

Contents

Part I General Aspects of Internal Fixation

1 Principles of Internal Fixation

J. SCHATZKER 3

1.1 Introduction 3

- 1.1.1 Mechanical Properties of Bone 3
- 1.1.2 Types of Load and Fracture Patterns 4
- 1.1.3 Classification of Fractures 4
- 1.1.4 Effects of Fracture 8
- 1.1.5 Soft Tissue Component and Classification of Soft Tissue Injuries 8

1.2 Aims of Treatment 9

1.3 Previous Experience with Internal Fixation 10

1.4 Rigidity and Stability 10

1.5 Methods of Absolutely Stable Fixation 11

- 1.5.1 Lag Screw 11
- 1.5.2 Lag Screw, Neutralization, and Buttressing 12
- 1.5.3 Tension Band Plate and Compression Plate 12

1.6 Methods of Relative Stability or Splinting 14

- 1.6.1 External Skeletal Fixation 14
- 1.6.2 Intramedullary Nailing 15
- 1.6.3 Bridge Plating 16
- 1.6.4 Methods of Reduction 17

1.7 Changes to the Early Concepts in Internal Fixation 18

- 1.7.1 Articular Fractures 21
- 1.7.2 Diaphyseal Fractures 22
 - 1.7.2.1 Locked Intramedullary Nailing 22
 - 1.7.2.2 Reaming 22
 - 1.7.2.3 Bridge Plating 23
 - 1.7.2.4 Blood Supply to Bone and Implants 23
 - 1.7.2.5 The Limited Contact-Dynamic Compression Plate (LC-DCP) 23
 - 1.7.2.6 The PC Fix or the Point Contact Plate (PCP) and Angularly Stable Fixation 24
 - 1.7.2.7 The Advantages of Locked Fixation and Its Angular Stability 25

1.8 Biological Plating and Minimally Invasive Plate Osteosynthesis (MIPO) 27

1.9 Implant Failure and Bone Grafting 29

1.10 Implant Removal 30

References 30

2 Intra-articular Fractures

J. SCHATZKER 33

2.1 Introduction 33

2.2 Clinical Aspects 35

- 2.2.1 Physical Examination 35
- 2.2.2 Radiological Evaluation 35

2.3 Surgery 36

- 2.3.1 Timing 36
- 2.3.2 Approach and Technique 38

2.4 Postoperative Care 39

2.5 Late Intra-articular Reconstructions 39

References 43

3 Open Fractures

J. SCHATZKER and M. TILE 45

3.1 Introduction 45

3.2 Assessment of the Soft Tissue Wound 45

3.3 Classification 45

3.4 Management 46

- 3.4.1 Decision-Making 46
- 3.4.2 Immediate Treatment 46
- 3.4.3 Operative Treatment 47
 - 3.4.3.1 Limb Salvage 47
 - 3.4.3.2 Cleansing 47
 - 3.4.3.3 Débridement 47
 - 3.4.3.4 Choice of Fixation 48
 - 3.4.3.5 Implant Selection 48
 - 3.4.3.6 Care of the Soft Tissue Wound 50
 - 3.4.3.7 Secondary Fracture Care 51
- 3.4.3.8 Open Joint Injuries 52

3.5 Summary 53

References 54

Part II Fractures of the Upper Extremity

4 Fractures of the Proximal Humerus

M. TILE 57

4.1 Introduction 57

- 4.1.1 General Considerations 57
- 4.1.2 Anatomy 57
- 4.1.3 Vascular Anatomy 58
- 4.1.4 Four-Segment Classification 58

| | | |
|---------|--|----|
| 4.1.5 | Stability | 58 |
| 4.1.6 | Surgical Difficulties | 59 |
| 4.2 | Classification | 59 |
| 4.3 | Natural History and Surgical Indications | 60 |
| 4.3.1 | Stable Fractures | 60 |
| 4.3.2 | Unstable Fractures | 60 |
| 4.3.2.1 | Minimal Displacement | 60 |
| 4.3.2.2 | Major Displacement | 62 |
| 4.3.3 | Articular Fractures | 68 |
| 4.3.3.1 | Impacted (Hill-Sachs) | 68 |
| 4.3.3.2 | Humeral Head | 69 |
| 4.3.3.3 | Glenoid Labrum | 69 |
| 4.4 | Management | 74 |
| 4.4.1 | Assessment | 74 |
| 4.4.1.1 | Clinical | 74 |
| 4.4.1.2 | Radiological | 75 |
| 4.4.1.3 | Examination Under Anesthesia | 75 |
| 4.4.2 | Decision-Making | 75 |
| 4.4.2.1 | Stable Fractures | 75 |
| 4.4.2.2 | Unstable Fractures | 75 |
| 4.4.3 | Surgical Technique | 80 |
| 4.4.3.1 | Timing | 80 |
| 4.4.3.2 | Approaches | 81 |
| 4.4.3.3 | Reduction | 82 |
| 4.4.3.4 | Methods of Internal Fixation | 83 |
| 4.4.3.5 | Wound Closure | 86 |
| 4.4.3.6 | Postoperative Care | 87 |
| | References | 88 |

5 Fractures of the Humerus (12-A, B, and C)

| | | |
|--------|--|-----|
| | J. SCHATZKER | 91 |
| 5.1 | Introduction | 91 |
| 5.2 | Indications for Surgery | 91 |
| 5.2.1 | Failure to Obtain a Satisfactory Reduction | 91 |
| 5.2.2 | Failure to Maintain Reduction | 93 |
| 5.2.3 | Injuries to the Chest Wall | 93 |
| 5.2.4 | Bilateral Humeral Fractures | 93 |
| 5.2.5 | Multiple Injuries | 94 |
| 5.2.6 | Vascular Lesions | 94 |
| 5.2.7 | Neurological Lesions | 94 |
| 5.2.8 | Fractures of the Shaft Associated with Intra-articular Fractures or Articular Extensions of the Fracture | 95 |
| 5.2.9 | Open Fractures of the Humerus | 95 |
| 5.2.10 | Pathological Fractures of the Humerus | 95 |
| 5.3 | Surgical Approaches | 96 |
| 5.4 | Surgical Methods of Stable Fixation | 96 |
| 5.4.1 | Biomechanical Considerations | 96 |
| 5.5 | Postoperative Regimen | 102 |
| 5.6 | Removal of Internal Fixation | 102 |
| | References | 102 |

6 Fractures of the Distal End of the Humerus (13-A, B, and C)

| | | |
|-----|---------------------------------|-----|
| | J. SCHATZKER | 103 |
| 6.1 | Introduction | 103 |
| 6.2 | Fractures with a Good Prognosis | 103 |

| | | |
|---------|--|-----|
| 6.2.1 | Fractures of the Epicondyles | 103 |
| 6.2.1.1 | Fractures of the Lateral Epicondyle (13-A1.1) | 103 |
| 6.2.1.2 | Fractures of the Medial Epicondyle (13-A1.2) | 103 |
| 6.2.1.3 | Fractures of the Lateral Condyle (B1) | 105 |
| 6.2.1.4 | Fractures of the Capitellum (13-B3.1) | 105 |
| 6.3 | Fractures with a Poor Prognosis: The Extra-Articular Group A2 and A3 and Complete Articular Type C | 106 |
| 6.3.1 | Supracondylar Fractures | 106 |
| 6.3.1.1 | Natural History | 106 |
| 6.3.1.2 | Factors Influencing Decisions in Treatment | 108 |
| 6.3.1.3 | Indications for Surgery | 110 |
| 6.3.1.4 | Surgical Treatment | 110 |
| | References | 120 |

7 Fractures of the Olecranon (12-B1)

| | | |
|---------|---|-----|
| | J. SCHATZKER | 123 |
| 7.1 | Introduction | 123 |
| 7.2 | Methods of Evaluation and Guides to Treatment | 124 |
| 7.3 | Classification | 124 |
| 7.3.1 | Intra-articular Fractures | 124 |
| 7.3.1.1 | Transverse (21-B1.1) | 124 |
| 7.3.1.2 | Oblique (21-B1.1) | 125 |
| 7.3.1.3 | Comminuted Fractures and Associated Injuries | 125 |
| 7.3.2 | Extra-articular Fractures | 126 |
| 7.4 | Surgical Treatment | 126 |
| 7.4.1 | Positioning the Patient | 126 |
| 7.4.2 | Draping | 126 |
| 7.4.3 | Tourniquet | 126 |
| 7.4.4 | Surgical Exposure | 127 |
| 7.4.5 | Techniques of Reduction and Internal Fixation | 127 |
| 7.4.5.1 | Transverse Fractures | 127 |
| 7.4.5.2 | Transverse Fractures with Joint Depression | 128 |
| 7.4.5.3 | Oblique Fractures | 128 |
| 7.4.5.4 | Comminuted Fractures | 129 |
| 7.5 | Postoperative Care | 129 |
| | References | 129 |

8 Fractures of the Radial Head (21-A2.2, 21-B2.1, 21-B2.2, and 21-B2.3)

| | | |
|---------|---|-----|
| | J. SCHATZKER | 131 |
| 8.1 | Introduction | 131 |
| 8.2 | Mechanism of Injury | 131 |
| 8.3 | Guides to Treatment | 131 |
| 8.4 | Surgical Treatment | 132 |
| 8.4.1 | Classification | 132 |
| 8.4.2 | Positioning and Draping the Patient | 133 |
| 8.4.3 | Surgical Exposure | 133 |
| 8.4.4 | Techniques of Reduction and Internal Fixation | 133 |
| 8.4.4.1 | Comminuted Fractures | 133 |
| 8.4.4.2 | Split-Wedge Fractures | 134 |
| 8.4.4.3 | Impaction Fractures | 134 |
| 8.4.5 | Postoperative Care | 135 |
| | References | 135 |

9 Fractures of the Radius and Ulna

M. TILE 137

9.1 Introduction 137

9.2 Natural History 137

9.2.1 Closed Treatment 137

9.2.2 Open Treatment 137

9.2.3 AO/ASIF Techniques 137

9.3 Management 138

9.3.1 Principles 138

9.3.2 Indications for Surgery 138

9.3.2.1 Fractures of Both Bones 138

9.3.2.2 Fracture of One Bone 139

9.3.2.3 Open Fracture of the Forearm 140

9.3.3 Timing of Surgery 140

9.3.4 Surgical Technique 142

9.3.4.1 Preliminary Considerations 142

9.3.4.2 Surgical Approaches 142

9.3.4.3 Reduction Techniques 144

9.3.4.4 Technique of Fracture Fixation 147

9.4 Special Considerations 154

9.4.1 Fractures of Both Bones of the Forearm 154

9.4.2 Fractures of One Bone 155

9.4.2.1 Fractures of the Radius with Distal Radioulnar Subluxation (Galeazzi) 155

9.4.2.2 Fractures of the Ulna 156

9.4.3 Fractures of the Forearm in Adolescents 159

9.4.4 Open Fractures of the Forearm 162

9.5 Complications 164

9.5.1 Radioulnar Synostosis 164

9.5.2 Stress Fracture 164

9.5.3 Refracture and Plate Removal 165

References 166

10 Fractures of the Distal Radius

T. S. AXELROD 167

10.1 Distal Radius Fractures 167

10.1.1 Classification 168

10.1.2 Imaging 168

10.2 Overview of Treatment Options Based on Fracture Configuration 170

10.3 Closed Treatment 171

10.4 Operative Management of Distal Radius Fractures 171

10.4.1 Percutaneous Pinning 171

10.4.2 Pins and Plaster 171

10.4.3 External Skeletal Fixation 172

10.4.4 Limited Open Reduction 172

10.4.5 Open Reduction and Internal Fixation 173

10.5 Algorithm for Treatment 173

10.6 Surgical Technique 174

10.6.1 External Fixation Application 174

10.6.2 Limited Open Reduction 178

10.6.3 Open Reduction and Internal Fixation 178

10.6.3.1 Open Reduction and Internal Fixation of Shear Fractures (Volar Barton's, Radial Styloid) 178

10.6.3.2 Open Reduction and Internal Fixation of Joint Compression Fractures (Die-Punch Fractures) 180

10.6.3.3 Shear Plus Compression 180

10.6.3.4 Multifragmentary Combined Fractures 181

10.7 The Distal Radioulnar Joint 183

10.8 Postoperative Care 187

10.9 Complications 187

10.9.1 Pin Site Infection 187

10.9.2 Median Nerve Compression 187

10.9.3 Reflex Sympathetic Dystrophy 187

10.9.4 Malunion of the Distal Radius 187

10.9.5 Nonunion of the Distal Radius 187

10.9.6 Posttraumatic Osteoarthritis of the Radiocarpal Joint 188

10.10 Conclusions 188

References 188

Part III Fractures of the Spine, Pelvis, and Acetabulum

11 Fractures of the Spine

R. HU 193

11.1 Introduction 193

11.2 History 193

11.2.1 Internal Fixation and Fusion 193

11.2.2 Distraction Rod Fixation 194

11.2.3 Segmental Sublaminar Wires 194

11.2.4 Short-Segment Fixation 194

11.3 Initial Assessment and Management 195

11.3.1 Physical Examination 195

11.3.1.1 Neurological Examination 195

11.3.1.2 Sacral Reflexes 196

11.3.1.3 Corticosteroids 196

11.3.2 Initial Radiological Assessment 197

11.3.2.1 Plain Films and Tomography 197

11.3.2.2 Computed Tomography Scan 200

11.3.2.3 Myelography 200

11.3.2.4 Magnetic Resonance Imaging 201

11.4 Classification 203

11.5 Operative Decision-Making with Neurological and Biomechanical Goals 205

11.5.1 Indications 205

11.5.1.1 Does the Patient Have a Neurological Deficit? If so, to What Degree? 205

11.5.1.2 Are the Anterior Elements Intact? 206

11.5.1.3 Are the Posterior Elements Intact? 206

11.5.1.4 What Information to Assess with Imaging? 206

11.5.1.5 Will the Patient Tolerate Operative or Nonoperative Treatment? 206

11.6 Preparation for Surgery 207

11.6.1 Timing of Surgery 207

11.6.2 Patient Positioning 207

11.6.3 Intraoperative Blood Loss 208

11.7 Anatomy as Related to Surgical Approaches 208

11.7.1 Posterior Approach 208

11.7.1.1 Cervical Spine Posterior Approach 208

11.7.1.2 Cervical Spine Decompression 209

11.7.1.3 Thoracic Spine Posterior Approach 209

| | | |
|----------|---|-----|
| 11.7.1.4 | Lumbosacral Junction Posterior Approach | 209 |
| 11.7.2 | Thoracolumbar and Lumbar Spine Decompression | 209 |
| 11.7.3 | Anterior Approach | 211 |
| 11.7.3.1 | Cervical Spine | 211 |
| 11.7.3.2 | Cervicothoracic Junction | 212 |
| 11.7.3.3 | Thoracic Spine | 212 |
| 11.7.3.4 | Thoracolumbar Junction | 212 |
| 11.7.3.5 | Lumbar Spine | 213 |
| 11.7.3.6 | Lumbosacral Junction | 213 |
| 11.7.4 | Decompression Anterior Approach | 213 |
| 11.8 | Fractures and Specific Management | 214 |
| 11.8.1 | Upper Cervical | 214 |
| 11.8.1.1 | Atlas Injury | 215 |
| 11.8.1.2 | Atlas and Odontoid Injury | 216 |
| 11.8.1.3 | Odontoid Injury | 216 |
| 11.8.1.4 | C2 Injury | 216 |
| 11.8.2 | Lower Cervical Spine | 216 |
| 11.8.3 | Thoracic Spine | 221 |
| 11.8.4 | Thoracolumbar Junction | 223 |
| 11.8.4.1 | Internal Fixation | 224 |
| 11.8.5 | Lumbar Spine | 228 |
| 11.8.6 | Sacral Fractures | 229 |
| 11.8.6 | Osteoporotic Fractures | 231 |
| 11.9 | Postoperative Care | 232 |
| 11.9.1 | Brace Wear | 232 |
| 11.9.2 | Mobilization | 233 |
| 11.9.3 | Complications and Their Prevention | 233 |
| 11.9.4 | Pedicle Screw Insertion | 233 |
| 11.9.5 | Thromboembolic Disease | 233 |
| 11.9.6 | Urinary Care | 234 |
| 11.10 | Outcomes of Treatment of Spinal Injury | 234 |
| 11.11 | Conclusions | 234 |
| | References | 235 |

12 Fractures of the Pelvis

M. TILE 239

| | | |
|----------|--|-----|
| 12.1 | Introduction | 239 |
| 12.2 | Understanding the Injury | 239 |
| 12.2.1 | Ring Structure of the Pelvis | 239 |
| 12.2.2 | Anatomical Lesions | 241 |
| 12.2.3 | Stability of the Pelvis | 241 |
| 12.2.3.1 | Sacroiliac Complex | 243 |
| 12.2.3.2 | Pelvic Floor | 244 |
| 12.2.4 | Types of Injurious Forces Acting on the Pelvis | 244 |
| 12.2.5 | Effect of Forces on Soft Tissue | 246 |
| 12.3 | Classification | 246 |
| 12.3.1 | Comprehensive Classification (from Tile 1988) | 246 |
| 12.3.1.1 | General Concepts | 246 |
| 12.3.2 | Type A Stable Fractures (Table 12.2) | 247 |
| 12.3.3 | Type B – Partially Stable Fractures (Table 12.2) | 247 |
| 12.3.3.1 | Open Book (Anteroposterior Compression) Fractures (B1, B3.1) | 247 |
| 12.3.4 | Partially Stable Fractures (Type B2) | 250 |
| 12.3.4.1 | Lateral Compression Fractures (Tables 12.1, 12.2, 12.4) | 250 |

| | | |
|----------|---|-----|
| 12.3.5 | Type C – Unstable Fractures – Complete Disruption of the Posterior Arch (see Tables 12.1, 12.2) | 254 |
| 12.3.6 | Unusual Types of Fracture | 255 |
| 12.3.6.1 | Complex Fractures | 255 |
| 12.3.6.2 | Bilateral Sacroiliac Dislocation with an Intact Anterior Arch | 255 |
| 12.3.6.3 | Pelvic Disruptions Associated with Acetabular Fractures | 255 |
| 12.4 | Natural History | 255 |
| 12.5 | Management of the Pelvic Disruption | 257 |
| 12.5.1 | Assessment | 257 |
| 12.5.1.1 | General Assessment | 257 |
| 12.5.1.2 | Specific Musculoskeletal Assessment | 258 |
| 12.5.1.3 | Diagnosis of Pelvic Instability | 260 |
| 12.5.2 | Resuscitation | 260 |
| 12.5.3 | Provisional Stabilization | 261 |
| 12.5.3.1 | External Fixation or Pelvic Clamp | 262 |
| 12.5.3.2 | Role of Skeletal Traction | 263 |
| 12.5.3.3 | Early Internal Fixation | 263 |
| 12.5.4 | Definitive Stabilization | 265 |
| 12.5.4.1 | Stable Fractures (Type A) | 265 |
| 12.5.4.2 | Unstable Fractures (Type C) | 266 |
| 12.5.4.3 | Surgical Techniques | 276 |
| 12.5.4.4 | Postoperative Care | 287 |
| 12.5.4.5 | Complications | 287 |
| 12.6 | Conclusions | 288 |
| | References | 290 |

13 Fractures of the Acetabulum

M. TILE 291

| | | |
|----------|-----------------------------------|-----|
| 13.1 | Introduction | 291 |
| 13.1.1 | Natural History | 291 |
| 13.1.2 | Surgical Anatomy | 294 |
| 13.1.3 | Mechanism of Injury | 295 |
| 13.2 | Assessment | 296 |
| 13.2.1 | Clinical Assessment | 296 |
| 13.2.2 | Radiological Assessment | 296 |
| 13.2.2.1 | Special Radiographs of the Pelvis | 296 |
| 13.2.2.2 | Specific Acetabular Views | 296 |
| 13.2.2.3 | Tomography | 298 |
| 13.2.2.4 | Computed Tomography | 298 |
| 13.2.2.5 | Magnetic Resonance Imaging | 300 |
| 13.3 | Classification | 300 |
| 13.4 | Treatment | 303 |
| 13.4.1 | Decision-Making | 303 |
| 13.4.2 | Fracture Factors | 303 |
| 13.4.2.1 | Nonoperative Management | 303 |
| 13.4.3 | Operative Management | 308 |
| 13.4.3 | Postoperative Care | 334 |
| 13.5 | Complications | 335 |
| 13.5.1 | Nerve Injury | 335 |
| 13.5.2 | Role of Total Hip Arthroplasty | 335 |
| 13.6 | Conclusions | 335 |
| | References | 339 |

Part IV Fractures of the Lower Extremity

14 Subcapital and Intertrochanteric Fractures

J. SCHATZKER 343

14.1 Anatomy and Blood Supply 343

14.1.1 Cross-Sectional Anatomy of the Head 343

14.1.1.1 Neck Shaft Angle 343

14.1.1.2 Greater Trochanter 343

14.1.2 Blood Supply 344

14.2 Classification 344

14.3 Subcapital Fractures 345

14.3.1 Classification 345

14.3.2 History and Physical Examination 347

14.3.3 Imaging Techniques 347

14.3.3.1 X-Rays 347

14.3.3.2 Bone Scan 348

14.3.3.3 Computerized Axial Tomography 348

14.3.3.4 Magnetic Resonance Imaging 348

14.3.4 Surgical Treatment 348

14.3.4.1 Method of Reduction 348

14.3.4.2 Methods of Internal Fixation 350

14.3.4.3 Methods of Joint Replacement 352

14.3.5 Decision-Making 353

14.3.5.1 Undisplaced Fractures 353

14.3.5.2 Displaced Fractures 353

14.3.5.3 Special Fracture Situations 355

14.3.6 Postoperative Management 355

14.3.7 Complications 355

14.3.7.1 Nonunion 355

14.3.7.2 Avascular Necrosis and Loss of Fixation 356

14.4 Intertrochanteric Fractures 357

14.4.1 Surgical Anatomy and Classification 357

14.4.2 History and Physical Examination 358

14.4.3 Surgical Treatment 358

14.4.3.1 Reduction 359

14.4.3.2 Internal Fixation 359

14.4.4 Postoperative Management 361

14.4.5 Common Early and Late Postoperative

Complications 362

References 365

15 Subtrochanteric Fractures of the Femur

J. SCHATZKER 367

15.1 Biomechanical Considerations 367

15.1.1 Mechanical Forces 367

15.1.2 Degree of Comminution 367

15.1.3 Level of the Fracture 368

15.1.4 Pattern of the Fracture 368

15.1.5 Deformity 368

15.2 Natural History 368

15.3 Indications for Open Reduction and Internal Fixation 369

15.4 Surgical Techniques 370

15.4.1 Diagnosis 370

15.4.2 Classification 370

15.4.3 Planning the Surgical Procedure 370

15.4.3.1 Implants 370

15.4.3.2 Preoperative Planning 376

15.4.4 Surgery 379

15.4.4.1 The Operating Table 379

15.4.4.2 Positioning the Patient 379

15.4.4.3 Surgical Approach for Plating 380

15.4.4.4 Technique of Insertion of Guide Wires and Insertion of the Fixation Devices 381

15.4.4.5 Bone Grafting 383

15.4.5 Postoperative Care 383

15.4.5.1 Signs of Instability 383

15.4.5.2 Infection 383

References 384

16 Fractures of the Femur

J. SCHATZKER 385

16.1 Introduction 385

16.2 Factors Important in Evaluating the Mode of Treatment 385

16.3 Surgical Treatment 386

16.3.1 Timing of Surgery 386

16.3.1.1 Multiple System Injuries 386

16.3.1.2 Head Injury 387

16.3.1.3 Open Fractures 388

16.3.1.4 Vascular Injury 388

16.3.1.5 Ipsilateral Neck Fracture or Dislocation of the Hip 388

16.3.1.6 Ipsilateral Fracture of the Femoral Shaft and Ligamentous Disruption of the Knee 388

16.3.1.7 Floating Knee Syndrome 389

16.3.1.8 Isolated Fractures of the Femoral Shaft 389

16.3.2 Surgical Technique 389

16.3.2.1 Positioning the Patient, Skin Preparation, and Draping 389

16.3.2.2 Surgical Approach 389

16.3.2.3 Technique of Open Reduction 390

16.3.2.4 Technique of Fracture Fixation 392

16.3.2.5 Bone Grafting 405

16.3.2.6 Wound Closure 405

16.3.3 Postoperative Care 405

16.4 Special Considerations: Open Fractures of the Femur 405

References 406

17 Supracondylar Fractures of the Femur (33-A, B, and C)

J. SCHATZKER 409

17.1 Introduction 409

17.2 Guides to Treatment and Indications for Surgery 411

17.2.1 Absolute Indications 412

17.2.1.1 Intra-articular Fractures in Which Adequate Joint Congruity Cannot Be Restored by Manipulation 412

17.2.1.2 Open Intra-articular Fractures 413

17.2.1.3 Associated Neurovascular Injuries 413

17.2.1.4 Ipsilateral Fracture of the Tibial Plateau or Patellar Fracture 414

| | | |
|----------|--|-----|
| 17.2.1.5 | Ipsilateral Fracture of the Tibia (the Floating Knee) | 414 |
| 17.2.1.6 | Multiple Injuries | 414 |
| 17.2.1.7 | Pathological Fractures | 414 |
| 17.2.2 | Relative Indications | 414 |
| 17.3 | Surgical Treatment | 414 |
| 17.3.1 | Timing of Surgery | 414 |
| 17.3.2 | History and Physical Examination | 415 |
| 17.3.3 | Radiological Examination | 415 |
| 17.3.4 | Classification | 415 |
| 17.3.5 | Planning the Surgical Procedure | 416 |
| 17.3.6 | Surgical Anatomy of the Distal Femur | 417 |
| 17.3.7 | Positioning and Draping the Patient | 419 |
| 17.3.8 | Surgical Exposure | 419 |
| 17.3.8.1 | Lateral Exposure | 419 |
| 17.3.8.2 | Anterior Exposure | 420 |
| 17.3.9 | Techniques of Reduction and Internal Fixation | 421 |
| 17.3.9.1 | Type A Fractures | 421 |
| 17.3.9.2 | Type B Fractures | 426 |
| 17.3.9.3 | Type C Fractures | 427 |
| 17.3.9.4 | Minimally Invasive Plate Osteosynthesis, the Condylar LCP and LISS | 429 |
| 17.3.9.5 | The Open Supracondylar Fracture | 434 |
| 17.3.10 | Bone Grafting | 436 |
| 17.3.11 | Methyl Methacrylate | 436 |
| 17.4 | Postoperative Care | 437 |
| 17.5 | Complications | 437 |
| 17.6 | Conclusions | 438 |
| | References | 439 |

18 Fractures of the Patella

J. SCHATZKER 441

| | | |
|----------|--|-----|
| 18.1 | Introduction | 441 |
| 18.2 | Methods of Evaluation and Guides to Treatment | 441 |
| 18.3 | Classification | 441 |
| 18.3.1 | Osteochondral Fractures | 441 |
| 18.3.2 | Stellate Fractures | 441 |
| 18.3.3 | Transverse Fractures | 442 |
| 18.3.4 | Multifragmentary Displaced Fractures | 442 |
| 18.4 | Surgical Treatment | 442 |
| 18.4.1 | Undisplaced Fractures | 442 |
| 18.4.2 | Displaced Fractures | 442 |
| 18.4.2.1 | Surgical Approaches | 443 |
| 18.4.2.2 | Biomechanical Considerations | 443 |
| 18.4.2.3 | Techniques of Internal Fixation | 443 |
| 18.5 | Postoperative Care | 444 |
| | References | 445 |

19 Fractures of the Tibial Plateau

J. SCHATZKER 447

| | | |
|--------|---|-----|
| 19.1 | Introduction | 447 |
| 19.2 | Classification and Guides to Treatment | 448 |
| 19.2.1 | Type I (41-B1) | 448 |
| 19.2.2 | Type II (41-B3.1) | 449 |
| 19.2.3 | Type III (41-B.2) | 450 |

| | | |
|----------|--|-----|
| 19.2.4 | Type IV (41-B1, 41-B2, and 41-B3) | 451 |
| 19.2.5 | Type V (41-C1) | 453 |
| 19.2.6 | Type VI | 454 |
| 19.2.7 | Relationship of the Comprehensive Classification to the Six Fracture Types | 455 |
| 19.2.8 | Absolute Indications for Surgery | 455 |
| 19.2.8.1 | Open Fractures | 455 |
| 19.2.8.2 | Acute Compartment Syndrome | 455 |
| 19.2.8.3 | Associated Vascular or Neurological Injury | 455 |
| 19.3 | Methods of Assessment | 456 |
| 19.3.1 | History | 456 |
| 19.3.2 | Physical Examination | 457 |
| 19.3.3 | Radiological Examination | 457 |
| 19.4 | Surgical Treatment | 458 |
| 19.4.1 | Planning the Surgical Procedure | 458 |
| 19.4.2 | Approaches | 458 |
| 19.4.3 | Positioning the Patient | 461 |
| 19.4.4 | Timing the Surgical Procedure | 461 |
| 19.4.5 | Methods of Open Reduction and Internal Fixation | 462 |
| 19.4.6 | Internal Fixation of Different Fracture Types | 465 |
| 19.4.6.1 | Type I | 465 |
| 19.4.6.2 | Type II | 465 |
| 19.4.6.3 | Type III | 465 |
| 19.4.6.4 | Type IV | 465 |
| 19.4.6.5 | Type V | 466 |
| 19.4.6.6 | Type VI | 466 |
| 19.4.7 | Ligament and Meniscal Repair | 467 |
| 19.4.8 | Postoperative Care | 467 |
| 19.5 | Summary and Conclusions | 468 |
| | References | 469 |

20 Fractures of the Tibia

M. TILE 471

| | | |
|----------|--|-----|
| 20.1 | Introduction | 471 |
| 20.2 | Natural History | 471 |
| 20.2.1 | Nonoperative School | 472 |
| 20.2.2 | Operative School | 473 |
| 20.2.3 | Plaster Disease | 474 |
| 20.2.3.1 | Compartment Syndromes | 474 |
| 20.2.3.2 | Reflex Sympathetic Dystrophy | 475 |
| 20.2.3.3 | Thromboembolic Disease | 475 |
| 20.2.3.4 | Severe Soft Tissue Injury | 476 |
| 20.2.4 | Factors Influencing the Natural History | 476 |
| 20.2.4.1 | Pathoanatomy of the Fracture | 476 |
| 20.2.4.2 | Soft Tissue Injury | 478 |
| 20.2.4.3 | Other Injuries to the Limb | 478 |
| 20.2.4.4 | Patient Factors | 478 |
| 20.2.4.5 | The Health Care Team | 479 |
| 20.2.5 | Summary | 479 |
| 20.3 | Assessment | 479 |
| 20.3.1 | Clinical Assessment | 479 |
| 20.3.1.1 | History | 479 |
| 20.3.1.2 | Physical Assessment | 479 |
| 20.3.2 | Radiological Assessment | 481 |
| 20.4 | Management | 482 |
| 20.4.1 | Decision-Making | 482 |
| 20.4.2 | Nonoperative Treatment | 482 |
| 20.4.3 | Indications for Surgery | 483 |
| 20.4.3.1 | Primary Indications | 484 |

| | | |
|----------|---|-----|
| 20.4.3.2 | Delayed Primary Indications | 492 |
| 20.4.3.3 | Secondary Indications | 492 |
| 20.4.4 | Role of Amputation in Severe Tibial Fractures | 492 |
| 20.4.5 | Timing of Surgery | 492 |
| 20.4.6 | Surgical Methods | 494 |
| 20.4.6.1 | Approaches | 494 |
| 20.4.6.2 | Reduction Techniques | 496 |
| 20.4.6.3 | Fixation | 496 |
| 20.4.6.4 | Wound Closure | 517 |
| 20.4.6.5 | Postoperative Course | 518 |
| 20.5 | Conclusions | 518 |
| | References | 520 |

21 Fractures of the Distal Tibial Metaphysis Involving the Ankle Joint: The Pilon Fracture

D. STEPHEN 523

| | | |
|----------|--|-----|
| 21.1 | Introduction | 523 |
| 21.2 | Overview | 523 |
| 21.2.1 | Nature of the Injury | 523 |
| 21.2.1.1 | Axial Compression | 523 |
| 21.2.1.2 | Shear (Tension) | 524 |
| 21.2.1.3 | Combined | 525 |
| 21.2.2 | State of the Bone | 526 |
| 21.2.3 | State of the Soft Tissues | 526 |
| 21.2.4 | Technical Difficulties | 527 |
| 21.2.5 | The Dilemma | 526 |
| 21.2.6 | Summary | 528 |
| 21.3 | Classification | 529 |
| 21.3.1 | Comprehensive Classification | 529 |
| 21.3.2 | Use of Classification in Decision-Making | 529 |
| 21.3.2.1 | Fibula | 529 |
| 21.3.2.2 | Articular Surface of the Tibia | 529 |
| 21.3.2.3 | Distal Tibial Metaphysis | 529 |
| 21.3.3 | Personality of the Fracture | 531 |
| 21.4 | Assessment | 534 |
| 21.4.1 | Clinical | 534 |
| 21.4.2 | Radiological | 534 |
| 21.5 | Indications for Surgery | 534 |
| 21.5.1 | Minimal Displacement | 534 |
| 21.5.2 | Significant Displacement | 535 |
| 21.5.2.1 | Operable | 536 |
| 21.6 | Surgical Technique | 537 |
| 21.6.1 | Timing | 537 |
| 21.6.2 | Approach | 539 |
| 21.6.2.1 | Soft Tissue | 539 |
| 21.6.2.2 | Skeletal Tissue | 539 |
| 21.6.3 | Technique of Internal Fixation | 540 |
| 21.6.3.1 | Without Fibular Fracture | 540 |
| 21.6.3.2 | With Fibular Fracture | 540 |
| 21.6.4 | Wound Closure | 545 |
| 21.6.5 | Postoperative Care | 546 |
| 21.6.5.1 | Early | 546 |
| 21.6.5.2 | Late | 547 |
| 21.7 | Common Pitfalls of Treatment | 547 |
| 21.7.1 | Poor Decision-Making | 547 |
| 21.7.2 | Operating Through Poor Skin | 547 |
| 21.7.3 | Technical Difficulties with the Fibula | 547 |

| | | |
|--------|---|-----|
| 21.7.4 | Technical Difficulties with the Tibial Fracture | 547 |
| 21.7.5 | Poor Postoperative Care | 547 |
| 21.8 | Late Reconstruction: Malunion | 548 |
| | References | 550 |

22 Fractures of the Ankle

M. TILE 551

| | | |
|----------|--|-----|
| 22.1 | Introduction | 551 |
| 22.1.1 | Basic Principles | 551 |
| 22.1.2 | Anatomical Considerations | 551 |
| 22.1.2.1 | Stability | 551 |
| 22.1.2.2 | Congruity | 551 |
| 22.1.2.3 | Physiology | 552 |
| 22.1.2.4 | Pathoanatomy | 552 |
| 22.1.3 | Natural History | 554 |
| 22.1.4 | Mechanism of Injury | 557 |
| 22.1.4.1 | Supination-Adduction | 557 |
| 22.1.4.2 | Eversion-Abduction | 558 |
| 22.2 | Classification | 559 |
| 22.2.1 | Introduction | 559 |
| 22.2.2 | Comprehensive Classification (Fig. 22.14) | 561 |
| 22.2.2.1 | Type A | 562 |
| 22.2.2.2 | Type B | 562 |
| 22.2.2.3 | Type C | 563 |
| 22.2.2.4 | Isolated Medial Malleolus Fracture | 564 |
| 22.3 | Assessment of Stability | 564 |
| 22.3.1 | Clinical Assessment | 564 |
| 22.3.1.1 | History | 564 |
| 22.3.1.2 | Physical Examination | 565 |
| 22.3.2 | Radiological Assessment | 565 |
| 22.3.2.1 | Lateral Complex: Fibula and Tibiofibular Syndesmosis | 566 |
| 22.3.2.2 | Talus | 568 |
| 22.3.2.3 | Posterior Tibial Process | 568 |
| 22.3.2.4 | Medial Complex | 568 |
| 22.4 | Management | 569 |
| 22.4.1 | Decision-Making | 569 |
| 22.4.1.1 | Type A | 569 |
| 22.4.1.2 | Types B and C | 570 |
| 22.4.1.3 | Isolated Medial Malleolar Fracture | 571 |
| 22.4.2 | Surgical Technique | 571 |
| 22.4.2.1 | Tourniquet | 571 |
| 22.4.2.2 | Timing | 573 |
| 22.4.2.3 | Incisions | 573 |
| 22.4.2.4 | Open Reduction and Internal Fixation | 574 |
| 22.4.3 | Wound Closure | 584 |
| 22.4.4 | Postoperative Program | 584 |
| 22.4.4.1 | Immediate Management | 584 |
| 22.4.4.2 | Early Motion | 584 |
| 22.5 | Special Problems in Ankle Fractures | 584 |
| 22.5.1 | Open Ankle Fractures | 584 |
| 22.5.2 | Ankle Fractures in the Elderly | 585 |
| 22.5.3 | Primary Ankle Arthrodesis | 586 |
| 22.5.4 | Fibular Lengthening for Malunion | 586 |
| 22.5.5 | Supramalleolar Osteotomy | 587 |
| 22.5.6 | Ankle Fractures in Adolescents | 587 |
| | References | 589 |

23 Fractures of the Talus

M. TILE 591

23.1 Introduction 591**23.2 Anatomical Considerations 591****23.2.1 Vascular Anatomy 591****23.2.1.1 Extraosseous Arterial Supply 592****23.2.1.2 Intraosseous 593****23.2.1.3 Summary 593****23.2.2 Mechanism of Injury 595****23.2.2.1 Common Pattern 595****23.2.2.2 Atypical Patterns 596****23.2.2.3 Total Dislocation of the Talus 596****23.3 Classification and Natural History 597****23.3.1 Fractures of the Body of the Talus 597****23.3.2 Fractures of the Talar Neck 597****23.3.2.1 Type A: Undisplaced Fractures of the Talar Neck 597****23.3.2.2 Type B: Displaced Fractures of the Talar Neck with Subluxation of Subtalar Joint 597****23.3.2.3 Type C: Displaced Fractures of the Talar Neck with Posterior Dislocation of the Body 599****23.3.3 Subtalar Dislocation 599****23.3.4 Total Dislocation of the Talus 601****23.4 Management 604****23.4.1 Assessment 604****23.4.1.1 Clinical Assessment 604****23.4.1.2 Radiological Assessment 604****23.4.2 Decision-Making 605****23.4.2.1 Fractures of the Body 605****23.4.2.2 Fractures of the Talar Neck 606****23.4.3 Surgical Technique 608****23.4.3.1 Timing 608****23.4.3.2 Antibiotics 608****23.4.3.3 Tourniquet 609****23.4.3.4 Skin Approaches 609****23.4.3.5 Stable Internal Fixation 611****23.4.3.6 Postoperative Care 611****23.4.4 Special Problems 616****23.4.4.1 Open Fractures and Fracture-Dislocations 616****23.4.4.2 Comminuted Fractures of the Talar Body 617****References 617****24 Fractures of the Calcaneus**

M. TILE 619

24.1 Introduction 619**24.2 Anatomy 620****24.3 Pathoanatomy****(Mechanism of Injury; Fig. 24.3) 621****24.4 Classification 621****24.5 Assessment 623****24.5.1 Clinical Assessment 623****24.5.2 Radiographic Assessment 624****24.6 Decision-Making 626****24.6.1 Fracture Factors 626****24.6.2 Patient Factors 626****24.7 Treatment 626****24.7.1 Nonoperative Treatment 626****24.7.2 Operative Treatment 627****24.7.2.1 General Aspects 627****24.7.2.2 Specific Aspects 627****24.8 Postoperative Care 631****24.9 Prognosis and Results 632****24.10 Conclusions 633****References 633****25 Injuries of the Midfoot and Forefoot**

D. J. G. STEPHEN 635

25.1 Fractures of the Navicular 635**25.1.1 Anatomy 635****25.1.2 Treatment 635****25.2 Fractures of the Cuboid 638****25.3 Fractures of the Metatarsals 638****25.3.1 Anatomy 638****25.3.2 Treatment 638****25.3.3 Fractures of the Proximal Fifth Metatarsal 640****25.3.3.1 Anatomy 640****25.3.3.2 Clinical and Radiological Diagnosis 643****25.3.3.3 Treatment 644****25.4 Fractures of the Phalanges 645****25.5 Tarsometatarsal (Lisfranc) Fracture-Dislocations 646****25.5.1 Anatomy 646****25.5.2 Mechanism and Classification 647****25.5.3 Clinical and Radiological Diagnosis 647****25.5.4 Treatment 648****25.6 Dislocations of the Metatarsophalangeal Joints 651****25.7 Compartment Syndromes of the Foot 653****References 654****Subject Index 657**

<http://www.springer.com/978-3-540-22850-9>

The Rationale of Operative Fracture Care

Schatzker, J.; Tile, M.

2005, XXIV, 668 p. 1718 illus., 321 illus. in color.,

Hardcover

ISBN: 978-3-540-22850-9