anatomical abnormalities:* Keyhole surgery may be contraindicated if congenital, posttraumatic or postsurgical anatomical variations exist. For rectus muscle surgery, Harms' conjunctival opening and for oblique muscles one large opening should be used. With increasing experience in MISS surgery, the surgeon will be able to handle such cases

through keyhole cuts. If surgery has been started using MISS openings and cannot be continued because of an unclear situation, enlargement of the cuts or, for rectus muscle surgery, joining at the limbus, will be necessary.

6.7.2 Postoperative Complications

Subconjunctival hemorrhage: In a few cases, normally during the first postoperative night, a subconjunctival hemorrhage may occur. In MISS patients this will not increase discomfort; however, conjunctival redness will last longer. *Local allergies:* Allergic reactions from topical eye drops will induce an increasing conjunctival injection and yellowish conjunctival swelling, often combined with eyelid swelling. The patient will report a burning sensation when the eye drops are applied. All topical medications should be discontinued. *Corneal dellen formation:* Corneal dellen are rarely seen with the MISS technique. If they arise, they are small and resolve quickly. Patients with severe dry eye syndrome or ocular surface diseases might, however, still suffer from more pronounced corneal dellen. *Prolapse of the Tenon's tissue:* If the Tenons' tissue prolapses through the small openings, it will be minimal and will normally not require any additional intervention. *Foreign body granuloma:* A foreign body granuloma usually occurs in the first couple of weeks after surgery. It develops around a suture, swab fragment, or eyelash. The foreign body should be removed with the slit-lamp. In younger children this may not be possible. A transient increase of topical steroids can sometimes induce a regression and, therefore, prevent removal under general anesthesia. *Serous conjunctival cysts:* In MISS patients serous conjunctival cysts may occur. Removal techniques do not differ from those used for cysts developing after open surgery. *Postoperative hypotonia:* As already mentioned, penetration into the anterior chamber while applying a traction suture may induce a filtering bleb and hypotonia. Such patients may be disturbed by the refractive shift if a shallow anterior chamber persists. Although spontaneous regression can be expected, prescription of a local carbonic dehydrase inhibitor may speed-up regression. Injection

of autologous blood may also be considered. *Refractive changes:* Postoperative refractive changes may also occur with MISS openings, especially with larger displacements. Their frequency and size seem to be comparable to changes seen using Harms' limbal opening [9]. *Permanent increase of conjunctival redness:* Hardly ever will the MISS technique permanently increase the conjunctival redness visible in primary position. In contrast, after rectus muscle surgery, seldom will a permanent increase of redness be seen on eccentric gaze. Often in these patients the opposite, unoperated eye, will disclose larger vessels and a slight redness of the conjunctiva in the region of the muscle insertion. If this is seen preoperatively, the patient should be informed that possibly this redness will increase. In severe cases having a normal perilimbal conjunctiva, it might be advisable to avoid MISS openings and do surgery using Harms' limbal approach with two short relaxing cuts. Permanent, increased, perilimbal redness may be seen in a few patients after converting the small openings to a large Harms' limbal opening. Therefore, the surgeon should first try if the operation can be continued by enlarging the two small cuts before joining them at the limbus. *Repeat surgery after MISS:* If a muscle, which has been operated through MISS openings, needs repeat surgery, the same conjunctival access should be used. Usually, the previous scar will be visible, at least if the microscope is used to perform the procedure. Often, because of increased parainsertional scarring, the cuts need to be slightly larger.

6.8 Suggestions on How to Start Doing MISS

6.8.1 Instruments Suitable for MISS

Instruments indispensable for strabismus surgery are as follows: eye speculum, forceps, scissors, muscle hooks, spatula calipers, needle-holders, clips, sponge-swabs and cautery. While usually for open surgery the size of the instruments is not critical, conjunctival tearing will occur if very large instruments are used to operate through MISS keyhole openings. Table 6.1 includes a list of instruments suitable to perform MISS. It is up to every surgeon to decide if he wants to switch to the suggested instruments or if he believes that MISS may also be performed with the instruments he has. Using his own instruments, as long as they work, will probably make transition easier. The following instruments are useful to perform MISS. By clamping a serrefine to the eyelid speculum, a hypomochlion is created for traction sutures applied medially (Fig. 6.17a, b). A colubrie forceps with interdigitating teeth is used to fix the conjunctiva while performing the keyhole openings and to stabilize the eye for traction and scleral anchoring sutures (Fig. 6.17c). A small, curved needle holder is optimal to perform suturing through small openings (Fig. 6.17d). A small conjunctival scissor with a curved, blunt tip is used to cut the conjunctiva, the sutures and the muscle or tendon insertions (Fig. 6.17e). Curved forceps with serrated tips should be used to hold the conjunctiva after performing the keyhole openings as this

Table 6.1 Instruments suitable for MISS

Type of instrument	Size	Company
Bangerter blade speculum	15 mm	Janach
Dieffenbach Serrefine	55 mm straight	Storz
Stevens tenotomy hook, small	90°, angled	Janach
Barraquer needle holder	125 mm, curved, without lock	Janach
Colubrie corneal forceps	1 × 2 straight, 0.25 mm teeth, with tying platform	Janach
Conjunctival scissors	Curved, 10 mm long blades, blunt tips	Janach
Dressing forceps curved	0.60 mm, serrated jaws	Janach
Dressing forceps angled	Special manufactured	Janach
Caliper straight	20 mm spread	Janach
Wecker spatula	2 × 0.4 mm	Bernhard Hermle
Wecker spatula	3 × 0.4 mm	Bernhard Hermle
Wecker spatula	6 × 0.4 mm	Bernhard Hermle
Diathermy	20G Endo Diathermy Tip, Diathermy Handle, short	Oertli Instruments
Sub-Tenon's anesthesia cannula	20G × 1 in.	Hurricane Medical

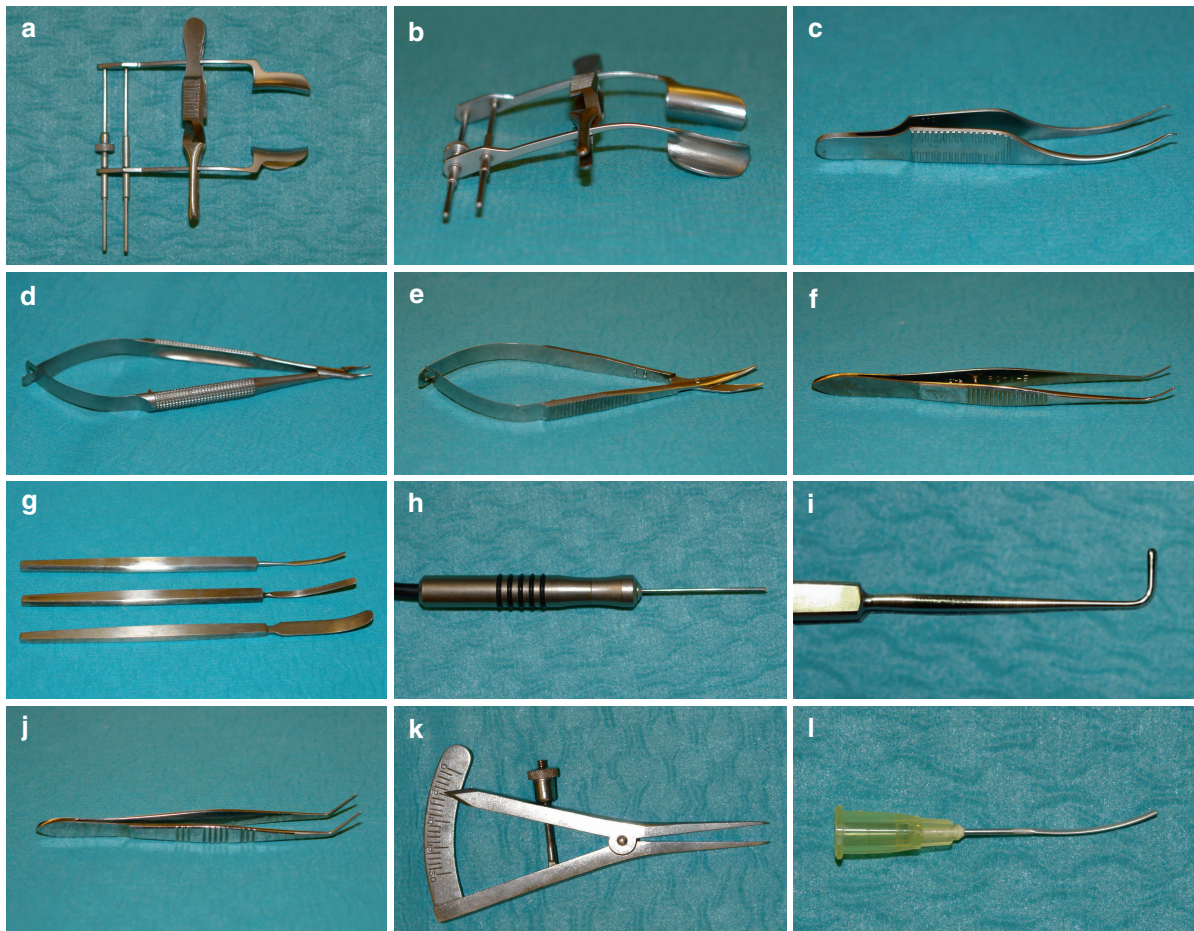


Fig. 6.17 Useful instruments to perform MISS. (a, b) Eyelid speculum with serrefine, (c) colibri forceps, (d) needle holder, (e) curved scissors, (f) curved forceps, (g) small, medium and

large spatula, (h) bipolar, coaxial diathermy, (i) small strabismus hook, (j) angled forceps, (k) caliper, (l) blunt cannula

will prevent unnecessary conjunctival trauma (Fig. 6.17f). Spatulas of different sizes are useful to visualize the tissue through the small, conjunctival cuts (Fig. 6.17g). Diathermy is best performed using a system with a bipolar, coaxial tip (Fig. 6.17h). This will allow gentle cauterization of vessels at the muscle insertion through the tunnel, without damaging the overlying conjunctiva. A small strabismus hook can be easily introduced through the small openings (Fig. 6.17i). Angled forceps are necessary to stabilize the muscle insertion during desinsertion (Fig. 6.17j). By pressing the tips of Castroviejo calipers for about ten seconds against the sclera, a bluish indentation mark is formed, which will be visible for up to one minute (Fig. 6.17k). This indentation technique works also transconjunctivally, as there

is no need to apply a dye to the tip. A blunt cannula is helpful to safely displace a needle through a tunnel (Fig. 6.17l). This is necessary for MISS inferior and superior oblique recessions and MISS rectus muscle transpositions.

6.8.2 Suture Materials Used for MISS

The limbal traction suture is performed with PERMA-Hand silk® 6-0 (Ethicon), with a round needle (BV-1). Having no cutting edge, such needles will minimize the risk of scleral tearing. The inconvenience of round needles is the difficulty in guiding them because they

cannot be held firmly by the needle holder. For scleromuscular attachment in recessions and plications of rectus muscles and the inferior oblique muscle, Vicryl® 7-0 with a GS-9 spatula needle (Ethicon) is used. This synthetic, braided suture will be fully absorbed after 3 months. The spear-shaped needle can be grasped firmly and minimizes the risk of scleral penetration. Some surgeons believe that diamond-shaped spatula needles further reduce the risk of injury to the retina. For scleromuscular attachment in recessions and plications of the superior oblique muscle and for retroequatorial myopexia, a nonabsorbable PremiCron® 5-0 with 3/8 taper point needle (B.Braun) is used. Vicryl® 8-0 rapid, a synthetic, braided suture with a GS-9 spear-shaped spatula needle (Ethicon) is used to readapt the Tenon's capsule and the conjunctiva.

6.8.3 General Remarks Regarding MISS Procedures

Although it might not be mandatory to use the operating microscope to perform minimally invasive strabismus surgery, its use will certainly help to further reduce tissue traumatism and to control intraoperative bleeding better. The higher magnification will also help to perform scleromuscular sutures more precisely and, may, therefore, decrease the risk of globe penetration. Theoretically, a certain freedom of movement can be retained by rotating the operating microscope and the surgeon's chair, depending on which eye is being operated, which surgical procedure is done, or within the same procedure, depending on which surgical steps are done. However, as usually the immobility of the surgeon's body can be easily compensated by an increase in arm movements and by learning to perform more demanding tasks like suturing with the non dominant hand, it is advisable to always sit at the head of the operating table. Surgeons switching from magnifying glasses to the operating microscope should first get used to the unusual situation by performing several procedures with their own technique. First, easy operations such as primary muscle recessions, resections and plications should be performed. Then, more demanding procedures such as repeat surgeries, posterior muscle anchorages and transposition can be carried out. Only then, a transition to minimally invasive techniques is advisable. Again, when starting with MISS, several primary

recessions and plications should be performed before going for more difficult operations. Although muscle resections also could be performed using two keyhole openings, transition to plications is recommended. Surgeons inexperienced with plications would benefit from trying it first with open surgery, using Harms' limbal approach. Initially, it is inevitable that instrument introduction, use, and retraction through the keyhole openings will be associated with larger displacements of the openings. With more experience, the surgeon will learn to minimize such displacements as they induce conjunctival tearing in older patients. Fortunately, usually, a tear will remain without any consequence as long as the Tenon's tissue is not involved and it is not over the muscle. In order to minimize the risk of conjunctival tearing, avoid initially patients older than approximately 40 years and also patients younger than approximately 14 years, because with increasing thickness of the Tenon's capsule, keyhole surgery becomes more demanding. It is recommended that children below the age of 2 years are only operated with MISS by experienced surgeons. The keyhole opening sizes mentioned in previous chapters will usually be too small for beginners. Therefore, do not hesitate to initially increase the cut size. Postoperative swelling, redness, and patient discomfort will be less compared to most other access techniques. Rectus muscle recessions and plications of more than 4 mm are also more demanding, compared to muscle displacements of 4 mm or less. Muscular fibrosis, e.g., secondary to thyroid endocrine orbitopathy, will also make surgery more difficult, because of decreased passive eye rotations; therefore, a more posterior location of the cuts is recommended. In summary, it is recommended that surgeons start with MISS in patients aged between 14 and 40 years, needing primary rectus muscle recessions or plications of 4 mm or less. The level of difficulty will not differ, whether only a rectus muscle displacement is performed in an eye or combined with a displacement of another muscle.

6.8.4 MISS Dose-Response Relationships

MISS muscle displacements are performed in the same manner as open surgery. Therefore, it seems rather unlikely that dose-response will differ if the operating technique is changed. However, it is mandatory that muscle sutures,

scleral anchoring, and use of the measuring calipers remain unchanged. If a surgeon modifies one or more of these things while changing to MISS, there will be a risk of a systematic under or overcorrection. For such surgeons and possibly also for all other surgeons starting with minimal incisions, it is worthwhile to perform several times the recession and plication technique described for MISS using Harms' limbal opening to check if displacement distances correspond to the way muscles were previously displaced. The literature also suggests that transition using the same muscle displacement technique will allow one to continue the use of the same dose-response relationship [9, 17]. However, due to the low number of MISS and open surgery patients, the retrospective character of these studies and the fact that some comparisons were performed using patients operated in other clinics, there is a necessity for confirmation. Consequently, it is prudent if surgeons switching to MISS look for a change in their dose-response relationships.

References

1. Coats DK, Olitsky SE (2007) Strabismus surgery and its complications. Springer, Berlin
2. Ehrt O, Boergen KP (2004) A concept for the surgical treatment of trochlear palsy. *Strabismus* 12:75–83
3. Gobin MH, Bierlaagh JM (1994) Chirurgie horizontale et cycloverticale simultanée du strabisme. *Centrum voor Strabologie, Antwerp*, pp 545–549
4. Harms H (1949) Über Muskelvorlagerung. *Klin Monatsbl Augenheilkd* 115:319–324
5. Haslwanter T, Hoerantner R, Priglinger S (2004) Reduction of ocular muscle power by splitting of the rectus muscle I: biomechanics. *Br J Ophthalmol* 88:1403–1408
6. Hoerantner R, Priglinger S, Haslwanter T (2004) Reduction of ocular muscle torque by splitting of the rectus muscle II: technique and results. *Br J Ophthalmol* 88:1409–1413
7. Kaufmann H (2003) *Strabismus* (2003) Georg Thieme, Stuttgart, pp 545–549
8. Kushner BJ (2007) Comparison of a new, minimally invasive strabismus surgery technique with the usual limbal approach for rectus muscle recession and plication. *Br J Ophthalmol* 91:5
9. Mojon DS (2007) Comparison of a new, minimally invasive strabismus surgery technique with the usual limbal approach for rectus muscle recession and plication. *Br J Ophthalmol* 91:76–82
10. Mojon DS (2009) Minimally invasive strabismus surgery. *Br J Ophthalmol* 93:843–844
11. Mojon DS (2008) Minimally invasive strabismus surgery (MISS) for horizontal rectus muscle reoperations. *Br J Ophthalmol* 92:1648–1652
12. Mojon DS (2009) Minimally invasive strabismus surgery (MISS) for inferior oblique recession. *Graefes Arch Clin Exp Ophthalmol* 247:261–265
13. Mojon DS (2009) Minimally invasive strabismus surgery (MISS) for rectus muscle transpositions. *Br J Ophthalmol* 93:747–753
14. Mojon DS (2009) Minimally invasive strabismus surgery for rectus muscle posterior fixation. *Ophthalmologica* 223: 111–115
15. Muhlendyck H (1996) Jaensch-Brown syndrome—etiology and surgical procedure. *Klin Monatsbl Augenheilkd* 208: 37–47
16. Parks MP (1968). Fornix incision for horizontal rectus muscle surgery. *Am J Ophthalmol* 65:907–915
17. Pellanda N, Mojon DS (2010) Minimally invasive strabismus surgery technique in horizontal rectus muscle surgery for esotropia. *Ophthalmologica* 224:67–71
18. Plager DA (2004) *Strabismus surgery, basic and advances strategies*. Oxford University Press, Oxford
19. Rosenbaum AL, Santiago AP (1999) *Clinical strabismus management, principles and surgical techniques*. WB Saunders, Philadelphia
20. Roth A, Speeg-Schatz C (2001) *Eye muscle surgery*. Swets & Zeitlinger, Lisse
21. Sami DA (2007) Conjunctival incisions for strabismus surgery: a comparison of techniques. *Tech Ophthalmol* 5:125–129
22. Santiago AP, Isenberg SJ, Neumann D, Spierer A (1998) The paralimbal approach with deferred conjunctival closure for adjustable strabismus surgery. *Ophthalmic Surg Lasers* 29: 151–156
23. Saxena R, Sinha A, Sethi H, Menon V (2007) Trypan blue-assisted posterior tenectomy of the superior oblique. *J Pediatr Ophthalmol Strabismus* 44:45–46
24. Swan KC, Talbot T (1954) Recession under Tenon's capsule. *AMA Arch Ophthalmol* 51:32–41
25. Tessler HH, Urist MJ (1975) Corneal dellen in the limbal approach to rectus muscle surgery. *Br J Ophthalmol* 59:377–379
26. Velez G (1980) Radial incision for surgery of the horizontal rectus muscles. *J Pediatr Ophthalmol Strabismus* 17: 106–107
27. von Noorden GK (1968) The limbal approach to surgery of the rectus muscles. *Arch Ophthalmol* 80:94–97
28. von Noorden GK (1969) Modification of the limbal approach to surgery of the rectus muscles. *Arch Ophthalmol* 82:349–350
29. von Noorden GK (2002) The history of strabismology. *JP Wayenborgh, Oostende*

7.1 Instrumentation

In addition to standard instrumentation commonly used in ophthalmic microsurgery, specialized instrumentation is invaluable. The surgeon often needs instruments such as forceps, scissors, and needle holders that can be inserted and maneuvered through small incisions. Vitreo-retinal instruments designed for the pars plana generally meet these needs. For the anterior segment, Iqbal “Ike” Ahmed has designed a set of anterior segment instruments for the anterior segment, similar to vitreo-retinal instruments in their coaxial action. These instruments are available from MicroSurgical Technologies (MST) of Redmond, WA. The assorted end pieces are designed to be interchanged from common handles, reducing total cost.

7.2 Sutures

Any suturing of the iris should employ a suture that does not biodegrade. Most commonly, polypropylene (Prolene) is used, although monofilament polyester (Mersilene) is acceptable. Nylon will biodegrade over several years in the anterior chamber and therefore is usually not a good choice. 10-0 caliber is adequate; the extra strength of 9-0 is not needed, as the iris tissue will typically tear if force exceeding the tensile strength of 10-0 polypropylene is needed to draw the iris edges together.

R. F. Steinert
University of California, The Gavin Herbert Eye Institute,
118 Med Surge I, Irvine, CA 92697-4375, USA
email: roger@drsteinert.com

Minimally invasive, closed chamber iris suturing can be performed with small needles manipulated inside the anterior chamber by microinstruments or with long needles that pass across the anterior chamber, controlled by a needle holder that remains external to the anterior chamber. In the case of a small needle, a noncutting taper needle is preferred, as it will not create a hole in the iris as it passes. These needles are typically created for use by vascular surgeons. An example is the Ethicon BV-100.

Examples of longer needles available with 10-0 polypropylene suture material are the very thin and long CTC-6 (curved) and STC-6 (straight) needles and the thicker CIF-4 needle, all made by Ethicon. Alcon, SharpPoint, and other suture manufacturers have their own similar needles with proprietary designations.

7.3 Surgical Principles of Iris Suturing

Although iris deformities have an infinite number of possible configurations, the basic principles of surgical repair can be summarized in a few basic techniques.

7.3.1 Mobilization

The first principle is to free up and mobilize as much iris tissue as possible. Synechia to the cataract or capsule should be bluntly dissected. Most iridocapsular adhesions are strongly attached only at the sphincter edge. Often there is some proliferation of iris pigment epithelium from the posterior iris surface to the capsule involving the more peripheral iris, but these adhesions

are weak and can be easily separated with an instrument such as a cyclodialysis spatula or a cannula with viscoelastic agent.

If iridocapsular adhesions cannot be bluntly dissected, then careful excision with a scissors or blade should be performed, preserving as much iris tissue as possible by taking care not to excise any iris tissue that is salvageable.

After freeing up all iridocapsular adhesions, the surgeon should then release any peripheral adhesions. Peripheral anterior synechia usually can be released with traction using forceps or a pointed hook such as a Sinskey hook or Osher Y hook or by sweeping maneuvers with a spatula. In addition, inflammation sometimes causes the iris stroma to form adhesions internally, causing contraction of the iris in a manner similar to accordion pleats. Again, gentle traction can release many of these adhesions and produce a surprising amount of iris tissue necessary for the subsequent repair.

7.3.2 Intraocular Suturing and Knot Tying

The second fundamental principle is the method for suturing iris and tying knots within the eye. Often the knot is central, and traction to bring the iris with the knot to a limbal incision will damage the iris repair. Figure 7.1 illustrates the basic technique for passing the suture into the anterior chamber via a paracentesis, through a radially oriented iris defect, and then out through the peripheral cornea on the opposite side of the paracentesis.

A flaccid iris and a knot close to a wound may allow the surgeon to tie the knot at the limbus without undue iris damage. Successful completion of many cases of iris reconstruction requires that no additional traction be placed on the iris, however. The knot must be advanced into the eye and tied internally. One method to accomplish a knot deep inside the anterior chamber is to form the knot loop externally and then use a hook

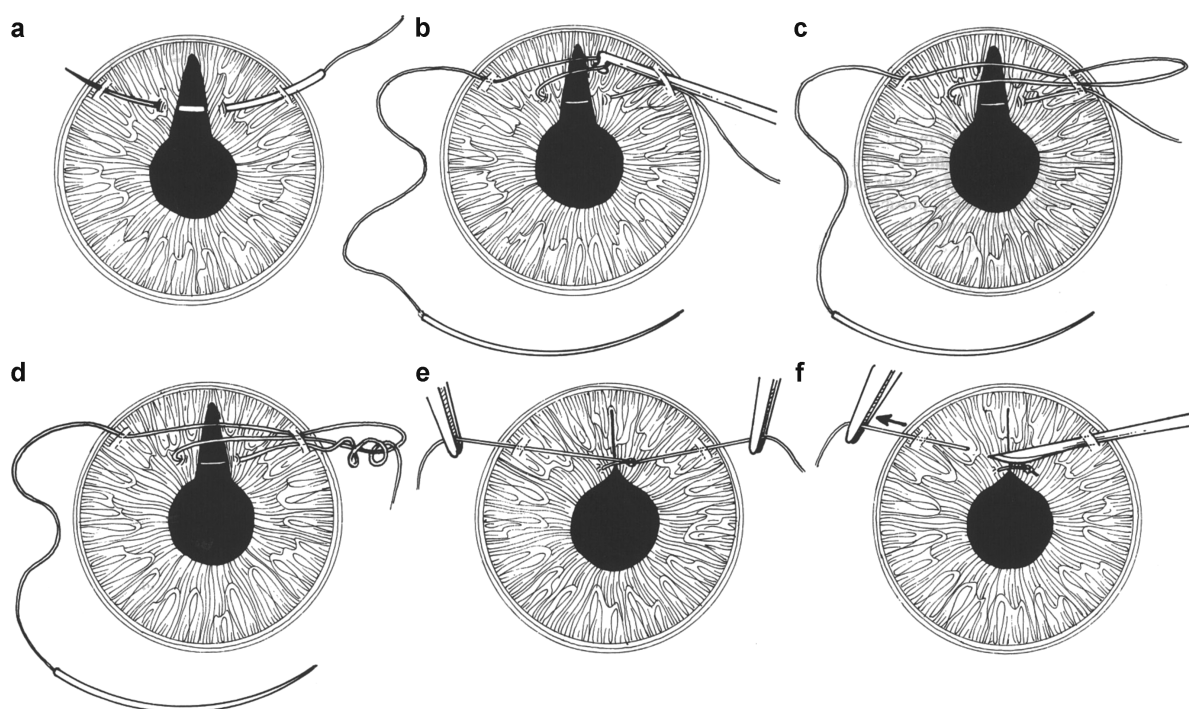


Fig. 7.1 (a) Long needle enters through a paracentesis, across the iris defect, and exits by puncturing through the peripheral cornea. (b) Hook such as a Kuglen hook retrieves a loop of the distal arm of the suture, making sure that the needle end of the suture remains external to the eye. (c) Loop is now external through the paracentesis. (d) Proximal end of the suture is

wrapped around the suture loop twice, creating one throw of what will become the knot. (e) Tension on each end of the suture draws the knot into the eye and tightens it. (f) After four throws, the suture ends are cut with a thin sharp knife such as a wheeler blade.

such as a Kuglen hook to advance the loop into the eye and make it snug. The procedure is repeated 3 or 4 times, achieving a secure knot at completion. The disadvantage of this technique is that it requires a skilled assistant, as it is necessary to maintain gentle traction on each of the suture ends while simultaneously advancing the knot with the hook. Three skilled hands are therefore needed.

Figure 7.1 illustrates an alternative two-handed technique popularized by Stephen Seipser. In this variation, the knot is tied by passing loops externally, but the two ends of the suture can then be tightened, which draws the knot internally into the eye. This technique is elegant and does not require the third hand of a skilled assistant. A second throw is typically placed. In the original description by Seipser, the second throw creates a “granny” knot. Robert Osher teaches a true locking knot in which the second throw is passed either in mirror image of suture orientation or in the opposite direction around the suture loop to create a more

“square” locking knot [5]. Once the knot is tied, the suture may be cut using microscissors through an unenlarged paracentesis, or with Vannas scissors through a slightly enlarged limbal incision.

7.3.3 Reattachment of Iris to Sclera

The third principle is the technique for repair of a peripheral iris defect with the use of horizontal mattress sutures. A double-armed suture is employed. The mattress suture brings the iris back to its origin, if possible (Fig. 7.2), or closes a peripheral defect using available adjacent iris tissue (Fig. 7.3a, b). The knot is tied externally, but then rotated below the surface so that only a smooth loop of external suture remains, to be covered subsequently by a conjunctival flap. By using this technique of suture rotation and burying the knot, only a smooth loop of suture material remains.

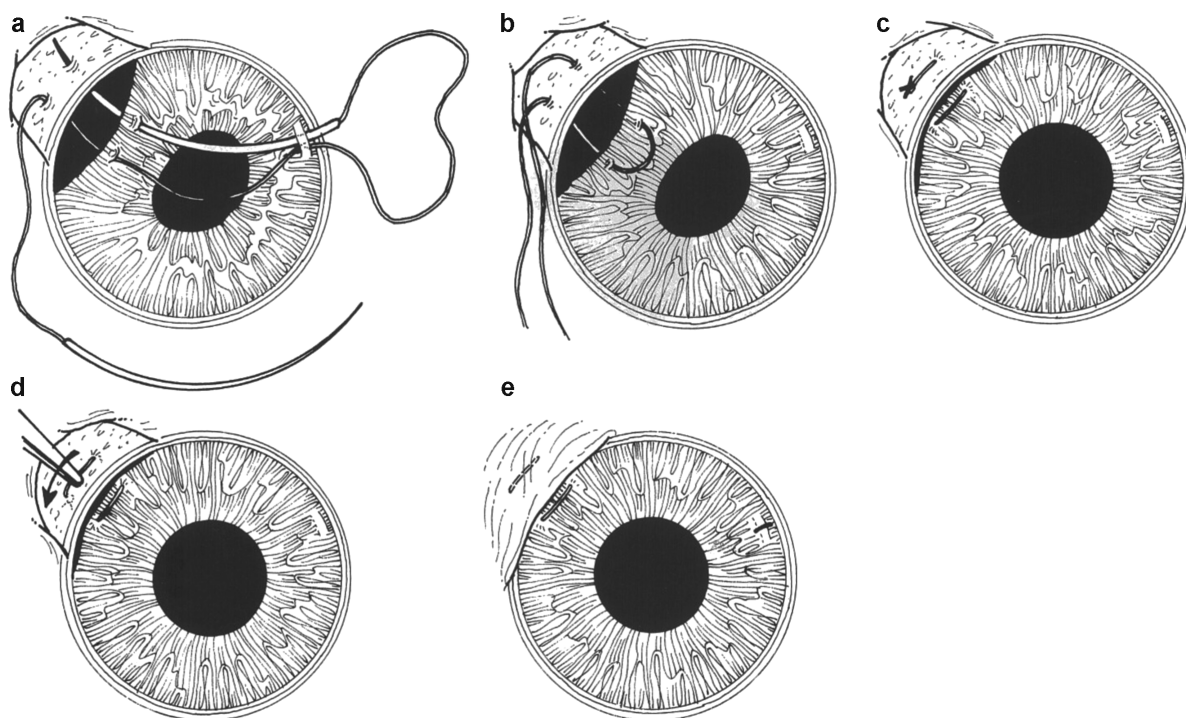


Fig. 7.2 (a, b) Iridodialysis is repaired with one or more mattress sutures of double-armed 10-0 polypropylene sutures tied externally under a conjunctival flap. Both arms of the polypropylene suture are introduced through a paracentesis opening on the opposite side of the anterior chamber. The dialyzed edge of iris is engaged by each needle in turn, and the needle is passed

through the sclera. (c) Mattress suture is tied. (d) Knot is rotated below the surface of the sclera, preventing later suture erosion through the conjunctiva. (e) Conjunctival flap is then closed over the polypropylene mattress suture with corner sutures of 8-0 Vicryl or other absorbable suture material.

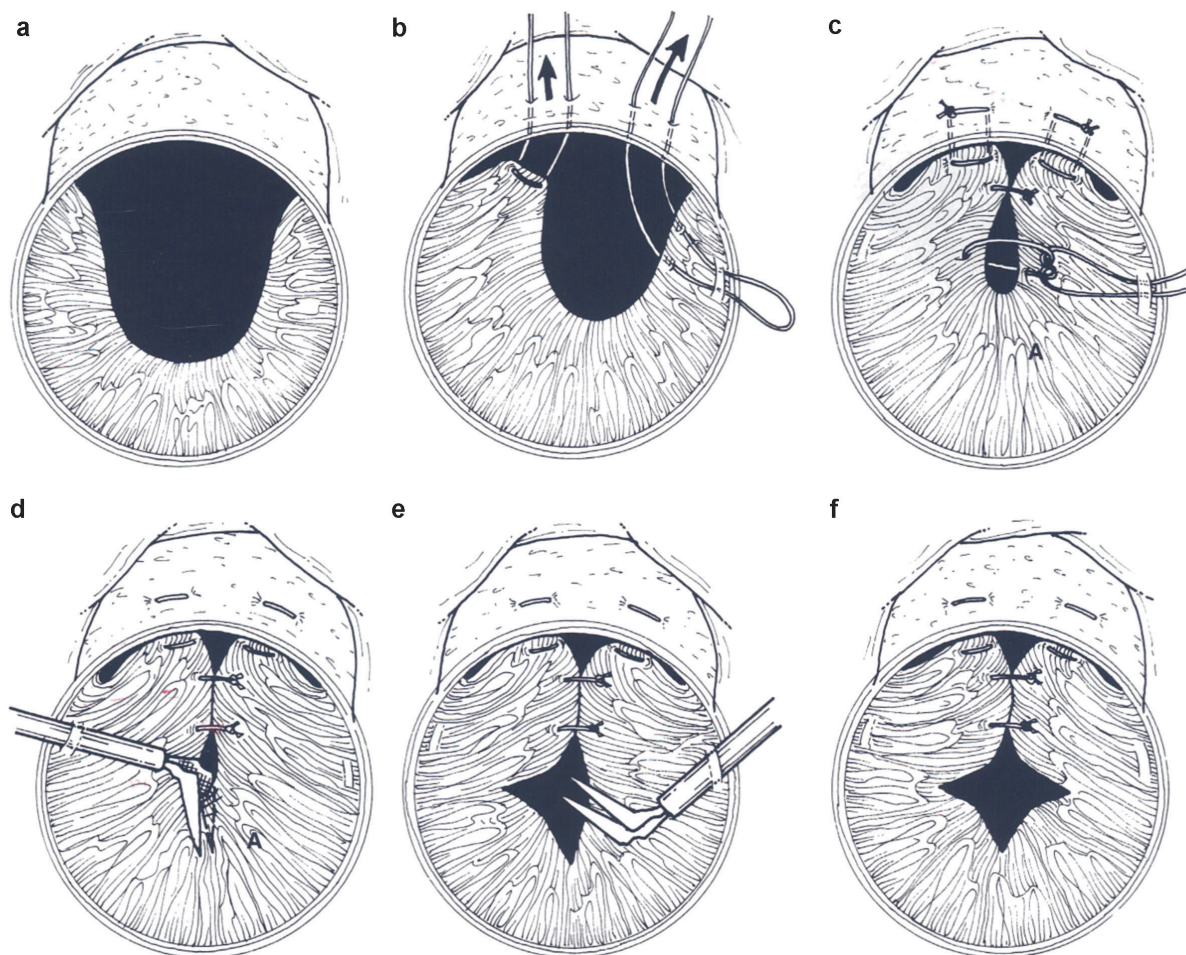


Fig. 7.3 (a) Conjunctival flap is recessed in the area of a sector iris defect. (b) Horizontal mattress sutures bring midperipheral iris tissue into the basal area without iris. (c) Interrupted sutures

close the midperipheral space. (d–f) “Sphincterotomies” in the central zone create a new pupillary aperture.

A scleral flap does not need to be dissected, and conjunctiva alone provides adequate coverage of the suture material. Alternatively, if it is desired that both suture material and knot lie below the scleral surface, then creating a scleral groove with a beaver blade before placement of the sutures can be helpful. This allows the suture material to lie in a trench beneath the scleral surface when the knot is tied. The knot can similarly be rotated into the sclera. A large iridodialysis will require several adjacent horizontal mattress sutures. The size of each suture “bite” of iris should be about 1.5 clock hours.

A large defect may require a combination of these techniques (see Fig. 7.3). Typically, the repair begins by using horizontal mattress sutures to create as much

coverage of the peripheral and midperipheral cornea as possible (see Fig. 7.3a, b). Often this results in a distortion of the pupil itself (see Fig. 7.3c). A new pupil is constructed by judicious incisions in the iris and placement of additional sutures (see Fig. 7.3c–f). The iris is highly visible in some individuals and often important to the patient cosmetically as well as optically.

In general, the surgeon should err on the side of leaving a pupil too small rather than too big. Postoperatively, a surgeon can use the neodymium:yttrium-aluminum-garnet (Nd:YAG) laser to expand the pupil by performing sphincterotomies with Nd:YAG laser pulses. The technique is similar to performing peripheral iridectomies with the Nd:YAG laser. A focusing contact lens is helpful. The laser setting is typically 6 mJ.

7.3.4 Pupil Repair

Blunt trauma often causes injury to the iris sphincter. An isolated rupture of the sphincter muscle is repaired with single interrupted sutures, similar to the technique illustrated in Figs. 7.1 and 7.2. When there is more generalized damage to the iris sphincter, caused by either multiple ruptures or ischemia, a different technique is needed. The surgeon can generally determine by careful preoperative inspection whether generalized iris sphincter injury has occurred. At the preoperative slit lamp examination, while varying the illumination through the pupil, the surgeon can inspect whether there is reactivity of the iris sphincter. In addition, the iris sphincter architecture is carefully inspected. When the iris sphincter architecture is not preserved and there is little to no reactivity, then a larger-scale repair of the pupil is needed.

The surgeon has two choices. The simpler choice is to place multiple interrupted sutures. This will typically result in a square- or diamond-shaped pupil (Fig. 7.4). Although cosmetically suboptimal, the optical benefit to the patient is substantial.

Alternatively, the surgeon can perform a 360° purse-string suture. This procedure was originally demonstrated by Dr. Pius Bucher of Austria and is illustrated in Fig. 7.5. The placement of the suture occurs after the completion of any cataract removal and IOL placement, of course. In the iris cerclage purse-string suture technique, a 10-0 Prolene suture on a CTC-6 needle (Ethicon) is recommended. In addition to the larger principal incision used for simultaneous cataract and IOL surgery, the surgeon should place two or three paracentesis openings at approximately equally spaced intervals. The needle is introduced through the principal incision and is passed in and out of the midperipheral iris stroma, typically for three or four passes.

The needle is then passed out of the paracentesis by “docking” the needle tip into the end of a blunt 27-gauge irrigating cannula that has been passed through the paracentesis into the anterior chamber. In this manner, the pointed needle can be externalized without engaging the corneal tissue around the paracentesis. The needle is then regrasped with the needle holder and reintroduced into the eye, repeating the process for another quadrant or third of the iris. In reintroducing the needle through the paracentesis, great care must be taken not to inadvertently engage the lip of Descemet’s

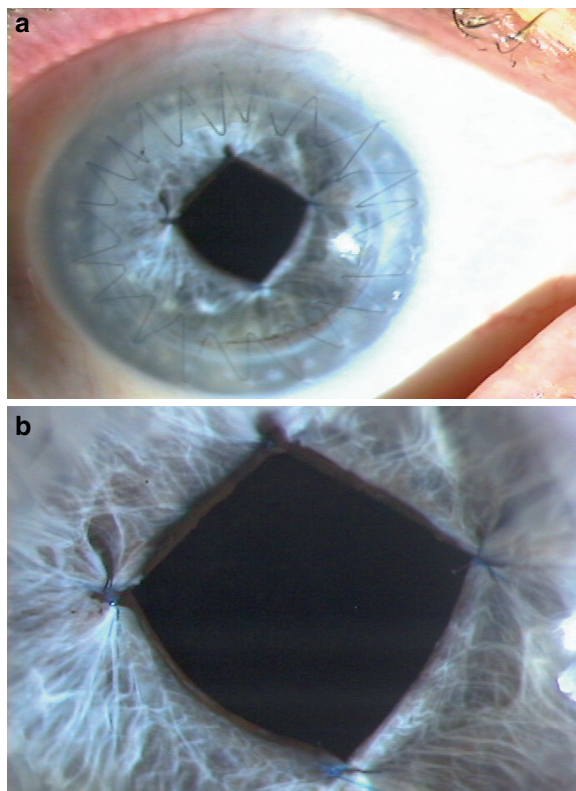


Fig. 7.4 (a) Diamond-shaped appearance of the pupil after four interrupted sutures reduced a large atonic pupil at the time of penetrating keratoplasty. (b) High magnification shows the four polypropylene suture knots

membrane or any of the stroma. It is of great help during needle reintroduction to wiggle and side-sweep the needle tip while advancing the needle within the paracentesis to ensure that no corneal stromal fibers are engaged. If the surgeon encounters difficulty passing the tip of the needle through the paracentesis cleanly, placement of some viscoelastic in the paracentesis can be a great aid in opening the passageway.

In one approach, the bites of the cerclage suture are placed in the midperipheral iris, not close to the pupillary margin. The reason is that, once the suture is tightened, the suture between each of the bites will tighten and constrict. If the suture bites are near the pupillary edge, the suture material will be pulled into the pupillary opening, resulting in scalloping and a petalloid appearance to the pupil border. In contrast, if the suture material is kept in the midperiphery, the suture material itself will not be able to cross over the pupillary zone itself. In an alternate approach, the sutures bite

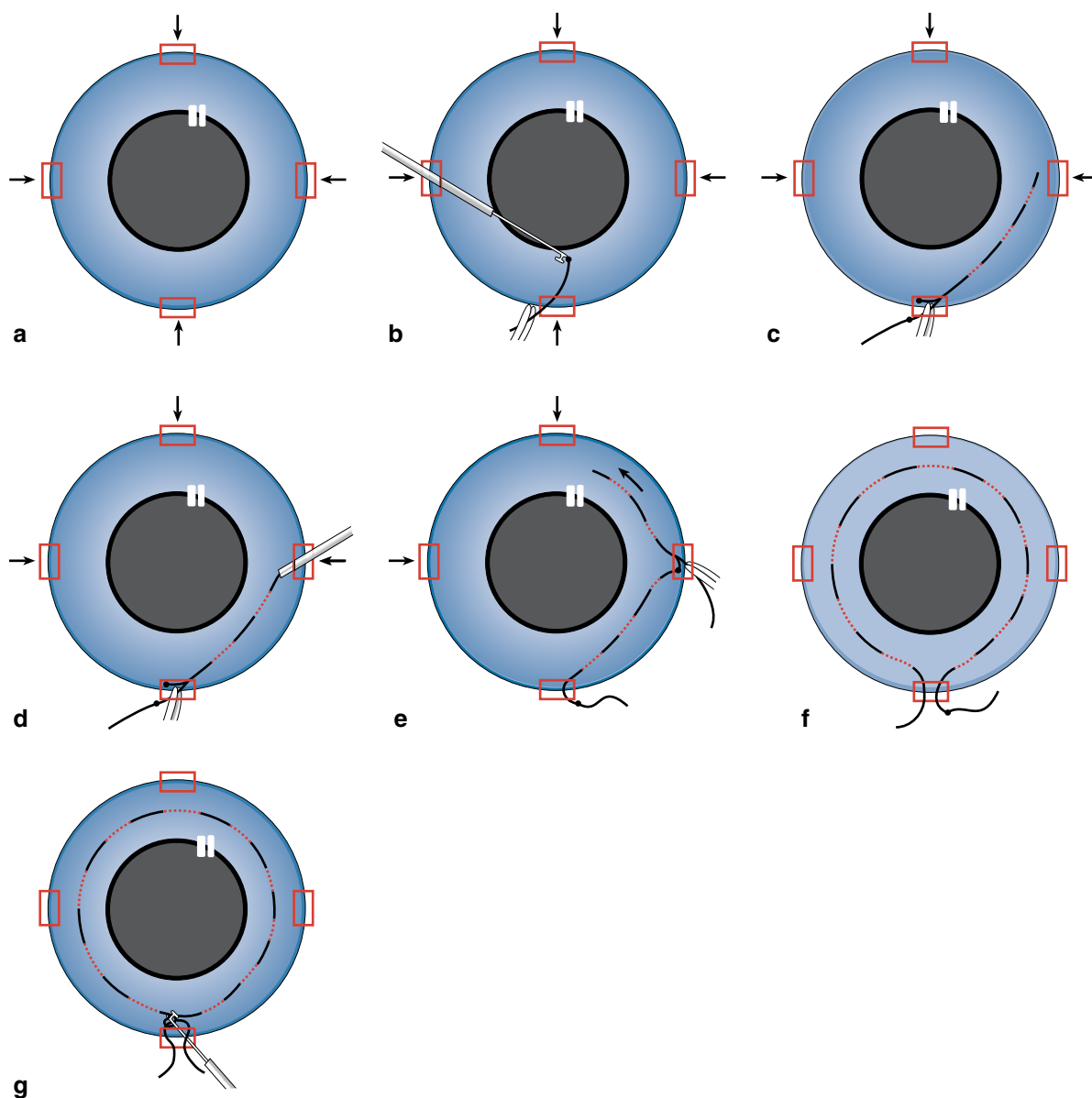


Fig. 7.5 (a) Four side-port incisions are required, spaced at 90° intervals. (b) A long needle such as the Ethicon CTC6L is employed. As the needle passes through the incision, care must be taken to avoid piercing any corneal tissue. The needle pierces the iris about 2 mm peripheral to the pupil border. An instrument such as the Kuglen hook is usually needed to support the highly flexible iris so that the needle will penetrate. (c) The needle is passed up and down through the iris in small bites until one quarter of the iris is sutured. (d) The sharp needle point is docked into the end of a blunt-tip cannula so that the needle can be guided out of the side-port without engaging any corneal tissue.

(e) The needle is then regripped by the needle holder and reintroduced into the side-port incision, continuing the process of suturing the next quadrant of iris. (f) After completing a full 360° of suturing, both ends of the suture are ready to be tied. (g) The knot is created outside the eye and then advanced into the eye and tightened with the aid of an instrument such as a Kuglen hook. The pupil will then contract as the purse-string is tightened. At least 4 throws of the knot are made for a secure knot and the suture ends are cut short with an intraocular scissors or blade. Illustration by Christiane Solodkoff, Neckargemünd/Heidelberg, Germany

are passed near the sphincter margin in a “spiral or baseball” stitch fashion in which the majority of the bites are placed through the iris tissue from the underside, then the needle tip is wrapped around the pupil margin and the next bite is taken. Both approaches result in an excellent cosmetic and functional result. If there is any difficulty controlling the passage of the needle through the iris tissue, microforceps, such as those used for bi-axial microincision surgery, introduced through a paracentesis may be helpful by grabbing iris tissue during the needle pass.

After completing the 360° passage of the suture, the knot is carefully tied through the principal limbal incision. Alternatively, the needle can be passed out through a paracentesis, and the suture tied through the main incision using the Siepser sliding knot technique. The pupil is drawn down to a size of 3–4 mm, which is a good compromise between cosmetic and functional result and fundus visualization. During knot tying, pulling on the suture ends often results in a smaller than desired pupil size, and it is often helpful to deliberately start with a pupil size that is larger than required, and then draw it down to size. The postoperative appearance of the pupil is usually circular or only slightly irregular.

If a major retinal problem occurs subsequently, such as retinal detachment, the iris cerclage suture can be released with either laser spots or intraoperatively by cutting the suture.

7.3.5 Adjunctive Pupil Repair Techniques

Adjunctive pupil repair techniques are useful in situations where the pupil is distorted or eccentric. Pupil

distortion and ovalization may occur resulting from trauma itself, or sometimes after repair of an iris dialysis. This may be remedied by the strategic placement of an interrupted suture to the pupil margin, with or without pupil sculpting techniques to round it off. Pupil reshaping may be achieved with a vitrector on the lowest available cut rate and moderate vacuum, or by using intraocular scissors. If the pupil is markedly eccentric, the pupil may be translocated by opening up a new pupil in the center with a vitrector, and closing the peripheral one with one or more interrupted sutures.

Acknowledgement The figures and portions of the text were previously published by, and are taken from, Steinert [6], Chap. 29, with permission.

References

1. Britten MJA (1965) Follow-up of 54 cases of ocular contusion with hyphaema, with special reference to the appearance and function of the filtration angle. *Br J Ophthalmol* 49:120–127
2. Weidenthal DT (1964) Experimental ocular contusion. *Arch Ophthalmol* 71:77–81
3. Wolff SM, Zimmerman LE (1962) Chronic secondary glaucoma associated with retrodisplacement of iris root and deepening of the anterior chamber angle secondary to contusion. *Am J Ophthalmol* 54:547–563
4. Paton D, Craig J (1973) Management of iridodialysis. *Ophthalmic Surg* 4:38–39
5. Osher RH, Snyder ME, Cionni RJ (2005) Modification of the Siepser slip-knot technique. *J Cataract Refract Surg* 31: 1098–1100
6. Steinert RF (ed) (2004) *Cataract surgery*, 2nd edn. Elsevier, London

Elie Dahan, Stefan de Smedt, Juliàn Garcia Feijoo,
José Maria Martinez de la Casa, André Mermoud, Bojan Pajic,
and Sylvain Roy

Introduction

In the last 15 years glaucoma surgery has evolved greatly with the emergence of several new and less invasive surgical techniques. The major innovation after trabeculectomy was deep sclerectomy, which has been proved safe and efficacious after more than a decade of clinical experience.

With the advent of minimally invasive glaucoma surgery, the number of complications has been significantly reduced compared to classic trabeculectomy and Seton technique. Based on long-time results, we can now assume that these new non-invasive techniques will ensure that patients undergo safe glaucoma surgery even in early the stages of the disease.

Dr Roy and Dr Mermoud will present the deep sclerectomy technique, the mechanisms of filtration, and the results and management of complications. Dr De Smedt will present in the attached CD-ROM several videos on deep sclerectomy.

More recently, the Ex-PRESSTM tube has been proposed as a means to simplify glaucoma surgery. It can make trabeculectomy as well as deep sclerectomy easier. The Ex-PRESSTM tube offers a reproducible and stable resistance to aqueous humor outflow. This advantage provides safer surgery and a quieter postoperative follow-up. Dr Dahan will present the chapter on Ex-PRESSTM implant describing in detail the surgical technique, the clinical results, the indications, and the mechanisms.

Dr Pajic will present the sclerostomy ab interno and comment on the results from his clinical experience with this procedure. This new technique allows opening of the trabeculum and Schlemm's canal from the anterior chamber using a very atraumatic method.

The i-stent[®] technique is a surgery very similar to sclerostomy ab interno. Dr Julian Garcia Feijoo and Dr José Maria Martinez de la Casa will present this novel procedure with comments on the results from their clinical experience with this method. Using this new device, Schlemm's canal is opened directly through the anterior chamber by means of a micro-tube.

In the past few years more innovations and ideas have been developed and proposed by several authors. Due to space constraint they will not be detailed in this chapter. Nevertheless, it would be unfair not to mention viscocanaloplasty, which dilates the lumen of Schlemm's canal using a micro-catheter. Similarly, the trabectome, developed by George Baerveldt and his colleagues, also permits comfortable enlargement of Schlemm's canal and to perform an ab interno trabeculotomy, just like the Pajic's technique reported in this chapter. Another minimally invasive glaucoma surgery has been proposed with the Golden shuntTM. The subchoroidal space is connected to the anterior chamber using a gold plate made of multiple micro-tubes set in parallel.

8.1 Deep Sclerectomy: A Nonpenetrating Filtering Surgery

8.1.1 Introduction to Deep Sclerectomy

The goal of deep sclerectomy, a nonpenetrating filtering surgery, is to lower the outflow resistance of the aqueous humor while respecting the anatomy and

S. Roy (✉)
Centre du Glaucome Clinique de Montchoisi
Ch. des Allinges 10 CH-1006 Lausanne Switzerland
e-mail:sylvain.roy@epfl.ch

physiology of the drainage pathways of the eye. In other words, the surgery aims at increasing the outflow facility of the aqueous humor between the source of the humor and the extraocular drainage routes while minimizing alterations of the natural structure of the eye [1–6]. Achieving this goal is challenging, for the surgery should be efficient enough to ensure a significant lowering the intraocular pressure (IOP), which and should remain stable over time. The surgery should be equally safe, not leading to excessive egress of aqueous humor, or resulting in prolonged overfiltration, but providing durable ocular IOP control. In order to achieve these combined goals, nonpenetrating deep sclerectomy requires a sound knowledge of the eye structures being dissected, a good set of instruments, and a great deal of surgical precision.

8.1.2 Anesthesia

The anesthesia may be either local or general [7–9]. The choice of the anesthesia technique depends on the clinical situation. For pediatric patients, anxious patients, or subjects unable to stay calm and cooperate with the surgeon, general anesthesia is recommended. In most of the other cases, a local procedure provides enough relaxation and pain relief to ensure safe and precise surgery. A retrobulbar or peribulbar injection can be given to achieve efficient anesthesia. In this case, it is important to limit the volume of anesthetic solution to about 3–4 mL. Greater volume in the orbital cone would likely tend to expand the orbital structures, thus leading to a significant rise in the IOP. This should be avoided in glaucoma patients, who already have compromised optic nerve head blood supply [7, 9]. Expansion of intraorbital structures could also impede free movements of the eye ball, potentially exposing the region of the sclera that will be operated (see below, anchoring of the eye using a silk thread).

8.1.3 Surgical Technique

The region of the highest resistance to aqueous humor outflow is located at the level of the juxtacanalicular trabeculum and at the inner wall of Schlemm's canal [10–12]. By selectively removing this obstacle to the

egress of aqueous humor, and by leaving an anatomical structure that will act as a barrier to prevent excessive outflow, the IOP may be gently lowered without abrupt perioperative changes.

8.1.3.1 Preparation

The eye is secured by a silk 6.0 thread that may either be inserted through the upper rectus muscle, or through the cornea, taking care not to penetrate into the anterior chamber. The advantage of using such a thread is that the eye can be moved easily and tilted down to expose the sclera for dissection. The conjunctiva is dissected at the level of the limbus for a fornix-based flap, a technique which gives a good result in terms of subconjunctival bleb function and prevention of postoperative scarring. Conversely the conjunctiva may as well be opened 8–10 mm from the limbus, next to the upper rectus muscle, for a limbus-based flap. In this latter case, it is very important to safely suture the conjunctiva at the end of the surgery to prevent bleb leakage, wound dehiscence, and the risk of blebitis and possible endophthalmitis. The Tenon's layer is cut to a 10 mm length and the subTenon space is undermined using blunt scissors. Care is taken to not perforate either the Tenon's layer or the conjunctiva. The sclera surface is then carefully cleaned, removing any remaining portion of tissue, fibrosis, or scarring, using a hockey knife (Fig. 8.1). This is an important step, preventing excessive postoperative scarring, eventually leading to bleb fibrosis. Hemostasis is generally achieved after using the hockey knife (Fig. 8.2). In cases of persistent bleeding, gentle wet field electro-coagulation might be performed, or cellulose

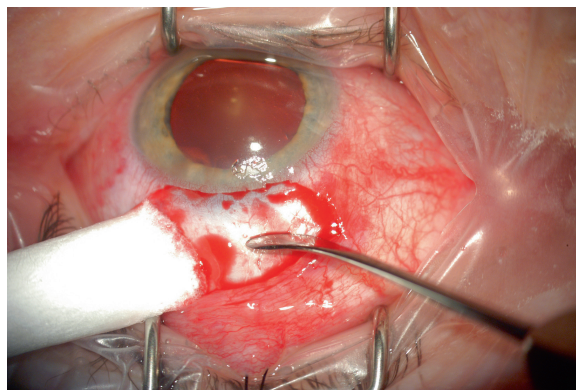


Fig. 8.1 Cleaning of the sclera using the hockey knife

sponges soaked with vasoconstrictive solution might be used.

8.1.3.2 Superficial Flap Preparation

A superficial scleral flap measuring 5×5 mm is delineated with a steel knife (Fig. 8.3). The depth of the incision represents about one-third of the entire sclera thickness. Using a ruby crescent knife, the superficial flap is then dissected further toward the cornea. It is important to extend this dissection into clear cornea for about 1–1.5 mm (Fig. 8.4). Depending on the clinical situation, e.g., in young patients, patients prone to develop hypertrophic scars, and patients of African origin, it might be useful to prevent excessive scarring of the subconjunctival space and the flap by applying antifibrotic agents. Such agents are generally antimitabolite chemicals, e.g., Mitomycin C or 5-fluorouracil.

A square cellulose sponge soaked with a 0.2 mg/mL solution of Mitomycin C is applied at the interface between the superficial flap and the remaining deeper sclera, as well as between the flap and the conjunctiva, taking care not to touch the edges of the conjunctiva opening, for 30–60 s. The cellulose sponge is then removed and the tissues are thoroughly rinsed using a balanced salt solution.

8.1.3.3 Deep Flap Preparation

The superficial scleral flap is lifted to allow good access to the deep sclera. The sclera is cut radially with a safety margin of about 0.5 mm on each side, to obtain a 4 mm wide deep flap (Fig. 8.5). The posterior cut is performed last, ideally using a diamond knife, the safety margin being then slightly wider. The depth of the dissection extends close to the choroid.

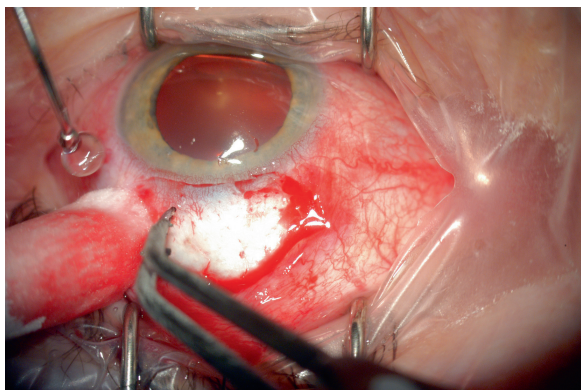


Fig. 8.2 Hemostasis using wet-field bipolar cautery

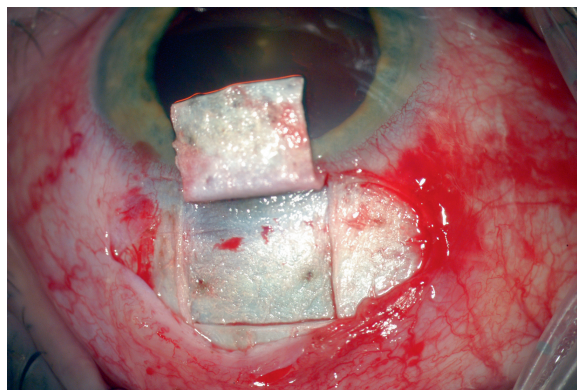


Fig. 8.4 Dissection of the superficial scleral flap 1×1.5 mm into clear cornea

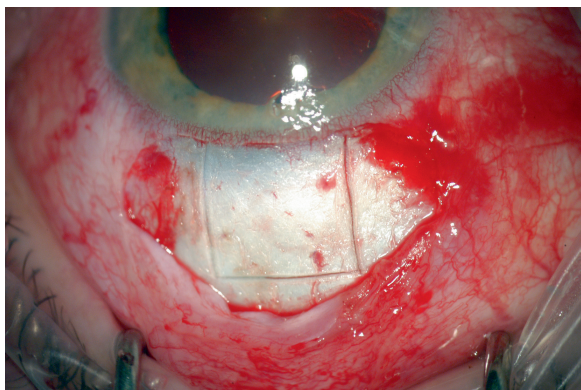


Fig. 8.3 Superficial scleral flap 5×5 mm

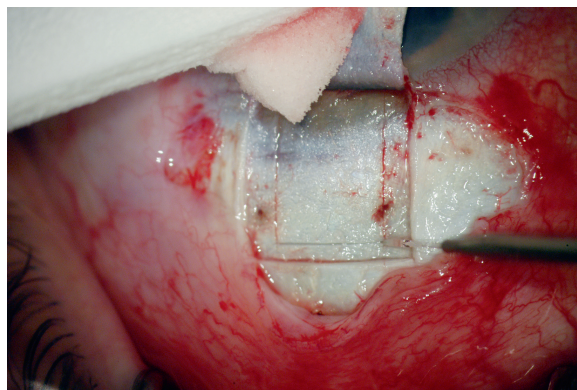


Fig. 8.5 Delineation of the deep flap 4×4 mm

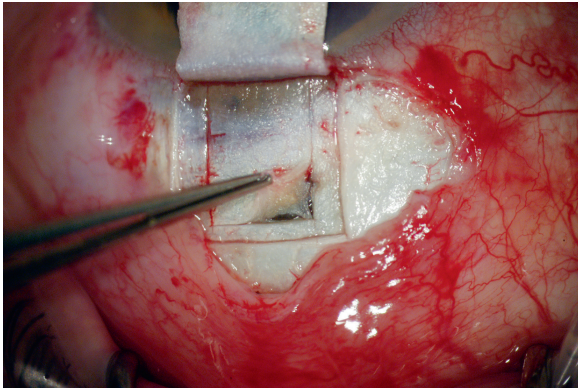


Fig. 8.6 Opening of the choroidal space for determination of the total scleral thickness

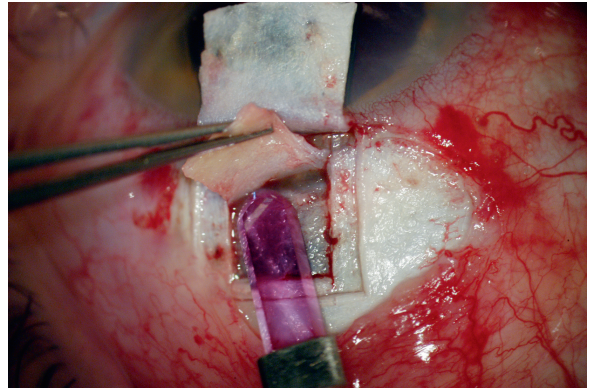


Fig. 8.8 Opening of Schlemm's canal

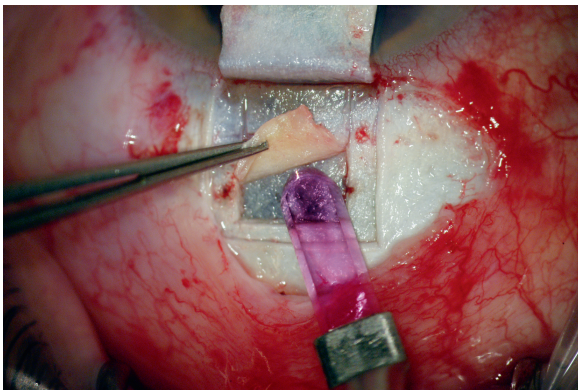


Fig. 8.7 Dissection of the deep flap with a ruby blade

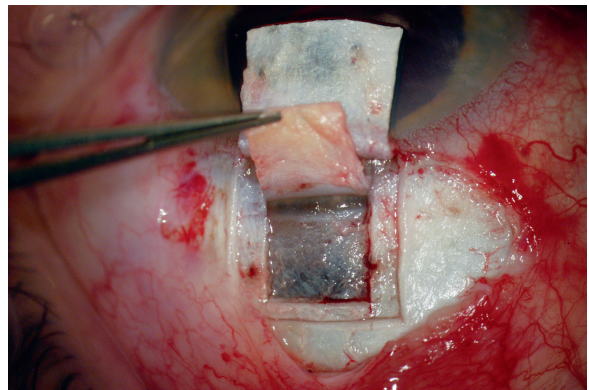


Fig. 8.9 Scleral spur seen posterior to Schlemm's canal with horizontal fibers

A fine layer of remaining sclera is what forms the floor of the filtering scleral bed. A good means to precisely determine the depth of the dissection consists of performing small cuts of the sclera down to the underlying choroid at the edges of the flap (Fig. 8.6). These minute perforations do not induce any complication or supplementary difficulties. The flap is then carefully and progressively dissected forward using the crescent ruby knife (Fig. 8.7). It is important at this stage in the surgery to proceed with great care to remain at the same level during the entire dissection. Uneven dissection could lead to large perforation of the sclera with protrusion of the choroid, or could result in too-thin a deep scleral flap with subsequent reduction in the filtering function of the scleral bed.

8.1.3.4 Dissection of the Trabeculo-Descemet's Membrane

Further dissection of the deep scleral flap allows access to the Schlemm's canal (Fig. 8.8). The scleral spur is an excellent landmark for reckoning the anatomical features of this region and to help in identifying the precise location of Schlemm's canal. Indeed the collagen fibers forming the posterior sclera are randomly organized, while the fibers in the more anterior sclera become better aligned and organized, to form a ligament (the scleral spur) running parallel to the limbus just posterior to Schlemm's canal (Fig. 8.9). Further dissecting unveils this canal. Before opening Schlemm's canal along its posterior border, a paracentesis is

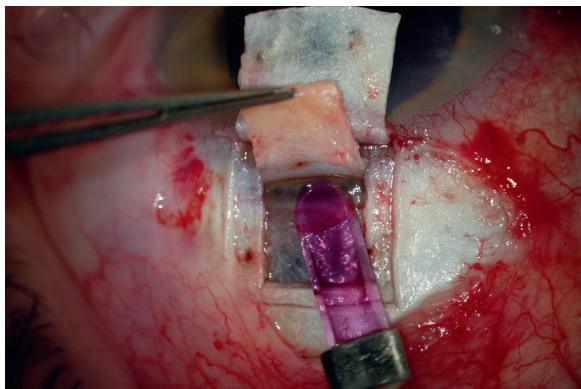


Fig. 8.10 Anterior dissection to expose the Descemet's membrane

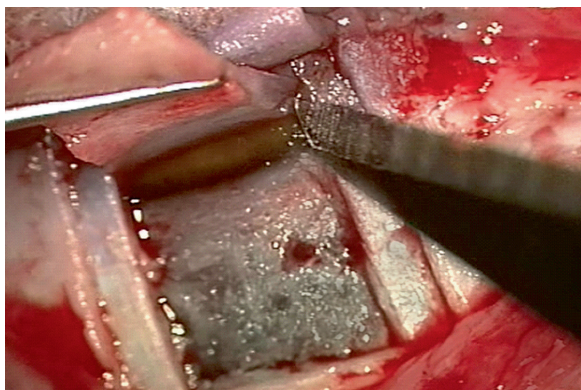


Fig. 8.11 Lateral cuts with number 11 blade upside down

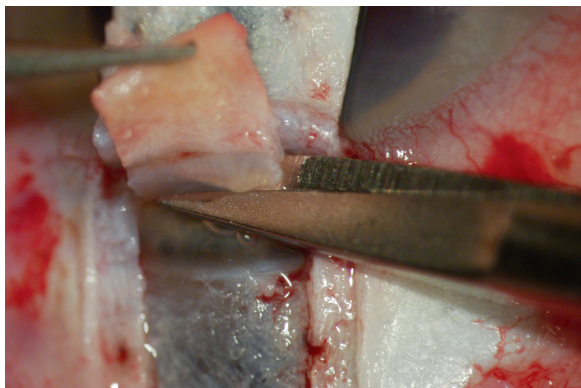


Fig. 8.12 Excision of the deep flap with Galan scissors

performed through the cornea to decrease the IOP. This paracentesis would allow introduction of viscoelastic material to maintain the anterior chamber

should a large perforation of the trabeculo-Descemet window occur. After deroofting Schlemm's canal, the dissection is terminated 1–1.5 mm forward to remove the sclerocorneal tissue in front of the anterior trabeculum and trabeculo-Descemet's membrane (TDM) (Fig. 8.10). This step is very delicate and difficult, for there is a high risk of breaking this very thin membrane. To ease dissection of the sclerocorneal tissue, two thin radial incisions are made in the corneal tissue. The metal blade is held upside down, the sharp edge in the upper position. The TDM is gently dissected in the anterior plane (Fig. 8.11). A wet triangular cellulose sponge, or a fine metal blade, a spatula, or a ruby knife can be used to undermine the membrane to complete the exposure by pressing down while simultaneously lifting up the deep scleral flap with the other hand. Upon completion of the anterior dissection, the scleral flap is initially cut using a diamond knife. The cutting is extended further using Galan's scissors (Fig. 8.12). Percolation of aqueous humor from the anterior chamber through the TDM is a good indicator for an effective and correct dissection of the latter.

8.1.3.5 Peeling of Schlemm's Canal and Juxtacanalicular Meshwork

To enhance filtration of aqueous humor through the TDM, the major obstacles to egress of aqueous humor, i.e., the inner wall of Schlemm's canal and the juxtacanalicular trabeculum, are removed [13]. These structures are thought to offer the highest resistance to aqueous humor outflow in primary and probably other types of secondary open-angle glaucoma. This is a crucial step in the surgical procedure that will warrant success or failure of nonpenetrating surgery. In the course of an external trabeculectomy, both the inner wall of Schlemm's canal and the juxtacanalicular trabeculum are peeled away using blunt forceps. After drying out the surface of Schlemm's canal, the blunt tips of the forceps are used to grasp the edge on the floor of the canal. A gentle lift of the forceps will peel off about 4 mm of continuous membrane, resulting in a significant decrease in the resistance to outflow and consequently a notable increase in the previously mentioned percolation of aqueous humor (Fig. 8.13).

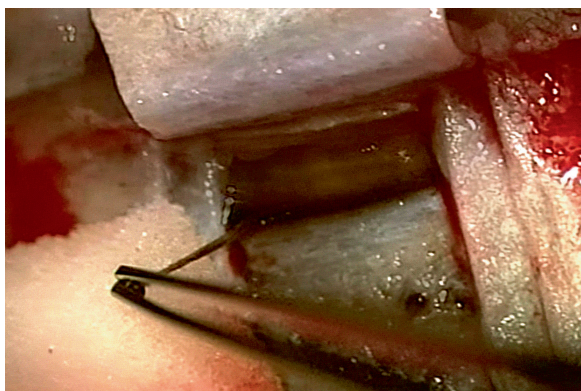


Fig. 8.13 Peeling of the inner wall of Schlemm's canal including the endothelium of Schlemm's canal and the juxta-canalicular trabeculum

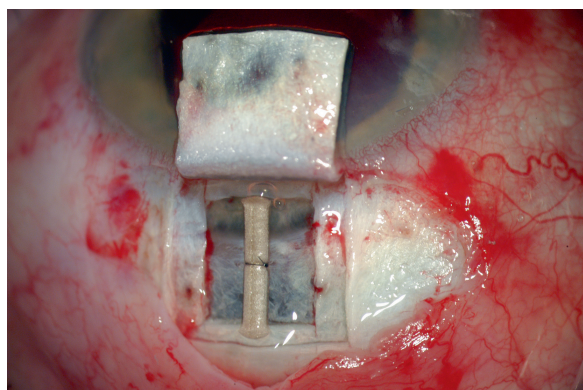


Fig. 8.14 Suture of the collagen implant

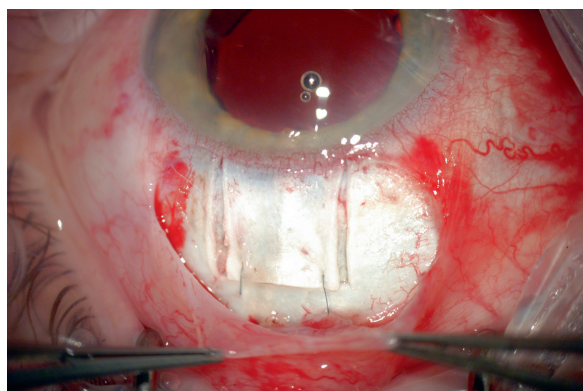


Fig. 8.15 Closure of the superficial flap with two stitches

8.1.3.6 Drainage Device

The initial and most important goal of deep sclerectomy has been achieved with the removal of both the inner wall of Schlemm's canal and the juxtacanalicular trabeculum, and the dissection of the Descemet's window. This step allows a gentle and continuous drop in the IOP, unlike what is seen with the penetrating procedure, such as trabeculectomy or insertion of the Seton tube where pressure can drop to zero. The second goal of the surgery is to maintain efficient filtration through the Descemet's window and the trabeculum by preventing collapse of the superficial scleral flap. It is crucial to keep the scleral space patent, a space where aqueous humor is collected before further routing into the intrascleral drainage pathways. Several devices may be used for this purpose. A cylindrical implant made of lyophilized porcine scleral collagen (Aquaflow®, Staar Surgical, Nidau, Switzerland), a triangular implant made of reticulated hyaluronic acid (SK gel®, Allergan, Irvine, California, USA), a high-viscosity viscoelastics (Healon GV®, Advanced Medical Optics, Inc., Santa Ana, California, USA), and a nonabsorbable drain made of highly hydrophilic acrylic (T-Flux®, IOLTech, La Rochelle, France) have all been used with success [5, 6, 14–18]. The cylindrical collagen implant Aquaflow® is about 4 mm in length and about 0.5 mm in diameter in a dry state. The implant is placed radially onto the bed of the scleral space and secured with a nonresorbable 10-0 suture (Fig. 8.14). The proximal end of the implant is located next to the TDM. Upon insertion, the highly hydrophilic implant absorbs aqueous humor percolating from the trabeculum and the Descemet's window and swells to about twice its dry state size. This collagen implant is digested about 6–9 months after surgery.

8.1.3.7 Wound Closure

The superficial scleral flap is repositioned into place, covering the space maintainer device, and a loose non-resorbable 10-0 suture is placed at each posterior corner of the flap (Fig. 8.15). The stitch is tightened and the knot buried. Conjunctiva and Tenon's layer are closed in two layers with a running resorbable 8-0 suture.

8.1.4 Postoperative Management and Medication

8.1.4.1 Medication

After surgery topical antibiotics and anti-inflammatory medications are given to reduce the risk of bleb infection, endophthalmitis, and to prevent the onset of severe inflammation. A broad-spectrum topical antibiotic may be used five times a day, with a dose that is progressively tapered after 2–3 weeks. Because deep sclerectomy is a nonpenetrating procedure, the postoperative inflammation is highly reduced from what would normally be the case with trabeculectomy [19]. Anti-inflammatory medications, such as corticosteroids, improve the success of glaucoma surgery, the influence of which is greatest during the initial inflammatory phase, the first 3–4 days after surgery [20]. The effect of corticosteroids is to prevent excessive scarring and development of fibrosis of the tissues involved in the filtration, i.e., the conjunctiva, the subconjunctival space, and the superficial flap. The dosage of topical corticosteroids is between 3 and 5 drops a day, and this medication is often combined with topical antibiotics. It is worth mentioning in this context that some eyes might be sensitive to topical corticosteroids, a situation that can eventually lead to steroid-induced ocular hypertension. The corticosteroids are therefore tapered after a few weeks, followed by non-steroidal inflammatory drugs, three times a day for at least 3 months after surgery.

8.1.4.2 Management

The eye is regularly checked at the slit lamp for postoperative assessment. The examination should be performed on the first and third postoperative day, every week for the first month, then every month for the 3 first months, then twice a year thereafter. This schedule is to be adjusted according to the clinical situation, depending on the severity and complexity of the case, with more frequent examination if required. During the assessment, the bleb is carefully examined and the clinical aspect, the extent, the vascularization, and any sign of infection are reported. The cornea is checked as well for any decrease in clarity or epithelial defect. The anterior chamber depth is assessed, and any degree

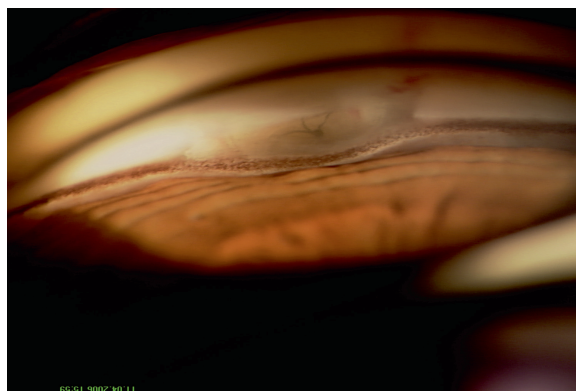


Fig. 8.16 Trabeculo-Descemet's membrane (TDM), gonioscopic view. The collagen implant is seen through the TDM



Fig. 8.17 Decompression hemorrhage

of iris touch reported. A mild hyphema from minor iris hemorrhages might be present that resolves in a few days. Flare and cell count is generally moderate, and any sign of severe inflammation shall immediately be addressed by the use of adequate medication. The IOP and time of measurement are reported. An inspection of the angle by gonioscopy reveals the dissected TDM and Schlemm's canal (Fig. 8.16). It is not uncommon to observe some blood in the canal during the first postoperative days, e.g., after a Valsalva maneuver, which disappears within a week. As is the case for every filtering procedure, the filtration might temporarily be important, leading to transient ocular hypotony. In severe cases the fundus might show signs of choroidal detachment or suprachoroidal hemorrhages (Fig. 8.17). Most of these complications resolve themselves upon recovery to a normal IOP above 6 mmHg. In the most complicated cases and when the situation lasts for weeks, drainage of the choroidal fluid might be proposed to solve the problem.

8.1.5 Adjunctive Treatments

8.1.5.1 Bleb Needling

Tissue remodeling and scarring response are two healing processes that occur after any surgery. In the case of glaucoma filtration, aqueous humor is drained in the subconjunctival space before further routing to the drainage vessels. This space may be prone to the development of a fibrosis, leading eventually to the growth of a fibrous capsule around the surgical site, which may significantly reduce the absorption of aqueous humor (Fig. 8.18). This can lead to a significant increase in the IOP. To solve this problem, needling the filtering bleb, with or without the use of adjunctive antimetabolites (such as Mitomycin C or 5-fluorouracil) might be proposed to restore the function of the filtering bleb and reduce the IOP. The needling is performed after instilling the topical anesthetic and placement of a lid speculum. The patient is instructed to look down and a 30-gauge needle mounted on a 1 mL syringe is introduced beneath the conjunctiva near the surgical site. The tip of the needle is advanced to gently enter in the fibrous capsule or cysts in the Tenon's layer, and then the tip is carefully moved back and forth to break the capsule and/or the cysts. Care is taken to not puncture the nearby running blood vessels or the overlying conjunctiva. Antimetabolites, e.g., 0.2 mg/mL Mitomycin C or 50 mg/mL 5-fluorouracil, are injected (0.3 mL) during the needling procedure. The eye is then thoroughly rinsed using a sterile balanced salt solution for about 1 min to flush any excess antimetabolite solution. Topical combined antibiotics and corticosteroids are

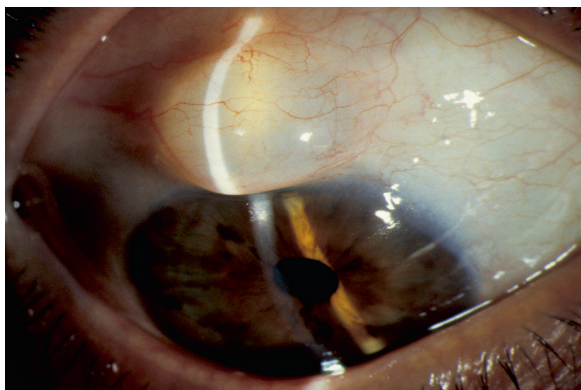


Fig. 8.18 Cystic bleb

given three times a day for a week. The IOP is checked 10–15 min after this procedure to assess efficacy of the treatment.

8.1.5.2 Nd:YAG Goniopuncture

Aqueous humor should flow easily through the TDM. After the initial drop in IOP, any significant rise in pressure (above 20 mmHg) in the early postoperative period (~10 days) might be indicative of an impaired percolation through this membrane. A goniopuncture of the latter using a gonioscope and a Neodymium: Yttrium Aluminium Garnet (Nd:YAG) laser can be proposed to create minute perforations in the membrane to improve aqueous humor egress [21, 22]. The laser is set on free-running Q-switched mode, with an energy of 4–5 mJ. The laser spot is aimed at the membrane and a series of shots are given to create very fine holes creating a direct route from the anterior chamber to the intrascleral and subconjunctival spaces. Postoperative management consists of topical antibiotics and corticosteroids for a few days.

8.1.6 Complications and Management

8.1.6.1 General

The complications that might occur in the course of nonpenetrating deep sclerectomy can be classified into three groups. The first group relates to the peroperative complications that happen during the dissection of the TDM, the implantation of the filtering device (cylindrical collagen implant, viscoelastics, SK gel®, T-Flux®, etc.), or at any time during completion of the surgery. The second group reports the occurrences during the first days after surgery, such as wound leaks, hypotony, shallow anterior chamber, choroidal detachment, hyphema, inflammation, infection, and ocular hypertony. The third group encompasses complications observed in the weeks or months after the filtering procedure was performed and can comprises of problems related to the filtering bleb, such as onset of fibrosis of the bleb, encysted bleb, prolonged increase in the IOP, detachment of the Descemet's membrane, development of peripheral anterior synechia, or chronic hypotony.

8.1.6.2 Perioperative Complications

Perforation of the TDM can easily happen during the learning phase of this technique. A small perforation that does not reduce anterior chamber depth will not compromise surgery, which can be resumed normally. Larger perforations usually lead to the formation of a long tear, which is usually followed by immediate iris prolapse and subsequently a shallow or flat anterior chamber. In this situation, a peripheral iridectomy should be performed after injection of low molecular weight viscoelastics to increase the anterior chamber depth. The superficial scleral flap should then be tightly sutured with 6–8 interrupted 10-0 nonresorbable stitches and viscoelastics injected in the scleral space to limit the egress of aqueous humor (Fig. 8.19).

Blood might reflux from the drainage vessels, the collector channels through Schlemm's canal ostia when the episcleral venous pressure is higher than the IOP. Dissection of the TDM might be more difficult in this case. Blood reflux might be prevented by injecting some high molecular weight viscoelastics into the Schlemm's canal ostia with a fine Grieshaber canula or by injecting some balanced salt solution into the anterior chamber to increase the IOP.

8.1.6.3 Early Postoperative Complications

A small wound leak or positive Seidel test may happen after insufficient wound closure. They generally seal by themselves, but in persistent cases a second wound closure should be performed to solve the problem.

The IOP on the first postoperative day is generally low, in the range of 0–5 mmHg. This is a reliable

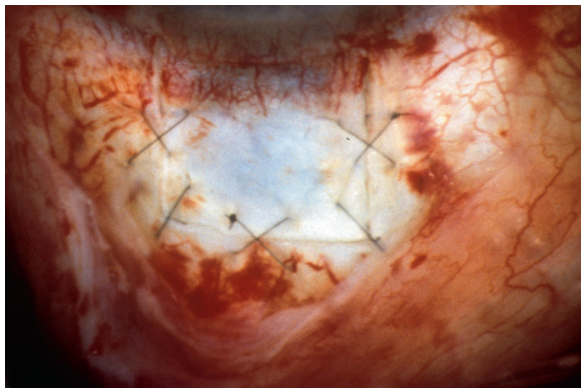


Fig. 8.19 Superficial flap closed with eight 10-0 Nylon sutures in case of trabeculo-Descemet's membrane perforation

indicator for a good dissection of the membrane. The pressure gradually increases to reach, 1 week after surgery, a plateau at around 9–12 mmHg. A wound leak or positive Seidel test should be considered in case of prolonged hypotony (over 1 week).

Owing to the nonpenetrating nature of deep sclerectomy, a completely flat anterior chamber has never been reported after such a procedure. Yet a shallowing of the anterior chamber may be seen in patients with a significant drop in IOP. In this case, perforation of the TDM, wound leak, suprachoroidal hemorrhage, pupillary block, or malignant glaucoma should be ruled out.

Choroidal detachment is a rare complication after deep sclerectomy. In most of the cases, no specific treatment is needed, the problem resolves spontaneously within a few days. In more serious cases, cycloplegics and anti-inflammatory drops should be given. In the most severe cases, drainage of the suprachoroidal space is proposed to prevent subsequent retinal and/or cornea damages. A small sclerectomy is performed in the lower quadrant, about 8–10 mm away from the limbus, to drain as much suprachoroidal fluid as possible.

Hyphema may result from rupture of a small iris vessel or from a flow of erythrocytes through the TDM. For this there is no specific treatment and the problem will resolve spontaneously.

Inflammation is generally modest after nonpenetrating surgery, for the anterior chamber and the iris are left untouched. Inflammation can nevertheless be more pronounced in uveitic glaucoma, pseudoexfoliative glaucoma, pigmentary glaucoma, or traumatic glaucoma. Severe inflammation shall be addressed by extensive anti-inflammatory drugs, i.e., corticosteroids, which are tapered after the inflammation subsides, to prevent secondary steroid-induced ocular hypertony.

Infection of the bleb is a very rare event, which can be seen in patients with a compromised immunological system. An intensive regimen of topical broad-spectrum antibiotics is prescribed and close monitoring of the eye structure is advocated to detect any extension of the infection, i.e., endophthalmitis.

Ocular hypertension can occur if the surgery is not performed correctly, when the TDM is not sufficiently dissected, peeling of Schlemm's canal is not performed properly, in case of excessive viscoelastics remaining in the anterior chamber, large hemorrhage, or postoperative rupture of the membrane with subsequent iris prolapse. Nd:YAG laser goniopuncture might solve some of the problems related to the surgical technique. The pressure spikes shall resolve spontaneously a few

weeks after the surgery. In the most severe cases, a second surgery might be proposed.

8.1.6.4 Late Postoperative Complications

Postoperative tissue remodeling can induce important scarring of the subconjunctival space. Fibrosis of the conjunctiva or encysted filtering bleb results from this scarring response and outflow of aqueous is impeded. Bleb needling with concomitant antimetabolites injection is recommended when on examination the bleb shows signs of fibrosis and the IOP is elevated (>20 mmHg). The subconjunctival cysts are treated the same way.

Sustained increase in the IOP may result from a decreased flow through the TDM. An Nd:YAG laser goniotomy is performed to enhance filtration through the membrane. Extended fibrosis of the filtering space, the conjunctiva, or the superficial flap may lead to an increase in IOP. Revision of the filtering surgery may be

proposed to address this problem by reopening the scleral space and revising the superficial flap.

A detachment of the Descemet's membrane may occur after nonpenetrating filtering surgery. This complication is caused by the passage of aqueous humor from the scleral space into the sub-Descemet's space at the anterior edge of the Descemet's window. A bleb is visible on the posterior plane of the cornea, which corresponds to the separation of the Descemet's layer from its overlying stroma (Figs. 8.20 and 8.21). A decrease in the visual acuity is reported when the detachment extends over the visual axis. To solve this problem, a descemetotomy is performed after drainage of the underlying fluid.

Intraoperative microruptures of the TDM, a large goniotomy hole, or traumatic rupture of the TDM, are all associated with entrapment or incarceration of the iris, and will likely promote onset of peripheral anterior synechia. When the iris incarceration is important, outflow is compromised and the IOP increases (Figs 8.22 and 8.23). Laser peripheral anterior synechia lysis may be attempted

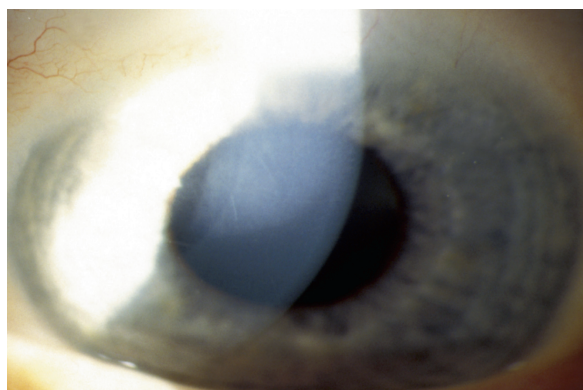


Fig. 8.20 Descemet's detachment

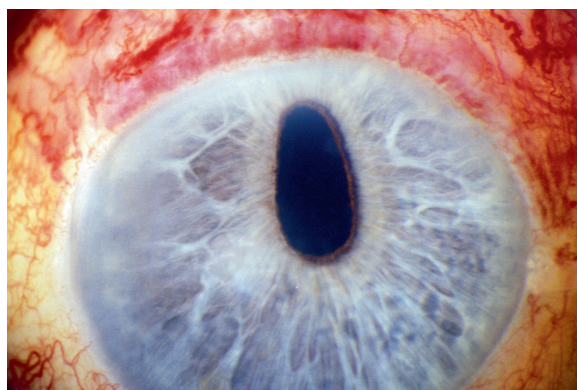


Fig. 8.22 Iris prolapsed through the Trabeculo-Descemet's membrane



Fig. 8.21 Ultrabiomicroscopic image of a Descemet's detachment

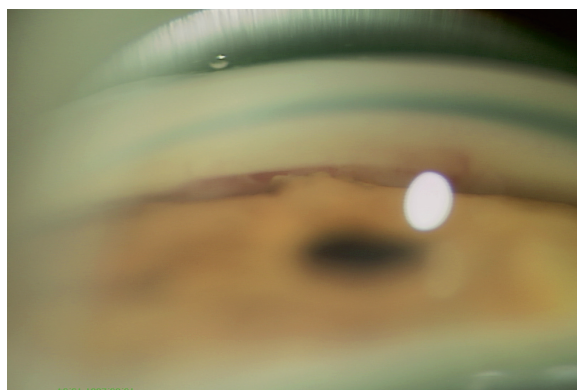


Fig. 8.23 Iris incarceration reduced with the Nd:YAG laser

to reposition the iris back, or a secondary surgery could be performed to restore a normal filtration.

A thin ischemic conjunctival bleb may lead to excessive filtration, thus resulting in prolonged late chronic ocular hypotony with, in some occasions, hypotony-related maculopathy. Intraoperative antimetabolites (e.g., Mitomycin C) application might favor occurrence of this complication. Revision of the filtering bleb and conjunctival graft is proposed to solve this problem.

References

1. Demailly P, Jeanteur-Lunel MN, Berkani M (1996) Non penetrating deep sclerectomy associated with collagen implant device in primary open angle glaucoma: middle term retrospective study. *J Fr Ophtalmol* 19:659–666
2. Fjodorov SN, Ioffe DI, Ronkina TI (1984) Deep sclerectomy: technique and mechanism of a new glaucomatous procedure. *Glaucoma* 6:281–283
3. Karlen M, Sanchez E, Schnyder CC et al (1999) Deep sclerectomy with collagen implant: medium term results. *Br J Ophthalmol* 83:6–11
4. Kozlov VI, Bagrov SN, Anisomova SY (1990) Deep sclerectomy with collagen. *Eye Microsurg* 3:44–46
5. Stegmann R (1995) Viscocanalostomy: a new surgical technique for open angle glaucoma. *An Inst Barraquer* 25:225–232
6. Stegmann R, Pienaar A, Miller D (1999) Viscocanalostomy for open angle glaucoma in black African patients. *J Cat Refract Surg* 25:316–322
7. O'Donoghue E, Batterbury M, Lavy T (1994) Effect on intraocular pressure of local anaesthesia in eyes undergoing intraocular surgery. *Br J Ophthalmol* 78:605–607
8. Sauder G, Jonas JB (2002) Topical anaesthesia for penetrating trabeculectomy. *Graefes Arch Clin Exp Ophthalmol* 240:739–742
9. Zabriskie NA, Ahmed II, Crandall AS et al (2002) A comparison of topical and retrobulbar anesthesia for trabeculectomy. *J Glaucoma* 11:306–314
10. Bill A, Svedbergh B (1972) Scanning electron microscopic studies of the trabecular meshwork and the canal of Schlemm's: an attempt to localize the main resistance to outflow of aqueous humour in man. *Acta Ophthalmol (Copenh)* 50:295–320
11. Ethier CR, Kamm RD, Palaszewski BA et al (1986) Calculation of flow resistance in the juxtacanalicular meshwork. *Invest Ophthalmol Vis Sci* 27:1741–1750
12. Johnson M, Kamm RD (1983) The role of Schlemm's canal in aqueous outflow from the human eye. *Invest Ophthalmol Vis Sci* 24:320–325
13. Vaudaux J, Mermoud A (1998) Aqueous dynamics after deep sclerectomy: ex-vivo study. *Ophthalmic Pract* 16:204–209
14. Ateş H, Uretmen O, Andaç K et al (2003) Deep sclerectomy with a nonabsorbable implant (T-Flux): preliminary results. *Can J Ophthalmol* 38:482–488
15. Lüke C, Dietlein TS, Jacobi PC et al (2003) A prospective randomised trial of viscocanalostomy with and without implantation of a reticulated hyaluronic acid implant (SKGEL) in open angle glaucoma. *Br J Ophthalmol* 87:599–603
16. Marchini G, Marraffa M, Brunelli C et al (2001) Ultrasound biomicroscopy and intraocular-pressure-lowering mechanisms of deep sclerectomy with reticulated hyaluronic acid implant. *J Cataract Refract Surg* 27:507–517
17. Shaarawy T, Nguyen C, Schnyder C et al (2003) Five year results of viscocanalostomy. *Br J Ophthalmol* 87:441–445
18. Sourdille P, Santiago PY, Villain F et al (1999) Reticulated hyaluronic acid implant in nonpenetrating trabecular surgery. *J Cataract Refract Surg* 25:332–339
19. Chiou AG, Mermoud A, Jewelewicz DA (1998) Postoperative inflammation following deep sclerectomy with collagen implant versus standard trabeculectomy. *Graefes Arch Clin Exp Ophthalmol* 236:593–596
20. Roth SM, Spaeth GL, Starita RJ et al (1991) The effects of postoperative corticosteroids on trabeculectomy and the clinical course of glaucoma: five-year follow-up study. *Ophthalmic Surg* 22:724–729
21. Mermoud A, Karlen ME, Schnyder CC et al (1999) Nd:YAG goniotomy after deep sclerectomy with collagen implant. *Ophthalmic Surg Lasers* 30:120–125
22. Shaarawy T, Mansouri K, Schnyder C et al (2004) Long-term results of deep sclerectomy with collagen implant. *J Cataract Refract Surg* 30:1225–1231

8.2 Minimally Penetrating Glaucoma Surgery with the Ex-PRESS™ Miniature Shunt

8.2.1 Introduction to Glaucoma Surgery with the Ex-PRESS™

Glaucoma is defined as a group of eye conditions that share either the common feature of progressive optic neuropathies (the open-angle variants) or the common feature of occludable drainage angles in the anterior chamber (the closed-angle variants). The primary goal of glaucoma therapy is to reduce IOP to the point where deterioration of the optic disk or visual fields ceases with a minimum of side effects or complications. The therapy currently available can be divided into three main groups: medical therapy, laser trabeculoplasty, and filtering surgery.

In its essence, glaucoma surgery has always aimed to be minimally invasive, but recently nonpenetrating and minimally penetrating techniques have been proposed to improve the classic techniques further.

The Ex-PRESS™ glaucoma implant is a miniature glaucoma shunt that was designed with the primary intention of offering a straightforward and safe drainage operation for the general ophthalmologist. The inventors (Belkin and Glovinsky) and the manufacturers (Optonol Ltd, Neve Ilan, Israel) initially suggested that the implant be inserted at the limbus under a conjunctival flap [1–9]. This technique was soon abandoned for a safer and more efficient technique of implantation under a scleral flap [10, 11]. This chapter will deal only with the use of Ex-PRESS implant under a scleral flap because the implantation under a conjunctival flap is not advised by the manufacturers. Furthermore, the great majority of the Ex-PRESS users worldwide are using it exclusively under a scleral flap.

The Ex-PRESS™ device is a nonvalved implant made of medical-grade implantable stainless steel (316L) identical to the material used for cardiac stents worldwide [4]. The Ex-PRESS™ device and its material are FDA-approved for ophthalmic applications since 2002. Although it is metallic, the Ex-PRESS™ is MRI-safe [4, 8]. The manufacturers advise not to do an MRI within 2 weeks after implantation to be on the safe side.

At present, two models of the Ex-PRESS™ implants are available (Fig. 8.24). The basic design is of a 27-gauge (0.4 mm external diameter) tube, the length

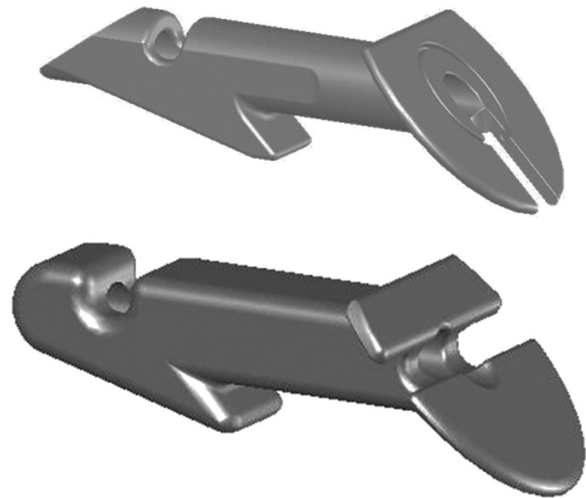


Fig. 8.24 Ex-PRESS™. *Top:* Model P. *Bottom:* Model X. Both models are available in 50 and 200 μ m inner bore diameter

of which varies from 2.4 to 3.0 mm. The internal diameter of the device is available in 50 or 200 μ m. The distal end can be bevelled and sharp or rounded off according to the device model (Fig. 8.24). The proximal end has a disk-like flange that limits the device penetration into the anterior chamber (A/C). A spur-like projection is situated on the lower external surface of the tube to prevent extrusion once the device has been implanted. Both the flange and the spur are angled to conform to the anatomy of the sclera and the distance between them corresponds to the scleral thickness at the limbus. The distal end has extra holes to provide alternative routes for the aqueous humor in case the main hole becomes obstructed.

The main concept of the Ex-PRESS™ glaucoma implant is to allow a restricted aqueous humor flow from the A/C to the subsclearal and subconjunctival spaces (Fig. 8.25). The restricted internal diameter (50 or 200 μ m) of the device provides a certain consistency and standardization to the filtration procedure. In classic trabeculectomy, wide variations occurred not only with different surgeons but also in the hands of the same surgeon. These variations occur during sclerostomy that is done either by manual incisions or by punch. The Ex-PRESS™ implantation does not require any tissue excision or removal whereas in trabeculectomy, a sclerostomy is mandatory and an iridectomy is performed by a great majority of surgeons.

Therefore, the Ex-PRESS™ implantation can be described as minimally penetrating glaucoma surgery

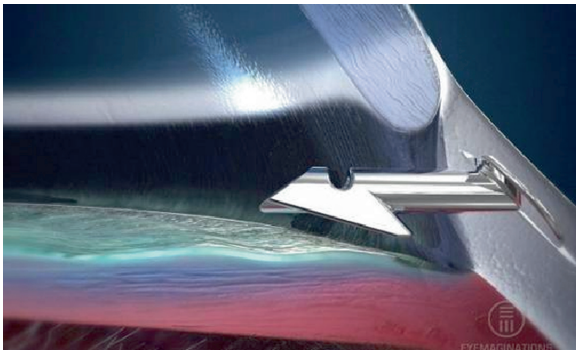


Fig. 8.25 Artist's impression showing an Ex-PRESS™ Model P inserted in the anterior chamber, under a scleral flap at the limbus

(MPGS). Both the device and the required incision into the A/C are miniaturized. Reflecting upon the two approaches of glaucoma surgery – penetrating and non-penetrating – the Ex-PRESS™ device offers a valid compromise between these two opposites. Trabeculectomy (penetrating), considered as the golden standard, has severe shortcomings because of its high-risk immediate postoperative course [12]. Nonpenetrating glaucoma surgery (NPGS) is recognized as a very safe drainage procedure but it has a long learning curve and the notorious reputation of being difficult to master [13]. MPGS with the Ex-PRESS™, being similar to trabeculectomy, has a very short learning curve and at the same time mimics NPGS with its restricted flow.

Until recently, glaucoma surgery was offered as a last-resort treatment when medical therapy or laser interventions failed to lower IOP to acceptable levels. The Ex-PRESS™ miniature glaucoma device has demystified glaucoma surgery to a point where it can be offered earlier during the course of the disease to provide a safe and efficient treatment for glaucoma. The cost of the device is easily counterbalanced by the savings in medicine costs, shortened operating time, and reduced post-operative complications. Its development will further advance to the benefits of glaucoma patients worldwide.

8.2.1.1 Indications for MPGS with the Ex-PRESS™ Mini-Shunt Under a Scleral Flap

In general, the indications for MPGS with the Ex-PRESS™ are wider and more inclusive than those for classical trabeculectomies for two reasons: (1) MPGS with the Ex-PRESS™ is safer but not less

efficient than trabeculectomies [10–36]; and (2) MPGS with the Ex-PRESS™ is indicated in certain types of glaucoma where trabeculectomies normally fail or are not feasible [21, 26, 29, 35].

Glaucoma surgery is generally regarded as the last resort in the treatment of glaucoma. When medical therapy and laser fail to lower IOP to an acceptable level, glaucomatologists explain to their patients that an operation is necessary to halt the progression of the disease. The Ex-PRESS™ with its lower complication rate can be offered earlier in the course of the disease. In fact, MPGS with the Ex-PRESS™ can be offered as a first-line treatment in cases where it is obvious that medical treatment will not lower IOP to acceptable levels. This factor is particularly important in glaucoma patients under 40 years who have a longer lifespan. Furthermore, glaucoma surgery is more successful in glaucoma patients who were not exposed to medical treatment [14–17, 28]. The noxious effects of topical medications on the conjunctiva are well documented [14–17, 28]. The conjunctival tissues undergo scarring processes when exposed to certain topical medications. Scarred conjunctiva, as found in patients who have been medically treated for years, is less amenable to the formation of a healthy diffuse bleb than a “virgin” conjunctiva. It is therefore logical to propose glaucoma surgery earlier than later when the chances of favorable outcomes are greater. The previous teaching of “first medical & laser treatment and then surgical treatment” has to be reviewed with the advent of the with promising outcomes of MPGS the Ex-PRESS™.

Open-Angle Glaucoma

Open-angle glaucoma is the commonest type of glaucoma and MPGS with the Ex-PRESS™ is the best indication for it. During MPGS the limbus is incised at the level of the trabecular meshwork (TM) and the Ex-PRESS™ implant is inserted into the A/C to allow a controlled flow of aqueous from the A/C to the intrascleral and subconjunctival spaces. Furthermore, the eye is less inflamed following MPGS because of the lower postoperative concentration of TGFs [36].

Pigmentary Glaucoma

MPGS with the Ex-PRESS™ is indicated for pigmentary glaucoma because it occurs more frequently in

young myopic male adults, and it is better to offer a safe surgical solution without depending on complex combination medical treatment. The Ex-PRESS™ bypasses the site of pathology, namely the pigment-loaded TM.

Pseudoexfoliation Glaucoma

Pseudoexfoliation glaucoma is a form of open-angle glaucoma where there is accumulation of exfoliation material along all the aqueous outflow pathways. Since the exfoliation material is found especially in the TM and Schlemm's canal, MPGS with the Ex-PRESS™ is the treatment of choice for this condition because the blocked TM is bypassed during this procedure. MPGS can be done alone or in conjunction with cataract extraction according to patient age, cataract status, and refractive error.

Aphakic Glaucoma

Formerly, glaucomatologists relied heavily on medication to lower IOP to acceptable levels in aphakic glaucoma. Progressive loss of visual field and eventual loss of vision were often the rule. Trabeculectomies were not regarded as a valid proposition because they necessitate peripheral iridectomies. In aphakic glaucoma, iridectomy is not desirable because the vitreous may move forward through the iridectomy and block the filtration site. Extensive basal vitrectomy is needed to prevent blockage, but it is difficult to accomplish. The ever-present residual vitreous often finds its way to the filtration site and blocks it. Traction retinal detachment is not an uncommon complication in these combined vitrectomy-trabeculectomies. MPGS with the Ex-PRESS™ does not require iridectomy; therefore, it is particularly indicated in aphakic glaucoma.

Sturge–Weber Syndrome

Sturge–Weber syndrome, a cutaneous haemangiomatous disorder, is often associated with congenital or developmental glaucoma. The greater numbers and tortuosity of the conjunctival blood vessels can be an indicator of glaucoma. Minor angle abnormalities, heterochromia, and choroidal haemangioma are often

present in Sturge–Weber syndrome patients with glaucoma. Since choroidal effusions following trabeculectomy are notoriously known in these patients, MPGS with the Ex-PRESS™ offers a safer alternative because of its lower rate of prolonged postoperative hypotony.

Glaucoma Secondary to Uveitis

Glaucoma surgery is indicated when elevated IOP persists after the uveitis has subsided. MPGS with the Ex-PRESS™ can offer efficient IOP reduction in these cases because it bypasses the inflamed nonfunctional TM. Furthermore, since its postoperative course is quieter than in trabeculectomies MPGS has an advantage over the classic trabeculectomy. Nevertheless, in cases where multiple peripheral anterior synechiae are present, the surgeon has to take special care when positioning the Ex-PRESS™ in order to avoid iris tissue touch.

8.2.1.2 Relative Contraindications for MPGS with the Ex-PRESS™ Mini-Shunt Under a Scleral Flap

The relative contraindications for MPGS depend on the depth of the A/C and on the expected outcome for a particular pathology.

Congenital and Juvenile Glaucoma

Congenital and juvenile glaucoma patients cannot rely on medication because of their longer lifespan. Generally, their glaucoma is severe and results in rapid optic-nerve damage and loss of vision. Practically, surgery is the only treatment available for these patients. Goniotomy and trabeculotomy are the preferred procedures for congenital and juvenile glaucoma. NPGS is a safe alternative for these classic interventions but it requires skill and long experience and should not be tried by a novice. When these operations fail MPGS with the Ex-PRESS™ can be considered, with caution because that it is still a new operation with less than 10 years follow-up in humans. The long-term complications are still unknown and children should not be exposed to operations with relatively new implants unless everything else has failed.

Aniridia and Anterior Segment Dysgenesis Syndromes

In aniridia and anterior segment dysgenesis syndromes the angle structures are abnormal and may not suit Ex-PRESS™ implantation. In these cases, MPGS should be avoided unless all other operations have failed and the surgeon is confident of having found a site where the Ex-PRESS™ can be safely positioned. Obviously, the Ex-PRESS™ should be implanted only by an experienced surgeon who has already performed many implantations in less complicated cases.

Narrow-Angle Glaucoma

The Ex-PRESS™ should not be used in narrow-angle glaucoma (NAG) unless the lens is extracted at the same time. At present, many glaucomatologists suggest that cataract/lens extraction should be considered as an important step in the treatment of NAG. Laser iridotomy or surgical iridectomy provide a temporary measure only, whereas removal of the crystalline lens, irrespective of its transparency, deepens the anterior chamber and widens its angle. When NAG has persisted for some time, the TM may not recover its function even when the lens has been extracted. In that case, filtration surgery may be needed in combination with lens extraction.

Posttrauma Angle-Recession Glaucoma

In angle-recession glaucoma, the TM has been damaged and its filtering function may not recover. MPGS with the Ex-PRESS™ implant is feasible because of its minimal tissue manipulation. The outcomes might be less rewarding than in OAG because of the scarring and the reactivity of the ocular tissues following the trauma.

Neovascular Glaucoma

Neovascular glaucoma (NVG) is a unique form of glaucoma that results from ocular or extraocular disease that produces ischemia of the eye. It is characterized by intractable ocular hypertension caused by neovascularization of the iris and the anterior chamber angle. NVG can occur after central retinal vein occlusion (CRVO)

or in proliferative diabetic retinopathy (PDR). Until the present, filtering surgery for NVG has been difficult because of the high risk of intraoperative bleeding and the intense postoperative inflammatory response. The high risk of postoperative hyphema in MPGS is a serious drawback because the Ex-PRESS™ implant orifices can be totally occluded by the blood clot. Furthermore, the intense postoperative inflammatory response might cause severe adhesions of the scleral flap, impairing adequate filtration.

8.2.1.3 Absolute Contraindications for MPGS with the Ex-PRESS™ Mini-Shunt Under a Scleral Flap

Narrow-Angle Glaucoma in a Young Patient

Because the Ex-PRESS™ requires a deep A/C and an open angle its application in NAG without lens extraction is absolutely contraindicated. The Ex-PRESS™ implant may be too close to the iris and cornea in a crowded A/C. Consequently, it may cause damage to these tissues.

Pseudophakic Glaucoma with an A/C IOL

The presence of an A/C IOL in cases of pseudophakic glaucoma complicates the outcome of any filtration operation. The immediate postoperative risk of hypotony and A/C loss endangers further the corneal endothelium that is often already compromised. Removal of an A/C IOL can be complicated and traumatic; therefore, such a procedure is best left for the experienced anterior segment surgeon. The potential corneal endothelial damage occurring in the case of immediate postoperative A/C loss cannot be ignored in pseudophakic eyes with A/C IOLs.

8.2.1.4 Preoperative Considerations

Candidates for MPGS with the Ex-PRESS™ are often under maximal topical antiglaucoma treatment. Some of these medications might have adverse effects on the conjunctiva. When feasible, topical medication should be reduced to a minimum with the temporary help of oral acetazolamide. This will reduce the postoperative inflammatory response and favor efficient filtration.

8.2.2 Anesthesia

MPGS with the Ex-PRESS™ implant can usually be performed under local anesthesia. General anesthesia is needed only in young uncooperative patients or disorientated patients. Sub-tenon anesthesia is probably the safest and the most efficient of the different types of local anesthesia as it provides excellent analgesia as well as akinesia. Subconjunctival or topical anesthesia can be considered in very cooperative patients.

8.2.3 Surgical Technique and Potential Modifications

A fornix-based conjunctival flap is formed in an upper quadrant (Fig. 8.26). A 5×5 mm limbus-based scleral flap of approximately 50% depth is created taking care that the dissection passes the vascular arcade and reaches clear cornea. At the surgeon's discretion, Mitomycin C (MMC) 0.02% can be applied under the conjunctiva and the scleral flap (Fig. 8.27). A preincision is made into the anterior chamber under the scleral flap, in the lower part of the blue–grey transition zone between the white sclera and clear cornea (Fig. 8.28). Misplacement of the preincision can lead to inadequate device positioning. A preincision that is too scleral might lead to iris touch whereas a preincision that is too corneal might cause anterior migration of the device. The size of the preincision differs according to the model of the Ex-PRESS™ used. A 25 gauge needle is recommended for the P models. For the X models, a 23 gauge needle is needed to allow an easy insertion of the Ex-PRESS™. The needle should be held nearly parallel to the iris plane and aimed at the pupil while entering the anterior chamber in order to ensure proper positioning of the device. The anterior chamber is then filled with a viscoelastic material through a separate paracentesis.

An alternative to the use of viscoelastic during the operation is the use of an anterior chamber maintainer (ACM) with balanced salt solution (BSS). The ACM provides intraoperative control of the IOP and a deep A/C throughout the operation.

Recently, the Ex-PRESS is mounted on a self-release device for ease of handling (Fig. 8.29). The



Fig. 8.26 A fornix-based conjunctival flap is created and a 5×5 mm, 50% depth scleral flap is dissected at the 12 o' clock position

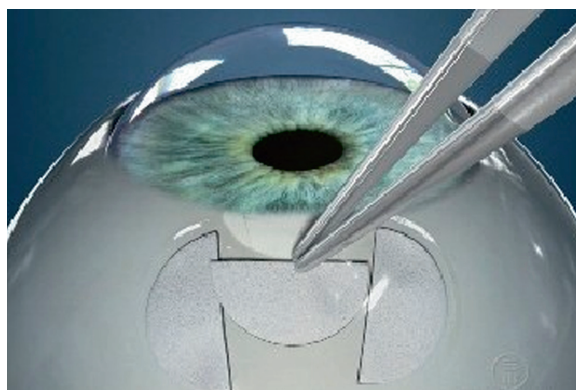


Fig. 8.27 Application of Mitomycin C under the conjunctival and scleral flap

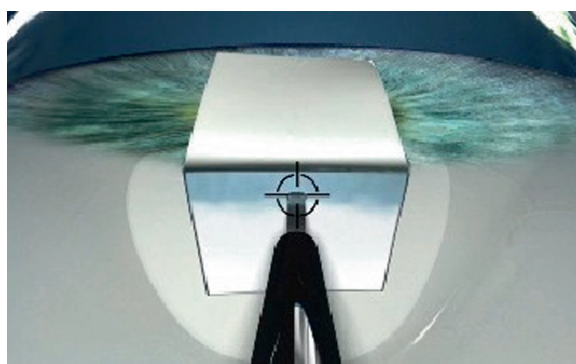


Fig. 8.28 A preincision (anterior chamber penetration) is made in the lower part of the grey zone between the white sclera and clear cornea. A 25 gauge needle is used for the P model and a 23-gauge needle is used for the X model

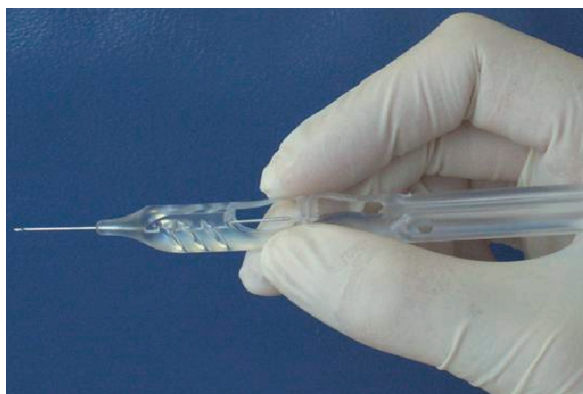


Fig. 8.29 The Ex-PRESS™ mini-shunt mounted on a self-release device

implant is inserted into the anterior chamber via the preincision site (Figs. 8.30 and 8.31).

The scleral flap is then securely sutured, using 10/0 nylon sutures, to cover the Ex-PRESS™ implant plate. The sutures are usually placed at the distal corners of the flap and at 1/4 the distance between the limbus and the corner of the scleral flap (Fig. 8.32). The conjunctiva is sutured securely back in place (Fig. 8.33). Once correctly placed, the flange of the device lies flat under the scleral flap with the conjunctiva completely covering the scleral flap, and the device body should lie parallel to the iris. At the end of the operation, most of the surgeons prefer to leave a certain amount of standard viscosity viscoelastic material in the A/C in order to prevent immediate postoperative over filtration, hypotony,

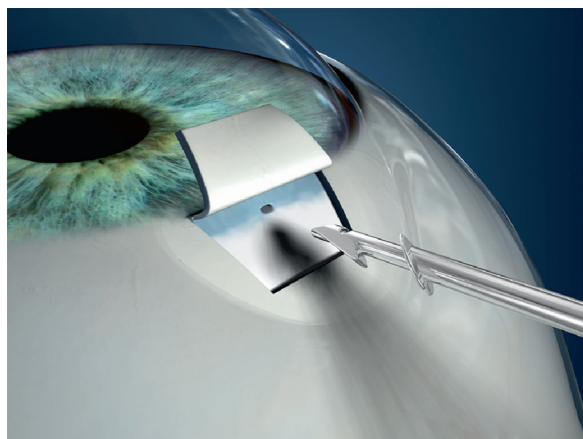


Fig. 8.30 The Ex-PRESS™ is inserted into the anterior chamber via the preincision

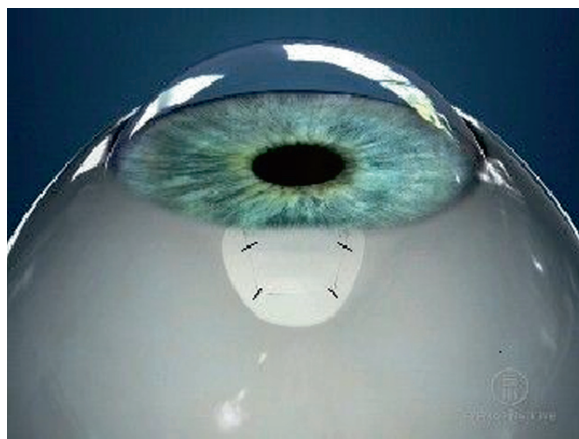


Fig. 8.32 The scleral flap is secured back in place with four tight 10/0 nylon sutures

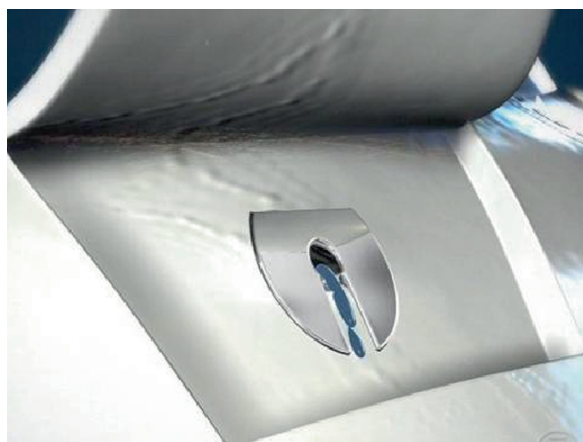


Fig. 8.31 Ex-PRESS™ model P inserted under a scleral flap

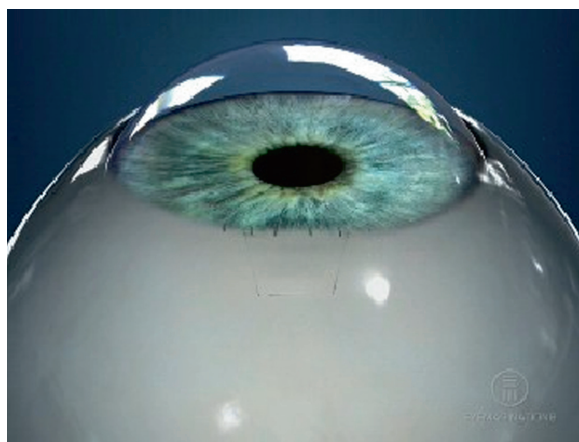


Fig. 8.33 The conjunctival flap is securely sutured back in place

and loss of A/C. The suggested amount of viscoelastic material differs with each model of the Ex-PRESS™. It might also differ according to the personal technique of the scleral flap size, shape, and suturing. The P models with its rounded body will need approximately one-third of the A/C filled with viscoelastic. The X models with their square-shaped bodies will need two-thirds of the A/C filled with viscoelastic.

Some users of the Ex-PRESS™ prefer to create a limbal-based conjunctival flap and a smaller triangular (3×3 mm) scleral flap. In that case, one 10/0 nylon suture might suffice to secure the scleral flap, whereas the conjunctiva is closed with a running absorbable suture.



Fig. 8.34 Ex-PRESS™ model X200 inserted under a scleral flap. Note the absence of a visible bleb

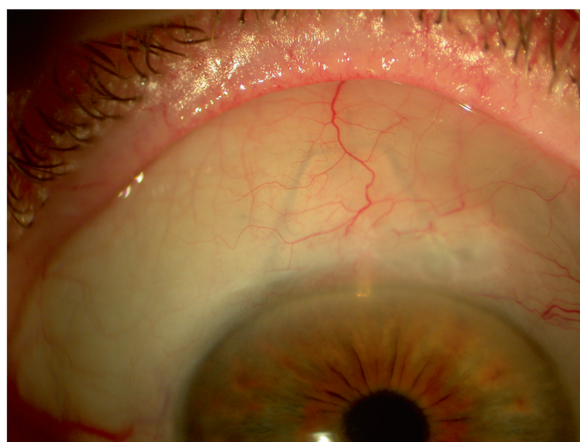


Fig. 8.35 Ex-PRESS™ model X200 inserted under a scleral flap. Note the appearance of the mild diffuse bleb 2 years after the operation

Some surgeons, who were familiar with NPGS prior to the Ex-PRESS introduction, suggest adding a deep sclerectomy under the superficial scleral flap without opening Schlemm's canal [35]. This modified deep sclerectomy creates an intrascleral space that might enhance intrascleral bleb formation and lessen subconjunctival bleb formation (Figs. 8.34–8.38). This technique is particularly suited for intractable cases, although no studies have been published yet on its added efficacy.

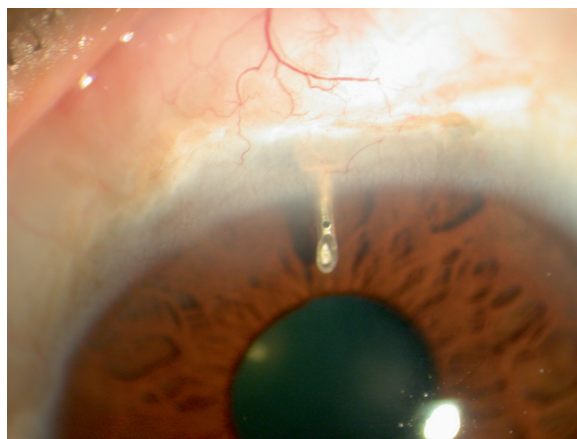


Fig. 8.36 Ex-PRESS™ model R50 inserted under a scleral flap. Note the diffuse elevated conjunctival filtration bleb

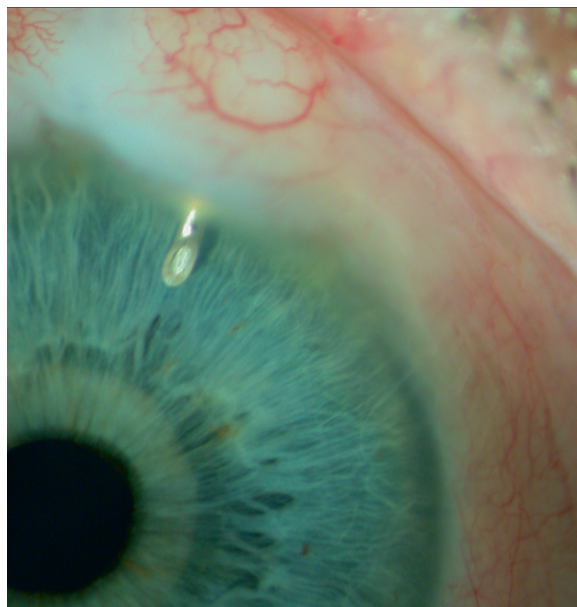


Fig. 8.37 Ex-PRESS™ model R50 inserted under a scleral flap. Note the elevated scleral flap forming an intrascleral bleb

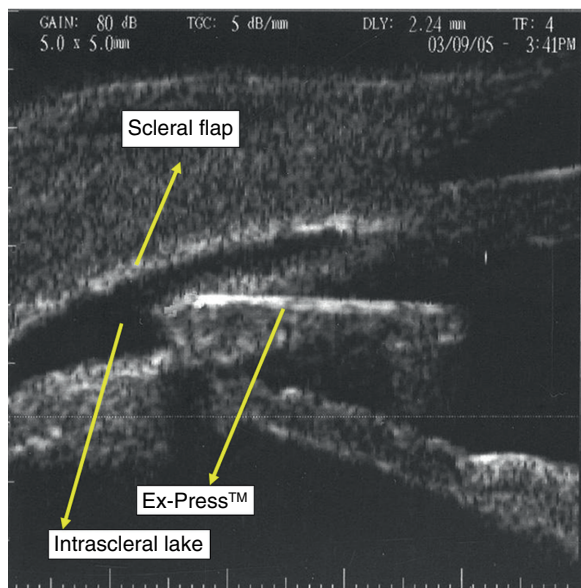


Fig. 8.38 Ultrabiomicroscopy imaging of an Ex-PRESS™ forming an intrascleral bleb. (Courtesy Dr Andre Mermoud)

8.2.4 Postoperative Management and Medication

Postoperative treatment consists of a steroid–antibiotic combination drops three to four times a day for a minimum of 2 weeks. On day one, the IOP can vary from 0 to mid-20s mmHg. In case of severe hypotony and a very shallow A/C, a viscoelastic substance can be injected into the A/C via an existing paracentesis in order to reform the A/C and normalize the IOP. This procedure can be performed under topical anesthesia with the slit lamp or in the theatre according to the surgeon's convenience. When the IOP is above 22 mmHg on day one, the A/C can be decompressed by releasing some viscoelastic material via the existing paracentesis.

At 2 weeks or later postoperatively, is expected a temporary rise of IOP. This temporary IOP rise is usually self-limited and subsides within 2 weeks. It is suggested the topical steroids are stopped and substituted with nonsteroidal anti-inflammatory drugs (NSAIDs). The treatment with topical NSAIDs four times a day should be continued for a period of 8 weeks in order to reduce the postoperative inflammatory response and to favor efficient filtration. Some surgeons who are familiar with sutures release choose to cut some of the scleral flap sutures when the IOP rises postoperatively.

8.2.5 Outcomes and Comparison with Other Techniques

The outcomes of MPGS with the Ex-PRESS™ as reported by the present users have been so far very encouraging [10–13, 18–27, 29–36] because they mimic two accepted techniques, namely trabeculectomies and NPGS. Depending on the personal technique of scleral flap formation, MPGS with the Ex-PRESS™ can yield good IOP control with or without conjunctival bleb formation (Figs. 8.34–8.36). In some cases, there is evidence of intrascleral bleb formation, especially when a deep sclerectomy has been added under the superficial scleral flap (Figs. 8.37 and 8.38). Prospective randomized studies comparing trabeculectomy, MPGSL with Ex-PRESS™, and NPGS are underway. Surgeons who were familiar with trabeculectomies and/or NPGS have switched to MPGS because of its relative advantages in terms of safety and simplicity. MPGS with the Ex-PRESS™ can be performed in aphakic eyes without the need of iridectomy which is an advantage over the classic trabeculectomy. Glaucoma surgeons who were performing trabeculectomies before using the Ex-PRESS™ implant tend to use the same basic technique and report comparable results except for the lower incidence of early postoperative complications [13, 30]. They also report on a quieter A/C on day one compared to trabeculectomies. Sherwood et al. confirmed this clinical impression in an experimental study on rabbits' eyes when he measured the TGFs $\beta 2$ in the aqueous humor postoperatively in trabeculectomies and MPGS with the Ex-PRESS™ [5].

The Ex-PRESS™ implant has not been compared yet to Setons, namely Molteno, Baerveldt, and Ahmed valves, in clinical studies. The Setons direct the aqueous to a posteriorly formed bleb whereas the Ex-PRESS™ shunts it to an anteriorly formed bleb as in trabeculectomy and NPGS.

8.2.6 Complications and Management

8.2.6.1 General

The usual complications encountered in filtration surgery can also occur in MPGS with the Ex-PRESS™ implant. Immediate postoperative hypotony, shallow

A/C, hyphema, and choroidal detachment do occur, although to a lesser extent because of the small drainage orifice. The usual directives on how to avoid these complications in other filtrations procedures are also applicable to the MPGS with the Ex-PRESS™.

8.2.6.2 Specific to the Technique

Early postoperative high IOP: At the end of the operation it is recommended to fill the A/C with viscoelastic material. Overfilling of the A/C might result in high IOP on day one. It is recommended to fill only one-third of the A/C with standard viscosity viscoelastic material when the P model is used. When the X50 and X200 models are used, it is recommended to fill two-thirds of the A/C with standard viscosity viscoelastic material. The larger lumen and/or square body of the X models allow more drainage, and hence there is a greater risk of early postoperative hypotony. The surgeon can vary these amounts at his discretion according to his personal technique.

A preexisting side port at the temporal limbus created during the original surgery can be of use when the IOP is ≥ 22 mmHg on day one. The A/C can be decompressed under local anesthesia using a 25-gauge needle with the slit lamp. This simple maneuver lowers the IOP immediately and avoids the use of hypotonic agents.

Early postoperative hypotony, loss of A/C depth, and choroidal detachment: A large, securely sutured scleral flap is the best way to prevent early postoperative overfiltration in MPGS with the Ex-PRESS™. A preexisting side port at the temporal limbus created during the original surgery can be of use when the A/C is dangerously shallow and implant iris touch occurs. The A/C can be reformed by injecting viscoelastic material into the A/C under local anesthesia. This maneuver can be performed with the slit lamp if the patient is cooperative and when the surgeon is familiar with the procedure. Mild cases of hypotony or shallow A/C can be treated in the same manner as in the classic filtration procedures, i.e., pressure bandage or double padding.

Implant iris touch: A preincision that is not parallel to the iris can result in iris implant touch. When the implant indents the iris aggressively, especially in phakic cases, it is recommended that the Ex-PRESS™ implant is repositioned in the theatre. This requires removing the implant and making a new preincision adjacent to the original one, and reinserting the

Ex-PRESS™. Removing the Ex-PRESS™ implant is done by holding its plate, twisting it so its spur is positioned horizontally and then retrieving it by enlarging the wound with a 15° superblade to allow enough room for the passage of the spur.

Early subconjunctival fibrosis: The manufacturers suggest using MMC in every case to prevent early conjunctival fibrosis and failure of the drainage operation. This is particularly true for patients with failed previous glaucoma surgery and/or for patients who were treated with maximal medical therapy over long periods [9, 10, 13, 21, 23, 29, 31]. Further reports on the comparison between trabeculectomy and MPGS with Ex-PRESS™ will shed light on the fibrosis and filtration failure.

Conjunctiva and scleral flap erosion: True scleral flap erosion over the device plate has not yet been reported in the literature but it cannot be ruled out as a serious potential complication. This complication can occur when the scleral flap is too thin or when conjunctival and scleral tissue melting occurs as a late complication.

8.2.6.3 Several Characteristics of the Ex-PRESS™ Are Unique

- a. It is made of metallic material. At present most, if not all, of the widely used glaucoma shunts are made of acrylic material and silicone rubber. The introduction of metal as a biocompatible material in glaucoma surgery is quite new [4]. It initially caused resistance and rejection amongst many ophthalmologists who could not accept the idea of a metallic foreign body in the eye because of associations with accidental iron foreign bodies. Because it is made of medical-grade stainless steel (316L) that is identical to cardiac stents widely used worldwide, its biocompatibility and safety are practically beyond doubt. At present, the Ex-PRESS™ has been used in humans for more than 9 years with number reaching 30,000. FDA approval for use in ophthalmology in humans was granted in 2002. Very few reports on severe complications were published in the literature [2, 5, 6, 9]. All these complications occurred during the early period of initial use when the Ex-PRESS™ was implanted under the conjunctiva. Since the method of implantation was changed to under a scleral flap there have not been reports of

serious complications in the literature. In terms of toxicity of the material no adverse reports have been published yet. On the contrary, many first-time users report on the quietness of the eye on day one, postoperatively. Sherwood et al. have reported on the molecular biology reasons for this phenomenon in a rabbit model [36]. Longer-term follow-up will further clarify the biocompatibility and the safety of the material.

Glaukos and Solx are metallic glaucoma shunts in development. They appeared several years after the Ex-PRESS™. These new devices are in the experimental phases of development and they have not yet been approved by the FDA for unrestricted use in the USA.

- b. The Ex-PRESS™ is unique because of its miniature size. Prior to the appearance of the Ex-PRESS™, no other glaucoma shunt could offer an external diameter of 0.4 mm and a lumen as narrow as 50 µm. Its miniature size allows minimal surgical trauma and a restricted outflow of aqueous for added safety. Both these characteristics add to the safety of the device.
- c. The Ex-PRESS™ is versatile and allows variations in surgical techniques. Once it is agreed that the Ex-PRESS™ should be implanted under a scleral flap, the surgeon can choose his preferences in terms of scleral flap shape and size. Large volume users of Ex-PRESS™ report on different surgical methods with very similar end results [10–13, 18–27, 29–36]. North American surgeons prefer small size scleral flap (3–4 mm) whereas their Europeans and South African colleagues prefer a larger scleral flap (5 mm). Some proponents of the NPGS add a simplified deep sclerectomy under the superficial scleral flap when they use the Ex-PRESS™. MMC concentration and site of application differ from surgeon to surgeon. All these variations do not seem to affect the positive approach for the use of the Ex-PRESS™.

Most first time users continue to use the Ex-PRESS™ with increasing frequency. Any surgeon, who is familiar with trabeculectomies, when properly assisted during the first implantation, continues to use the Ex-PRESS™ because of its superiority to trabeculectomies and NPGS. Since the commercialization of the Ex-PRESS™, its sales have augmented exponentially in the USA, the European Union, and South Africa.

In terms of its primary goal, the Ex-PRESS™ has achieved its target: It has simplified glaucoma surgery and made it accessible to the general ophthalmologist. Its additional achievement was discovered by glaucoma specialist surgeons. Experienced glaucoma surgeons who have embraced the Ex-PRESS™ have widened its applications to complicated cases as well. Mermoud, Dahan, Moster, and Netland are refining surgical techniques with the use of the Ex-PRESS™ that can be applied to cases that have had multiple previous filtering surgeries.

8.2.6.4 Summary and Key Points

The Ex-PRESS™ glaucoma implant is a miniature stainless steel device that offers a straightforward and safe alternative to the classic trabeculectomy. MPGS with the Ex-PRESS™ can be perceived as a standardized and simplified trabeculectomy because of the predetermined size of the implant lumen. The rate of postoperative complications is lower than with trabeculectomy [13, 25, 30]. It does not require removal of scleral tissue or iridectomy; hence the appearance of a quiet A/C on day one, postoperatively. MPGS with the Ex-PRESS™ mimics NPGS because it allows a restricted flow of aqueous from the A/C to the sub-scleral and subconjunctival spaces. MPGS is shorter to perform and has a shorter learning curve than NPGS. Surgeons who are familiar with trabeculectomy or with NPGS can easily convert their filtering operations to MPGS with the Ex-PRESS™.

References

1. Gandolfi S, Traverso CF, Bron A et al (2002) Short-term results of a miniature draining implant for glaucoma in combined surgery with phacoemulsification. *Acta Ophthalmol Scand Suppl* 236:66
2. Garg SJ, Kanitkar K, Weichel E et al (2005) Trauma-induced extrusion of an Ex-PRESS™ glaucoma shunt presenting as an intraocular foreign body. *Arch Ophthalmol* 123: 1270–1272
3. Kaplan-Messas A, Traverso C, Glovinsky Y et al (2001) The Ex-PRESS™ miniature glaucoma implant: intermediate results of a prospective multi-center study. *Invest Ophthalmol Vis Sci* 42: S55
4. Nyska A, Glovinsky Y, Belkin M et al (2003). Biocompatibility of the Ex-PRESS™ miniature glaucoma drainage implant. *J Glaucoma* 12:275–280

5. Stewart RM, Diamond JG, Ashmore ED et al (2005) Complications following Ex-PRESSTM glaucoma shunt implantation. *Am J Ophthalmol* 140:340–341
6. Tavalato M, Babighian S, Galan A (2006) Spontaneous extrusion of a stainless steel glaucoma drainage implant (Ex-PRESSTM). *Eur J Ophthalmol* 16:753–755
7. Traverso C, De Feo F, Messas-Kaplan A et al (2005) Long term effect on IOP of a stainless steel glaucoma drainage implant (Ex-PRESSTM) in combined surgery with phacemulsification. *Br J Ophthalmol* 89:425–429
8. Verbraak FD, De Bruin DM, Sulak M et al (2005) Optical coherence tomography of the Ex-PRESSTM miniature glaucoma implant. *Lasers Med Sci* 20:41–44
9. Wamsley S, Moster MR., Rai S et al (2004) Results of the use of the Ex-PRESSTM miniature glaucoma implant in technically challenging, advanced glaucoma cases: a clinical pilot study. *Am J Ophthalmology* 138:1049–1051
10. Dahan E, Carmichael TR (2005) Implantation of a miniature glaucoma device under a scleral flap. *J Glaucoma* 14:98–102
11. Mermoud A. Ex-PRESSTM implant – fast, simple, safe, efficient? *Br J Ophthalmol* 89:396–397
12. Schwartz KS, Richard K. et al (2006) Glaucoma drainage implants: a critical comparison of types. *Curr Opin Ophthalmology* 17:181–189
13. De Jong LA (2005) Ex-PRESSTM positioned under a scleral flap, trabeculectomy and Ex-PRESSTM positioned under conjunctiva in patients with open angle glaucoma. A prospective comparison randomized 3-arms study. *Invest Ophthalmol Vis Sci* 46:E-Abstract 68
14. Baudouin C, Pisella PJ, Fillacier K et al (1999) Ocular surface inflammatory changes induced by topical antiglaucoma drugs: human and animal studies. *Ophthalmology* 106:556–563
15. Broadway DC, Chang LP (2001) Trabeculectomy, risk factors for failure and the preoperative state of the conjunctiva. *J Glaucoma* 10:237–249
16. Broadway DC, Grierson I, O'Brien C et al (1994) Adverse effects of topical antiglaucoma medications I – the conjunctival cell profile. *Arch Ophthalmol* 112:1437–1445
17. Broadway DC, Grierson I, O'Brien C et al (1994) Adverse effects of topical antiglaucoma medications II – the outcome of filtration surgery. *Arch Ophthalmol* 112:1446–1454
18. Carmichael TR, Dahan E (2007) Functional filtration with minimal bleb formation using express miniature glaucoma device under a scleral flap. *Invest Ophthalmol Vis Sci* 48:E-Abstract 821
19. Coupin A, Li Q, Risse I (2007) Ex-PRESSTM miniature glaucoma implant inserted under a scleral flap in open glaucoma surgery: a retrospective study. *J Fr Ophtalmologie* 30:18–23
20. Dahan E, Ben-Hur M (2006) Performance of two different versions of the Ex-PRESSTM mini-shunt under a scleral flap in open angle glaucoma patients. *Invest Ophthalmol Vis Sci* 47:E-Abstract 22
21. Dahan E, Carmichael TR (2005) The surgical treatment of neovascular glaucoma with a 200 micron miniature glaucoma shunt. *Invest Ophthalmol Vis Sci* 46:E-Abstract 77
22. De Feo F, Bagnis A, Bricola G et al (2006) Efficacy and safety of a stainless steel glaucoma drainage device implanted under a scleral flap. *Invest Ophthalmol Vis Sci* 47:E-Abstract 25
23. De Feo F, Papadia M, Bricola G et al (2005) Long term efficacy and safety of a stainless steel glaucoma drainage implant (Ex-PRESSTM). *Invest Ophthalmol Vis Sci* 46:E-Abstract 72
24. De Feo F, Roccatagliata L, Bonzano L et al (2007) Artefacts of magnetic resonance imaging in patients implanted with a stainless steel glaucoma drainage micro-device. *Invest Ophthalmol Vis Sci* 48:E-Abstract 483
25. De Jong LA (2006) Ex-PRESSTM mini shunt under scleral flap compared to standard trabeculectomy. *Invest Ophthalmol Vis Sci* 47:E-Abstract 3544
26. Evangelista JA, Johnson DL, Trespalacios R et al (2006) Ex-PRESSTM shunt under a scleral flap for neovascular glaucoma. *Invest Ophthalmol Vis Sci* 47:E-Abstract 24
27. Johnson D, Bair C, Evangelista J et al (2006) Ex-PRESSTM shunt under a scleral flap as primary surgical treatment for open angle glaucomas. *Invest Ophthalmol Vis Sci* 47:E-Abstract 23
28. Lavin MJ, Worvald RFL, Migdal CS et al (1990) The influence of prior therapy on the success of trabeculectomy. *Arch Ophthalmol* 108:1543–1548
29. Lopes JF, Moster MR, Wamsley S et al (2005) Ex-PRESS shunt implantation with scleral flap technique for complicated glaucoma. *Invest Ophthalmol Vis Sci* 46:E-Abstract 70
30. Maris PJ, Ishida K, Netland PK (2007) Comparison of trabeculectomy with Ex-PRESSTM miniature glaucoma device implanted under a scleral flap. *J Glaucoma* 16:14–19
31. Maris PJ, Smith ME, Netland PA (2005) Clinical outcomes with the Ex-PRESSTM miniature glaucoma implant. *Invest Ophthalmol Vis Sci* 46:E-Abstract 71
32. Netland PA, Sarkisian SR Jr, Kanner EM et al (2007) Consecutive case series of the Ex-PRESSTM miniature glaucoma device implanted under a scleral flap. *Invest Ophthalmol Vis Sci* 48:E-Abstract 819
33. Pourmaras JAC, Mermoud A (2007) Safety and efficacy of the new optonol microtube (DS Version) combined with modified deep sclerectomy in POAG patients: preliminary results. *Invest Ophthalmol Vis Sci* 48:E-Abstract 818
34. Reis R, Lankaranian D, Ramos-Esteban JC et al (2006) Intermediate-term results of Ex-PRESSTM miniature glaucoma implant under scleral flap. *Invest Ophthalmol Vis Sci* 47:E-Abstract 50
35. Roy S, Bissig A, Broquet J et al (2007) Deep sclerectomy with the Ex-PRESSTM X-200 implant for the surgical treatment of refractory glaucomas. *Invest Ophthalmol Vis Sci* 48:E-Abstract 816
36. Sampson EM, Esson DW, Schultz GS et al. (2005) Expression of transforming growth factor β 2 following sclerostomy and Ex-PRESSTM R50 glaucoma drainage implant under a scleral flap in a rabbit model. *Invest Ophthalmol Vis Sci* 46:E-Abstract 52

8.3 New Minimally Invasive, Sclerotherlamotomy Ab Interno Surgical Technique

8.3.1 Introduction to the Sclerotherlamotomy Ab Interno

Trabeculectomy, first described in the 1960s [1–3], was the surgical procedure of choice for glaucoma till recently. The original intention of trabeculectomy was to the bypass the resistance of the trabecular meshwork by channeling aqueous humor directly to the Schlemm's canal. It soon became evident that successful reduction in IOP following trabeculectomy was clearly related to the presence of a subconjunctival filtering bleb [4]. Despite initial success, there was a progressive rate of failure of trabeculectomy due to subconjunctival fibrosis in the filtering bleb in most cases. Trabeculectomy was also associated with serious vision-threatening complications like postoperative choroidal effusions and hemorrhage, delayed bleb leaks, and bleb-related infections including endophthalmitis. These complications were seen more frequently when wound-healing agents like 5-fluorouracil (5-FU) and MMC were used.

The concept of trabecular meshwork bypass as a surgical principle for glaucoma treatment evolved from the discovery that pathologic outflow resistance was caused primarily by the juxtacanalicular trabecular meshwork and, in particular, by the inner wall of the Schlemm's canal [5, 6]. A further study showed that 35% of the outflow resistance arises distally to the inner wall of the Schlemm's canal [7].

The more recent methods of nonpenetrating deep sclerectomy and viscocanalostomy, first described by Fjodorov [8] and Stegmann [9], respectively, attempted at improving uveoscleral outflow and were therefore not considered depending on the presence of a filtering bleb. In 1976, Benedikt [10] described a surgical technique for glaucoma in which the ciliary body was exposed (i.e., a form of penetrating sclerectomy). He successfully reported long-term IOP regulation in 27 of 38 cases (63.2%) involving hemorrhagic, aphakic, and irreversible angle-closure glaucoma after initially failed filtering surgery. This technique was the basis for the later development of perforating deep sclerectomy by the authors of this study. This technique used

since 1985 was termed *sclerotherlamectomy* [11]. Spiegel et al. [12] have described a new surgical technique involving the use of an implanted tube, the trabecular meshwork bypass tube shunt, which should provide a direct connection between Schlemm's canal and the anterior chamber. This surgical technique avoids the technical difficulties related to the nonpenetrating surgical procedures. Sclerotherlamotomy ab interno evolved from sclerotherlamectomy, and this subchapter will explain the surgical technique and comment on the results of this technique used to control IOP in glaucoma patients.

8.3.1.1 Indications for the Sclerotherlamotomy Ab Interno

The main indication for the sclerotherlamotomy ab interno procedure is insufficient response to medical treatment of IOP. Patients with primary open-angle glaucoma and juvenile glaucoma are good candidates for such a procedure.

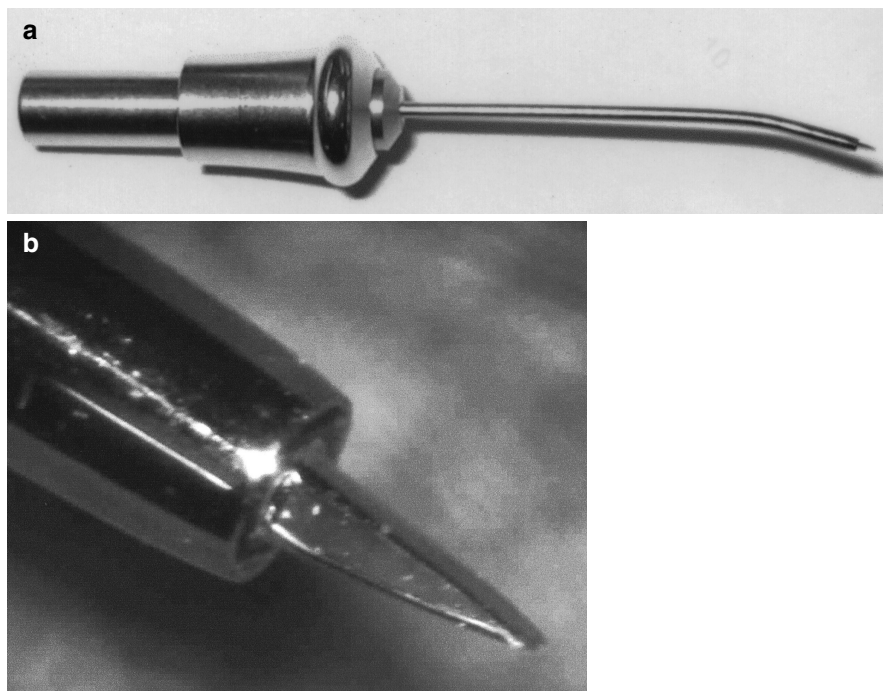
8.3.2 Anesthesia

This procedure can usually be performed under local anesthesia. Nonetheless, for anxious or uncooperative patients, or for those unable to stay calm, general anesthesia is preferred. In most cases, a local procedure provides enough relaxation and analgesia to ensure safe and precise surgery. Sub-tenon anesthesia is the procedure of choice as it provides excellent analgesia as well as akinesia. Subconjunctival or topical anesthesia can be considered in cooperative patients.

8.3.3 Surgical Technique

The aim of this technique is to create a new space, a sort of cavity, in the sclera by performing a deep sclerotomy ab interno. The so-called sclera thalami are made using a diathermy probe inserted in the anterior chamber. The sclerotherlamotomy ab interno is performed under gonioscopic view using a gonioscopy lens. The main advantage of this technique is that the anterior chamber

Fig. 8.39 (a, b) STT glaucoma tip (Oertli Reference VE 201750)



is not penetrated; only a paracentesis is made to insert the probe. The IOP is gently lowered after the trabecular meshwork and Schlemm's canal are locally removed by the diathermy probe. Aqueous humor is then collected through intrascleral drainage pathways draining into episcleral veins, similar to one of the routes proposed for deep sclerectomy.

8.3.3.1 Preparation

A clear cornea incision (1.2 mm wide) is placed in the temporal upper quadrant using a diamond knife. A second corneal incision is performed 120° apart from the first followed by any injection of Healon GV™. The high-frequency diathermy probe (Oertli, Switzerland) consists of an inner platinum electrode which is isolated from the outer coaxial electrode. The platinum probe tip is 1 mm in length, 0.3 mm high, and 0.6 mm in width and is bent posteriorly at an angle of 15° (Fig. 8.39a, b). The external diameter of the probe measures 0.9 mm. The modulated 500 kHz current generates a temperature of approximately 130°C at the tip of the probe. The setup provides high-frequency power dissipation in the vicinity of the tip. As a result, heating of tissue is locally very limited and is applied as a rotated ellipsoid.

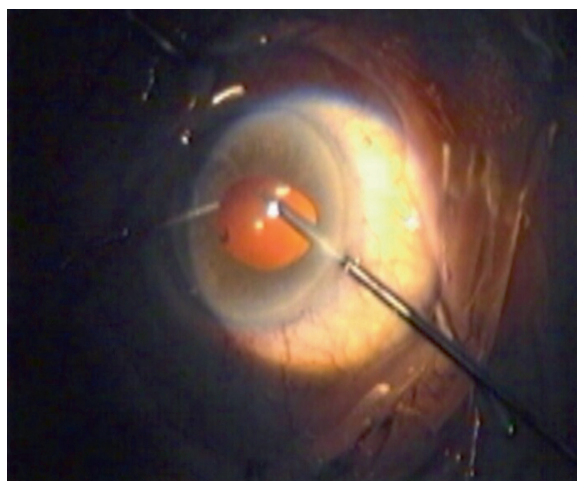


Fig. 8.40 Insertion of the high-frequency diathermy probe (Oertli) through the temporal corneal incision

8.3.3.2 Diathermy Probe Insertion

The high-frequency diathermy probe is inserted through the temporal corneal incision (Fig. 8.40). Visual inspection of the target zone (opposite irido-corneal angle) is observed by a four-mirror gonioscopic lens (Fig. 8.41). The high-frequency tip penetrates up to 1 mm nasal into the sclera through the

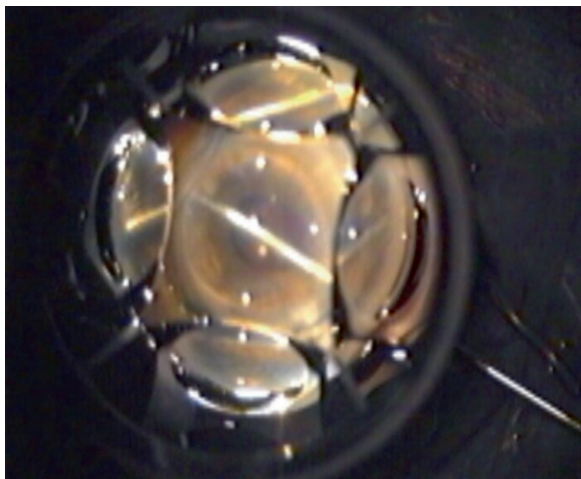


Fig. 8.41 Visual inspection of the target zone (opposite irido-corneal angle) by a four-mirror gonioscopic lens

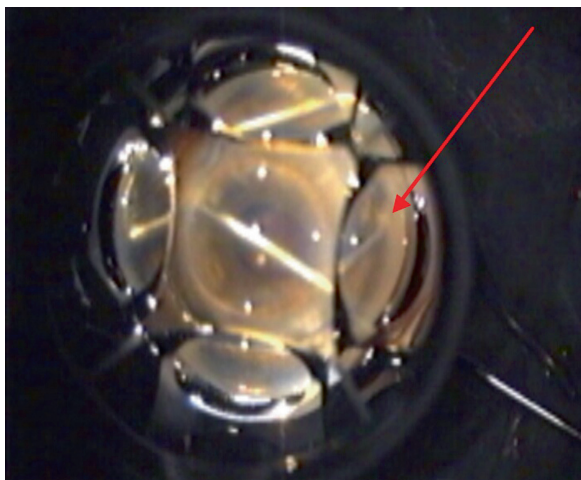


Fig. 8.42 Penetration of the high-frequency tip

trabecular meshwork and Schlemm's canal, forming a deep sclerotomy (i.e., "thalami") 0.3 mm high and 0.6 mm wide (Figs. 8.42 and 8.43). This procedure is repeated four times within one quadrant. Healon GV is evacuated from the anterior chamber with bimanual irrigation/aspiration (Fig. 8.44).

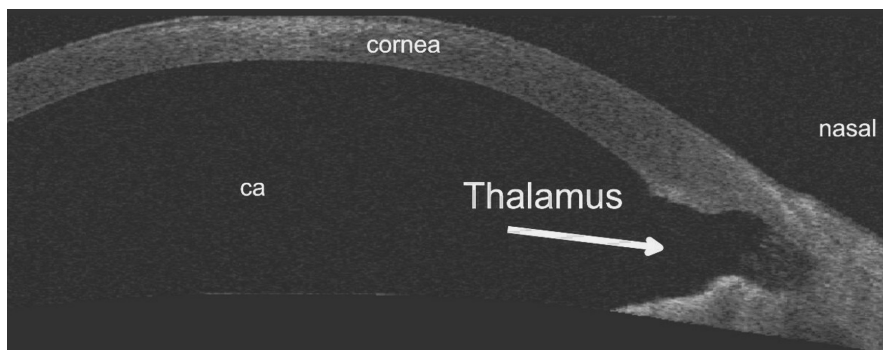
8.3.4 Postoperative Management and Medication

Postoperative treatments include topical antibiotics and corticosteroids three times a day for a month and topical 2% pilocarpin three times a day for 10 days. The corticosteroids should be tapered after a few weeks to prevent steroid-induced ocular hypertension. Depending on the clinical assessment they can be followed by non-steroidal inflammatory drugs, three times a day for 2–3 months after surgery.

8.3.5 Outcomes and Comparison with Other Techniques

This technique has been performed on patients suffering from open-angle glaucoma (53 eyes) or juvenile glaucoma (5 eyes). The mean age was 72.3 (± 12.3) years [mean (\pm SD)] for the open-angle glaucoma and 9 (± 1.4) years for the juvenile glaucoma. For all patients the follow-up was 72 months. The mean pre-operative IOP was 25.6 (± 2.3 mmHg) (range 18–48 mmHg) for patients with primary open-angle glaucoma and 39.6 ± 2.3 mmHg (range 34–46 mmHg) for patients with juvenile glaucoma. Mean IOP after

Fig. 8.43 Penetration up to 1 mm nasal into the sclera through the trabecular meshwork and Schlemm's canal



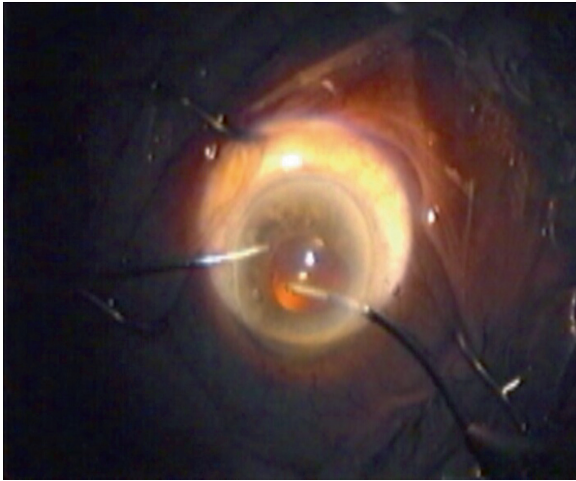


Fig. 8.44 Healon GV® was evacuated from the anterior chamber with bimanual irrigation/aspiration

72 months was 14.7 ± 1.8 mmHg (range 10–21 mmHg) for primary open-angle glaucoma and 13.2 ± 1.3 mmHg (range 12–15 mmHg) for juvenile glaucoma (Figs. 8.45 and 8.46). After 72 months 77% of treated patients in the open-angle glaucoma group achieved >30% reductions of the IOP, whereas 100% of treated patients with juvenile glaucoma achieved >30% reductions of the IOP. The complete success rate, defined as an IOP lower than 21 mmHg without medication, was 79.2% in the group of open-angle glaucoma group and 80% in the juvenile glaucoma group at 72 months.

The average preoperative administration of pressure-reducing eye agents was $2.6 (\pm 1.0)$ for the open-angle

glaucoma group and $3.0 (\pm 1.2)$ for the juvenile glaucoma group. After surgery, this value decreased to $0.51 (\pm 0.97)$ for open-angle glaucoma group (Fig. 8.47) and $0.2 (\pm 0.44)$ for the juvenile glaucoma group at 72 months.

8.3.6 Complications and Management

8.3.6.1 General

This surgery is quite a safe and efficient technique with few postoperative complications. As for any filtering procedure some complications can occur and these can be rapidly identified and handled to reduce the extent of such mishaps. For instance, immediate postoperative hypotony, shallow A/C, hyphema, and choroidal detachment may be present, although to a lesser degree due to the intrinsic properties of the small drainage orifice made by the diathermy probe. The usual directives on how to avoid these complications in other filtrations procedures are also applicable to the sclerostomy ab interno.

8.3.6.2 Specific to the Technique

Temporary IOP elevation higher than 21 mmHg can be observed. In the above-mentioned trial about 22.6% of all cases encountered such a complication. These patients responded well to pressure-reducing treatment with one agent and medication could gradually be withdrawn

Fig. 8.45 Average level of intraocular pressure after sclerostomy ab interno surgery for all 53 cases with open-angle glaucoma

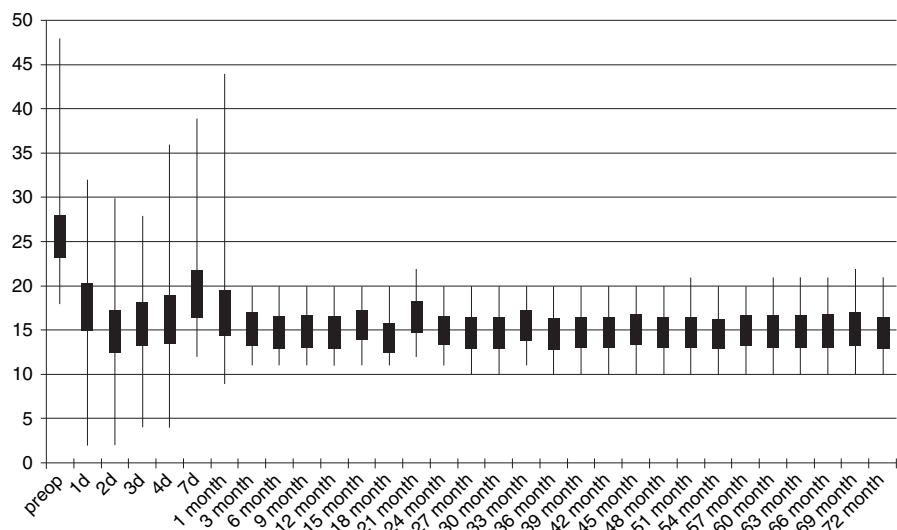


Fig. 8.46 Average level of intraocular pressure after sclerostomy ab interno surgery for all five cases with juvenile glaucoma

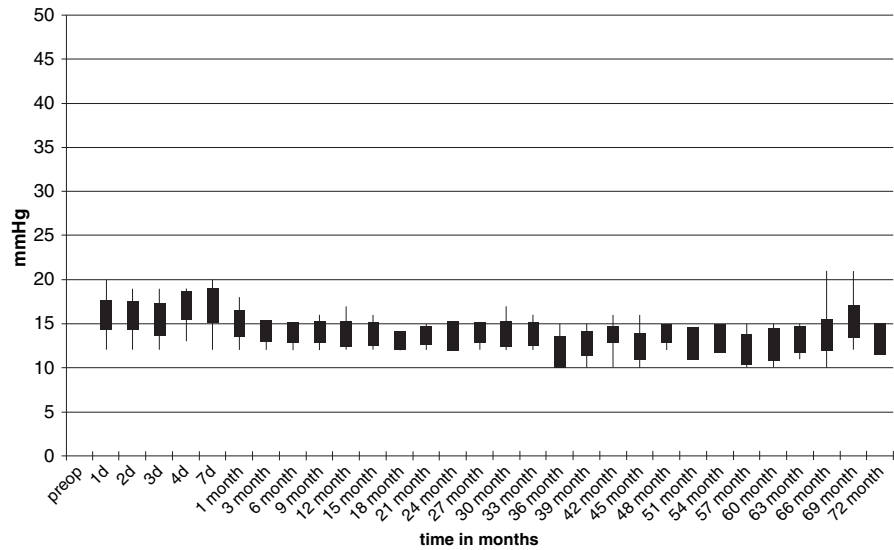
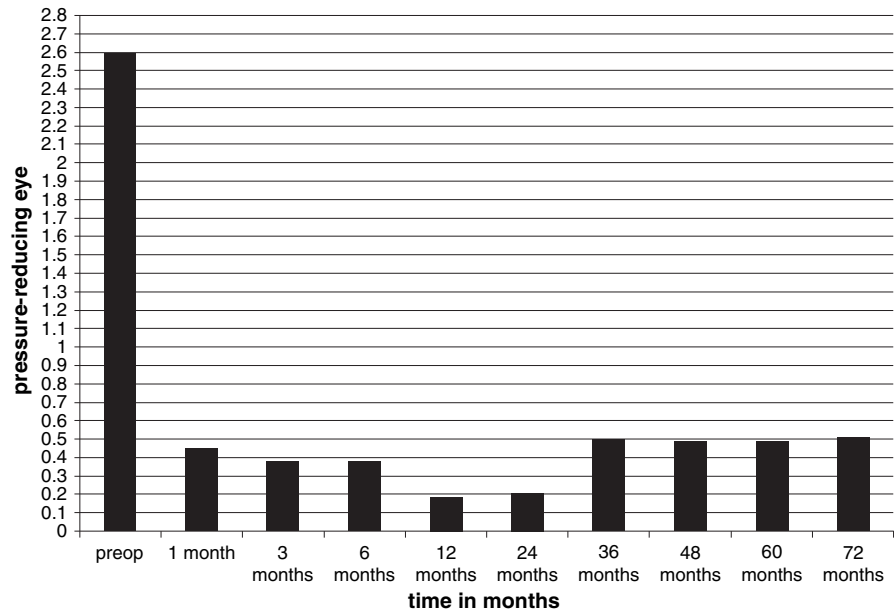


Fig. 8.47 Administration of pressure-reducing eye agents during 72 months for the open-angle glaucoma group



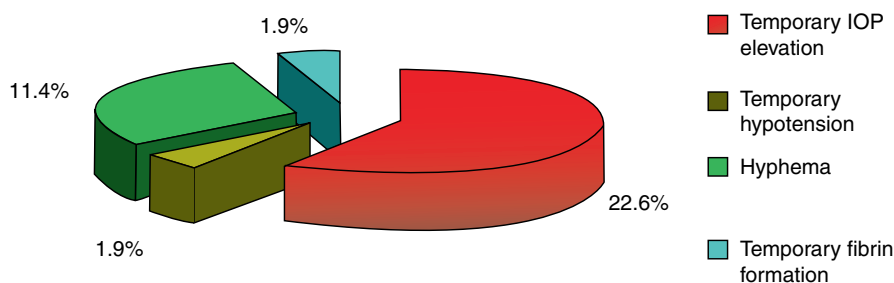
in all of these patients. Conversely, hypotension may be present that can last for a few days after surgery.

The trabecular meshwork and Schlemm's canal are removed with the high-frequency diathermy probe. Despite the automatic cautery provided by the diathermy probe, it is possible that some small vessels from the iris vascular circle may be affected. Some hemorrhage will result from such insult. Mild hyphema can be observed for a few days after surgery which disappears within the first 2 weeks after the procedure. Similarly the pooling of blood in the anterior chamber

can trigger transient fibrin formation (Fig. 8.48). Fibrin can be cleared within 1 day after frequent application of topical corticosteroids.

Transient IOP elevation after sclerostomy ab interno may occur in the first 6 weeks and can be effectively brought under control with the use of a topical antiglaucoma medication. In most of the cases, this therapy can be gradually withdrawn after 3 weeks postsurgery. It is believed that moderate tissue swelling around the thalami could be the reason for transient postoperative IOP peaks.

Fig. 8.48 Complications after sclerosthamotomy ab interno surgery for the open-angle glaucoma group



To be efficient the high-frequency diathermy creates a thermal energy in the tissues surrounding the probe whereas the temperature at the tip can easily reach 130°C. While the temperature is focused on a small area, we cannot rule out that some of this thermal energy may spread to the surrounding tissues. We cannot rule out that some of this thermal energy may affect the metabolism of the lens. Some degree of cataract development after sclerosthamotomy ab interno have been reported and some cases have resulted in a decrease in the visual acuity.

8.3.6.3 Conclusions

Sclerosthamotomy ab interno is a new surgical technique for treating open-angle glaucoma and juvenile glaucoma. This ab interno method creates a direct channel between the anterior chamber and the outer portion of Schlemm's canal. Persistence of the sclerotomy can be investigated with a three-mirror gonioscopy. Sclerosthamotomy ab interno creates a deep sclerotomy with subsequent access of aqueous to the scleral layer. Both aspects may facilitate a bypass effect of aqueous outflow. In light of the fact that about 85% of the aqueous humor drains through the trabecular meshwork, we suspect there is an additional route for aqueous humor absorption in the case of elevated IOP. There is evidence in the literature that such bypass effects which do not lead to the formation of filtering blebs may be present after surgical intervention. In a previous study [11], it was ascertained that eyes without filter bleb exhibited very stable long-term IOP regulation postoperatively. In addition to the bypassing of trabecular outflow resistance caused by sclerosthamotomy ab interno treatment, outflow resistance may be further reduced by scleral thinning at the base of the thalamus. In addition, aqueous humor could perhaps be absorbed by the ciliary body [11, 13]. After early postoperative

reduction, the average IOP continues to decline gradually over a period of 6 months before reaching a relatively constant level. It can be speculated that newly formed blood vessels and lymph vessels close to the surgical site, may contribute to the decrease of IOP level during follow-up [10].

In the literature, the success rate for trabeculectomy ranges between 57 and 96% [2, 14–26], for deep sclerectomy without collagen device between 57 and 74%, and for deep sclerectomy with collagen device between 58 and 90% [14, 27–29]. The sclerosthamotomy ab interno technique with a complete success rate of 90.6% after 24-month follow-up [30], 83% after 48 months and 79.2% after 72 months for open-angle glaucoma is comparable with other so far published surgery methods. The complete success rate for juvenile glaucoma after 48-month follow-up is 80%.

Advantages of the sclerosthamotomy ab interno method, compared with trabeculectomy and perforating and nonperforating deep sclerectomy seem to be the low rate of postoperative complications and a constant level of reduced IOP. Hypotension, a frequent finding in trabeculectomy, perforating deep sclerectomy, and nonperforating deep sclerectomy, is a relatively rare postoperative complication. The most frequent early complications in trabeculectomy are hyphema (24.6%), shallow anterior chamber (23.9%), hypotony (24.3%), wound leak (17.8%), and choroidal detachment (14.1%). The most frequent late complications are cataract (20.2%), visual loss (18.8%), iris incarceration (5.1%), and encapsulated bleb (3.4%). After sclerosthamotomy ab interno cataract development was seen in 17% with only 5.7% loss of one line of visual acuity after 72 months for open-angle glaucoma. Compared with other techniques sclerosthamotomy ab interno seems to be a relatively safe surgical technique [14, 17, 27, 28, 31–33].

Transient IOP elevation after sclerosthamotomy ab interno may occur in the first 6 weeks and can be

effectively brought under control with the use of a topical medication. In most cases, IOP-reducing therapy can be gradually withdrawn after 3 weeks post surgery. The moderate tissue swelling round the thalamus observed in vitro could be the reason for transient postoperative IOP peaks. Preliminary histological investigations of two post mortem human eyes following sclerotherlamotomy ab interno did not indicate signs of indirect necrosis in cell layers adjacent to the thalamus formed by high-frequency diathermy. It is as yet not clear if the inner surface of the thalamus will be covered by endothelial cells of corneal or trabecular origin, and whether the thalamus and its function will remain intact on a much longer timescale.

Advantages of sclerotherlamotomy ab interno include the comparative simplicity and quickness of the surgical procedure itself. The technique also avoids stimulation of episcleral and conjunctival tissues as in trabeculectomy and conventional nonpenetrating surgery. In the example presented in this section, diathermy was used to create four thalami and this corresponds to a resorption surface area of 2.4 mm². The number of thalami chosen was arbitrary and seemed to provide a sufficient long-term decrease of IOP as a low rate of postoperative complications. There is potential for a further IOP drop if six applications are made. Further investigations will be performed to support this hypothesis. Further studies will be conducted to compare sclerotherlamotomy ab interno, trabeculectomy, and deep sclerectomy for the surgical treatment of primary open-angle glaucoma.

References

- Burian HM (1960) A case of Marfan's syndrome with bilateral glaucoma. With a description of new type of operation for developmental glaucoma (trabeculectomy ab externo). *Am J Ophthalmol* 50:1187–1192
- Fronimopoulos J, Lambrou N, Pelekis N et al (1970) Elliot's trepanation with scleral cover (procedure for protecting the fistula in Elliot's trepanation with a lamellar scleral cover). *Klein Monatsbl Augenheilkd* 156:1–8
- Starita RJ, Fellmann RL, Spaeth GL et al (1985) Short- and long-term effects of postoperative corticosteroids on trabeculectomy. *Ophthalmology* 92:938–946
- Schwartz AL, Anderson DR (1974) Trabecular surgery. *Arch Ophthalmol* 92:134–138
- Grant WM (1963) Experimental aqueous perfusion in enucleated human eyes. *Arch Ophthalmol* 69:738–801
- Johnson DH, Johnson M (2001) How does nonpenetrating glaucoma surgery work? Aqueous outflow resistance and glaucoma surgery. *J Glaucoma* 10:55–67
- Schuman JS, Chang W, Wang N et al (1999) Excimer laser effects on outflow facility and outflow pathway morphology. *Invest Ophthalmol Vis Sci* 40:1676–1680
- Fjodorov SN, Loffe DI, Ronkina TI (1984) Deep sclerectomy: technique and mechanism of new glaucomatous procedure. *Glaucoma* 6:281–283
- Stegmann R, Pienaar A, Miller D (1999) Viscocanalostomy for open-angle glaucoma in black African patients. *J Cataract Refract Surg* 25:316–322
- Benedikt O, Hiti H (1976) Die Ziliarkörperfreilegung. Eine neue Operationsmethode zur Behandlung des irreversiblen Winkelblockglaukoms und des Aphakieglaukoms. *Klein Monatsbl Augenheilkd* 169:711–716
- Pallas G, Pajic B (2000) Die Sklerotherlamiektomie (STE): stabile postoperative Augendruckregulierung beim Offenwinkel- und Kapselhäutchenglaukom. *Klein Monatsbl Augenheilkd* 216:256–260
- Spiegel D, Kobuch K (2002) Trabecular meshwork bypass tube shunt: initial case series. *Br J Ophthalmol* 86:1228–1231
- Schwenn O, Dick B, Pfeiffer N (1998) Trabekulotomie, tiefe Sklerektomie und Viskokanalostomie. *Ophthalmologie* 95: 835–843
- Akafo SK, Goulstine DB (1990) Long-term post trabeculectomy intraocular pressure. *Acta Ophthalmologica* 70: 312–316
- Cairns JE (1968) Trabeculectomy. Preliminary report of a new method. *Am J Ophthalmol* 66:673–679
- Mermoud A, Salmon JF, Barron A et al (1993) Surgical management of posttraumatic angle recession glaucoma. *Ophthalmology* 100:634–642
- Mills KB (1981) Trabeculectomy: a retrospective long-term follow-up of 444 cases. *Br J Ophthalmol* 65:790–795
- Molteno ACB, Bosma NJ et al (1999) Otago glaucoma surgery outcome study. *Ophthalmology* 106:1742–1750
- Morell AJ, Searle AET, O'Neill EC (1992) Trabeculectomy as an introduction to intraocular surgery in an ophthalmic training program. *Ophthalmic Surg* 23:38–39
- Popovic V, Sjöstrand J (1991) Long-term outcome following trabeculectomy: visual field survival. *Acta Ophthalmologica* 69:305–309
- Roth SM, Spaeth G, Starita RJ et al (1991) The effects of postoperative corticosteroids on trabeculectomy and the clinical course of glaucoma: five-year follow-up study. *Ophthalmic Surg* 22:724–729
- Saiz A, Alcuaz A, Maquet JA et al (1990) Pressure-curve variations after trabeculectomy for chronic primary open-angle glaucoma. *Ophthalmic Surg* 21:799–801
- Tanihara H (1993) Surgical effects of trabeculectomy ab externo on adult eyes with primary open angle glaucoma and pseudoexfoliation syndrome. *Arch Ophthalmol* 111: 1653–1661
- Vernon SA, Spencer AF (1995) Intraocular pressure control following microtrabeculectomy. *Eye* 9:299–303
- Watson PG, Barnett F (1975) Effectiveness of trabeculectomy in glaucoma. *Am J Ophthalmol* 74:831–845
- Watson PG (1987) When to operate an open angle glaucoma. *Eye* 1:51–54
- Demailly P, Lavat P, Kretz G et al (1997) Non-penetrating deep sclerectomy with or without collagen device in primary open-angle glaucoma: middle-term retrospective study. *Int Ophthalmol* 20:131–140

28. Mermoud A, Schnyder CC, Sickenberg M et al (1999) Comparison of deep sclerotomy with collagen implant and trabeculectomy in open-angle glaucoma. *J Cataract Refract Surg* 25:323–331
29. Sanchez E, Schnyder CC, Sickenberg M et al (1997) Deep sclerectomy: results with and without collagen implant. *Int Ophthalmol* 20:157–162
30. Pajic B, Pallas G, Gerding H et al (2006) A novel technique of ab interno glaucoma surgery: follow-up results after 24 months. *Graefes Arch Clin Exp Ophthalmol* 244:22–27
31. Edmunds B, Thompson JR, Salmon JF et al (2002) The national survey of trabeculectomy. III. Early and late complications. *Eye* 16:297–303
32. El Sayyad F, Helal M, El-Kholify H et al (2000) Nonpenetrating deep sclerectomy versus trabeculectomy in bilateral primary open-angle glaucoma. *Ophthalmology* 107: 1671–1674
33. Konstans AGP, Jay JL, Marshall GE et al (1993) Prevalence, diagnostic feature, and response to trabeculectomy in exfoliation glaucoma. *Ophthalmology* 100: 619–627

8.4 Glaukos® iStent® Trabecular Micro-Bypass Implant

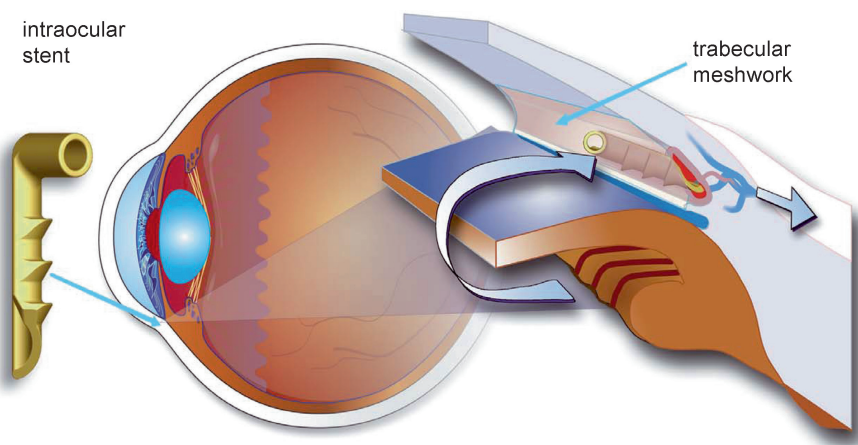
8.4.1 Introduction to Glaucoma Surgery with a Micro-Bypass Implant

In any field of medicine, the ideal surgery combines high effectiveness with a low rate of intraoperative and postoperative complications. In glaucoma, as in other subspecialties of ophthalmology, the search for new surgical techniques is never-ending. Given the impossibility of treating the optic nerve directly, the most commonly used surgical options try to establish communication between the anterior chamber and the subconjunctival space, either by removing part of the trabecular meshwork and thus decreasing resistance to the passage of the aqueous humor, or by means of drainage tubes that conduct the aqueous humor toward extraocular subconjunctival reservoirs. Although they achieve a high level of hypotensive effectiveness, these forms of surgery are not exempt from potential complications and are highly dependent on the inflammatory and healing response of the patient [1]. The use of antimetabolites to regulate this healing response is also linked to a higher rate of complications [2–7].

The Glaukos trabecular stent attempts to restore the physiology of the conventional drainage path of the aqueous humor through the trabecular meshwork and the Schlemm's canal, toward the collecting channels and the episcleral veins [1]. Grant demonstrated that the greatest resistance to drainage of the aqueous humor in glaucoma patients is located at the level of the trabecular meshwork and, more specifically, at the inner wall of the Schlemm's canal [1]. Once implanted, the trabecular stent allows direct communication between the anterior chamber and the Schlemm's canal, thus decreasing the resistance of the juxtacanalicular tissue to drainage of the aqueous humor. Bahler et al. demonstrated in cadaver eyes that the implantation of a trabecular stent increased the aqueous humor outflow facility by 84%, producing a decrease in IOP of 9 mmHg (21.4 ± 3.8 to 12.4 ± 4.2 mmHg) [8].

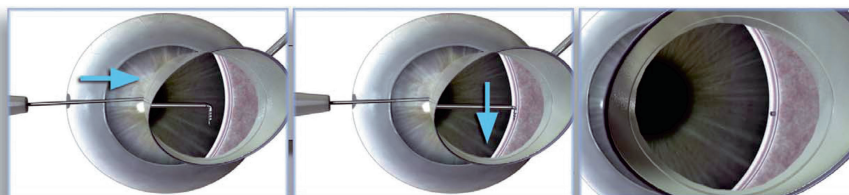
The Glaukos® iStent® trabecular micro-bypass is made of titanium and coated with a layer of heparin (DuraFlo® powder). It is L-shaped and measures 1×0.4 mm, with an external diameter of $180 \mu\text{m}$ designed to fit in the lumen of the Schlemm's canal (Fig. 8.49). The distal portion of the stent is bevelled and sharpened

Fig. 8.49 Artist's impression showing the intraocular stent Glaukos® iStent® (left) inserted into the trabecular meshwork (right)



surgical procedure

Fig. 8.50 Artist's impression showing the surgical procedure of inserting the implant in the irido-corneal angle, as viewed under a gonioscopic lens



to facilitate penetration into the tissue of the trabecular meshwork. The external surface features three retention bars that impede the movement of the stent once it has been implanted. The implant weighs approximately 0.1 mg. It is delivered preloaded on an insertion device and it is implanted at the level of the trabecular meshwork with the aid of a Swan–Jacob-type gonioscopes (Fig. 8.50) [9, 10].

8.4.1.1 Indications for Implantation of Glaukos® iStent® Micro-Bypass Implant

Type of Glaucoma

The indications for the trabecular stent are reduced to cases with primary open-angle, pigmentary, or pseudo-exfoliative glaucoma. In secondary open-angle glaucoma, this type of surgery may be indicated as long as the Schlemm's canal and collecting channels are found to be undamaged. In cases of glaucoma due to elevation of the episcleral venous pressure, the implantation of the trabecular stent is contraindicated.

The extraction of the lens in combination surgery can widen the angle and enable the surgery to be performed in cases with angles that are not very open, in which the trabecular meshwork was not initially accessible.

Stage of Glaucoma

The ideal candidate for this type of surgery is a patient with early or moderate stage glaucoma. Patients with advanced glaucoma or those who require very low target pressures to obtain stabilization of their disease are not suitable candidates for this type of surgery, given that the episcleral venous pressure restricts the pressure decrease obtained with the trabecular stent.

Combined Surgery

The coexistence of a surgical stage cataract means that combined surgery can be performed [11–13]. The implantation of the trabecular stent does not increase the surgery time excessively, nor does it modify the

postoperative course of isolated cataract surgery significantly. The extraction of the cataract makes it possible to increase the iridocorneal angle and facilitates the placement of the implants.

8.4.2 Anesthesia

In the case of phakic patients, the instillation of a miotic is recommended to minimize the risk of lens injury. If the procedure is carried out under topical anesthesia it is advisable to introduce lidocaine 1% into the anterior chamber, as some of the surgical maneuvers can be uncomfortable for the patient. It is perfectly possible to carry out the surgery under topical anesthesia with intracameral lidocaine; however, when performing the operation for the first few times, it may be advisable to use some form of locoregional anaesthetic (retrobulbar, peribulbar, or sub-Tenon).

8.4.3 Surgical Technique

The trabecular stent can be implanted by means of the same incision used for phacoemulsification in cases of combined surgery, or by means of a 1.5 mm incision, when the stent is implanted as an isolated operation. In any case, the corneal incision should be temporal in order to be able to implant the stent in the nasal region of the trabecular meshwork, where the number of collecting channels is greatest.

8.4.3.1 Preparation

Once the incision has been made in the temporal cornea, the anterior chamber must be filled with a cohesive viscoelastic that makes it possible to enlarge the region of the angle where the stent is to be implanted.

To perform this surgery, a perfect view of the trabecular meshwork must be achieved. The most common error when performing the operation for the first few times is failure to position the microscope and/or the patient properly to obtain an adequate view of the trabeculum. The patient's head must be inclined some 45° to the side opposite the eye to be operated on. For example, if we are operating on the right eye we will

ask the patient to turn his/her head to the left. Moreover, the microscope should be tilted by approximately 30°, as when performing a goniotomy. We check whether the position is correct by using the goniolens (Fig. 8.50).

Next, the applicator corresponding to the eye to be operated on must be selected, as there are implants for the right eye and implants for the left eye. The difference lies in the orientation of the bevel, designed to facilitate the penetration of the implant into the trabecular meshwork. The distal tip of the implant always should always point toward the patient's feet at all times.

8.4.3.2 Implantation of the Micro-Bypass Stent

The tip of the stent should approach the trabecular meshwork at an angle of 15° to facilitate penetration of the tissue. Excessive resistance indicates a path that is too perpendicular to the trabeculum. Once the trabecular meshwork covers all of the implant, it should be released by pressing the applicator button. Only the proximal end of the stent should remain visible in the anterior chamber. The stent can be seated in its final position by gently tapping the side of the snorkel with the inserter tip. The stent should be placed parallel to the plane of the iris with the inner part covered by the meshwork and the lumen away from the iris (Fig. 8.51). A small reflux of blood from the Schlemm's canal is common and reflects proper positioning of the stent.

Surgery concludes with the extraction of the viscoelastic material and the hydration of the corneal incision.

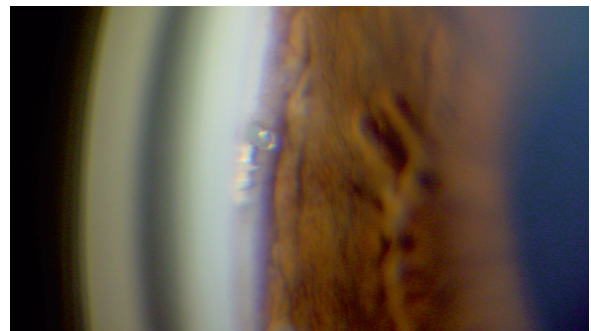


Fig. 8.51 Gonioscopic view of the Glaukos® iStent® inserted in the trabecular meshwork

8.4.4 Postoperative Management and Medication

Postoperative treatment should include a topical anti-biotic during the first week and topical corticosteroids for 4 weeks. These corticosteroids should be tapered after a few weeks to prevent steroid-induced ocular hypertension. They should be followed by nonsteroidal inflammatory drugs, three times a day, for at least 3 months after surgery.

8.4.5 Outcomes and Combination with Other Techniques

Experience with the trabecular stent is limited, although the results are encouraging, both from the point of view of the hypotensive effectiveness and with regard to the safety of the procedure and the biocompatibility of the device. The results are essentially from three clinical trials carried out over recent years, involving different groups of patients. The most relevant information from these three studies is as follows:

- Implantation of the trabecular stent in refractory glaucoma patients
- Phacoemulsification surgery combined with implantation of a trabecular stent [6]
- Comparative study of isolated cataract surgery vs. combination cataract surgery with two trabecular implants. In one subgroup of patients in this study, fluorophotometry was used to analyze the increase

in ease of passage of the aqueous humor caused by the implantation of the trabecular stents

8.4.5.1 Trabecular Implant in Refractory Glaucoma Patients

For the first study of the trabecular stent in humans, patients were selected with pressures above 21 mmHg, maximum toleration of medical treatment and at least one failed conventional filtering operation [10].

A prospective, multicenter study was designed that included 45 patients. The 12-month results are currently available; however, the study runs over 24 months. The principal objective of the study was to evaluate the effect of the implantation of the trabecular stent on IOP. All the hypotensive medications were discontinued after the surgery and reintroduced at the discretion of the investigator.

The average age of the study patients was 64.9 (± 11) years [mean (\pm SD)]. All patients had primary open-angle glaucoma; 16 and 2% were also diagnosed with pseudoexfoliative and pigmentary glaucoma, respectively. The average baseline pressure was 28.8 (± 6.28) mmHg, with patients using an average of 2.1 topical hypotensive medications. At 12 months postoperatively, the mean IOP for all treated eyes had decreased to 19.3 (± 5.1) mmHg ($n = 28$) and for patients without (or before) secondary surgical intervention had decreased to 18.8 (± 4.7) mmHg ($n = 24$), without diminution of effect over time (Fig. 8.52). For all treated eyes, the mean decrease from the medicated baseline IOP ranged from 4.9 to 11.0 mmHg and for patients without (or before) intervention the mean decrease ranged from 5.2 to 12.2 mmHg. At 12-month, for all eyes ($n = 28$), the mean decrease in the number of medications compared

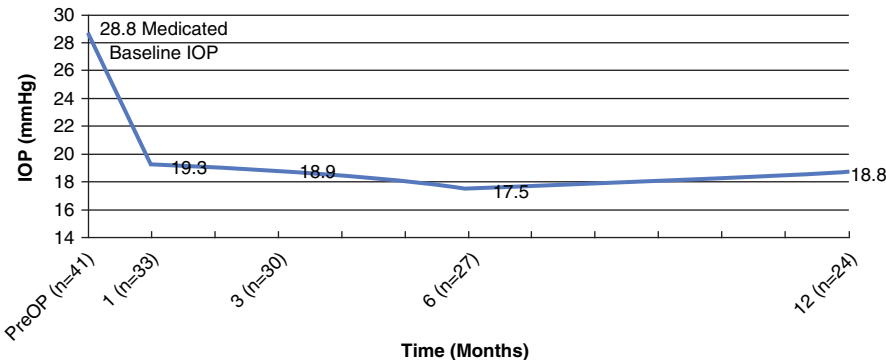


Fig. 8.52 Graph of the mean intraocular pressure measurement at each visit after implantation in refractory glaucoma patients

Fig. 8.53 Graph of the mean number of medication to lower intraocular pressure at each visit after implantation in refractory glaucoma patients

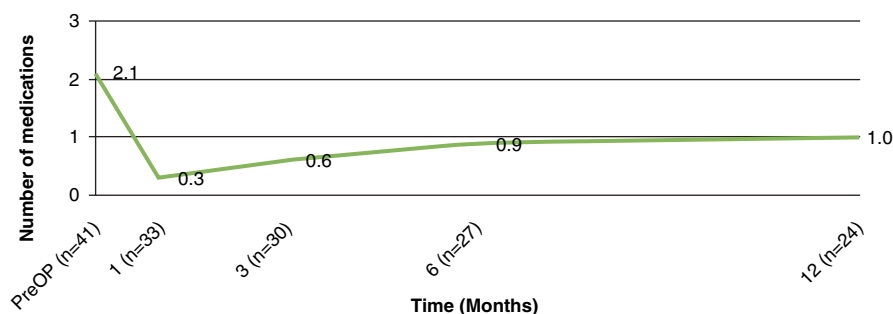
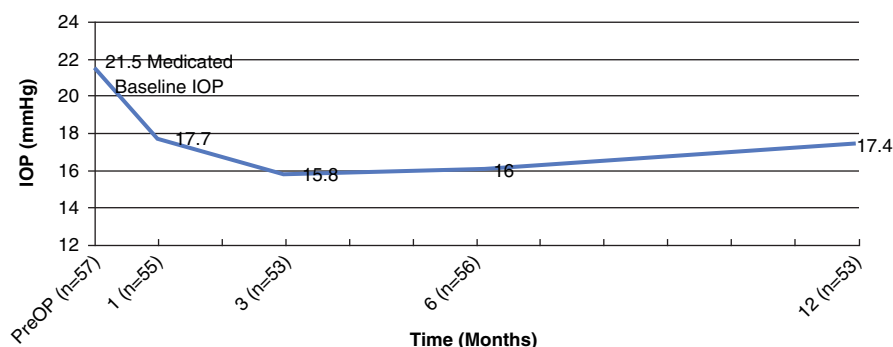


Fig. 8.54 Graph of the mean intraocular pressure measurement at each visit after combined phacoemulsification and iStent® procedure



with baseline was $1.4 (\pm 1.1)$ and for the patients without intervention ($n = 24$) was $1.0 (\pm 1.2)$ (Fig. 8.53).

No significant intraoperative complications were recorded. The most common postoperative complication was malpositioning of the stent (3/45, 6.6%), which required replacement in two cases. One case presented above-average bleeding in the anterior chamber, which did not require additional treatment. In 10 of the 45 patients, adequate pressure control was not achieved after implantation of the stent, requiring a new filtering operation to be carried out.

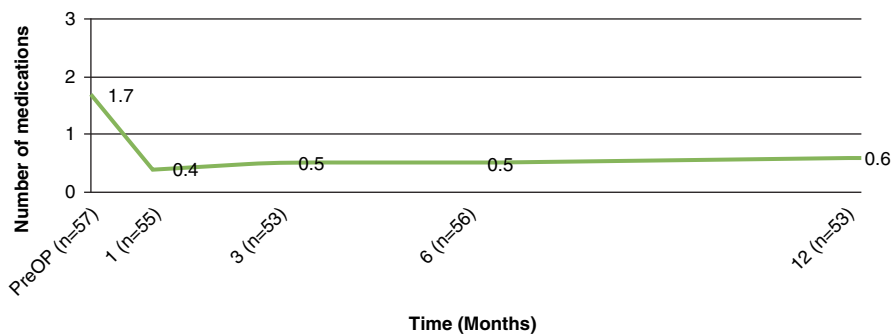
8.4.5.2 Phacoemulsification Cataract Surgery Combined with Implantation of a Trabecular Stent

Possibly the most favorable scenario for the use of the trabecular stent is combined surgery with phacoemulsification [12, 13]. Implantation of the stent during cataract surgery can produce an additional pressure decrease that makes it possible to reduce or eliminate the need for pharmaceutical antiglaucoma treatment. This study was designed to evaluate the efficacy and safety of the trabecular stent associated with conventional phacoemulsification.

Fifty-nine patients were included in a prospective, multicenter, nonrandomized study. The surgical technique used was that described previously, with no significant intraoperative complications being recorded. The average age of the operated patients was 74.6 (range: 28–87) years. As in the previous case, the majority of patients had primary open-angle glaucoma (75.6%) and a small percentage had pigmentary or pseudoexfoliative glaucoma. At the time of the surgery, all antiglaucoma treatment was discontinued and was reintroduced gradually at the discretion of the investigator.

At baseline, average medicated IOP was $21.5 (\pm 4.1)$ mmHg [mean (\pm SD)]. At 12 months, mean IOP had dropped to $17.4 (\pm 3.2)$ mmHg, a mean IOP reduction of $4.3 (\pm 4.9)$ mmHg (17.5%) (Fig. 8.54). At baseline, patients were taking a mean $1.7 (\pm 0.9)$ medication. By 12 months, the mean number of medications was reduced to $0.6 (\pm 0.9)$ (Fig. 8.55). Sixty-six percent (35/53 eyes) of all patients reached $\text{IOP} \leq 18$ mmHg and almost half the patients (24/53) achieved an $\text{IOP} \leq 18$ mmHg with no ocular hypotensive medications. The most commonly reported device-related adverse events were reports of stent malposition (9 eyes) and stent lumen obstruction (7 eyes). Of the 9 reports of stent malposition, 3 underwent treatment (replacement,

Fig. 8.55 Graph of the mean number of medication to lower intraocular pressure at each visit after combined phacoemulsification and iStent® procedure



$n = 2$; repositioning, $n = 1$). All eyes achieved a significant reduction in IOP and 6 also discontinued glaucoma medications. Of the 7 patients with stent lumen obstruction, 3 underwent treatment (rTPA injection, $n = 2$; goniotomy, $n = 1$). The remaining 4 achieved a significant reduction in IOP and discontinued glaucoma medications. None of the device-related adverse events were considered serious.

8.4.5.3 Phacoemulsification Cataract Surgery Combined with Implantation of Two Trabecular Implants

This is the most recent study carried out with the iStent. A multicenter, prospective study was designed, in which the patients were randomly divided into two groups. The patients in the first group had conventional cataract surgery, while the patients in the second group had cataract surgery combined with two trabecular stents [11].

No significant intraoperative complications were recorded in either group. Up to this time, only partial results were available, with a follow-up of 1 year. Starting with similar baseline pressures in both groups ($p = 0.2$), the decrease obtained was significantly higher in the group with combined surgery at all the follow-up points during the postoperative period. After 12 months of follow-up, the decrease in the group with combined surgery was $6.57 (\pm 2.95)$ mmHg compared to $3.86 (\pm 2.68)$ mmHg in the group that had cataract surgery ($p = 0.002$) [mean (\pm SD)]. The need for antiglaucoma treatment was also lower in the combined surgery group at the end of the follow-up ($p = 0.007$).

The most frequent complication was once again the malpositioning of the stent, although in all cases in which one of the stents was found to be malpositioned, the other stent was placed correctly. This fact could

explain, at least in part, the greater efficacy of the surgery when two stents are implanted. In one subgroup of patients in this study, the outflow facility of the aqueous humor was measured by fluorophotometry [11]. After surgery, there was a significant increase in outflow facility in both groups. This increase was significantly greater in the group with combined surgery after the 6-month follow-up. One year after surgery, the increase in outflow facility with respect to the baseline values was 275% in the group with combined surgery and 46% in the group with isolated cataract surgery.

8.4.6 Conclusions

The various studies have confirmed the use of the trabecular stent as an additional option in glaucoma surgery. Supported by the absence of complications, its hypotensive effectiveness can be sufficient in nonadvanced cases of glaucoma that require a moderate decrease in IOP or a decrease in the requirements for topical hypotensive medication. It is a suitable option in cases of combined surgery, having demonstrated a significant additional effect on the IOP and an increase in the long-term outflow facility of the aqueous humor. It has the additional advantage of not compromising the effectiveness of future filtering surgery in the event of poor control of the disease.

References

1. Grant WM (1963) Experimental aqueous perfusion in enucleated human eyes. *Arch Ophthalmol* 69:783–801
2. Anand N, Arora S, Clowes M (2006) Mitomycin C augmented glaucoma surgery: evolution of filtering bleb avascularity, transconjunctival oozing, and leaks. *Br J Ophthalmol* 90:175–180

3. Fontana H, Nouri-Mahdavi K, Lumba J et al (2006) Trabeculectomy with mitomycin C: outcomes and risk factors for failure in phakic open-angle glaucoma. *Ophthalmology* 113:930–936
4. Greenfield DS, Suner IJ, Miller MP et al (1996) Endophthalmitis after filtering surgery with mitomycin C. *Arch Ophthalmol* 114:943–949
5. Higginbotham EJ, Stevens RK, Musch DC et al (1996) Bleb related endophthalmitis after trabeculectomy with mitomycin C. *Ophthalmology* 103:650–656
6. Janz NK, Wren PA, Lichter PR et al (2001) The Collaborative Initial Glaucoma Treatment Study: interim quality of life findings after initial medical or surgical treatment of glaucoma. *Ophthalmology* 108:1954–1965
7. Soltan JB, Rothman RF, Budenz DL et al (2000) Risk factors for glaucoma filtering bleb infections. *Arch Ophthalmol* 118: 338–342
8. Bahler CK, Smedley GT, Zhou J et al (2004) Trabecular bypass stents decrease intraocular pressure in cultured human anterior segments. *Am J Ophthalmol* 138:988–994
9. Spiegel D, Kobuch K (2002) Trabecular meshwork bypass tube shunt: initial case series. *Br J Ophthalmol* 86: 1228–1231
10. Traverso CE, Jacobi P, Honrubia López FM et al (2007) The iStent trabecular micro-bypass stent in refractory open-angle glaucoma patients. In: *Proceeding of 2007 ESCRS Stockholm, Sweden*
11. Fernandez Barientos Y et al (2007) Fluorophotometric study of the effect of cataract surgery and trabecular micro bypass on aqueous humor dynamics. Preliminary results. In: *ARVO Annual Meeting*, pp B726
12. Martinez-de-la-casa JM, Garcia-Feijoo J (2007) Safety and efficacy of the iStent trabecular micro-bypass and concurrent cataract surgery: 12 month analysis. *Invest Ophthalmol Vis Sci* 48: E-Abstract 824
13. Spiegel D, García-Feijóo J, García-Sánchez J et al (2008) Coexistent primary open-angle glaucoma and cataract: preliminary analysis of treatment by cataract surgery and the iStent trabecular micro-bypass stent. *Adv Ther* 25: 453–464

The description for minimally invasive cataract surgery contained herein is for routine cases without a special need to address unusual or unique challenges, although they are certainly addressable utilizing the same techniques with certain modifications [1, 2].

Minimally invasive surgery starts with topical anesthesia, rather than injection anesthesia, which can create retrobulbar hemorrhage, forward displacement of the globe, subconjunctival hemorrhage, swelling of the lids, ptosis, muscle imbalance, injury to the optic nerve, and other potential problems. Obviously, general anesthesia has a small, but real, risk of death or systemic disability.

Patients instill one drop of a fourth-generation fluoroquinolone solution and one drop of a nonsteroidal solution, four times a day, starting 3 days, preoperatively. An instrument list, topical anesthesia protocol, prepping and draping of the patient, and postoperative care are detailed below.

9.1 Instrument List

A phaco system capable of lens removal with modulated power is needed. We have used the industry's newest technology phacoemulsification machines for biaxial surgery. This includes Advanced Medical Optics' Signature (AMO, Santa Ana, CA), Bausch & Lomb's Stellaris (San Dimas, CA), and Alcon's Infiniti with OZil (Alcon Laboratories, Fort Worth, TX). However, we have also used Sovereign with WhiteStar ICE technology (AMO), Legacy with NeoSonix programming (Alcon), STAAR Wave Sonic/Ultrasound in Random

Pulse mode (STAAR Surgical, Monrovia, CA), and the Millennium (Bausch & Lomb). The IV pole bottle height needs to be approximately 60 in. (150 cm) above the machine's pump level. We have accomplished this by adding two 6-in. pole extenders to some of our phaco units. Alternatively, a separate IV pole may be used. Other items necessary for this procedure include bimanual/biaxial instruments consisting of a micro-incision capsulorhexis forceps, a microincision blade, and bimanual/biaxial irrigators, aspirators, and irrigating choppers.

Draping:

- Two barrier drapes, one on forehead and one on operative side
- 1" Steristrips to retract lid (Suture Strips Plus – Genetic – TP1105)
- Tegaderm Transparent Dressing to cover lashes, cut in half (3M NDC#8333–1624–05)
- Ophthalmic Drape (Allegiance, Cat. 7445)
- Lieberman Lid Speculum (Karl ILg Instrument Co., #13–108)
- Nineteen-gauge irrigation cannula (Katena Products, Denville, NJ, K7–5050) on balance salt solution (BSS) 15 mL for first assistant to irrigate the cornea.

Procedure:

Two side-port incisions 60–90° apart:

- Fine-Thornton stabilization ring 13 mm (Mastel Precision Instruments, Rapid City, SD, #23116132) or (Katena #K3–6161); and
- Paratrap 0.7–1.2 diamonds (Mastel G1158 or G1145), or
- Fine bimanual diamond 1.2 mm lance (Mastel G1770 or G1858), or Sapphire, 1.0–1.3 (Micro-Surgical Instruments – MST, Redmond, WA), or

I. H. Fine (✉)
Oregon Health and Science University, 1550 Oak Street,
Suite 5, Eugene, OR 97401-7701, USA
e-mail: hfine@finemd.com

- Microsurgical technology (MST) duet metal paracentesis knife, 1.2–1.4 mm (Du-pbm-02020), or
- ASICO (Westmont, IL) diamond 8463, 1.2–1.4 mm, or
- Rhein 3D Trapezoid, 1.2–1.4 mm (Rhein Medical, Tampa, FL).

Intraocular Anesthesia:

Xylocaine 1%: Xylocaine-MPF 4% 40 mg/mL (NDC#0186–0235–03, ASTRA) diluted to 10 mg/mL w/BSS. Instill 0.5 mL with a TB syringe w/26 gauge cannula (K7–5170, Katena).

Viscoelastic:

Viscoat (Duovisc; Alcon Laboratories).

Capsulorhexis:

- MST Fine/Hoffman Capsulorhexis forceps (DF-0002), or
- MPF Fine-Ikeda Forceps AE-43895.

Cortical Cleaving Hydrodissection and Delineation:

- Twenty-six gauge irrigation cannula (Katena K7–5150) on 3 mL syringe w/BSS.

Phacoemulsification:

Tune the handpiece as usual with straight, 30°, 20-gauge phaco tip and cut off the silicone sleeve. With Infiniti, use reverse-bevel 20-gauge Kelman tip from Mastel or MicroSurgical Technology (MST). We may use STAAR cruise control (STAAR # CRUISE CNTL) on the aspiration line when a venturi system is used. After tuning the handpiece, remove the irrigation tubing from the phaco handpiece, attach it to the MST biaxial irrigating handpiece, and choose a tip according to nucleus density:

For Dr. Fine:

- For 2+ to 4+ nucleus use Fine/Olson vertical chopper (half blue, half silver);
- For 2+ to 3+ nucleus use Hoffman/Tsuneoka vertical chopper (green at tip);
- For 1+ nucleus use Fine/Nagahara (all silver) horizontal chopper;
- For 0 nucleus (RLE) use the 45° Fine open-ended I/A irrigator tip.

For Dr. Packer:

- For 1+ to 4+ nucleus use Tsuneoka vertical chopper (purple);
- For 0 nucleus (RLE) use 45° Fine open-ended I/A irrigator tip.

For Dr. Hoffman:

- For 4+ nucleus may use Tsuneoka vertical chopper (purple), or a Hoffman/Tsuneoka vertical chopper;
- For 1+ to 3+ nucleus use Fine/Nagahara horizontal chopper (all silver);
- For 0 nucleus (RLE) may use the closed-ended I/A irrigator tip.

You should plug the now empty phaco infusion port with a stopper to avoid potential backflow. The irrigating handpiece is to be handed to the surgeon first, and the phaco handpiece second.

I/A cortex removal, if required:

MST Duet Bimanual 20-gauge Starter Kit (DU-2020).

For Dr. Fine:

- MST blue irrigator handpiece with 45°, open-ended tip; and
- MST gold aspirator handpiece with 0.3 soft tip (silicone covered).

Rarely used for Dr. Fine:

- A 0.3 port tip or 0.2 port tip (gold, sandblasted front and back).

For Dr. Packer:

- A 45°, open-ended irrigating tip and 0.2 port tip (1/2 gold, all sand blasted) aspirator.

For Dr. Hoffman:

- Closed-ended irrigator and 0.3 port (all gold, all sand blasted) aspirator.

Viscoelastic:

Provisc (Alcon Laboratories), then Viscoat (Duovisc, Alcon Laboratories). Any indicated Limbal Relaxing Incisions are done at this point.

IOL Incision:

- Fine-Thornton ring (Bausch & Lomb Storz Instruments, Item #E9018; Accutome, Model #AR0195; Medtronic ENT, SKU 0502 and SKU 8230, 8231) is used to stabilize the eye;
- Incision is placed between the two side-port incisions
 - For a 2.5-mm incision, a 3D Trapezoidal diamond, 2.5–3.5 mm (Rhein 05–5086) is used.
 - For a 2.2-mm incisions, a 3D Trapezoidal diamond 2.2–2.5 mm (Rhein) is used.

Lens Injector:

The scrub will load the lens utilizing the appropriate lens injector and cartridge. The Fine-Thornton ring is used to stabilize the eye during insertion.

*I/A Viscoelastic Removal:**Dr. Fine:*

- Coaxial I/A with curved silicone tip from MST for 2.5 mm incision surgeries.
- Biaxial I/A with MST blue irrigator with 45°, open-ended tip; and with MST gold aspirator with 0.3 soft tip (silicone removed) for 2.2 mm incision surgeries.

Dr. Packer:

- Biaxial I/A using same as for cortex removal.

Dr. Hoffman:

- Coaxial I/A with curved metal 0.3 mm port.

Miotic:

Carbachol (0.01%) diluted to 0.5 strength. Instill 0.5 mL, on a 26-gauge cannula (K7–5150). Dr. Hoffman does not use Carbachol.

Stromal Hydration:

A 3-mL syringe of BSS with a 26-gauge cannula (Katena, K7–5150). Drs. Hoffman and Packer use a 30-gauge cannula.

Check Incisions:

Fluorescein dye strip (Ayerst Labs #481048).

9.2 Topical Anesthesia Protocol

Patients may have a light breakfast of toast, juice, black coffee or tea one hour prior to admission. They may take their AM medications with this light breakfast. If they take Lasix or any other “water” pill in the morning, they are asked to hold that medication until after their surgery. Patients on antihypertension medication are instructed to take their normal dosage.

Diabetic patients having cataract surgery may eat their regular breakfast the morning of their surgery and take their morning medications as they normally do (including any diabetic medications). They are asked not to take their Lasix or other “water” pill until after surgery.

9.2.1 Topical Technique

9.2.1.1 Materials

- Gelfoam Sponges (1 per patient);
- Syringes 5–10 mL
- Glass medicine cup 50 mL
- Plastic medicine cups 50 mL (1 per patient)
- Topical cocktail

– Marcaine-MPF 0.75%	12.5 mL
– Cyclogel 2%	2.5 mL
– AK Dilate 10%	2.5 mL
– Vigamox	2.5 mL
– Mydracyl 1%	2.5 mL
– Flurbiprophen 0.03%	2.5 mL

Total 25 mL

9.2.1.2 Procedures

Fill a glass medicine cup with the topical cocktail and soak pledgets in the cocktail. Fill 10 mL syringes with Marcaine-MPF 0.75%; cap syringes. Place saturated pledget into plastic medicine cup and place at the patient’s bedside as patients are admitted. When the patient arrives, place monitors on the patient, administer nasal oxygen, and start the IV. Sedate the patient with an appropriate amount of Versed. Place Alcaine drops into the operative eye; also place Marcaine MPF 75% into the operative eye. Place one pledget under upper eyelid of the operative eye with this method:

- Using smooth Nugent forceps, ask the patient to look down and to nonoperative side while placing the pledget into the temporal fornix under the upper eyelid.
- Ask patient to keep eyes closed.
- Supplement topical anesthesia with Marcaine-MPF 0.75% in 10 mL syringe.
- Drop Marcaine onto eye at 5–10 “intervals.”
- Check pupil dilation and supplement with dilating drops if needed.

9.2.3.3 Operating Room

- Position the patient;
- Remove the pledget;
- Instill four drops of topical 0.75% Marcaine.

- **Cataract Prep.** A drop of 5% Ophthalmic Betadine solution is instilled into the eye. Next, a 5% Povidine Iodine Prep solution is used to prep the upper half of the operative side of the face. The upper and lower lashes of the operative eye are scrubbed with sterile cotton tips dipped in Povidine solution. Povidine soaked 4 × 4s are then used to prep the face beginning at the medial aspect of the operative eye (taking care not to instill Povidine into the nonoperative eye). Using a circular, ever-expanding fashion, continue with the prep until the entire field is covered. Prep in this manner three times. After the solution has been left in contact for two minutes rinse the cornea, conjunctiva, and the palpebral fornices with sterile saline.
- Instill four drops of the topical Marcaine again.
- Tape the upper lid open with 1 × 5 sterile strip, drape the patient with aperture and Tegaderm drapes and insert lid speculum just before surgeon arrives (Figs. 9.1–9.3).
- Instill topical Marcaine 0.75% four drops to operative eye at the beginning of procedure.
- During surgery 0.5 mL 1% nonpreserved Xylocaine is used intercamerally. Viscoelastics used in the eye include DuoVisc: Provisc and Viscoat. After lens placement, carbochol is instilled (0.5 mL carbochol 0.1% is mixed with BSS as a 1:1 ratio). The BSS irrigating solution contains 0.5 mg (0.5 mL) of 1:1,000 epinephrine, 10 mg (0.2 mL) of Vancomycin (reconstituted with 10 mL bacteriostatic water to make 500 mg; can be used up to 14 days after being

reconstituted), and 4 mg (0.1 mL) Gentamycin. Note: Check manufacturers' insert for all medications regarding reconstituting, concentration, length of use, etc.

- All lot numbers for intraocular medications and disposable supplies (e.g., phacoemulsification tubing, lens cartridges, viscoelastics, etc.) are recorded and saved.
- Postoperative medications given routinely are drops of Vigamox, Pred Forte, 2% Pilocarpine drops, Voltaren, and Genteal Gel.
- Standing orders in Operating Room
 - Sterile 0.5% Tetracaine drops available.
 - IV sedation (Versed available if necessary).

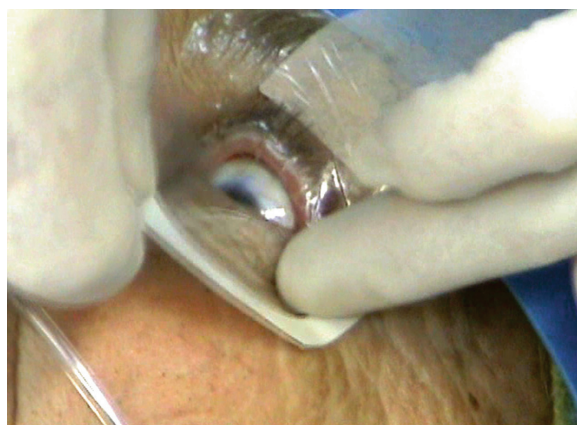


Fig. 9.2 The Tegaderm drape being applied to the lower lid over the everted lashes and meibomian orifices



Fig. 9.1 The sterile strip everts the lashes and holds them away from the surgical field allowing the drape to cover the meibomian glands



Fig. 9.3 Operative drape isolates the surgical field which is limited to the conjunctival fornices and the anterior surface of the globe

9.2.3.4 Helpful Hints

- Work toward a well-dilated pupil.
- Have patient's eye closed preoperatively to prevent corneal exposure.
- Give positive support and explanation to patient preoperatively.
- Hold the patient's hand.
- Patient should be comfortable after initial Marcaine drops – if not:
 - Check effectiveness (bad lot)
 - Use freshly opened bottle.
 - IV sedation optional, but most patients have received 1 or 2 mg IV Versed prior to surgery start.

9.3 Surgical Procedure

9.3.1 Incision Construction

The least traumatic method for purchase of the globe is with a Fine/Thornton fixation ring since it does not cause bleeding, does not pinch tissue, does not tear, distort or disturb conjunctiva. Once the globe is fixated with a Fine/Thornton ring, incision construction is commenced (Fig. 9.4) [3].

What follows is a description of biaxial phacoemulsification, although coaxial phacoemulsification can be done with some limitations in a similar manner. The details of incision construction have been published [4, 5]. For biaxial phacoemulsification, the incision construction for the side-port incisions of 1.1 mm wide, internally, and 1.3 mm, externally, have also been described [6]. These incisions are made anterior to the insertion of the conjunctiva. They are made in the plane of the cornea (Fig. 9.4 above), and for a coaxial phaco incision, the incision is 1.8–2.2 mm wide, depending on the phaco system, and 2.0 mm long. For biaxial microincision phaco, the incisions are at least 1.0 mm long, preferably 1.2 mm long (Figs. 9.5–9.7). All incisions are trapezoidal because they allow movement of the instruments within the incisions, oarlocked only at the internal margin of the incision with added room because of the trapezoidal shape at the external edge of the incision.

Incisions are constructed in the following way. The blade is applanated to the globe just anterior to the conjunctival edge and the knife is directed in the plane of the cornea for a full 2.0 mm for coaxial phaco and at least 1.0 mm for biaxial phaco. Once that length has been achieved, the point of the blade is tilted down to incise Descemet's membrane and then the blade is once again applanated and advanced into the incision to the appropriate length. In this way, we get



Fig. 9.4 Construction of a side-port incision, after fixation with a Fine/Thornton Ring

Fig. 9.5 Incisions from one case on 22 February 2007: Clear corneal temporal incision



Fig. 9.6 Incisions from one case on 22 February 2007: Phaco hand paracentesis



the curvilinear architecture as described in our previously published papers, and as demonstrated by optical coherence tomography [5, 6].

If one desires, intracameral anesthesia, 0.5 mL of 1% preservative-free Xylocaine, can be injected immediately

following incision construction and epinephrine [7] can be added to facilitate pupil dilation. For extremely dense cataracts or a poor red reflex, the installation of air following intracameral Xylocaine is then followed by a painting of the anterior lens capsule with VisionBlue

Fig. 9.7 Incisions from one case on 22 February 2007: Irrigation hand paracentesis



(Trypan blue; DORC International bv, The Netherlands; Dutch Ophthalmic USA, Kingston, NH) under air. Trypan blue does render the capsule less elastic and more brittle [8]. Following that, a dispersive viscoelastic, our preference being Viscoat® (Alcon Laboratories) is injected through one of the side-port incisions into the distal chamber angle allowing the expanding wave of viscoelastic to extrude residual anesthetic solution, air, and aqueous humor out of the injection incision, resulting in a stiff anterior chamber (Fig. 9.8). It is also our preference, after making the side-port incisions, to similarly inject viscoelastic prior to constructing the coaxial phacoemulsification incision, since with a stiff anterior chamber, that incision is constructed much more accurately and reproducibly because the eye cannot distort unpredictably, as a soft eye does, during the incision construction.

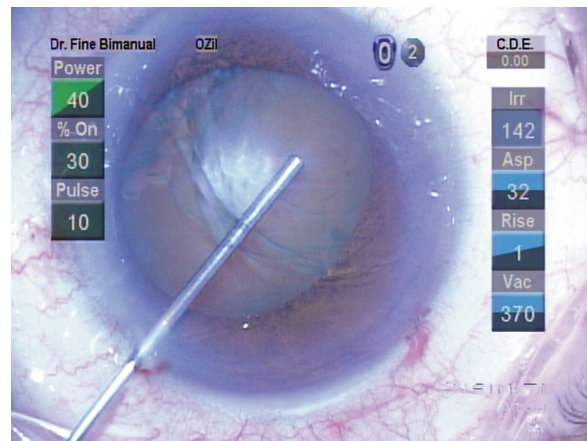


Fig. 9.8 Instilling viscoelastic through one of the side-port incisions into the distal chamber angle allowing the expanding wave of viscoelastic to extrude residual anesthetic solution, air, and aqueous humor out of the injection incision, resulting in a stiff anterior chamber

9.3.2 Capsulorhexis

We find capsulorhexis is best performed with a Fine-Hoffman microincision capsulorhexis forceps (DFH-0002, MST) through one of the side-port incisions because it facilitates a much more reproducible and predictable capsulorhexis size and shape.

The microincision capsulorhexis forceps is oarlocked to the 1.1 mm incision and one can utilize only fingers, not the wrist, in performing the capsulorhexis. This allows greater precision in the same way as that in utilizing an ink pen, one fixates the wrist and writes with just movement of the fingers. In addition, a microincision capsulorhexis is performed with almost no loss of

viscoelastic and this is a great advantage with respect to eliminating shallowing of the anterior chamber and a tendency for the capsulorhexis tear to run peripherally. We prefer capsulorhexes that are round, central, and sized so that there is at least 0.5 mm of capsulorhexis overlapping the anterior surface of the IOL 360°.

The Fine-Hoffman microincision capsulorhexis forceps is brought into the eye through one of the side-port incisions, and then opened and brought down against the capsule, after which the forceps are closed. This creates a pinch in the anterior capsule which is lifted slightly and then pulled to the left or the right. This results in the beginning of a curvilinear tear. The capsule flap is then inverted so that anterior capsule is on anterior capsule. The anterior capsular flap is grasped near, but not at, the tear point and then torn circumferentially with multiple regripping near the tear point to move in a circumferential pattern with the force tangential to the circle at the tear point. If the tear starts to move out peripherally, one can regain control by unfolding the flap and pulling the flap near its tear point, centrally. This will bring the tear back from the periphery toward the center after which the flap can then be reinverted and the rhexis continued in the usual manner [9].

9.3.3 *Hydrodissection and Hydrodelineation*

Following the completion of a capsulorhexis through a side-port incision, we perform gentle cortical cleaving hydrodissection [10]. Hydrodissection of the nucleus in cataract surgery has traditionally been perceived as the injection of fluid into the cortical layer of the lens under the lens capsule to separate the lens nucleus from the cortex and the capsule [11]. With increased use of continuous curvilinear capsulorhexis and phacoemulsification in cataract surgery, hydrodissection became a very important step to mobilize the nucleus within the capsule for disassembly and removal [12–15]. Following nuclear removal, cortical cleanup proceeded as a separate step, using an irrigation and aspiration handpiece.

Fine first described cortical cleaving hydrodissection, which is a hydrodissection technique designed to cleave the cortex from the lens capsule and thus leave the cortex attached to the epinucleus [10]. If cortical

cleaving hydrodissection is performed correctly, it lyses the connections between the cortex and the equator of the lens capsule resulting in greater ability to rotate the cataract and dramatically facilitates cortical clean-up. In fact, cortical cleaving hydrodissection usually eliminates the need for cortical cleanup as a separate step in cataract surgery, thereby eliminating the risk of capsular rupture during cortical clean-up. In a large percentage of cases, cortical clean-up is not necessary as a separate step in that during the mobilization of the epinucleus, the cortex is mobilized at the same time. We generally do this in two aliquots, one through each of the side-port incisions with decompression following the injection of each aliquot. We then try to rotate the lens within the capsular bag.

A small capsulorhexis, 5–5.5-mm, optimizes the procedure. The large anterior capsular flap makes this type of hydrodissection easier to perform. The anterior capsular flap is elevated away from the cortical material with a 26-gauge blunt cannula (e.g., Katena, K7–5150) prior to hydrodissection. The cannula maintains the anterior capsule in a tented-up position at the injection site near the lens equator. Irrigation prior to elevation of the anterior capsule should be avoided because it will result in transmission of a fluid wave circumferentially within the cortical layer, hydrating the cortex and creating a path of least resistance that may disallow later cortical cleaving hydrodissection. Once the cannula is properly placed and the anterior capsule is elevated, gentle, continuous irrigation results in a fluid wave that passes circumferentially in the zone just under the capsule, cleaving the cortex from the posterior capsule in most locations (Fig. 9.9). When the fluid wave has passed around the posterior aspect of the lens, the entire lens bulges forward because the fluid is trapped by the firm equatorial cortical-capsular connections. The procedure creates, in effect, a temporary intraoperative version of capsular block syndrome as seen by enlargement of the diameter of the capsulorhexis (Fig. 9.10). At this point, if fluid injection is continued, a portion of the lens prolapses through the capsulorhexis. However, if prior to prolapse the capsule is decompressed by depressing the central portion of the lens with the side of the cannula in a way that forces fluid to come around the lens equator from behind, the cortical-capsular connections in the capsular fornix and under the anterior capsular flap are cleaved. The cleavage of cortex from the capsule equatorially and

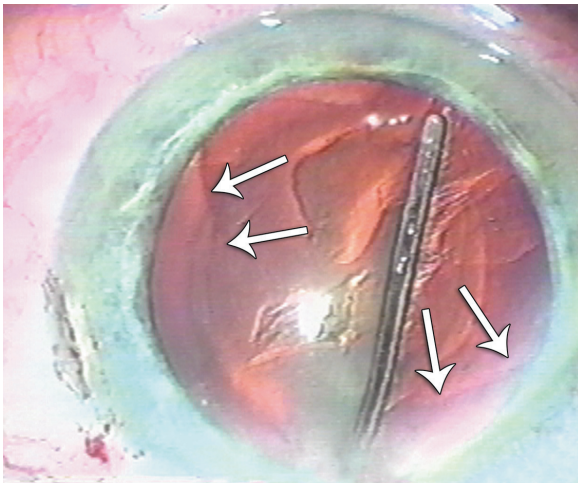


Fig. 9.9 Anterior capsule is tented up by the cannula, fluid wave is moving posteriorly, and capsulorhexis is enlarged (arrows fluid wave)

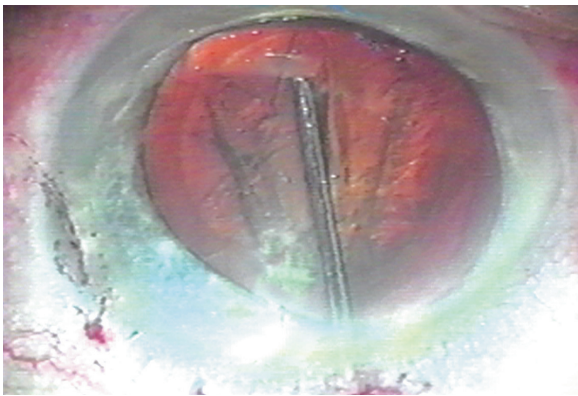


Fig. 9.10 Capsulorhexis is enlarged by the posterior loculated fluid pushing the lens forward

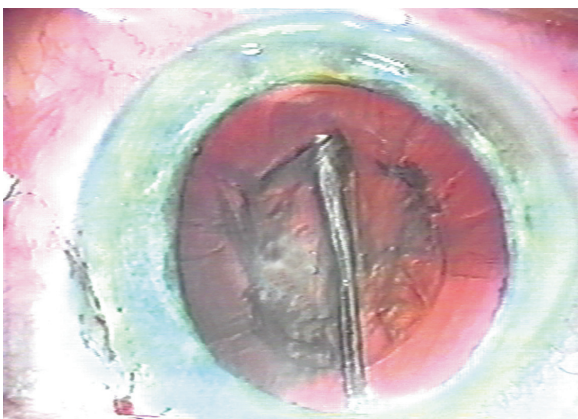


Fig. 9.11 Return of the capsulorhexis to its previous size after decompression of the capsule

anteriorly allows fluid to exit from the capsular bag via the capsulorhexis, which constricts to its original size (Fig. 9.11), and mobilizes the lens in such a way that it can spin freely within the capsular bag. Repeating the hydrodissection and capsular decompression starting in the opposite distal quadrant may be helpful. Adequate hydrodissection at this point is demonstrable by the ease with which the nuclear-cortical complex can be rotated by the cannula.

Following at least two cortical cleaving hydrodissection injections and rotation of the lens, we then perform hydrodelineation [10, 16]. Hydrodelineation is a term first used by Anis to describe the act of separating an outer epinuclear shell or multiple shells from the central compact mass of inner nuclear material, the endonucleus, by the forceful irrigation of fluid (balanced salt solution) into the mass of the nucleus [17]. Hydrodelineation circumferentially separates the endonucleus from the epinucleus and facilitates mobilization of the endonucleus away from the epinucleus. The epinucleus remains in the capsule and keeps the bag stretched throughout the procedure, thereby making it much more unlikely that a knuckle of capsule will vault anteriorly, occlude the phaco tip, and rupture. In addition, hydrodelineation reduces the size of the nucleus that has to be mobilized through disassembly and emulsification, thereby reducing the amount of energy into the eye. Circumferential division reduces the volume of the central portion of nucleus removed by phacoemulsification by up to 50%. This allows less deep and less peripheral grooving and smaller, more easily mobilized quadrants after cracking or chopping. Hydrodelineation thus creates additional safety and reduces the invasiveness of the procedure.

The 26-gauge cannula is placed in the nucleus, off center to either side, and directed at an angle downward and forward towards the central plane of the nucleus. When the nucleus starts to move, the endonucleus has been reached. It is not penetrated by the cannula. At this point, the cannula is directed tangentially to the endonucleus, and a to-and-fro movement of the cannula is used to create a tract within the nucleus. The cannula is backed out of the tract approximately halfway, and a gentle but steady pressure on the syringe allows fluid to enter the distal tract without resistance. Driven by the hydraulic force of the syringe, the fluid will find the path of least resistance, which is the junction between the endonucleus and the epinucleus, and

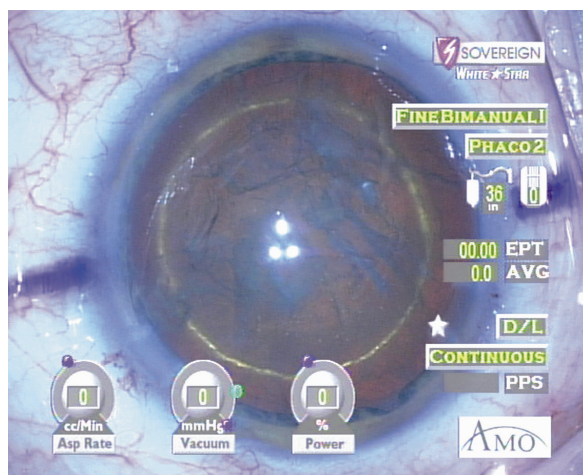


Fig. 9.12 The golden ring outlining the cleaving between the epinucleus and the endonucleus is clearly visible

flow circumferentially in this contour. Most frequently, a circumferential golden ring will be seen outlining the cleavage between the epinucleus and the endonucleus (Fig. 9.12). Sometimes the ring will appear as a dark circle rather than a golden ring.

Occasionally, an arc will result and surround approximately one quadrant of the endonucleus. In this instance, creating another tract of the same depth as the first but ending at one end of the arc, and injecting into the middle of the second tract, will extend that arc (usually another full quadrant). This procedure can be repeated until a golden or dark ring verifies circumferential division of the nucleus.

For very soft nuclei, the placement of the cannula allows creation of an epinuclear shell of any thickness. The cannula may pass through the entire nucleus if it is soft enough, so the placement of the tract and the location of the injection allow an epinuclear shell to be fashioned as desired. In very firm nuclei, one appears to be injecting into the cortex on the anterior surface of the nucleus, and the golden ring will not be seen. However, a thin, hard epinuclear shell is achieved even in the most brunescant nuclei. That shell will offer the same protection as a thicker epinucleus in a softer cataract. However, in very dense nuclei, the epinuclear shell is stiff and cannot be folded or flipped. It will, with the same maneuvers for softer epinuclei, crack into three pie-shaped segments following the posterior Y suture. Each pie-shaped segment can be rotated peripherally and mobilized (see below).

9.3.4 Chopping and Phacoemulsification

We prefer chopping in almost all cases, rather than grooving and cracking. Grooving the endonucleus requires a considerable amount of ultrasound energy, whereby in chopping, we can embed the tip utilizing vacuum and tiny amounts of ultrasound energy and disassemble the nucleus mainly with mechanical forces (i.e., chopping), thereby dramatically reducing the energy into the eye.

We use 30°, bevel-down, 20-gauge phacoemulsification tips for all machines except for the Alcon Infiniti. With the Infiniti we use a 20-gauge, reverse-bevel bent tip. This tip from MST or Mastel has the bend closer to the tip than a standard bent tip. The bevel is 30° and the bend is 20°. The approach to the endonucleus through clear corneal incision is about 30° and therefore, with a 30° tip bevel-down, we can occlude the tip almost immediately upon contact with the endonucleus and thereby invoke vacuum as an aid to embedding the tip and to chopping with very little ultrasound energy. With a bevel-up tip, the bevel has to be completely embedded into the endonucleus by ultrasound energy in order to achieve occlusion and vacuum. There are other advantages of a bevel down orientation. All of the energy is delivered toward the cataract and none toward the corneal endothelium or the trabecular meshwork. In addition, following disassembly of the endonucleus, pie-shaped segments can be mobilized with a bevel-down tip from the plane of the capsulorhexis up, rather than having to go deeply into the endolenticular space to mobilize segments. All of these advantages minimize invasiveness.

We prefer horizontal chopping for grades 1+ to 2.5+ nuclear densities because of the added safety of being able to stabilize the endonucleus during its disassembly. The irrigating chopper is inserted before the phaco needle. It is inserted by holding the horizontal portion of the chopper up vertically so that the chop element is horizontal and parallel to the incision. Once the tip of the chop element clears the internal lips of the incision, the handle of the chopper is rotated down horizontally and this brings the chop element vertically, directed toward the nucleus. The phaco needle is inserted bevel-down as it slips into the slit incisions more easily and as the leading edge of the bevel of the phaco needle touches the endothelium at the internal lip of the incision, the phaco needle is rotated bevel-up so it slips more easily through the incision without tearing Descemet's, and then is rotated bevel-down.

The chopper touches the center of the endonucleus with the vertical portion of the chop instrument, and is pushed towards the golden ring distal to the phaco incision. One doesn't have to identify the capsulorhexis to avoid purchasing the capsule because the vertical portion of the chop instrument, as it is pushed peripherally, will reflect the capsulorhexis edge and then drop into the hydrodelineation circle (golden ring) (see Fig. 9.12). Once that has happened, the endonucleus can be pulled toward the phaco tip, and elevated and then the phaco tip can be buried in the endonucleus. This maneuver allows us to trap the endonucleus between two instruments, the chop instrument and the phaco tip, and avoid any downward force on the posterior capsule or the zonular apparatus (Fig. 9.13) [18].

Once the phaco needle is embedded, 2.0–3.0 mm deep, we pull the chop instrument toward the side of the phaco needle, thus scoring the nucleus, and then move the phaco needle up and to the right, while at the same time, bringing the chop instrument left and slightly down. This allows for complete fracture of the nucleus through its floor, which creates two heminuclei (Fig. 9.14). We then rotate the heminuclei clockwise and in a similar fashion of stabilizing the distal heminucleus, trap it between the chop instrument and the phaco needle, score, and chop it in the same way. We then mobilize the quadrants by occluding the bevel down tip from above. Then the residual heminucleus is rotated to the distal periphery, stabilized, scored, and chopped in a similar manner. Each of the last two quadrants is mobilized from above in the same manner (Fig. 9.15).

In all of our procedures, we eliminate foot position zero so there is continuous irrigation throughout the procedure. The irrigation washes the ocular surface on entering the eye with the irrigating chopper or the coaxial phaco tip, and stabilizes the anterior chamber during the phaco portion of the procedure.

Vertical chopping is done in a slightly different manner. The bevel-down tip is buried in the endonucleus with sufficient lollipopping so that the nucleus is held stable. Vacuum assists in this maneuver. We do not push down on the endonucleus as we are embedding the tip, but allow phaco energy and vacuum to both drive the tip into the endonucleus, and at the same time, pull the endonucleus up toward the phaco tip, once again avoiding downward forces on the capsule and the zonular apparatus. Once the phaco needle is embedded

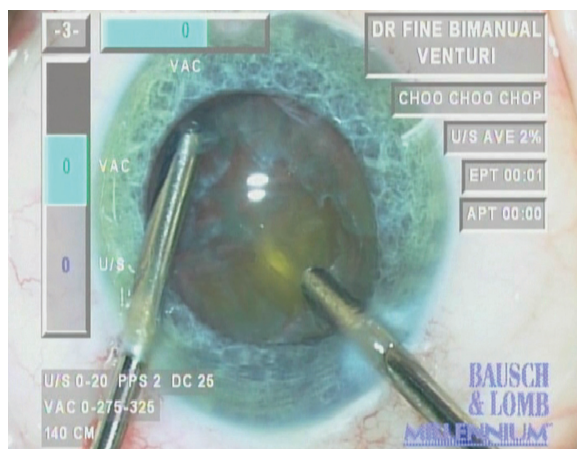


Fig. 9.13 Trapping the endonucleus between the two instruments (chop instrument and the phaco tip)

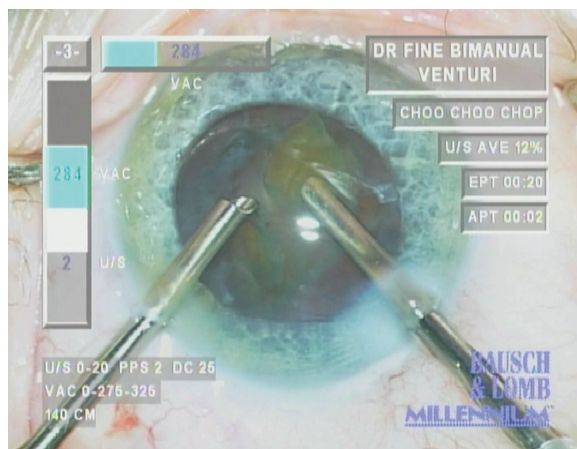


Fig. 9.14 Fracture of the nucleus through its floor

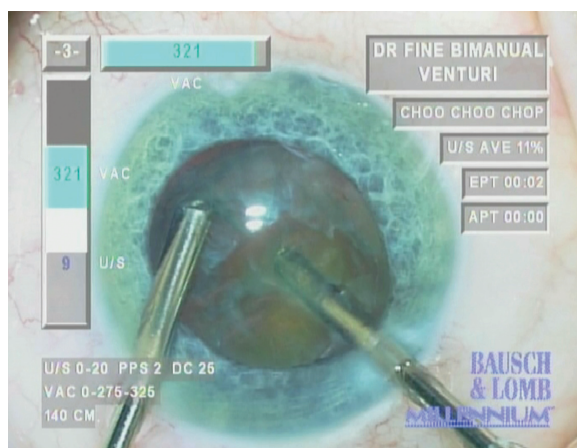


Fig. 9.15 Mobilization of the final quadrant

approximately 2.5–3.0 mm in the nucleus, we tend to lift the phaco needle up and pull it to the right while pulling the slightly embedded chop instrument diagonally to the left and only slightly downward, so that we are again avoiding any force on the capsule or zonular apparatus. After we have split it into two heminuclei, we rotate the heminuclei 90°, chop the second heminucleus, and if it is a very hard endonucleus, we will subdivide the quadrants further so that we end up with small, bite-sized pieces. In hard nuclei, in which we are doing vertical chopping, we tend to disassemble the endonucleus into a sufficient number of small, pie-shaped segments before we begin to mobilize those segments.

Mobilization is again done by bringing the phaco needle bevel down on top of the segment, occluding the tip and using vacuum and bursts of ultrasound consuming the segment as it moves up into the tip. We try to keep the phaco tip slightly below and behind the tip of the irrigating chopper to avoid irrigating nuclear material off the phaco tip. If we need to further disassemble the material on the phaco tip, we move it forward and up to the chop element, maintaining irrigation above it. In coaxial phaco we keep the chopper close to the tip of the phaco needle to manipulate nuclear material occluded at the tip to facilitate its consumption.

For soft nuclei, we do cortical cleaving hydrodissection and hydrodelineation, and then hydroexpress the lens into the plane of the capsulorhexis. With the bevel of the phaco needle sideways facing the equator of the lens, we carousel the endonucleus in the plane of the capsulorhexis until it is completely evacuated. The irrigating handpiece, usually without a chopper, is held above the endonucleus preventing any contact between the spinning endonucleus and the corneal endothelium, while maintaining the endonucleus in the plane of the capsulorhexis [19].

We believe that biaxial phacoemulsification is a much less invasive technique because it gives us fluidic advantages that are unachievable with coaxial phacoemulsification. Specifically, through the separation of infusion from aspiration and ultrasound energy, all of the fluid enters through one side of the eye and exits through the other side of the eye, with an elimination of competing currents at the phaco tip and enhanced chamber stability. In addition, if the capsule does become torn, the circulating fluid in the anterior chamber allows us to reach into the posterior chamber with

an unsleeved tip and mobilize the nuclear material, whereas with a coaxial tip, the fluid coming from the sleeve surrounding the tip would drive the nuclear material into the vitreous body.

It is very important to utilize ultrasound power modulations because this has allowed us to dramatically reduce the amount of energy into the eye, and it has allowed us to achieve cold phacoemulsification, and with that the ability to do biaxial phacoemulsification with an unsleeved tip [18, 20]. The new phacoemulsification technology has allowed us to dramatically reduce ultrasound energy placed into the eye, and has created a situation in which we have been able to achieve, essentially, vacuum extraction of the pie-shaped segments with small bursts of phaco power, rather than utilizing continuous ultrasound energy to emulsify the nucleus and aspirate it from the eye. We have shown that with lower energy into the eye, we are able to achieve clearer corneas, nearly immediate rehabilitation of vision, with excellent uncorrected visual acuities [18, 20]. The newest technology on the Alcon Infiniti, torsional phacoemulsification, has allowed us to further reduce the invasiveness of the procedure by lowering vacuum as well [21]. This may be possible, as well, with the new AMO Signature, which has elliptical phacoemulsification [22] (see Appendix for parameter settings for the following phacoemulsification systems: AMO Sovereign, AMO Signature with Ellips, Bausch & Lomb Stellaris Venturi, Bausch & Lomb Stellaris Advanced Flow System, Alcon Infiniti with Torsional and OZil).

Once all of the endonucleus has been mobilized we address the epinucleus. The bevel of the phaco tip is now turned up and the epinuclear rim and roof are purchased distally, in foot position two, pulled centrally and then swept with the phaco needle at a low power, in foot position three (3), to trim the roof and rim of the epinucleus. This is associated with mini-occlusion breaks and mini-surges, which allow the cortex in that quadrant to flow over the rim of the epinucleus and into the phaco needle. The epinucleus is allowed to settle back and then is rotated twice more, and two additional quadrants of peripheral epinuclear roof and rim are mobilized along with the cortex under them. The final quadrant of epinuclear rim is rotated distally, purchased with the phaco tip in foot position 2, and pulled centrally, while the second handpiece is used to push the floor of the epinucleus, distally, thereby

creating antiparallel forces that flip the residual floor and the last quadrant of the epinuclear rim upside down within the confines of the anterior chamber, removing it from its proximity to the posterior capsule, as it is mobilized mostly by vacuum with low power bursts of ultrasound energy.

9.3.5 Cortical Clean-up

If there is residual cortex, more common with smaller gauge phaco tips, we simply sweep the cortical aspirator circumferentially around the capsulorhexis, port facing the fornix of the capsule, and easily bring the remaining fragments out. Because the connections to the capsule have previously been lysed by cortical cleaving hydrodissection, we rarely need to strip the cortex centrally. If there are some fine strands of cortex still attached to the capsule, we find it efficacious to use a 0.2-mm aspiration port, compared to a 0.3-mm port, as it will occlude more easily.

Following the removal of the epinucleus and cortex, and polishing of the posterior capsule with the silicone-covered sleeve of the aspiration handpiece port up with minimal or no aspiration, we then fill the posterior capsule and the anterior chamber with a highly cohesive viscoelastic, usually ProVisc (Alcon Laboratories). We don't polish the undersurface of the posterior capsule because there has been documentation that polishing the posterior capsule is associated with higher levels of YAG laser posterior capsulotomy at about 3-year-interval [23, 24].

9.3.6 Limbal Relaxing Incisions

At this point, with the eye stiffened with viscoelastic, we perform limbal relaxing incisions utilizing the nomogram developed by Louis Nichamin, MD [25]. We have had good luck with our limbal relaxing incisions because we try to always perform them at the same optical zone, 10 mm, and we utilize preoperative pachymetry and an adjustable blade (Elite II Micrometer Scalpel with Corneal View Footplate, Mastel Adjustable LRI, MM1109, Mastel Adjustable LRI, MM1083; or Seibel LRI Diamond Knife, #055039, Rhein Medical).

However, for large amounts of astigmatism, greater than 2.5 diopters, we may use a toric IOL. Limbal relaxing incisions to address pre-existing and surgically induced astigmatism gives us the option of placing presbyopia-correcting IOLs into the capsular bag. The single-piece acrylic ReStor (Alcon Laboratories) has an anterior edge that is squared and therefore this lens cannot be placed in the sulcus. Because of the difficulties with interlenticular opacification, we never place two lenses within the capsular bag [26–28].

9.3.7 IOL Implantation

For IOL implantation, we prefer cartridge injection rather than folding forceps, which require larger incisions because the bulk of the lens and the forceps is larger than the lens within a cartridge. We also prefer bevel-down cartridge because it slips into a slit incision with minimal distortion of the incision. It is very important that we do not allow tearing of the incision by trying to inject a lens into a smaller incision than it can easily accommodate. Tearing of the edges of the incisions compromises self-sealability.

Viscoelastic removal is then achieved with biaxial irrigation and aspiration handpieces (Duet Bimanual System, MST). We routinely lift the IOL and place the aspirator with the port up under the IOL to get all of the viscoelastic out of the bag from under the optic of the IOL. We then remove the aspirator first, and then the irrigator, so that the chamber tends not to shallow.

9.3.8 Stromal Hydration and Testing of Incisions

We then stromally hydrate all incisions [29] in order to cause swelling of the stroma and forcing of the floor of the incision up against the roof of the incision, creating a situation which facilitates endothelial pumping to the upper reaches of the cornea. We are careful throughout the operation to never grasp any of the incisions with a forceps, which can disrupt the epithelium on the roof of the incisions and violate the fluid barrier that an intact epithelium allows, and which then compromises endothelial pumping and vacuum sealing of the incision.

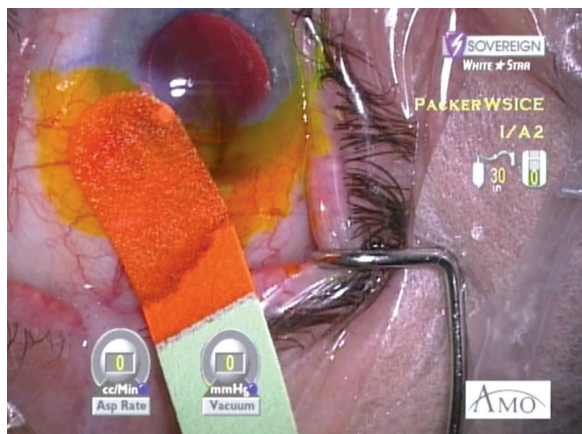


Fig. 9.16 Testing the incisions with fluorescein to make sure they are sealed

We test all incisions with fluorescein to make sure that they are sealed (Fig. 9.16). If they are not sealed, we will place a single 10–0 nylon stitch. On occasion, we will place a horizontal suture, rather than a radial suture, because this creates no forces on the cornea which distorts the corneal curvature and thus induces no astigmatism. For all difficult and challenging cases we utilize biaxial phaco as detailed in previous publications [1, 2].

We are strong advocates of the use of artificial tears in the immediate postoperative period, in addition to antibiotics, nonsteroidal and steroidal anti-inflammatory drops. We have found that the most frequent impediment to recovery of excellent visual acuity immediately postoperatively tends to be drying of the cornea and artificial tears mediate this problem.

We also use miotics, carbachol intracamerally prior to stromal hydration of the incision and one drop of 1% Pilocarpine after testing of the incisions with fluorescein, to constrict the pupil. This reduces glare, haloes, and other unwanted retinal images that interfere with the return of excellent acuity in the immediate postoperative period.

9.4 Postoperative Management

No patch is placed at the end of the procedure. The patient instills eye drops (fourth-generation fluoroquinolone, prednisolone acetate, and a nonsteroidal), four times per day, starting on the day of surgery. A shield is

worn at night for four days to avoid inadvertent eye rubbing. The patient is evaluated on postoperative day 1, and 10–14 days later, when spectacles may be prescribed.

References

1. Fine IH, Alio JL, Hoffman RS, Packer M Biaxial microincision phacoemulsification for difficult and challenging cases. In: JL Alio, IH Fine (eds) *Minimizing incisions and maximizing outcomes in cataract surgery*. Springer, Heidelberg, Germany
2. Fine IH, Hoffman RS, Packer M (2008) Use of bimanual microincision phacoemulsification for difficult and challenging cases. In: Garg A, Fine IH, Alio JL, Chang DF, Weinstock RJ, Mehta KR, Bovet JJ, Tsuneoka H, Malyugin B, Pinelli R, Pajic B, Mehta CK (eds) *Mastering the techniques of advanced phaco surgery*. Jaypee Brothers, New Delhi, India
3. Fine IH (2007) Is clear cornea incision a risk factor for postoperative endophthalmitis? Presentation in Spotlight on Cataract: current controversies in cataract surgery, clear corneal incision preferred. DF Chang, M Packer, Chairs, the annual meeting of the American Academy of Ophthalmology, New Orleans, LA
4. Fine IH, Hoffman RS, Packer M (2004) Incision construction. In: Steinert R (ed), Fine IH, Gimbel HV, Koch DD, Lindstrom RL, Neuhann TF, Osher RH (associate eds) *Cataract surgery: technique, complications and management*, 2nd edn. Saunders, Philadelphia, PA
5. Fine IH, Hoffman RS, Packer M (2007) Profile of clear corneal cataract incisions demonstrated by ocular (optical) coherence tomography. *J Cataract Refract Surg* 33(1): 94–97
6. Fine IH, Hoffman RS, Packer M (2007) Architecture of clear corneal incisions demonstrated by ocular coherence tomography. *Highlights Ophthalmol* 35(4):2–4, 6–9
7. Sugar JK (2006) Intracameral epinephrine for IFIS prophylaxis. *Cataract Refract Surg Today* 32(9):72–74
8. Dick HB, Aliyeva SE, Hengerer F (2008) Effect of trypan blue on the elasticity of the human anterior lens capsule. *J Cataract Refract Surg* 34(8):1367–1373
9. Little BC, Smith JH, Packer M (2006) Little capsulorhexis tear-out rescue. *J Cataract Refract Surg* 32(9):1420–1422
10. Fine IH (1992) Cortical cleaving hydrodissection. *J Cataract Refract Surg* 18(5):508–512
11. Faust KJ (1984) Hydrodissection of soft nuclei. *Am Intraocular Implant Soc J* 10:75–77
12. Davison JA (1989) Bimodal capsular bag phacoemulsification: a serial cutting and suction ultrasonic nuclear dissection technique. *J Cataract Refract Surg* 15:272–282
13. Fine IH (1991) The chip and flip phacoemulsification technique. *J Cataract Refract Surg* 17:366–371
14. Gimbel HV (1991) Divide and conquer nucleofractis phacoemulsification: development and variations. *J Cataract Refract Surg* 17:281–291
15. Sheperd JR (1990) In situ fracture. *J Cataract Refract Surg* 16:436–440

16. Fine IH, Packer M, Hoffman RS (2004) Hydrodissection and hydrodelineation. In: Steinert R (ed), Fine IH, Gimbel HV, Koch DD, Lindstrom RL, Neuhann TF, Osher RH (associate eds) *Cataract surgery: technique, complications and management*, 2nd edn. Saunders, Philadelphia, PA
17. Anis A (1991) Understanding hydrodelineation: the term and related procedures. *Ocular Surg News* 9:134–137
18. Fine IH, Packer M, Hoffman RS (2001) Use of power modulations in phacoemulsification: Choo-choo chop and flip phacoemulsification. *J Cataract Refract Surg* 27(2): 188–197
19. Fine IH, Hoffman RS, Packer M (2004) Optimizing refractive lens exchange with bimanual microincision phacoemulsification. *J Cataract Refract Surg* 30(3):550–554
20. Fine IH, Packer M, Hoffman RS (2004) Power modulations in new technology: improved outcomes. *J Cataract Refract Surg* 30:1014–1019
21. Fine IH (2007) The evolution of phacoemulsification. *Cataract Refract Surg Today* 7(9):43–47
22. Steinert, RF. Making a lateral move (17 December 2007) *EyeWorld Supplement*, Customizing cataract and corneal refractive surgery
23. Menapace R, Wirtitsch M, Findl O, Buehl W, Kriechbaum K, Sacu S (2005) Effect of anterior capsule polishing on posterior capsule opacification and neodymium:YAG capsulotomy rates: three-year randomized trial. *J Cataract Refract Surg* 31(11):2067–2075
24. Miller KM (2002) Effect of anterior capsule polishing on the need for laser posterior capsulotomy. Paper presented at ASCRS/ASOA Symposium on cataract, IOL, and refractive surgery, Philadelphia, Pennsylvania
25. McDonald JE II (2006) A look at limbal-relaxing incisions. *EyeWorld*, May Opinion and Commentary
26. Gayton JL, Apple DJ, Peng Q et al (2000) Interlenticular opacification: a clinicopathological correlation of a new complication of piggyback posterior chamber intraocular lenses. *J Cataract Refract Surg* 26:330–336
27. Gayton JL, VanderKarr M, Sanders V (2001) Neodymium:YAG treatment of interlenticular opacification in a secondary piggyback case. *J Cataract Refract Surg* 27: 1511–1513
28. Werner L, Apple DJ, Pandey SK, Solomon KD, Snyder ME, Brint SF, Gayton JL, Shugar JK, Trivedi RH, Izak AM (2002) Analysis of elements of interlenticular opacification. *Am J Ophthalmol* 133:320–326
29. Fine IH (1992) Self-sealing corneal tunnel incision for small-incision cataract surgery. *Ocular Surg News* 10(9): 38–39

Appendix 1

Dr. Fine B & L Stellaris Advance Flow System-Vac October, 2007

Choose "Dr. Fine AFM V" program

Phaco tip: 20 g thin tip All silver	Incision 1.2mm	Disposable-no cruise control
--	----------------	---------------------------------

Phaco		May use this for flomax		Bi-manual IA .2 metal	Bi-man Visc. removal	Co-ax IA Viscoat Removal Curved silicone	vit
Mode	CHOP VAC	CHOP FLOW	Epinucleus	IA			600 cpm
Power	0-20% linear	0-20%	0-20%				
Mode	30 pps	2 PPS	Fixed burst 10 msec duration 30 msec interval				
Duty Cycle	30%	30%					
Vac	125-325 linear	325-450 linear	250-300 linear	0-500 linear	500 fixed	500 fixed	0-150 linear
Flow		40 fixed	30 fixed		0-30 linear	25-50 linear	25 fixed
Vacuum Response	1	2	2	2	2	2	2
Bottle ht	140	140	140	140	140	90	60

Dr. wants scrub to control continuous.
Can use these settings for co-axial, lower bottle to 110-120.

S:\MONICA\PHACO\Fine B&L Stellaris AFM V bimanual, Aug 2007.rtf

Appendix 2

Dr. Fine B & L Stellaris VENTURI September 24, 2007

Choose "Dr. Fine VFM" program

Phaco tip: 20 g thin tip All silver	Incision 1.2mm	Disposable-no cruise control
--	-----------------------	---

Phaco			Bi-manual IA .2 metal	Co-axial IA Curved silicone	vit
Mode	CHOP	Epinucleus	IA	Viscoat Removal— may use bimanual for this	
Power	0-30%	0-20%			
Mode	30 pps	Fixed burst 10 msec duration 30 msec interval			
Duty Cycle	25%				
Vac	200-325	100-200	500	550	150
U/S rise	2	2			500
Vacuum Response	2	2			
Bottle ht/air infusion	140	140	140	100	60

Dr. wants scrub to control continuous.

Can use these settings for co-axial, lower bottle to 110–120.

Appendix 3

Dr. Fine
AMO Signature
July 23, 2008
Programs: Fine VWS-ellips* & Fine Ellips only**

Tips: gold straight 20 Ga. 30° bevel

	ASP	VAC	POWER	POWER MODULATION	ELLIPSE ONLY PROGRAM Different in Quad only
CHOP	34 PANEL	450 PANEL	50 LINEAR CONTINUOUS	Whitestar 8 msec on/ 18 msec off (31%, 38 pps)	
QUAD	36/32 PANEL	405 PANEL 300 THRESHOLD	50 / 100 LINEAR CONT.	Whitestar variable set 1/ 5 msec on/ 5 msec off (50%, 100 pps)	ELLIPS ONLY 100 6 on/4 off (60%, 100 pps) 100 5 on/5 off (50%, 100 pps)
TRIM	24/16 PANEL	200 LINEAR 50 THRESHOLD	20/20 LINEAR CONT.	6 msec on/ 24 msec off (20%, 33 pps)	
FLIP	28/22 PANEL	300 LINEAR 80 THRESHOLD	20/20 LINEAR CONT.	6 msec on/ 24 msec off (20%, 33 pps)	
IA Venturi		400 LINEAR			
IA Viscoat Remov. Venturi		600 LINEAR			

Appendix 4

Dr. Fine
AMO Sovereign
Fine New
July 23, 2008

Phaco tip: 20 g gold AMO tip straight 30 degree Sleeve: Cut off yellow or royal blue sleeve	Incision: 0.7-1.2mm	Never cruise. Extra pole extender (2)
---	---------------------	---



Start here

Memory	VAR-WS Variable whitestar Mem 1	Chop Phaco mem 2	Trim Phaco mem 3	Flip Phaco Mem 4	IA Cortex Bi-man	Viscoat Removal Co-Axial Curved Silicone Tip
Power	40 Linear-Set 1	50 linear	20 linear	20		
Flow	32 panel	32 Linear	30/20 Panel	28/20 Panel	28 Panel	55 Linear
Vacuum	405 panel	405	200/50 Linear	300/150 Linear	500 Linear	550 Panel
Ramp	30%	30%	30%	30%	85%	85%
Mode Unocc/o ccl.	Variable ws CN/CL/CF/CD 18%/20/33/43 Set 1	Whitestar D/I Continuous linear	Whitestar DL Continuous linear	Whitestar DL Continuous linear		
Other						
bottle ht	36	36	36	36	36	24

Vitrectomy

#1 Oscillating Use blue wrapped	Flow 20	Vacuum 250	Cut rate 450	Bottle 20
#2 guillotine; Use disposable	Flow 20	Vacuum 250	Cut rate 400	Bottle 20

Whitestar % on

BL	14%	CF	33%	CN	18	CD	43	DI	31%
CL	20	CB	60	CI	25	DL	25		

S:\MONICA\PHACO\Fine Sov.New - no case or ice, July 23, 2008.rtf

Appendix 5

Dr. Fine Bimanual or Co-axial Alcon Infiniti October 20, 2008

Ozil	0.9 microtip 20*bend/30*bevel, reverse kelman all fuchsia tip from MST. (If co-axial may want fuchsia/silver reverse kelman, abs tip from Alcon)	Bimanual 3/7: used these settings for co- axial with bottle down, 2.5 incision with purple sleeve, or 2.2 incision with pink sleeve.	Choose Grade 2
------	--	--	-------------------

Grade 2

CHOP –Ozil Pulse

Power			Torsional Amplitude %		Irrig(bottle)
limit	% on	pulses	limit	% on	142
40(linear)	30	10	NA	NA	
vac	370 (fixed)		asp rate	32 (fixed)	

Dynamic rise 1

QUAD---Ozil Pulse

Power			Torsional Amplitude %			Irrig(bottle)
limit	% on		limit	% on	pulses	142
75	5		100%(linear)	40	8	
vac	270 (fixed)		asp rate	35(fixed)		

Dynamic rise 0

EPI—Ozil continuous

Power			Torsional Amplitude %		Irrig(bottle)
limit	% on		limit	%on	142
0	NA		25 (linear)	NA	
vac	300 (fixed)		asp rate	32 (fixed)	

Dynamic rise 1

IA

Cortex				Irrig (bottle)
vac	500(linear)	asp rate	35 (linear)	142
Viscoat Removal				
vac	500 (linear)	asp rate	50 (fixed)	142

Dynamic rise 0

Vit cut I/A

Cut rate	800	Vac (linear)	250	Asp	20 (linear)	Irrig (bottle)	60
----------	-----	--------------	-----	-----	-------------	----------------	----

Dynamic rise 0

10.1 Introduction

For almost three decades, ophthalmic surgeons used a standardized 20-gauge multiple port vitrectomy system to manage all types of vitreoretinal disorders. A broad array of instruments was developed with this approach to facilitate specific surgical techniques and objectives. The 20-gauge format required separate conjunctival and scleral incisions that were closed with sutures at the end of the procedure. For at least 15 years, the capability to create smaller gauge instrumentation was possible [1, 2]. However, it was the introduction and popularization of the transconjunctival, sutureless entry technique that accelerated the adaptation of smaller incision vitreoretinal surgery [3–5]. Currently, more than half of the vitrectomies in the United States and Japan are done utilizing 23- and 25-gauge small incision surgery. As surgical techniques and instrumentation advance, these authors believe that 23- and 25-gauge surgery will become the standard format for most vitreous surgery.

Endoscopic surgery also has been applied to vitreoretinal surgery. Currently, there seems to be limited application for this approach but as improvements in optical resolution develop, future interest may grow. A section of this chapter will summarize the current status of this technology for vitreoretinal surgery.

10.2 Microincision Vitrectomy

The size of the scleral incision required for 25-gauge surgery is 0.5 mm, over half the size of that required

for 20-gauge surgery (0.9 mm). Twenty-three gauge requires a 0.65 mm incision and 25 gauge requires 0.5 mm. Clearly, the size of the incision and the thickness of the sclera are the major determinants of whether the wound will be self-sealing or require suture closure. Thus, in general, smaller incision size would be preferable, but the performance of smaller gauge instruments may be less satisfactory depending on the complexity of the clinical scenario. With any unsutured sclerotomy wound, there is a transient period of hypotony that is probably time-dependent on the formation of a fibrin plug or vitreous plug that first seals the entry site. This period of low pressure is reduced and more predictable in a wound that is securely closed with a suture. Clinically, this may be more relevant in cases such as proliferative diabetic retinopathy in which there may be some residual oozing of blood after removal of surface neovascularization. In these cases, a long period of hypotony in the immediate postoperative period would not be desirable.

A single-step or two-step transconjunctival entry approach can be used to create the entry incisions. A one-step entry is only available with 25-gauge systems, and seems to provide a consistent self-sealing wound. A modified solid needle with a round shaft and polyviol cannulae is used (Fig. 10.1). With currently available 23-gauge systems, the one-step entry system uses

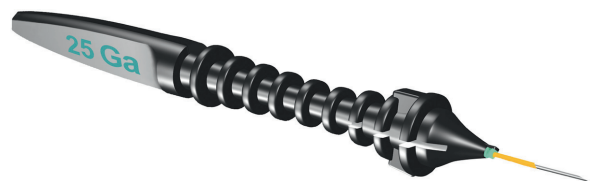


Fig. 10.1 Single-step 25-gauge disposable entry system. For use see Video 2

L-S. Leung (✉)
Edward S. Harkness Eye Institute, New York Presbyterian
Hospital, New York, NY, USA
e-mail: sc434@columbia.edu

a modified round solid needle, and the two-step approach (Fig. 10.2) uses an angled 23-gauge microvitreoretinal blade that is followed by a blunt trocar and metal cannula. A relatively flat entry blade is more



Fig. 10.2 Elements of the two-step 23-gauge entry system with angled MVR blade, fixation plate, forceps, and trocar/cannulae

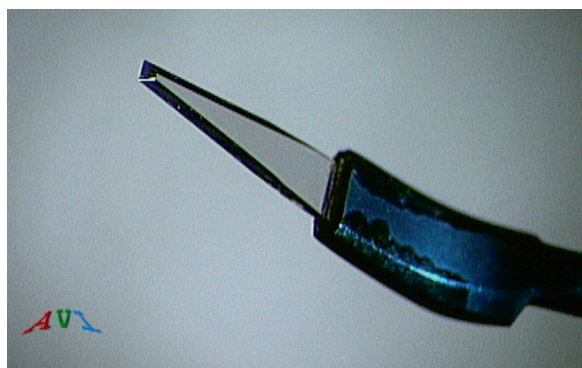


Fig. 10.3 Two-step entry using a diamond knife. The blade is tapered and inserted approximately half way in an oblique direction. See Video 1

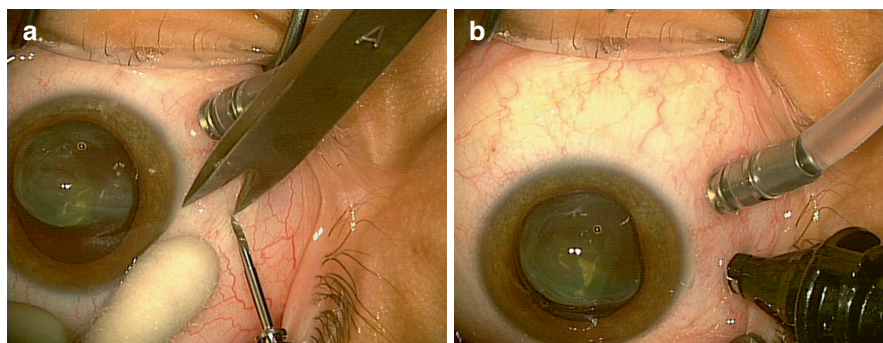
desirable than a round needle since scleral fibers may be torn or stretched as a round needle enters [6]. The flat incision closes more securely, and tends to seal better. Thus, a diamond blade has also been developed to create a flat, self-sealing tunnel entry into the sclera [Fig. 10.3, Video 1, Avi Grinblat, unpublished data]. With vigorous manipulation during vitrectomy, the scleral incisions may stretch, and one must bear in mind that any incision may leak at the end of surgery and thus require suturing.

It is important to displace the conjunctiva by sliding it before inserting the entry blade over the scleral site [Video2] [7]. This maneuver allows the conjunctiva to cover the scleral incision at the end of the procedure and reduces the possibility of direct access of bacteria into the eye from the fornices. The angle of the entry blade is oblique, about 30° to the tangent of the globe (Fig. 10.4). The needle should be inserted at a level parallel to the ora serrata so that the tip of the cannula does not pass into the peripheral retina or into the lens. When the tip of the needle has passed through the sclera, the entry angle is changed and the needle and cannula are further inserted in a radial direction toward the center of the globe [3, 8–12]. With the two-step entry, the microvitreoretinal blade is inserted, the conjunctiva is fixed, and the trocar and cannula are inserted obliquely, and then angled radially [3]. With the diamond blade, the tip of the trocar, has been modified to be a flat spatulated one that enters the scleral incision.

At the end of the procedure, the incision appearance differs between the one-step and two-step entry. The one-step entry with a round needle produces a \wedge shaped incision. The two-step incision with microvitreoretinal blade or diamond knife produces a linear incision.

The reported rates of postoperative hypotony (intraocular pressure ≤ 5 mmHg) range from 2 to 21% on the first postoperative day [13–15]. This rate is dependent on various factors including the type of entry wound, and

Fig. 10.4 One-step oblique entry with 23-gauge trocar-cannula. Note displacement of the conjunctiva with a cotton swab that also stabilizes the eye during insertion (a). When the tip passes through the sclera, the blade is angled in a perpendicular direction (b)



how frequently the incisions required suture closure at the end of the operation. In one series using 23-gauge vitrectomy, 11.2% of eyes required suturing of a leaky sclerotomy [16]. Usually hypotony resolves within a week of the procedure [8, 9, 15–23]. The use of an oblique two-step entry compared to conventional incision was demonstrated to have a lower rate of postoperative hypotony (2 vs. 18%) on the first postoperative day [9, 12]. Results of a retrospective study investigating the results on risk factors of sclerotomy leakage and postoperative hypotony in 322 eyes of 292 patients found that intraoperative sclerotomy leakage requiring suturing were in eyes with prior vitrectomy, vitreous base dissection, and young age of the patient [16, 24]. In all cases a two-step incision was used, and the incidence of hypotony was found to be 11.3% at 2h, 6.5% at 5h, 3.8% at 1 day, and 0% at 1 week. Longer periods of hypotony (2–3 weeks) may result in choroidal folds and maculopathy, which can affect visual outcome.

10.2.1 Models of Wound Architecture

Studies of the morphology of 23-gauge and 25-gauge microincisions through the sclera have been done in animal and human cadaver eyes [25–29]. These studies have found that angled incisions demonstrate less wound gape than incisions made with the trocar/cannula directed perpendicularly to the surface as studied by optical coherence tomography and histologic examination [30]. India ink applied to the conjunctiva demonstrated particles across the incisions in some perpendicular wounds [25]. These studies were made in rabbit eyes, and the sclera is considerably thinner compared to human eyes. In other studies of 25-gauge incisions in human cadaver eyes, it was demonstrated that not more than 55% of obliquely directed entry incisions resulted in two-plane wounds [31]. After brief periods of manipulation placing the vitrectomy instruments through the cannula, the inner aspect of the wound appeared to gape.

Studies using optical coherence tomography and ultrasound biomicroscopy in patients after small-gauge vitrectomy have shown that initially conjunctival blebs may be present over the sclerotomy sites early postoperatively, and that frequently the wound may be visualized within the first 2 weeks after surgery [11, 32–34]. By 1 month the wound is usually not visible, except for vitreous incarceration. Endoscopic viewing of the sclerotomy incisions have also reported a high rate of

vitreous incarceration in the sclerotomy incisions [35], but the sequelae of this observation is uncertain, and it remains controversial if small-incision vitrectomy results in a higher rate of postoperative retinal tears or retinal detachment.

10.2.2 Vitrectomy

Small-incision vitrectomy is highly dependent on the availability of an effective high-speed vitreous cutter. Cutting rates of up to 2,500 cuts/min are currently available [36–38], and recently cutters functioning at 5,000 cuts/min are being introduced. The higher speed allows safer trimming of tissue near the retinal surface with less chance of causing iatrogenic retinal breaks (Fig. 10.5). Other improvements in cutter design have been introduced. Compared to 20-gauge cutters, the 23- and 25-gauge cutters have a larger port opening and one placed closer to the tip of the probe (Fig. 10.6). A larger port allows greater flow through a smaller needle diameter and reduces the aspiration force necessary [39, 40]. Placing the port closer to the tip of the cutter allows better tissue resection at the surface of the retina, thereby reducing the need for additional instruments such as scissors. The safety and increased control of cutting has been also enhanced by the recent introduction of duty-cycle control. The duty cycle reflects the amount of time that the cutter port remains open as the excursion of the inner needle blade travels

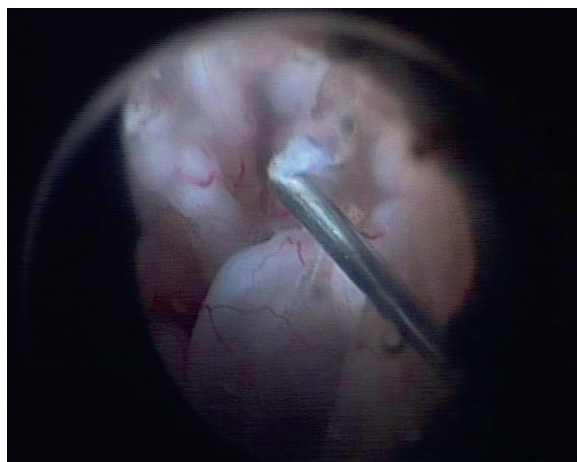


Fig. 10.5 The vitreous cutter should be able to cut and remove tissue close to the surface of mobile retina without causing iatrogenic retinal breaks

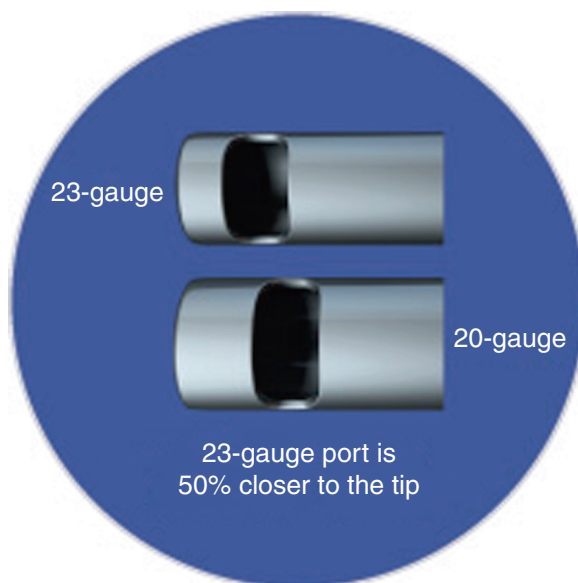


Fig. 10.6 The port size has been increased and brought closer to the tip in many small-gauge vitrectomy cutters

across the port. By increasing the duty cycle at higher cutting rates, the cutter can remove more vitreous cleanly without increasing the aspiration force. Reducing the duty cycle will allow working more closely to the retina without drawing retina into the port. With the combination of these refinements, vitrectomy cutters have substantially improved and have become more efficient in removing vitreous and membranes without causing iatrogenic retinal breaks [41].

Early implementers of 25-gauge surgery had to adapt to the increased flexibility and fragility of the 25-gauge instruments [42]. As the eye is moved in different directions during the operation, the instruments would sometimes flex as the globe was moved into extreme positions to access peripheral zones of the vitreous. The flexibility would also affect epiretinal membrane peeling

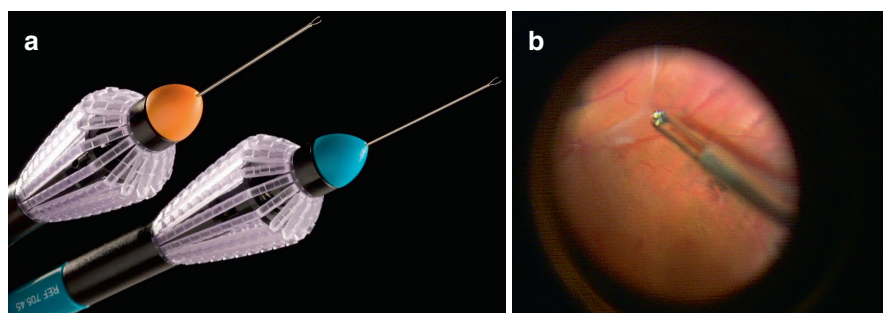
because the instrument tip would sometimes move in the opposite direction at the extreme limits of the eye movement. The flexibility also limits the ability to access the vitreous base effectively in more complex retinal detachments, and this feature in combination with less cutting efficiency has limited the use of 25 gauge by some surgeons to simpler cases such as macular surgery. Increased stiffness of the 25-gauge cutters is being developed. The modifications include shortening the length of the cutting tip, and changes in selection of stainless steel material for the cutters [3, 43].

In many respects the use of 23-gauge vitrectomy reduces many of the issues relating to too much flexibility [3]. The performance of the vitreous cutters is similar to 20 gauge. The ability to cleanly cut and aspirate vitreous is measured by the flow of tissue which is similar to that attained in 20-gauge cutters. The smaller diameter of the tip with a port closer to the end are features that are actually more advantageous than 20-gauge cutters allowing safer access between tissue planes and small openings between membranes that are adherent to the retinal surface, especially encountered in proliferative diabetic retinopathy. The stiffness of instruments allows better ability to move the globe in a controlled fashion without bending them. The greater rigidity of the probe also allows easier ability to work at the vitreous base when scleral depression is used. It is also possible to use silicone oils with higher viscosities such as 5,000 centistoke. With 25-gauge surgery, generally 1,000 centistoke silicone oil has been advocated [44–48].

10.2.3 Adjuncts

A host of instruments made for small-incision vitrectomy have been developed. These include disposable and nondisposable forceps (Fig. 10.7), vitreous

Fig. 10.7 Disposable endgripping forceps are used to peel epiretinal membranes. Because of the fragility of 25-gauge instruments, disposable are preferred, while reusable or disposable forceps can be used for 23-gauge vitrectomy



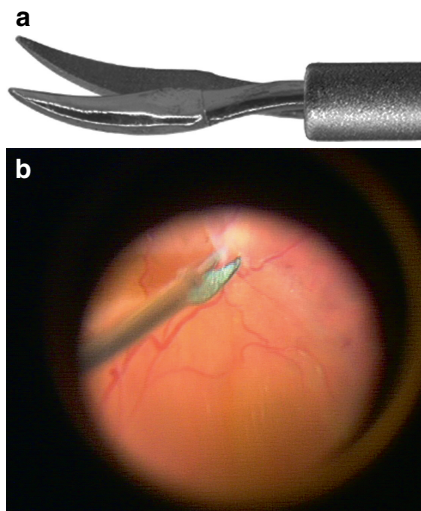


Fig. 10.8 Curved scissors pass through the 23 gauge cannulas, but with slightly lessened curvature. When scissors with greater curvature are required, the cannula may be removed and sclerotomy incision may be closed with a suture

Table 10.1 Additional microvitreoretinal instrumentation [49–51]

Wide angle endoilluminator
Chandelier light – 25 gauge, and 27 gauge twin-light
Disposable and reusable endgrasping forceps
Disposable and reusable asymmetric forceps
Disposable and reusable straight forceps
Disposable and reusable curved vitreous scissors
Diamond-dusted membrane scraper
23 Gauge fragmatome
Curved and straight endolaser probes
Double-barreled perfluorocarbon liquid cannula
Disposable and reusable extrusion needles
Silicone oil injection cannula
Curved vitreous cutter
One-piece contact lens and cannula-less entry system

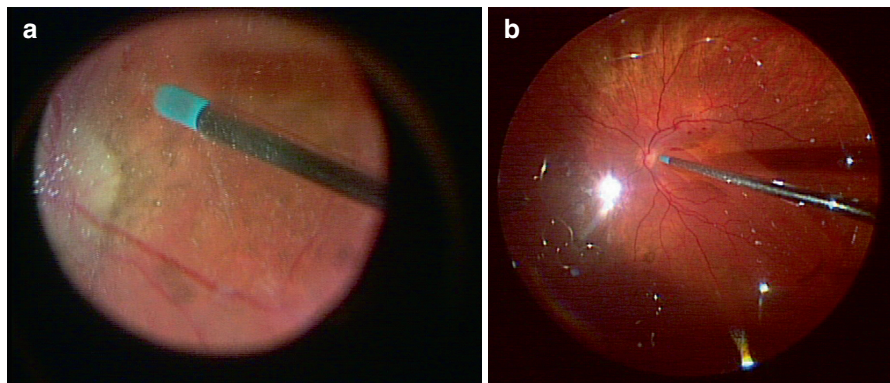


Fig. 10.9 A soft-tipped extrusion needle is used with active suction for aspiration of triamcinolone particles (a) or for fluid–air exchange (b)

scissors (Fig. 10.8), diamond-dusted membrane brush, extrusion tips (Fig. 10.9), and laser probes. These are listed in Table 10.1.

When cannulae are used, the potential is present for a greater flow of infusion fluid during the case, especially when pressurized infusion flow is used to maintain the intraocular pressure during surgery. Cannulae with silicone-covered openings have been developed that reduce the fluid flow when instruments are removed from the eye (Fig. 10.10). While these cannulae reduce fluid flow, sometimes they can be cumbersome when curved or silicone-tipped instruments must be inserted.

Small-incision vitreoretinal surgery may occasionally be enhanced by the addition of a fourth incision. The use of additional light fibers may be inserted

through the pars plana [52, 53]. This light fiber is inserted after a needle is inserted transconjunctivally to provide an opening, usually at the 6:00 position 3.5 mm posterior to the corneal limbus. The tip of the fiber is tapered and rounded to provide wide angle or panoramic illumination so that the surgeon has the ability to operate bimanually (Fig. 10.11).

10.2.4 Common Surgical Techniques

Selected techniques incorporating minimally invasive instrumentation are described for commonly operated vitreoretinal disorders [54–57]. The authors’ personal

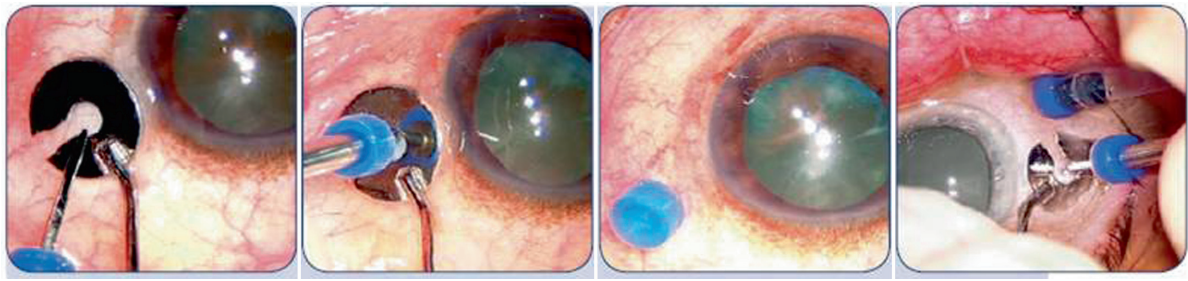


Fig. 10.10 Silicone-covered cannulas have been developed to maintain intraocular pressure and limit the volume of fluid used during vitrectomy



Fig. 10.11 Twin 27-gauge lights can be used for chandelier light. The one shown here was developed by Claus Eckhardt

preferences are for the use of 23-gauge technology, and therefore most of the techniques illustrated will exhibit this size but are applicable to 25 gauge.

10.2.4.1 Macular Surgery

Macular disorders such as macular holes, macular pucker [Video 3], and vitreofoveal traction are excellent types of cases for small-incision vitrectomy [21, 58–65]. Since progression of nuclear cataract is a common development after macular surgery, the feasibility of combined phacoemulsification and intraocular lens (IOL) implantation with vitrectomy and membrane peeling [66, 67] is excellent and reduces the rehabilitation time for the patient. The use of small-incision approach reduces the postoperative recovery time and the amount of postoperative medications necessary for healing, allowing the patient to resume normal activity more quickly [68]. After central vitrectomy, if the posterior hyaloid is not separated, triamcinolone suspension (10mg/mL) is injected into the vitreous cavity. After separating the posterior hyaloid, another intraoperative triamcinolone injection is sometimes used to delineate the extent of the epiretinal membrane. Another application of triamcinolone is sometimes

used to identify the edge of the internal limiting membrane (ILM), either in macular pucker or in macular hole surgery. At the conclusion of the procedure a fluid-air exchange is done with the appropriate gas-air mixture for tamponade used. The bubble also provides an internal tamponade that closes the inner part of the incision and reduces the risk of postoperative hypotony.

When combined with cataract surgery it may be helpful to insert the infusion trocar-cannula in the inferonasal quadrant. The infusion line is clamped, and the cataract surgeon can proceed with surgery through a temporal incision if desired. The infusion line will not disturb the phacoemulsification and can be opened after the IOL is implanted, restoring a normal intraocular pressure. A suture closing the cataract incision wound, which temporarily reduces the risk of anterior chamber shallowing during the ensuing vitrectomy, is also preferable. Removal of a cataract provides greater visualization of macular detail and more complete removal of proliferative epiretinal tissue.

In most cases both 23- and 25-gauge vitrectomy instrumentation would be able to provide excellent outcomes. A smaller incision using 25 gauge would be preferred to reduce postoperative leakage and hasten recovery. It is also feasible to combine 23- or 25-gauge incisions with 20 gauge in some cases to allow some sclerotomies to be self-sealing (Fig. 10.12) The increased flexibility of 25 gauge can be managed since most of the membranes peeled are in the posterior pole, and less manipulation in the periphery is necessary. However, in highly myopic eyes some of the 25-gauge instruments are shorter in length in order to increase stiffness [69] and therefore it may be preferable to use 23-gauge instruments.

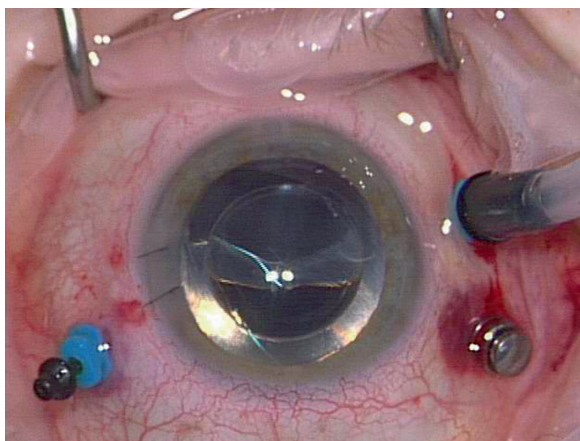


Fig. 10.12 A combination of 23- and 25-gauge instruments may be used to maximize the advantages of a small-gauge sutureless entry with the efficiency of larger gauge instruments, the so-called hybrid approach. This is useful in cases where vitrectomy is combined with phacoemulsification and intraocular lens insertion, placing the infusion in the inferonasal quadrant prior to phacoemulsification (keeping infusion closed) allowing the cataract surgery to proceed unimpeded from the temporal approach. The infusion is then turned on to allow easier insertion of the remaining sclerotomies

10.2.4.2 Proliferative Diabetic Retinopathy

Small-incision vitrectomy can be used in most cases of proliferative diabetic retinopathy with some modifications of technique to maximize outcomes [70–73]. Vitreous hemorrhages as well as more advanced forms of fibrovascular proliferation resulting in traction retinal detachment have been successfully managed. A vitrectomy cutter probe with smaller diameter and a cutting port located closer to the end is helpful since the tip can access fibrovascular tissue more easily, shaving the tissue from the retinal surface [Video 4]. It is estimated that the need for vitreous scissors has been reduced by approximately 50%. The curved and vertically cutting vitreous scissors used in diabetic retinopathy have smaller blades and are less curved to allow them to pass through the cannula. This may be occasionally cumbersome and managed by removing a cannula and enlarging the conjunctival incision and single sclerotomy to accommodate a 20-gauge scissors when necessary.

In diabetic vitrectomy the use of preoperative bevacizumab (1.25 mg) injected intravitreally 3–4 days before surgery has reduced the frequency and extent of intraoperative bleeding. However, it is common to see

some slight oozing of blood from areas where attachments of epicenters of fibrovascular proliferation have been removed. When this is observed, it is preferable to suture any sclerotomy openings that might appear to leak in order to reduce the possibility that a prolonged period of hypotony may persist in the first few hours postoperatively, promoting further bleeding. A single 8-0 reabsorbable suture can be passed transconjunctivally for this closure.

Good intraoperative visualization is necessary during diabetic vitrectomy and small incision vitrectomy may sometimes require the addition of additional light. A fourth pars plana incision can be used to place a “chandelier” light with broad illumination over the intended surgical area, or a multifunction illuminated-infusion cannula can be placed at the pars. When these are used, a strong light source (usually xenon) can provide sufficient illumination to allow the placement of a forceps and scissors through the superior sclerotomy openings for bimanual epiretinal membrane dissection. In some patients, good visualization is limited by lens opacities, and cataract surgery with IOL implantation may be suggested approximately 2 weeks prior to vitrectomy. The complexity of the fibrovascular proliferation determines whether preemptive cataract surgery is done. We choose eyes in which membrane dissection will be required peripherally to the equator or even more anteriorly to the ora serrata.

10.2.4.3 Retinal Detachment

Vitrectomy is becoming the preferred method of managing retinal detachment. Minimally invasive vitrectomy has been implemented with success [17, 74–76], although some surgeons have reported a lower rate of successful primary repair [48, 77, 78]. The differences in the outcomes are unexplained since the instrumentation used is the same. The choice of case, the location of the retinal breaks, amount of laser photocoagulation, and the vitrectomy technique may all be factors. A randomized clinical trial (with large numbers of patients) comparing small-gauge vitrectomy to 20-gauge vitrectomy would provide evidence for the safety and efficacy of the minimally invasive approach. So far, no such study has been done.

The surgical objectives for successful management of rhegmatogenous retinal detachment are to remove vitreous as completely as possible around retinal

breaks and in the periphery at the vitreous base. The retina should be flattened intraoperatively by using perfluorocarbon liquid or by draining internally through an existing peripheral retinal break, and laser treatment should be applied. A tamponade of sufficient duration should be used to allow the chorioretinal adhesion to form. Thus, the vitrectomy instrumentation should provide excellent illumination to be able to visualize retinal breaks and excellent cutting characteristics to remove vitreous traction at retinal breaks and lattice degeneration.

For more complex forms of retinal detachment such as giant retinal tears and retinal detachments complicated by proliferative vitreoretinopathy, the factors such as illumination and cutting are even more critical especially in visualizing and peeling epiretinal membranes. The use of silicone oil is more common in these cases and it is difficult to do a direct perfluorocarbon liquid to silicone oil exchange. Often with small-gauge techniques, the surgeon does a fluid–air exchange followed by instillation of silicone oil [48, 70]. In some cases where the use of silicone oil is anticipated preoperatively, it may be reasonable to use a 20-gauge silicone oil cannula for the infusion while still using other sclerotomy openings at 23 or 25 gauge.

10.2.4.4 Pediatric Vitreoretinal Surgery

The smaller gauge instrumentation would seem to be ideal for pediatric vitreoretinal surgery, and this modality has been popular for both the management of pediatric cataracts and retinal cases [25, 60, 79, 80]. The smaller size offers greater advantages in the newborn and pediatric eye, especially in cases of retinopathy of prematurity.

10.2.5 Complications

The complications reported from the use of small gauge vitrectomy are listed in Table 10.2, and in most instances do not appear to differ from those reported with conventional 20 gauge vitrectomy. The complication of greatest concern has been the rate of postoperative endophthalmitis [91]. Vitreous prolapse into the sclerotomy openings has been observed [90] and the

Table 10.2 Complications of minimally invasive vitrectomy [13, 18, 24, 81–91]

Cataract
Choroidal hemorrhage or infusion
Retinal tear or detachment
Vitreous incarceration
Hypotony
Chronic macular hypotony and choroidal folds
Increased risk of endophthalmitis
Dislodged 25-gauge cannula intravitreally
Subconjunctival silicone oil

sutureless conjunctival incision has been thought to provide a direct route of entry for bacterial infection. Some early studies have reported a 12-fold increase in the rate of endophthalmitis compared with conventional 20-gauge vitrectomy [92]. Another study reported almost a 30-fold higher incidence with 25-gauge vitrectomy [89]. Other series have not reported any greater risk [93–95]. Of note is that early reports on the higher incidence of postoperative endophthalmitis have focused attention on ways to decrease the infection rate. We believe that measures such as the oblique insertion of the trocar/cannula to create a longer biplane incision, the meticulous surgical preparation with povidone iodine, the displacement of the overlying conjunctiva, and a lower threshold for suturing leaky sclerotomies, all contribute to lowering the rate of endophthalmitis.

A higher incidence of retinal detachment following 25-gauge vitrectomy has been debated. In one study, the rate of retinal tears after 25-gauge vitrectomy was half of the rate observed in 20-gauge cases (3.1 vs. 6.4%) but this difference was not statistically significant [88].

10.2.6 Future Developments in Minimally Invasive Vitrectomy

Further advances in small-incision vitrectomy resulted in improvements in vitreous cutter technology (mentioned above), and using even smaller gauge instruments. Twenty-seven gauge instruments have been proposed for removal of macular puckers, so that minimal vitreous would be removed [96]. The retention of vitreous reduces the rate of progression of nuclear cataract postoperatively, for up to 5 years, and possibly

longer [97]. In this approach, only two incisions are necessary – one for illumination and one for a forceps that can be used to elevate the edge of the epiretinal membrane and grasping it. The smaller fiber must be connected to a very bright light source, and the tip of the light fiber must be modified to expand the angle of illumination.

The utilization of small-gauge vitreoretinal surgery has gradually increased, and many surgeons have advocated that at least 23 gauge will become the new standard for vitreoretinal surgery [98–101]. The advantages of the transconjunctival sutureless approach seem to be mainly intangible ones at this time. The main advantages – reduced postoperative pain [102], transient reduction of corneal astigmatism [103, 104], and faster recovery time – are difficult to quantify and measure. However, patients do seem to appreciate the advantages and frequently comment how there was no pain or discomfort. There are relatively few randomized clinical studies that prospectively measure the advantages of small-gauge vitrectomy compared to the conventional 20-gauge approach [15, 23, 59, 105–109]. Critics indicate that the small-gauge instrumentation is more costly, and presents an unacceptable rate of endophthalmitis [110, 111]. Until tangible advantages can be demonstrated, universal acceptance by retinal surgeons will be delayed. Continued advancements in technology will also convince surgeons that the smaller gauge format will provide the same or better performance than the conventional 20-gauge system.

10.3 Endoscopic Vitreoretinal Surgery

10.3.1 Introduction

The first endoscopic vitreoretinal procedure was described in 1934 by Thorpe for removal of a nonmetallic intravitreal foreign body [112, 113]. In the intervening 75 years, the application of endoscopic viewing systems had primarily been limited to foreign body extraction [113, 114]. Especially with the development of modern vitrectomy techniques and technology pioneered by Machemer, the uses for endoscopes that were unwieldy and difficult to navigate in the intraocular cavity have been seemingly few. However, technical advances have allowed for improved image

resolution and transmission and smaller and more flexible instrumentation for improved maneuverability and visualization of the eye as well as the ability to use existing surgical incisions [115–117]. Consequently, there is an expanding set of applications for endoscopy in many types of ophthalmic surgery [112, 118].

10.3.2 History and Development of Endoscopic Ophthalmic Surgery

Early intraocular endoscopy required external fixation, with the surgeon looking through a rigid scope composed of classical lenses [113, 119, 120]. The development of fiber-optic technology allowed for flexible endoscopes which were both easier to manipulate and maneuver, and allowed for images to be seen from a distance. The charge-coupled device was first developed in 1983, allowing an image to be transmitted electronically to a monitor or video recording device [121]. In addition, improved ability to manufacture optical fibers enabled both smaller and higher resolution endoscopes.

10.3.3 The Endoscope

Endoscopes using classical lenses have a minimum diameter of 1.3–2.0 mm, too large for use in ophthalmic surgery [113, 119]. Ophthalmic endoscopes currently in use typically employ one of two different modes of image transmission. Fused fiber-optic endoscopes transmit segmented images (image blocks or pixels partitioned into homogeneous groups such as color) through single fibers, allowing for long-distance transmission. However, image resolution is often limited by image segmentation. Gradient-index (GRIN) endoscopes, in contrast, transmit whole images through a single rod of varying refractive indices, allowing for refraction and transmission of light across flat surfaces without the minimal size limitations of classical lenses [119]. Both types of endoscopes are small enough to fit through a standard 20-gauge vitrectomy incision. However, GRIN lenses are available with a much smaller diameter of 0.35 or 0.5 mm and can be paired with two additional channels for illumination and laser and/or irrigation/aspiration, for a total

diameter of 0.89 mm or less, smaller than the 0.91 mm diameter of a 20-gauge vitrector. Furthermore, the GRIN lenses offer higher resolution than fused-fiber endoscopes [119].

10.3.4 Applications of Intraocular Endoscopy

In recent years, more applications for intraocular endoscopy have been described in the literature. The most obvious utility of an endoscope in vitreoretinal surgery is visualization and manipulation of the vitreous cavity and retina through opaque media. Yet endoscopy has also been advocated for eyes as an adjunct to traditional surgery with an operating microscope, not only for direct visualization during vitrectomy, but also for intraoperative and postoperative inspection of wounds and other difficult-to-visualize areas of the posterior segment.

10.3.4.1 Media Opacity

Vitreoretinal procedures such as retinal detachment repair in patients with ocular media opacity often require extensive intervention. Corneal opacity may require simultaneous or staged penetrating keratoplasty, temporary keratoprosthesis, or open sky vitrectomy. Presence of cataract may necessitate concomitant lens extraction. Additionally, eyes with previous surgical or nonsurgical trauma may have disruption of anterior chamber anatomy, including fibrosis and synechiae causing miosis, retrocorneal or retrolental membranes [112]. Endoscopy may be advantageous in these situations in reducing surgical manipulation of the eye.

Certain patients with retinal detachment may benefit from endoscopic surgery, especially those with little or no expected PVR, or those with opacity that could be expected to either resolve spontaneously or with medical therapy, or in those patients where surgical management of anterior segment pathology might be anticipated to be harmful to the eye or delay healing [122]. Successful endoscopic retinal detachment repair has been described in patients with significant corneal edema where keratoprosthesis or penetrating keratoplasty might have been considered. In these instances, it is suggested that proceeding with endoscopic

surgery may prevent further corneal endothelial damage and ultimately corneal endothelial failure [123].

In cases of endophthalmitis, visualization of the posterior segment is often significantly impaired, and there is considerable risk of damage to ocular structures when visibility is poor. A technique of combined microscopic and endoscopic vitrectomy has been described, in which core vitrectomy is performed using an operating microscope to create a clear fluid-filled pocket, followed by endoscope-guided vitrectomy for the remainder of the dissection, allowing for more controlled identification of anatomic landmarks within the eye [124].

Proliferative diabetic retinopathy poses a challenge, as neovascularization of the anterior segment can cause hyphema and fibrovascular proliferation and scarring as well as miosis that hamper visualization of the retina and vitreous using traditional wide-angle viewing systems [125, 126]. Though these issues may be dealt with using different modalities, including iris-expansion devices or anterior chamber washout, approaching a case endoscopically may be a potentially less traumatic modality, reducing the surgical burden on the eye. Of note, eyes undergoing traditional three-port vitrectomy using an operating microscope are not precluded from the use of endoscopic viewing should there be unanticipated issues or complications that arise, such as anterior tractional detachment or intraoperative hyphema [125].

10.3.4.2 Subretinal Fluid Drainage and Fluid–Gas Exchange

Subretinal fluid can be drained effectively through existing retinal breaks during fluid–gas exchange. However, this method can present several challenges to visualization; there can be glare and disturbances from the fluid–gas interface; additionally, if a primary retinal break is in the far periphery, direct visualization of fluid drainage under microscopy can be extremely difficult without creating a secondary posterior drainage retinotomy, which may lead to secondary proliferative vitreoretinopathy [112, 113]. Endoscopic subretinal fluid drainage with appropriate head positioning to allow for fluid to easily come out of a peripheral break has been described. This method obviates the need for a drainage retinotomy, and the process, extremely difficult to see with an operating microscope, may be

directly visualized at all times using the endoscope [28].

10.3.4.3 PVR and Subretinal Surgery

Even when the retina may be examined using wide-angle viewing, there are locations in the posterior segment that are inaccessible, such as the ciliary body, or are otherwise unable to be seen without manipulation such as scleral depression. These areas become important when evaluating for proliferative membranes.

Proliferative vitreoretinopathy remains the most common cause of failed retinal detachment surgery. Complete dissection and removal of proliferative membranes at the time of surgery is advisable; however, retinotomy and retinectomy are frequently indicated in order to prevent persistent reproliferation and traction on the ciliary body, and decrease the risk of redetachment and hypotony. Endoscopy has been used to inspect the anterior retina and ciliary body in post-vitrectomy patients undergoing large retinectomies. Ciliary body detachment and distortion of anatomy can be directly visualized and may be associated with hypotony, which may aid in postoperative management [127]. Furthermore, endoscopy may be useful for interior inspection of sclerotomies; proliferation in these locations after surgery may lead to recurrent detachment [112].

The use of micro-endoscopy has also been advocated for technically challenging subretinal surgery. Working through an iatrogenic retinotomy, subretinal choroidal neovascular membranes are directly visualized using a 20-gauge endoscope following standard three-port pars plana vitrectomy, then dissected manually or ablated using Nd:YAG laser [128–130].

10.3.4.4 Retained Lens Fragments

Complicated cataract extraction with retained lens fragments may require extensive surgery, and presents several difficulties, including localizing lens fragments in the vitreous cavity secondary to blood or fibrin in the vitreous base, as well as marked inflammation causing poor visualization through the anterior segment. Endoscopic vitrectomy for removal of lens fragments or dislocated IOL has been described, anecdotally shortening and simplifying cases, with good visual

outcomes [131]. Visualization of the vitreous base for 360°, as well as the posterior lens capsule, and zonules allows for complete dissection of adhesions and removal of blood and fibrinous debris, which may contribute to a lower risk of postvitrectomy detachment in these cases. Endoscopy also provides the advantage of direct visualization of retinal breaks and traction from multiple angles without external manipulation such as scleral depression.

10.3.4.5 Anterior and Retrolental Vitrectomy in Malignant Glaucoma

Ciliary block glaucoma is characterized by shallowing of the anterior chamber despite a patent iridectomy, classically occurring following intraocular surgery. It is believed to be caused by aqueous misdirected posteriorly. Surgical treatment with anterior vitrectomy is reserved for cases when medical treatment with cycloplegia and aqueous suppression or laser treatment with YAG hyaloidotomy fail. One of the difficulties with anterior vitrectomy in phakic patients lies in dissecting the anterior vitreous without inadvertent lens damage. Endoscopic visualization during anterior vitrectomy has been described as a useful adjunct in this case, in order to determine the extent of vitrectomy needed [132].

10.3.4.5 Sutured IOL and ECP

Endoscopic cyclophotocoagulation is used increasingly for intractable glaucoma, with reported benefits of less inflammation, less distortion of architecture, and direct visualization of ciliary processes in order to titrate treatment. Endoscopy is also advocated to aid in suturing intraocular lenses in the ciliary sulcus. Description of these techniques is beyond the scope of this discussion.

10.3.5 Limitations and Challenges

Endoscopic vitreoretinal surgery has several limitations. There is a learning curve, as with any new technique. The loss of stereoscopic viewing using the endoscope is compounded by the lack of other lighting

and positional cues inside the eye [117, 120]. Under the operating microscope, an eccentric light source casts shadows of instruments on the retina, allowing the surgeon to determine the depth and position of the instruments relative to other structures in the eye. These shadows are absent in endoscopic surgery; moreover, the field of view is limited and focus is achieved not by adjusting the microscope, but with miniscule movements of the hand and fingers. These difficulties translate to an increased risk of incidental contact with structures inside the eye, including the crystalline lens. There have been reports of iatrogenic retinal breaks during endoscopic removal of lens fragments [131], believed to be directly related to inexperience in maneuvering the endoscope inside the eye. However, with more experience, an increasing facility and technical skill is expected.

10.4 Future Directions of Minimally Invasive Vitreoretinal Surgery

While small-incision surgery is advancing rapidly and being adopted by the retinal physician community, there remain limitations to what microinstrumentation can accomplish. Thus, incorporation of advances in pharmacologic treatment [133], and in robotic technology may expand the capability of managing retinal diseases with a surgical approach. These efforts are already in progress and as new technologies and treatments are introduced the microincision platform should result in greater efficacy and safety of vitreoretinal surgery.

References

- Hilton GF, Josephberg RG, Halperin LS et al (2002) Office-based sutureless transconjunctival pars plana vitrectomy. *Retina* 22:725–732
- Peyman GA (1990) A miniaturized vitrectomy system for vitreous and retinal biopsy. *Can J Ophthalmol* 25:285–286
- Eckardt C (2005) Transconjunctival sutureless 23-gauge vitrectomy. *Retina* 25:208–211
- Fujii GY, De Juan E Jr, Humayun MS et al (2002) Initial experience using the transconjunctival sutureless vitrectomy system for vitreoretinal surgery. *Ophthalmology* 109:1814–1820
- Fujii GY, De Juan E Jr, Humayun MS et al (2002) A new 25-gauge instrument system for transconjunctival sutureless vitrectomy surgery. *Ophthalmology* 109:1807–1812; discussion 1813
- Inoue M, Shinoda K, Shinoda H et al (2007) 25-gauge cannula system with microvitrectoretinal blade trocar. *Am J Ophthalmol* 144:302–304
- Shimada H, Nakashizuka H, Hattori T et al (2008) Conjunctival displacement to the corneal side for oblique-parallel insertion in 25-gauge vitrectomy. *Eur J Ophthalmol* 18:848–851
- Hsu J, Chen E, Gupta O et al (2008) Hypotony after 25-gauge vitrectomy using oblique versus direct cannula insertions in fluid-filled eyes. *Retina* 28:937–940
- Inoue M, Shinoda K, Shinoda H et al (2007) Two-step oblique incision during 25-gauge vitrectomy reduces incidence of postoperative hypotony. *Clin Exp Ophthalmol* 35:693–696
- Lopez-Guajardo L, Pareja-Esteban J, Teus-Guezala MA (2006) Oblique sclerotomy technique for prevention of incompetent wound closure in transconjunctival 25-gauge vitrectomy. *Am J Ophthalmol* 141:1154–1156
- Rizzo S, Genovesi-Ebert F, Vento A et al (2007) Modified incision in 25-gauge vitrectomy in the creation of a tunneled airtight sclerotomy: an ultrabiomicroscopic study. *Graefes Arch Clin Exp Ophthalmol* 245:1281–1288
- Shimada H, Nakashizuka H, Mori R et al (2006) 25-gauge scleral tunnel transconjunctival vitrectomy. *Am J Ophthalmol* 142:871–873
- Amato JE, Akduman L (2007) Incidence of complications in 25-gauge transconjunctival sutureless vitrectomy based on the surgical indications. *Ophthalmic Surg Lasers Imaging* 38:100–102
- Fine HF, Iranmanesh R, Iturralde D et al (2007) Outcomes of 77 consecutive cases of 23-gauge transconjunctival vitrectomy surgery for posterior segment disease. *Ophthalmology* 114:1197–1200
- Schweitzer C, Delyfer MN, Colin J et al (2009) 23-gauge transconjunctival sutureless pars plana vitrectomy: results of a prospective study. *Eye* 2009 Jan 23 (Epub ahead of print)
- Woo SJ, Park KH, Hwang JM et al (2009) Risk factors associated with sclerotomy leakage and postoperative hypotony after 23-gauge transconjunctival sutureless vitrectomy. *Retina* 29:456–463
- Acar N, Kapran Z, Altan T et al (2008) Primary 25-gauge sutureless vitrectomy with oblique sclerotomies in pseudophakic retinal detachment. *Retina* 28:1068–1074
- Byeon SH, Chu YK, Lee SC et al (2006) Problems associated with the 25-gauge transconjunctival sutureless vitrectomy system during and after surgery. *Ophthalmologica* 220:259–265
- Gupta OP, Ho AC, Kaiser PK et al (2008) Short-term outcomes of 23-gauge pars plana vitrectomy. *Am J Ophthalmol* 146:193–197
- Kim MJ, Park KH, Hwang JM et al (2007) The safety and efficacy of transconjunctival sutureless 23-gauge vitrectomy. *Korean J Ophthalmol* 21:201–207
- Kusuhara S, Ooto S, Kimura D et al (2008) Outcomes of 23- and 25-gauge transconjunctival sutureless vitrectomies for idiopathic macular holes. *Br J Ophthalmol* 92:1261–1264
- Lakhanpal RR, Humayun MS, de Juan E Jr et al (2005) Outcomes of 140 consecutive cases of 25-gauge transconjunctival surgery for posterior segment disease. *Ophthalmology* 112:817–824

23. Romero P, Salvat M, Almena M et al (2006) Experience with 25-gauge transconjunctival vitrectomy compared to a 20-gauge system. Analysis of 132 cases. *J Fr Ophtalmol* 29:1025–1032
24. Byeon SH, Lew YJ, Kim M et al (2008) Wound leakage and hypotony after 25-gauge sutureless vitrectomy: factors affecting postoperative intraocular pressure. *Ophthalmic Surg Lasers Imaging* 39:94–99
25. Gupta OP, Maguire JJ, Eagle RC Jr et al (2009) The competency of pars plana vitrectomy incisions: a comparative histologic and spectrophotometric analysis. *Am J Ophthalmol* 147:243–250.e1
26. Singh A, Stewart JM (2009) 25-gauge sutureless vitrectomy: variations in incision architecture. *Retina* 29:451–455
27. Singh RP, Bando H, Brasil OF et al (2008) Evaluation of wound closure using different incision techniques with 23-gauge and 25-gauge microincision vitrectomy systems. *Retina* 28:242–248
28. Sonoda Y, Yamakiri K, Sonoda S et al (2006) Endoscopy-guided subretinal fluid drainage in vitrectomy for retinal detachment. *Ophthalmologica* 220:83–86
29. Taban M, Ventura AA, Sharma S et al (2008) Dynamic evaluation of sutureless vitrectomy wounds: an optical coherence tomography and histopathology study. *Ophthalmology* 115:2221–2228
30. Wan T, Hu J, Luo Y et al (2007) Experimental study of the healing condition of sclerotomy sites after 25-gauge transconjunctival sutureless sclerotomy and 20-gauge vitrectomy. *Yan Ke Xue Bao* 23:37–42
31. Nagpal M, Wartikar S, Nagpal K (2009) Comparison of clinical outcomes and wound dynamics of sclerotomy ports of 20, 25, and 23 gauge vitrectomy. *Retina* 29:225–231
32. Keshavamurthy R, Venkatesh P, Garg S (2006) Ultrasound biomicroscopy findings of 25 G transconjunctival sutureless (TSV) and conventional (20G) pars plana sclerotomy in the same patient. *BMC Ophthalmol* 6:7
33. Lopez-Guajardo L, Vleming-Pinilla E, Pareja-Esteban J et al (2007) Ultrasound biomicroscopy study of direct and oblique 25-gauge vitrectomy sclerotomies. *Am J Ophthalmol* 143:881–883
34. Taban M, Sharma S, Ventura AA et al (2009) Evaluation of wound closure in oblique 23-gauge sutureless sclerotomies with visante optical coherence tomography. *Am J Ophthalmol* 147:101–107.e1
35. Koch FH, Luloh KP, Singh P et al (2007) ‘Mini-gauge’ pars plana vitrectomy: ‘inside-out view’ with the grin solid rod endoscope. *Ophthalmologica* 221:356–362
36. Fang SY, DeBoer CM, Humayun MS (2008) Performance analysis of new-generation vitreous cutters. *Graefes Arch Clin Exp Ophthalmol* 246:61–67
37. Magalhaes O Jr, Maia M, Maia A et al (2008) Fluid dynamics in three 25-gauge vitrectomy systems: principles for use in vitreoretinal surgery. *Acta Ophthalmol* 86:156–159
38. Wals KT, Friberg TR (2008) Vitreous substitute removal rates with the accurus and millennium vitrectomy systems. *Ophthalmic Surg Lasers Imaging* 39:174–176
39. DeBoer C, Fang S, Lima LH et al (2008) Port geometry and its influence on vitrectomy. *Retina* 28:1061–1067
40. Hubschman JP, Gupta A, Bourla DH et al (2008) 20-, 23-, and 25-gauge vitreous cutters: performance and characteristics evaluation. *Retina* 28:249–257
41. Hubschman JP (2005) Comparison of different vitrectomy systems. *J Fr Ophtalmol* 28:606–609
42. Lommatzsch A, Heimes B, Trieschmann M et al (2008) Long-term results after pars plana vitrectomy with 25 gauge technique. *Ophthalmologe* 105:445–451
43. Ohji M, Tano Y (2007) A stiffer and safer light pipe for 25-gauge vitrectomy. *Arch Ophthalmol* 125:1415–1416
44. Erakgun T, Egrilmez S (2009) Surgical outcomes of transconjunctival sutureless 23-gauge vitrectomy with silicone oil injection. *Indian J Ophthalmol* 57:105–109
45. Kapran Z, Acar N, Unver YB et al (2008) Passive removal of silicone oil with a 25-gauge sutureless system. *Jpn J Ophthalmol* 52:63–66
46. Oliveira LB, Reis PA (2007) Silicone oil tamponade in 23-gauge transconjunctival sutureless vitrectomy. *Retina* 27:1054–1058
47. Shah CP, Ho AC, Regillo CD et al (2008) Short-term outcomes of 25-gauge vitrectomy with silicone oil for repair of complicated retinal detachment. *Retina* 28:723–728
48. Siqueira RC, Gil AD, Jorge R (2007) Retinal detachment surgery with silicone oil injection in transconjunctival sutureless 23-gauge vitrectomy. *Arq Bras Oftalmol* 70:905–909
49. Chalam KV, Shah VA (2004) Successful management of cataract surgery associated vitreous loss with sutureless small-gauge pars plana vitrectomy. *Am J Ophthalmol* 138:79–84
50. Naito T (2008) Transconjunctival sutureless 25-gauge vitrectomy with newly designed microcannulas. *J Med Invest* 55:51–53
51. Tei M, Shimamoto T, Yasuhara T et al (2005) A new non-trocar system for 25-gauge transconjunctival pars plana vitrectomy. *Am J Ophthalmol* 139:1130–1133
52. Eckardt C, Eckert T, Eckardt U (2008) 27-gauge twilight chandelier illumination system for bimanual transconjunctival vitrectomy. *Retina* 28:518–519
53. Oshima Y, Awh CC, Tano Y (2007) Self-retaining 27-gauge transconjunctival chandelier endoillumination for panoramic viewing during vitreous surgery. *Am J Ophthalmol* 143:166–167
54. Shimada H, Nakashizuka H, Mori R et al (2005) Expanded indications for 25-gauge transconjunctival vitrectomy. *Jpn J Ophthalmol* 49:397–401
55. Tewari A, Shah GK, Fang A (2008) Visual outcomes with 23-gauge transconjunctival sutureless vitrectomy. *Retina* 28:258–262
56. Yanyali A, Celik E, Horozoglu F et al (2006) 25-gauge transconjunctival sutureless pars plana vitrectomy. *Eur J Ophthalmol* 16:141–147
57. Yoon YH, Kim DS, Kim JG et al (2006) Sutureless vitreoretinal surgery using a new 25-gauge transconjunctival system. *Ophthalmic Surg Lasers Imaging* 37:12–9
58. Hikichi T, Matsumoto N, Ohtsuka H et al (2009) Comparison of one-year outcomes between 23- and 20-gauge vitrectomy for preretinal membrane. *Am J Ophthalmol* 147:639–643.e1
59. Kadosono K, Yamakawa T, Uchio E et al (2006) Comparison of visual function after epiretinal membrane removal by 20-gauge and 25-gauge vitrectomy. *Am J Ophthalmol* 142:513–515
60. Kychenthal A, Dorta P (2008) 25-gauge lens-sparing vitrectomy for stage 4a retinopathy of prematurity. *Retina* 28:S65–S68

61. Patelli F, Radice P, Zumbo G et al (2007) 25-gauge macular surgery: results and complications. *Retina* 27:750–754
62. Rizzo S, Genovesi-Ebert F, Murri S et al (2006) 25-gauge, sutureless vitrectomy and standard 20-gauge pars plana vitrectomy in idiopathic epiretinal membrane surgery: a comparative pilot study. *Graefes Arch Clin Exp Ophthalmol* 244:472–479
63. Rizzo S, Belting C, Cresti F et al (2007) Sutureless 25-gauge vitrectomy for idiopathic macular hole repair. *Graefes Arch Clin Exp Ophthalmol* 245:1437–1440
64. Shinoda H, Shinoda K, Satofuka S et al (2008) Visual recovery after vitrectomy for macular hole using 25-gauge instruments. *Acta Ophthalmol* 86:151–155
65. Valmaggia C (2007) Pars plana vitrectomy with 25-gauge instruments in the treatment of idiopathic epiretinal membranes. *Klin Monatsbl Augenheilkd* 224:292–296
66. Chang CJ, Chang YH, Chiang SY et al (2005) Comparison of clear corneal phacoemulsification combined with 25-gauge transconjunctival sutureless vitrectomy and standard 20-gauge vitrectomy for patients with cataract and vitreoretinal diseases. *J Cataract Refract Surg* 31:1198–1207
67. Oshima Y, Ohji M, Tano Y (2006) Surgical outcomes of 25-gauge transconjunctival vitrectomy combined with cataract surgery for vitreoretinal diseases. *Ann Acad Med Singapore* 35:175–180
68. Hubschman JP, Gonzales CR, Bourla DH et al (2007) Combined 25- and 23-gauge surgery: a new sutureless vitrectomy technique. *Ophthalmic Surg Lasers Imaging* 38:345–348
69. Singh A, Fawzi AA, Stewart JM (2007) Limitation of 25-gauge vitrectomy instrumentation in highly myopic eyes. *Ophthalmic Surg Lasers Imaging* 38:437–438
70. Altan T, Acar N, Kapran Z et al (2008) Transconjunctival 25-gauge sutureless vitrectomy and silicone oil injection in diabetic tractional retinal detachment. *Retina* 28:1201–1206
71. Arumi JG, Boixadera A, Martinez-Castillo V et al (2009) Transconjunctival sutureless 23-gauge vitrectomy for diabetic retinopathy. *Review. Curr Diabetes Rev* 5:63–66
72. Bahar I, Axer-Siegel R, Weinberger D (2006) Pars plana vitrectomy: comparison of three techniques for the treatment of diabetic vitreous hemorrhage. *Ophthalmic Surg Lasers Imaging* 37:364–369
73. Shinoda H, Nakajima T, Shinoda K et al (2008) Jamming of 25-gauge instruments in the cannula during vitrectomy for vitreous haemorrhage. *Acta Ophthalmol* 86:160–164
74. MA VONF, Kunjukunju N, Weber C et al (2009) 25-Gauge sutureless vitrectomy 20-gauge vitrectomy for the repair of primary rhegmatogenous retinal detachment. *Retina* 29:444–450
75. Miller DM, Riemann CD, Foster RE et al (2008) Primary repair of retinal detachment with 25-gauge pars plana vitrectomy. *Retina* 28:931–936
76. Tsang CW, Cheung BT, Lam RF et al (2008) Primary 23-gauge transconjunctival sutureless vitrectomy for rhegmatogenous retinal detachment. *Retina* 28:1075–1081
77. Heimann H (2008) Primary 25- and 23-gauge vitrectomy in the treatment of rhegmatogenous retinal detachment—advancement of surgical technique or erroneous trend? *Klin Monatsbl Augenheilkd* 225:947–956
78. Lai MM, Ruby AJ, Sarrafzadeh R et al (2008) Repair of primary rhegmatogenous retinal detachment using 25-gauge transconjunctival sutureless vitrectomy. *Retina* 28:729–734
79. Gonzales CR, Boshra J, Schwartz SD (2006) 25-Gauge pars plana vitrectomy for stage 4 and 5 retinopathy of prematurity. *Retina* 26:S42–S46
80. Gonzales CR, Singh S, Schwartz SD (2009) 25-Gauge vitrectomy for pediatric vitreoretinal conditions. *Brit J Ophthalmol* 98:787–790 Epub 2009 Feb 11
81. Acar N, Kapran Z, Unver YB et al (2008) Early postoperative hypotony after 25-gauge sutureless vitrectomy with straight incisions. *Retina* 28:545–552
82. Chen CJ, Satofuka S, Inoue M et al (2008) Suprachoroidal hemorrhage caused by breakage of a 25-gauge cannula. *Ophthalmic Surg Lasers Imaging* 39:323–324
83. Gupta OP, Weichel ED, Regillo CD et al (2007) Postoperative complications associated with 25-gauge pars plana vitrectomy. *Ophthalmic Surg Lasers Imaging* 38:270–275
84. Kapamajian M, Gonzales CR, Gupta A et al (2007) Suprachoroidal hemorrhage as an intraoperative complication of 25-gauge pars plana vitrectomy. *Semin Ophthalmol* 22:197–199
85. Liu DT, Chan CK, Fan DS et al (2005) Choroidal folds after 25 gauge transconjunctival sutureless vitrectomy. *Eye* 19:825–827
86. Lott MN, Manning MH, Singh J et al (2008) 23-gauge vitrectomy in 100 eyes: short-term visual outcomes and complications. *Retina* 28:1193–1200
87. Riemann CD, Miller DM, Foster RE et al (2007) Outcomes of transconjunctival sutureless 25-gauge vitrectomy with silicone oil infusion. *Retina* 27:296–303
88. Scartozzi R, Bessa AS, Gupta OP et al (2007) Intraoperative sclerotomy-related retinal breaks for macular surgery, 20- vs 25-gauge vitrectomy systems. *Am J Ophthalmol* 143:155–156
89. Scott IU, Flynn HW Jr, Dev S et al (2008) Endophthalmitis after 25-gauge and 20-gauge pars plana vitrectomy: incidence and outcomes. *Retina* 28:138–142
90. Shimada H, Nakashizuka H, Hattori T et al (2008) Vitreous prolapse through the scleral wound in 25-gauge transconjunctival vitrectomy. *Eur J Ophthalmol* 18:659–662
91. Taylor SR, Aylward GW (2005) Endophthalmitis following 25-gauge vitrectomy. *Eye* 19:1228–1229
92. Kunimoto DY, Kaiser RS (2007) Incidence of endophthalmitis after 20- and 25-gauge vitrectomy. *Ophthalmology* 114:2133–2137
93. Chen JK, Khurana RN, Nguyen QD et al (2008) The incidence of endophthalmitis following transconjunctival sutureless 25- vs 20-gauge vitrectomy. *Eye* 23:780–784
94. Parolini B, Romanelli F, Prigione G et al (2009) Incidence of endophthalmitis in a large series of 23-gauge and 20-gauge transconjunctival pars plana vitrectomy. *Graefes Arch Clin Exp Ophthalmol* 247:895–898
95. Shimada H, Nakashizuka H, Hattori T et al (2008) Incidence of endophthalmitis after 20- and 25-gauge vitrectomy causes and prevention. *Ophthalmology* 115:2215–2220
96. Sakaguchi H, Oshima Y, Tano Y (2007) 27-Gauge transconjunctival nonvitrectomizing vitreous surgery for epiretinal membrane removal. *Retina* 27:1302–1304
97. Sawa M, Ohji M, Kusaka S et al (2005) Nonvitrectomizing vitreous surgery for epiretinal membrane. Long-term follow-up. *Ophthalmology* 112:1402–1405
98. Augustin AJ, Offermann I (2007) Scope and limitations of innovative vitrectomy systems. *Klin Monatsbl Augenheilkd* 224:707–715

99. Faia LJ, McCannel CA, Pulido JS et al (2008) Outcomes following 25-gauge vitrectomies. *Eye* 22:1024–1028
100. Guyomarch J, Delyfer MN, Korobelnik JF (2008) Outcomes of 110 consecutive 25-gauge transconjunctival sutureless pars plana vitrectomies. *J Fr Ophthalmol* 31:473–480
101. Ibarra MS, Hermel M, Prenner JL et al (2005) Longer-term outcomes of transconjunctival sutureless 25-gauge vitrectomy. *Am J Ophthalmol* 139:831–836
102. Inoue Y, Kadosono K, Yamakawa T et al (2009) Surgically-induced inflammation with 20-, 23-, and 25-gauge vitrectomy systems: an experimental study. *Retina* 29:477–480
103. Okamoto F, Okamoto C, Sakata N et al (2007) Changes in corneal topography after 25-gauge transconjunctival sutureless vitrectomy versus after 20-gauge standard vitrectomy. *Ophthalmology* 114:2138–2141
104. Yanyali A, Celik E, Horozoglu F et al (2005) Corneal topographic changes after transconjunctival (25-gauge) sutureless vitrectomy. *Am J Ophthalmol* 140:939–941
105. Jorge R, Gomes AV, Siqueira RC et al (2007) 20-Gauge transconjunctival pars plana vitrectomy. *Ophthalmic Surg Lasers Imaging* 38:342–344
106. Kellner L, Wimpissinger B, Stolba U et al (2007) 25-gauge vs 20-gauge system for pars plana vitrectomy: a prospective randomised clinical trial. *Br J Ophthalmol* 91:945–948
107. Misra A, Ho-Yen G, Burton RL (2008) 23-Gauge sutureless vitrectomy and 20-gauge vitrectomy: a case series comparison. *Eye* 23:1187–1191
108. Williams GA (2008) 25-, 23-, or 20-gauge instrumentation for vitreous surgery? *Eye* 22:1263–1266
109. Wimpissinger B, Kellner L, Brannath W et al (2008) 23-Gauge versus 20-gauge system for pars plana vitrectomy: a prospective randomised clinical trial. *Br J Ophthalmol* 92:1483–1487
110. Lewis H (2007) Sutureless microincision vitrectomy surgery: unclear benefit, uncertain safety. *Am J Ophthalmol* 144:613–615
111. Wickham L, Aylward W (2007) 25-Gauge vitrectomy: the hidden costs. *Eye* 21:1443
112. Sabti KA, Raizada S, Kandari JA et al (2008) Applications of endoscopy in vitreoretinal surgery. *Retina* 28:159–166
113. Sheindlin JA, Hirose T, Hartnett ME (1999) Ophthalmic endoscopy: applications in intraocular surgery. *Int Ophthalmol Clin* 39:237–247
114. Norris JL, Cleasby GW (1982) Intraocular foreign body removal by endoscopy. *Ann Ophthalmol* 14:371–372
115. Norris JL, Cleasby GW (1978) An endoscope for ophthalmology. *Am J Ophthalmol* 85:420–422
116. Volkov VV, Danilov AV, Vassin LN et al (1990) Flexible endoscope for intraocular surgery. *Arch Ophthalmol* 108:1037–1038
117. Volkov VV, Danilov AV, Vassin LN et al (1990) Flexible endoscopes. *Ophthalmoscopy techniques and case reports. Arch Ophthalmol* 108:956–957
118. Al Sabti K, Raizada S, Al Abduljalil T (2009) Cataract surgery assisted by anterior endoscopy. *Br J Ophthalmol* 93:531–534
119. Fankhauser F, Kwasniewska S (2004) Cyclodestructive procedures. II. Optical fibers, endoscopy, physics: a review. *Ophthalmologica* 218:147–161
120. Norris JL, Cleasby GW, Nakanishi AS et al (1981) Intraocular endoscopic surgery. *Am J Ophthalmol* 91:603–606
121. Demling L, Hagel HJ (1985) Videoendoscopy. Fundamentals and problems. *Endoscopy* 17:167–169
122. de Smet MD, Mura M (2008) Minimally invasive surgery-endoscopic retinal detachment repair in patients with media opacities. *Eye* 22:662–665
123. Ben-nun J (2001) Cornea sparing by endoscopically guided vitreoretinal surgery. *Ophthalmology* 108:1465–1470
124. De Smet MD, Carlborg EA (2005) Managing severe endophthalmitis with the use of an endoscope. *Retina* 25:976–980
125. Ciardella AP, Fisher YL, Carvalho C et al (2001) Endoscopic vitreoretinal surgery for complicated proliferative diabetic retinopathy. *Retina* 21:20–27
126. Lee SC, Kim GO, Kim DH et al (2000) Endoscopic laser photocoagulation for management of neovascular glaucoma. *Yonsei Med J* 41:445–449
127. Faude F, Wiedemann P (2004) Vitreoretinal endoscope for the assessment of the peripheral retina and the ciliary body after large retinectomies in severe anterior PVR. *Int Ophthalmol* 25:53–56
128. Koch FH, Luloh KP, Augustin AJ et al (1997) Subretinal microsurgery with gradient index endoscopes. *Ophthalmologica* 211:283–287
129. Koch FH, Quiroz-Mercado H, Hattenbach LO et al (2004) Pigment epithelium endoscopic laser surgery for treatment of choroidal neovascularization. *Ophthalmologica* 218:162–175
130. Quiroz-Mercado H, Yeshurun I, Sanchez-Buefil E et al (2001) Subretinal, viscoelastic-assisted, endoscope-guided photothermal ablation of choroidal neovascular membranes by erbium:YAG laser. *Ophthalmic Surg Lasers* 32:456–463
131. Boscher C, Lebuissou DA, Lean JS et al (1998) Vitrectomy with endoscopy for management of retained lens fragments and/or posteriorly dislocated intraocular lens. *Graefes Arch Clin Exp Ophthalmol* 236:115–121
132. Chen SD, Salmon JF, Patel CK (2005) Videoendoscope-guided fluorescein-assisted vitrectomy for phakic malignant glaucoma. *Arch Ophthalmol* 123:1419–1421
133. Batman C, Ozdamar Y, Aslan O et al (2008) Tissue glue in sutureless vitreoretinal surgery for the treatment of wound leakage. *Ophthalmic Surg Lasers Imaging* 39:100–106

Index

A

Ab externo trabeculectomy, 165
Ablation profiles
 LASIK, 106
 spot size, 106
 wound healing, 106
Accommodative presbyopic intraocular lenses, 120
Accommodative strabismus, 124
ACRILISA 366D IOL, 118, 119
ACRILISA TORIC 466TD, 118
Acri.Smart 48S, 116
AcrySof IQ IOL, 117
AcrySof IQ SN6OWF, 117
AcrySof SN6OAT, 117
Acute dacryocystitis, 42
Acute ectropion, 7
Acyclovir, 77, 78
Adjustable sutures, 126, 135
Adrenaline, 1
Advanced surface ablations (ASA)
 haze, 106
 SCHWIND Amaris, 106
 thermal load, 106, 107
 wound-healing modulators, 106
Air fill, 86
Alcon LADARVISION 6000, 103
Alio hydromanipulator fingernail, 119
Alio MICS diamond blade, 118
Allergic reactions, 148
Allograft rejection
 endothelial rejection, 78
 prednisolone, 78
 topical steroid, 78
Amadeus II microkeratome, 99
Amblyopia, 60
Amniotic membrane (AM), 28
Amniotic membrane transplantation (AMT), 23, 93
Anatomical abnormalities, 148
Anesthesia, 1, 61, 89, 110, 114, 118, 124, 126, 148,
 168, 176, 179, 183, 192, 197–199, 202
 blebitis, 162
 bleb leakage, 162
 diamond knife, 163
 hockey knife, 162
 scleral flap, 163
 vasoconstrictive, 163

Angle-supported PIOL, 108–109
Aniridia, 175
Anterior chamber depth, 110
Anterior chamber hemorrhage, 69, 70
Anterior segment dysgenesis syndromes, 175
Anterior segment ischemia, 124, 133
Anterior synechiae, 76, 77
Anterior vitrectomy, 69
Antibiotics, 167, 168, 185, 193, 210
Anti-inflammatory medications, 167
Antimetabolites, 190
Anti-TGF- β , 107
Aphakia, 69
Aphakic bullous keratopathy, 82
Aqueous humor, 146
Artificial tears, 210
Artiflex PIOL, 109
Artisan and Visian ICL, 109
Aspheric ablation profiles, 102
Aspheric intraocular lenses, 116, 117
Aspirin, 61
Asthenopia, 124
Astigmatism, 60, 66, 68, 71, 73–74, 79, 82, 84,
 116–118, 209, 225
 sutures, 74
 visual acuity, 74
Atropine, 123
Autologous blood, 149
Automated corneal shaper (ACS), 98

B

Baikoff ZB intraocular lens, 108
Balanced salt solution (BSS), 68, 69, 73, 84, 86, 118, 168, 205
Balloon dilatation, 48–53
Bangerter graded foils, 124
Bare scleral technique, 28, 88, 92
Barraquer needle holder, 62
Barron corneal donor punch, 64
Basal vitrectomy, 174
Bausch and Lomb 217, 103, 106
BD K-4000 microkeratome, 99
Best corrected visual acuity (BCVA), 79, 86
Beta-irradiation, 93
Bevacizumab, 223
Biaxial phacoemulsification, 208
Biaxial surgery, 197

Bicanalicular intubation, 47
 Bifocals, 124
 Bimanual/biaxial irrigators, 197, 209
 Bipolar diathermy, 147
 Bleb. *See* Filtering bleb; Filtering bleb related infections
 Bleeding in the anterior chamber, 194
 Blepharospasm, 4, 7
 Boergens' modified Harada-Ito operation, 143
 Bone morphogenic proteins 2 and 4 (BMP), 107
 Botulinum toxin, 3–4, 15
 Brown's syndrome, 143–146
 Bullous keratopathy, 59
 Bupivacaine, 1
 Buttonhole, 148
 Button-hole stenosis, 48

C

Caliper, 66, 149, 152
 Canalicular stenosis, 46
 Canaliculoplasty, 46
 Cannula, 150, 154, 204–206, 218, 220, 224
 Cannulas and blades, 64
 Capsular block syndrome, 204
 Capsular rupture, 204
 Capsulorhexis, 118, 203, 204, 206–209
 Capsulorhexis forceps, 203
 Carbon dioxide (CO₂) laser, 42
 Carbonic anhydrase inhibitor, 73
 Cardinal sutures, 67–68
 Carriazo-Pendular microkeratome, 99, 100
 Cartridge injection, 209
 Cataract, 86, 109, 188, 224, 226
 choroidal hemorrhage or infusion, 224
 dislodged 25-gauge cannula intravitreally, 224
 endophthalmitis, 224
 extraction, 73
 retinal tear or detachment, 224
 subconjunctival silicone oil, 224
 surgery, 115–119, 194–195, 223
 vitreous incarceration, 224
 Cataract/lens extraction, 175
 Cautery, 70, 147, 149
 Cellulose sponge, 163
 Central retinal artery occlusion, 86
 Chandelier light, 223
 Chopping technique, 119, 198, 206–208
 Choroidal detachments, 70, 167–169, 180, 183, 186, 188
 Choroidal folds, 219
 Choroidal hemorrhage/infusion, 224
 Chronic macular hypotony and choroidal folds, 224
 Ciliary body detachment, 227
 Clariflex IOL, 117
 Clips, 149
 Coaxial phacoemulsification, 201
 Cold phacoemulsification, 208
 Collagen cross-linking, 60, 61
 Complications in pterygium removal
 lamellar patch graft, 94
 MMC, 94
 NSAIDs, 94
 Complications of MISS, 146–149

Compression sutures, 74
 Computer tomography (CT), 34
 Congenital and juvenile glaucoma, 174
 Congenital/developmental glaucoma, 174
 Conjunctiva and scleral flap erosion, 180
 Conjunctiva fibrosis, 170
 Conjunctival autograft 88, 92–94
 epinephrine, 90
 forceps, 90
 Conjunctival autograft placement, 93
 Conjunctival blebs, 219
 Conjunctival flap, 172, 176
 Conjunctival graft, 27, 28
 Conjunctival haemorrhage, 101
 Conjunctival injection, 148
 Conjunctival oedema, 101
 Conjunctival opening
 classification, 124
 type, 124
 Conjunctival redness, 149
 Conjunctival resection, 64
 Conjunctival rotational flaps, 28
 Conjunctival surgery, 23
 Conjunctival swelling, 148
 Conjunctival tearing, 146, 147, 149, 151
 Conjunctivochalasis (CCh), 23–26
 Conjunctivorrhinostomy, 35
 Contact lens, 71, 74, 123, 221
 Control distance, 132
 Cornea
 dystrophies, 59
 ectasias, 59, 60, 66
 opacification, 61
 punch, 64
 refractive surgery, 98–108
 ulceration, 92
 Cornea guttata, 82
 Cornea–iris angle, 110
 Corneal aberrations, 99
 Corneal allograft rejection, 75
 anterior segment inflammatory disease, 76
 graft diameter, trephine size, 76
 graft failure, 76
 graft rejection, 76
 herpes simplex keratitis, 76
 HLA-matching, 75
 ocular surface disease and age, 76
 trauma/infections, 75
 Corneal dellen, 124, 148
 Corneal endothelium, 175
 Corneal erosion, 146
 Corneal exposure, 6
 Corneal haze and pain, 107
 Corneal incisions, 201–203
 Corneal inflammation, 75
 Corneal protection, 4, 15
 Corneal relaxing incisions, 118
 Corneal thickness, 100
 Correction of post-keratoplasty astigmatism
 suture removal, 74
 wedge resections, 74

Cortical clean-up, 204
 polishing of the posterior capsule, 209
 Corticosteroids, 168, 169, 185, 187, 193
 Cosmesis, 124
 Cryocoagulation, 147
 Cryotherapy, 8
 Customised intraocular lenses, 120
 Cutting blocks, 64
 Cyclodialysis spatula, 154
 Cyclogyl, 86
 Cyclopentolate, 118
 Cycloplegia, 227
 Cycloplegic refraction, 123
 Cycloplegics, 169
 Cyclosporine A, 71, 84, 94
 Cyclotorsional deviation, 105, 141, 143
 Cyclotorsions, 142
 Cystic bleb, 168
 Cytochrome *c* peroxidase, 107

D

Dacryocystography, 34
 Dacryoendoscopy with transcanalicular
 laserdacryoplasty, 46–47
 Dacryolithiasis, 47
 Dacryoliths, 35, 42, 51
 Decompression hemorrhage, 167
 Deep anterior lamellar keratoplasty (DALK), 59
 Deep sclerectomy, 161–171, 183
 Depth of the anterior chamber, 174
 Descemetopexy, 170
 Descemet's membrane, 59, 84, 201
 Descemet's scrapper, 83
 Descemet's stripping endothelial keratoplasty
 (DSEK), 73, 83, 85, 86
 face up, 84
 forceps, 84
 full-thickness keratoplasty, 83
 postoperative medications, 84–85
 suture, 84
 suture-related problems, 82
 thickening of Descemet's membrane, 82
 wound healing, 82
 Detachment of the Descemet's membrane, 168
 Diathermy probe, 183, 184, 187
 Direct excision of eye lashes, 9
 Dislocated IOL, 227
 Dispersive viscoelastic, 203
 Distichiasis, 8–9
 Donor button, 69
 Donor cornea, 30
 cutting block, 67
 weck cell, 67
 Donor cornea preparation, 84
 lens/iris diaphragm, 85
 rubbing the eye, 85
 Double padding, 180
 Draeger lamellar keratome, 98
 Drainage device
 porcine scleral collagen (Aquaflow®), 166
 seton tube, 166

SK gel®, 166
 T-Flux®, 166
 trabeculectomy, 166
 viscoelastics, 166
 Dry eye syndrome, 23, 148
 DSEK. *See* Descemet's stripping endothelial
 keratoplasty
 Duploject, 90
 Duty cycle, 220
 Dye, 150
 Dye disappearance test, 34

E

Ectasia, 60, 99
 Ectropion, 4
 Elliptical phacoemulsification, 208
 Empyema, 35
 Encapsulated bleb, 188
 Encysted filtering bleb, 168, 170
 Endocrine orbitopathy, 123
 Endoilluminator, 221
 Endolaser probes, 221
 Endonasal endoscopic (microscopic)
 dacryocystorhinostomy (EDCR), 35–41
 Endonasal endoscopic laser dacryocystorhinostomy
 (ELDCR), 41–46
 Endonasal laser-assisted DCR, 41
 Endophthalmitis, 93, 162, 167, 183, 224
 Endoscopic cyclophotocoagulation, 227
 Endoscopic vitreoretinal surgery, 225–228
 opaque media, 224, 226
 penetrating keratoplasty, 226
 Endothelial cell
 damage, 69
 loss, 86, 108, 109, 113, 114
 Endothelial cornea dysfunction, 82
 Endothelial failure, 86
 Endothelial keratoplasty, 83
 Entropion, 1, 4
 involutional and cicatricial, 1
 Epidermal growth factor (EGF), 107
 Epi-LASIK, 106–108
 Epinephrine, 70
 Epiphora, 23, 42, 51
 Epiretinal membrane, 223, 225
 Epiretinal membrane peeling, 220
 Episcleral venous pressure, 191
 Epithelial button, 107
 Epithelial defects, 71–72
 donor tissue, 71
 ocular surface disease, 71
 Erbium-YAG laser, 46, 47
 Everting sutures, 2
 Evisceration, 70
 Excimer laser, 109, 118
 Ex-PRESS™ miniature shunt, 172–181
 Expulsive choroidal hemorrhage, 68, 70
 External DCR, 41
 Extrusion
 needles, 221
 tips, 220

- Eyelid
 - speculum, 62, 149
 - swelling, 148
- Eye patching, 210
- Eye penetration, 146
- Eye speculum, 149
- Eye trackers, 102
 - cyclotorsion, 105
 - decentred ablations, 104
 - horizontal and vertical displacements, 105
 - vertical/horizontal rotation, 105
- F**
- Fascia lata, 12
- Fibrosis of the filtering bleb, 168
- Fibrosiscapsule, 168
- Femtosecond laser, 98–102, 119
- Fibrin, 187
 - adhesive, 89
 - gel, 28
 - glue, 27
- Filtering bleb, 147, 148, 168, 173, 179, 183
- Filtering bleb related infections, 167, 169
- Fine/Thornton fixation ring, 198, 201
- Flap creation technology
 - buttonholes, 98
 - corneal aberrations, 99
 - corneal ectasia, 98
 - corneal flaps, 99
 - ectasia, 99
 - flap thickness, 98
 - Hansatome microkeratome, 98
 - partial/free flaps, 98
- Flat cornea, 74
- Flieringa rings, 62
- Fluid–air exchange, 222
- Fluid–gas exchange, 226
- Fluorescein dye, 71, 199, 210
- 5-Fluorouracil, 40, 163, 168, 183
- Flying-spot laser, 102
- Forceps, 20, 149, 221
- Foreign body granuloma, 148
- Fornix based conjunctival incision, 129
- Fox pentagon brow suspension, 12, 13
- Fractal rotating mask, 102
- Fragmatome, 221
- Fresh tissue technique, 16
- Fuchs endothelial dystrophy, 82
- Full thickness lid resection, 18
- Full thickness pentagon excision, 4
- Fumes, 146
- Fused fiber-optic endoscopes, 225
- G**
- 23-Gauge and 25-gauge microincisions, 217, 219, 220, 224
- 20-Gauge vitrectomy, 217, 220
- General anesthesia, 70, 197
- Giant retinal tears, 224
- Glasses, 123
- Glaucoma, 72, 73
 - aphakic, 174
 - malignant, 169, 227–228
 - narrow-angle, 175
 - neovascular, 175
 - pigmentary, 169, 173–174
 - posttraumatic angle-recession, 175
 - pseudoexfoliative, 169, 174
 - refractory, 193–194
 - secondary to uveitis, 174
 - shunt, 172
 - traumatic, 169
 - uveitic, 169
- Glaucoma drainage device (GDD), 73
- Glaucos® iStent, 181, 190–195
- Globe penetration, 151
- Gobin's conjunctival opening, 126
- Goldmann applanation tonometry, 73
- Goniotomy, 174
- Gradient-index (GRIN) endoscopes, 225
- Graft rejection, 59
- H**
- Halos, 114
- Hansatome microkeratome, 98, 100
- Haptic exchange, 113–114
- Harms conjunctival opening, 124, 133, 148, 149, 151, 152
- Harvey and Anderson's technique, 13
- Healon GV™, 184
- Heermann-Jones tube, 35
- Herpes simplex viral (HSV), 60
 - acyclovir, 77, 78
 - corneal scarring, 77
 - epithelial defect, 78
 - grafts, 78
 - HSV keratitis, 72, 77
- Hessburg-Barron vacuum trephine, 64
- High-frequency diathermy, 188
- Holmium:YAG laser, 42, 43
- Horizontal mattress sutures, 155
- Host cornea preparation
 - anesthesia, 84
 - astigmatism, 84
 - modified Sinskey hook, 84
 - viscoelastic, 84
- Hydrodelineation, 204–207
- Hydrodissection, 204–206, 208, 209
- Hyopotony, 223
- Hyperfiltration, 177, 180
- Hyperopic shift, 86
- Hyphema, 167–169, 175, 180, 186, 188, 226
- Hypomochlion, 146, 149
- Hypotonia, 146, 148
- Hypotony, ocular, 146, 148, 168, 169, 177, 179, 180, 186, 188, 217–219, 222, 227
 - chronic macular hypotony and choroidal folds, 224
 - dislodged 25-gauge cannula intravitreally, 224
 - endophthalmitis, 224
 - maculopathy, 219
 - subconjunctival silicone oil, 224

I

I/A cortex removal, 198
Iatrogenic retinal breaks, 228
Immunosuppressants, 71
Inadvertent eye rubbing, 210
Incomitant strabismus, 131
Indentation technique, 150
Inelastic conjunctiva, 147
Infection, 168
Infectious scleritis, 93
Inferior oblique muscle, 1
Inferior oblique overaction, 141
Inferior tarsus, 1
Infiniti phacoemulsification platform, 119
Inflammation, 168
Infusion trocar-cannula, 222
Injury to the optic nerve, 197
Instruments, surgical, 149–150
INTACS, 60
Interleukin (IL)-1, 107
Intermittent entropion, 2
Internal limiting membrane, 222
Intracorneal ring inserts, 60
Intralase® femtosecond laser, 99–102
Intraocular calipers, 109
Intraocular lens, 69
Intraocular pressure (IOP), 65, 69–73, 85, 92, 167, 169, 179, 183, 186, 188, 189, 193, 195
Intraocular refractive surgery, 108–115
Intraoperative adjustment, 126
Intraoperative complications
 posterior capsule, 69
 vitreous loss, 69
Intrasaccal stenosis, 35
Intrascleral bleb, 179
Inverting sutures, 7
Involutional entropion, 2
IOL implantation, 209
Iridectomy, 64, 172, 181, 227
Iridocapsular adhesions, 154
Iridocorneal endothelial syndrome (ICE), 83
Iridodialysis, 155
Iridotomy, 175
Iris, 180
Iris dialysis, 159
Iris-fixated Artisan PIOL, 109
Iris-lens diaphragm, 69
Irrigating choppers, 197
Irrigation, 207, 208
Ischemic conjunctival bleb, 170

J

Juxtacanalicular trabeculum, 165

K

Kaufmanns modified Hummelsheim procedure, 137
Kelman-Duet phakic intraocular lens, 112, 113
 endothelial cell density, 110, 111
 glare, 114
 haptic exchange, 110, 113–114
 refraction, 111

Kera IsoBeam, 103
Keratitis, 60
Keratitis, infectious, 61
Keratoconus (KCN), 60, 61
Keratocytes, 107
Keratoglobus, 60
Keratoprosthesis, 226
Kerrison rongeur, 37
Koornneef blepharotomy, 13–15
Krumeich, 64
KTP/532 laser, 43
Kuglen hook, 154, 155

L

LacriCath system, 49, 51
Lacrimal duct stent, 39
Lacrimal probe, 37
Lagophthalmos, 15
Lamellar keratoplasty, 30
Lamellar keratotomy, 101
Lamellar slippage, 2
Lamella sparing tumour excision, 18
Large diameter penetrating keratoplasty (LDPK)
 astigmatism, 79
 best corrected visual acuity (BCVA), 79
 cylinder, 80–81
Laser
 assisted DCR, 40
 coagulation, 147
 photocoagulation, 223
 probes, 220
Laser assisted in situ keratomileusis (LASIK), 74–75, 85, 97–106
Laser epithelial keratomileusis (LASEK), 107, 108
LaserSight Astrascan, 103
Late postoperative complications
 aphakic glaucoma, 174
 bleb needling, 17
 cataract extraction, 174
 Descemet's window, 170
 entrapment/incarceration of iris, 170
 excessive filtration, 171
 iridectomies, 174
 retinal detachment, 174
 vitreous, 174
Lattice degeneration, 224
Lazy-T procedure, 4
Lens
 decentration, 114
 designs, 108
 extraction, 191
 injector, 199
Lens opacification, 118
Levato palpebrae, 1
 function, 9
Lid
 anatomy of, 1
 laxity, 2
 retraction, 13–15
 speculum, 197
 swelling of, 197

tumours, 15–19
 Lid margin reflex distance, 9
 Lidocaine, 89, 90, 111, 118, 192
 Lieberman gravity-action corneal donor punch, 64
 Light fiber, 225
 Lignocaine, 118
 Limbal and conjunctival dermoids, 30
 Limbal dysfunction, 88
 Limbal stem cell deficiency (LSCD), 60
 Local carboanhydrase inhibitor, 148
 Loop, 143
 Loss of A/C, 180
 Lower lid ectropion, 4–5
 sutures, 7–8
 Lower lid entropion, 1–4
 Botulinum toxin, 3–4
 sutures, 2–3
 Lymphangiectasia, 23, 26

M

Macular pucker, 224
 Macular surgery, 222–223
 cataract, 222
 membrane peeling, 222
 self sealing sclerotomies, 222
 triamcinolone suspension, 222
 Magnetic resonance imaging (MRI), 34, 172
 Malignant glaucoma, 169, 227–228
 Mannitol, 65, 69
 Marking of the host cornea, 66
 Mechanical trauma, 60
 Medial canthal anterior limb plication, 4
 Membrane scraper, 220, 221
 Microdebrider burrs, 37
 Microdrill dacryoplasty (MDP), 47–48
 Microforceps, 158
 Micro-incisional cataract surgery (MICS),
 116–117, 119
 Micro-incision capsulorhexis forceps, 197
 Microkeratome, 84, 98
 Microprecision test model, 98
 Microvitrectomy instrumentation, 221
 Minimally invasive cataract surgery, 197–210
 Minimally invasive conjunctival surgery, 23–32
 Minimally invasive corneal surgery, 59–95
 Minimally invasive glaucoma surgery, 161–181
 Minimally invasive iris surgery, 153–159
 Minimally invasive lacrimal surgery, 33–54
 Minimally invasive oculoplastic surgery, 1–19
 Minimally invasive refractive surgery, 97–120
 Minimally invasive strabismus surgery (MISS), 126
 Minimally invasive vitreoretinal surgery, 217
 Miosis, pupil, 226
 Miotics, 199, 210
 MISS dose–response relationships, 151–152
 MISS inferior oblique muscle
 plication, 142
 recession, 141–142
 MISS rectus muscle
 advancement, 135
 plication, 135
 plication, 129
 posterior fixation suture, 131–132

 recession, 126–128, 135
 repeat surgery, 132–136
 transposition surgery, 137–139
 MISS superior oblique muscle
 plication, 142
 recession, 142
 Mitomycin C (MMC), 23, 28, 30, 39–40, 52, 75, 89, 92–94,
 115, 163, 168, 176, 180, 183
 M2 microkeratomes, 99
 Mobilization of epinucleus, 204
 Modulated power, 197
 Mohs' micrographic surgery, 15–18
 Monofilament polyester, 153
 Monoka intubation, 47
 Moria M2 microkeratome, 100
 Moria's one use-plus, 99
 MR-dacryocystography, 34
 Mucosal flaps, 37
 Mùhlendycks' partial posterior superior oblique tenectomy,
 143–146
 Muller's muscle, 1
 Muller's muscle-conjunctival resection, 9–10
 Multi-focal intraocular lenses, 116, 117
 Muscle
 hook, 149
 imbalance, 197
 paralysis, 1367
 splitting, 132, 137
 Muscle desinsertion, 147
 Muscle plication, 126, 139, 142, 148, 151
 Muscle recessions, 126, 151
 Myofibroblasts, 107
 Myopic and hyperopic corrections, 102

N

Nanosecond lasers, 120
 Narrow-angle glaucoma, 175
 Nasolacrimal duct obstruction, 42
 Nd:YAG laser, 156, 227
 Nd:YAG laser goniopuncture, 168–170
 Near/distance incomitance, 131
 Necrotizing scleritis, 94
 Needle-holders, 62, 146
 Neovascular glaucoma, 175
 Neovascularization, 75
 Nidek EC5000 CXIII, 103
 Night vision, 120
 Nonpenetrating glaucoma surgery, 161–171, 173
 Nonsteroidal anti-inflammatory drugs (NSAIDs), 179, 210
 Nylon sutures, 153
 Nystagmus, 131

O

Oblique muscle procedures, 139–146
 Oblique muscles, 148
 Occlusive contact lenses, 124
 Ocular hypertony, 168
 Ocular myasthenia gravis, 123
 Ocular surface diseases, 148
 Ofloxacin, 119
 One stitch aponeurosis repair, 10–12
 One use-plus SBK microkeratome, 99
 Opacifications of the crystalline lens, 115

Open-angle glaucoma, 173
Open sky vitrectomy, 226
Operating microscope, 151
Optical coherence tomography, 219
Optical zone, 102, 103
Orbital decompression, 123
Orbital fat, 147
Osher Y hook, 154
Overaction of the superior oblique muscle, 142

P

Painting of the anterior lens capsule, 202
Palpebral aperture, 9
Papillomavirus, 88
Paracentesis knife, 198
Paralytic ectropion, 5
Parks' fornix incision, 124, 133, 137
Parks' rectus muscle
 plication, 129–131
 recession, 129
Passive eye tracker, 102
Pellucid marginal degeneration (PMD), 60
Penetrating keratoplasty (PK), 59–81, 86
Penetration of the globe, 147
20/10 Perfect vision, 102
Perfluorocarbon liquid, 224
Perfluorocarbon liquid cannula, 221
Peripheral anterior synechia, 154, 168, 170
Peripheral iridotomy, 111, 114
Peroperative complications
 balanced salt solution, 169
 iridectomy, 169
 iris prolapse, 169
 shallow/flat anterior chamber, 169
 viscoelastics, 169
Phacoemulsification, 198, 223
Phacoemulsification machine's pump level, 197
Phacoemulsification tips, 206
Phaco incision, 201, 207
Phaco infusion port, 198
Phaco tip, 207
Phakic intraocular lens (PIOL), 108
Phakic intraocular lens surgery
 anterior chamber depth, 109
 endothelial cell loss, 108, 109
 incision size, 108
Phenylephrine, 86, 118
Phosphene tonometer, 73
Photorefractive keratectomy (PRK), 74, 75, 97,
 106–108, 115
Physical activities, 146
Pigmentary glaucoma, 169, 173–174
Pillar Tarsorrhaphy, 5–7
Pilocarpine, 65, 111
Pinguecula, 27
Platelet-derived growth factor (PDGF), 107
Polypropylene, 153, 155
Posterior anchoring of rectus muscle, 131
Posterior capsule, 207, 209
Posterior capsule rupture, 69
Posterior chamber lens-supported PIOL, 109
Posterior lamellar keratoplasty, 83
Postoperative complications, 147–148

 iris prolapse, 169
 suprachoroidal hemorrhage, 169
 trabeculo-Desemet's membrane perforation, 169
 wound leak, 169
Postoperative complications, PK
 bleb, 73
 corneal epithelial and stromal edema, 73
Postoperative handling, 146
Postoperative hypotony, 174
Postoperative management, PK
 suture removal, 70
Post-saccal stenosis, 35, 38
Posttraumatic angle-recession glaucoma, 175
Potassium titanyl phosphate, 42
Prednisone. *See* Steroids
Preoperative medications, PK
 antibiotic, 65
 cataract extraction, 65
 miosis, 65
Pre-saccal stenoses, 35
Presbyopia, 115, 117
Pressure bandage, 180
Priglingers' rectus muscle Y-split recession, 126, 132
Prismatic correction, 124
Probing, lacrimal, 42
Progressive lenses, 124
Prolapse of Tenon's tissue, 148
Proliferative diabetic retinopathy, 220, 223, 226
 retinal detachment, 223
 scissors, 223
 vitreous hemorrhages, 223
Proliferative vitreoretinopathy, 224, 226, 227
Pseudoexfoliative glaucoma, 169, 174
Pseudophakic bullous keratopathy, 82
Pseudophakic glaucoma with an A/C IOL
 A/C loss, 175
 hypotony, 175
Pseudopterygium, 30
Pseudostrabismus, 123
Pterygium, 88–95
 amniotic membrane, 89
 beta-irradiation, 89
 fibrin glue, 90
 lid speculum, 89
 sutures, 90
Ptosis, 9–13, 197
Ptosis induction, 15
Puncture incisions, 119
Pupil, 108, 113, 114, 117, 120, 158
Pupil distortion and ovalization, 159
Pupillary block, 85, 86, 169
Pupil repair, 157–159
360° Purse-string suture, 157
Pyogenic granuloma, 26

Q

Quality of life, 124

R

Radial markers, 63
Rectus muscle
 loop recession, 126
 procedures, 124–126

Recurrent pterygium, 92
 Recurrent subconjunctival hemorrhage, 24
 Refractive changes, 149
 Refractive–diffractive optics, 118
 Refractive error, 106
 Refractive surgery, 74
 Refractory glaucoma, 193–194
 Relaxing incisions, 74
 Removal of pterygium
 lidocaine, 89
 marking pen, 89
 Westcott scissor, 89
 Repeat surgery, 124, 126, 135, 147, 149, 151
 Repositioning donor tissue
 air fill, 85
 anterior chamber (AC), 85
 face up position, 85
 Retained lens fragments, 227
 Retinal breaks, 220, 224, 226, 227
 Retinal detachment, 132, 219, 223–224
 Retinal tears, 219
 Retinectomy, 227
 Retinotomy, 226, 227
 Retrobulbar hemorrhage, 197
 Retrocorneal or retrolental membranes, 226
 Retroequatorial fixation sutures, 135
 Rigid-gas permeable contact lenses (RGP), 60
 Rothman–Gilbard corneal punch, 64
 Royce Johnson suture, 5
 rTPA, 195

S

Santiago's conjunctival opening, 126
 Scarred conjunctiva, 173
 Schlemm's canal, 162, 165, 169, 190, 192
 Schwind Amaris laser, 102, 103
 Schwind Esiris laser, 102, 103
 Schwind Keratom F, 102
 Scintigraphy, 34
 Scissors, 64, 149, 220, 221
 Scleral depression, 220, 227
 Scleral fixation rings, 62, 66
 Scleral flap, 172, 176–180
 Scleral necrosis, 93
 Scleral perforation, needle, 69
 Scleral sutures loosened, 148
 Sclerostomy, 172
 Sclerothermalotomy ab interno, 183–189
 Secondary balloon DCRs, 52
 Sector iris defect, 156
 Sector occlusion, 146
 Seidel test, 71, 169
 Self-sealing tunnel, 218
 Sensar AR40e, 117
 Serous conjunctival cysts, 148
 Setons, 179
 Shallow anterior chamber, 168, 179, 186, 188
 Silicone "Cones," 39
 Silicone oil injection cannula, 221
 Silicone oils, 220, 224
 Silicone stenting for EDCR, 38–39

Silicone tube, 47
 Silicone tubed stent, 43
 Sinsky hook, 154
 Slip-knot technique, 90
 Sofport L161AO, 117
 Solx, 181
 Spatula, 149
 Spectacles, 60, 71
 Speculum, 66
 Spherical aberration, 106
 Sphincterotomies, 156
 Sponge-swabs, 149
 Square or diamond-shaped pupil, 157
 Start doing MISS, 148
 Stenoses of lacrimal drainage system, 33–54
 Stent lumen obstruction, 194, 195
 Stent malposition, 194, 195
 Stents, 42, 49
 Steroidal anti-inflammatory, 210
 Steroid–antibiotic combination, 179
 Steroid-induced ocular hypertension, 72, 167
 Steroids, 71, 72, 84, 85, 90, 119, 179
 Strabismus surgery, 30
 nonsurgical treatment, 123–124
 Stromal edema, 85
 Stromal hydration, 199, 209–210
 glare, 210
 haloes, 210
 Sturge–Weber syndrome, 174
 Subconjunctival fibrosis, 180
 Subconjunctival hemorrhage, 147, 148, 197
 Subconjunctival medications, 68
 Subconjunctival silicone oil, 224
 subretinal choroidal neovascular membrane, 227
 Subretinal fluid drainage 226–227
 Subretinal surgery, 227
 Sulcus-to-sulcus measurement, 110
 Superficial punctate keratopathy, 24
 Superior oblique muscle plications, 143
 Superior oblique muscle recessions, 142
 Superior oblique palsy, 141
 Superior oblique tendon, 143
 Suprachoroidal hemorrhages, 167
 Supramid brow suspension, 12–13
 Sutured IOL, 227
 Sutures, 68, 72, 90
 Swan's conjunctival opening, 124
 Systemic antibiotic, 147

T

Tamponade, 70
 Tarsal eversion, 4
 Tarsorrhaphy, 72
 TDM microruptures, 170
 Tecnis IOL, 117
 Tecnis Z9000, 117
 Temporary inverting sutures, 8
 Temporary lid lowering, 15
 Temporary ptosis, 4
 Temporary tarsorrhaphy, 6
 Tendon split, 143

Tenon's layer, 162
 Tenon's tissue, 147, 148, 151
 prolapsed, 124
 prolapsing, 147
 Tenotomy scissors, 64
 Thermal tissue damage, 103–104
 Thyroid associated ophthalmopathy (TAO), 13, 151
 Tisseel, 90
 Tono-pen, 73
 Toothed forceps, 62–63
 forceps, 62
 Topical carboanhydrase inhibitor, 146
 Topical eye drops, 148
 Topical steroids, 148
 Toric intraocular lenses, 109, 116, 118
 Torque reduction, 132
 Torsional phacoemulsification, 208
 Trabeculectomy, 73, 167, 173, 174, 179, 181, 183
 Trabeculo-Descemet's membrane, 162–163
 cellulose sponge, 165
 Galan's scissors, 165
 metal blade, 165
 paracentesis, 165
 ruby knife, 165
 Schlemm's canal, 164
 scleral spur, 164
 spatula, 165
 Traction suture, 146, 148
 Transconjunctival entry, 217
 Transforming growth factor (TGF), 179
 Transient light sensitivity syndrome, 101
 Transition to minimally invasive strabismus surgery, 151
 Transpalpebral stay suture, 146
 Transverse sutures, 2
 Traumatic glaucoma, 169
 Traumatic lacrimal stenosis, 51
 Treatment of rejection
 cataract, 85
 DSEK, 86
 IOP, 85
 steroids, 85
 Trephination, 69
 donor cornea, 67
 host cornea, 66–67
 Trephine, 66
 Trephine blades, 63
 Troutman corneal punch, 64
 Trypan blue, 146
 Tumour necrosis factor (TNF) α , 107

U

Ulcerative keratitis, 60
 Ultrasound biomicroscopy, 219
 Unsleeved tip, 208
 Urokinase-type plasminogen activator, 107
 Uveitic glaucoma, 169

V

Valsalva maneuver, 66, 70, 167
 Vancomycin, 200
 Vascularized corneas, 76

Velez' conjunctival opening, 126
 Verisyse/Artisan PIOL, 109
 Viral keratitis, 59
 Visante anterior segment optical coherence tomography, 109
 Visante AS-OCT, 110, 114
 Viscocanalostomy, 183
 Viscoelastics, 69–71, 73, 84, 115, 118, 119, 154, 157, 176–180,
 192, 198–200, 209
 Visian implantable collamer lens, 109
 anterior chamber depth, 114
 visual acuity, 115
 V3 ICLs, 109
 V4 ICLs, 109
 Visian implantable collamer lenses, 109
 Visian toric implantable collamer lens (TICL), 115
 Visthesia, 114
 Visual acuity (VA), 111, 112, 115, 116, 208, 210
 VISX S4, 103
 Vitrectomy, 219–220
 Vitreous base, 227
 Vitreous cutter, 219, 221, 224
 Vitreous incarceration, 219
 Vitreous loss, 69–70
 Vitreous prolapse, 224
 Vitreous strands, 64
 V-pattern incomitance, 143
 V4 Staar Visian ICL, 114

W

Wavefront driven corrections, 102
 Wavefront-guided ablation profiles, 106
 Wavefront-guided LASIK, 106
 Wavelight Allegretto Eye-Q, 103
 Wavelight Allegretto Wave, 103
 Wavelight Concerto, 103
 Wegener's granulomatosis, 94
 Westcott scissors, 64
 White-to-white distance of the cornea, 109
 Wound-healing modulators
 haze, 107
 myofibroblasts, 107
 Wound leaks, 168, 188
 antibiotic, 71
 iris, 71
 shallow/flat anterior chamber, 71

X

Xylocaine, 198

Y

YAG hyaloidotomy, 227
 YAG laser, 86
 YAG laser posterior capsulotomy, 209
 Y-muscle reinsertion, 132

Z

Zeiss MEL 80, 103, 106
 Zeiss VisuMax®, 101, 102
 Ziemer LDV system, 102
 Zonular apparatus, 207, 208
 Zyoptix XP microkeratome, 99

