

Chapter 2

Treatment Options for Severely Atrophic Maxillae

Abstract In this chapter, two main treatment options for severely edentulous atrophic posterior maxillae—bone augmentation procedure and zygomatic implant application—are presented. Poor bone quality and insufficient bone volume due to critical jawbone atrophy in the posterior maxillae are addressed as the main factors contribute to the failure of dental implant system. The rationales behind the introduction of each treatment option are discussed and compared for a better understanding. As this text placed an emphasis on the use of zygomatic implants, a high focus is given to this section covering the specification of zygomatic implants, advantages and disadvantages, indications and contraindications of treatment, types of surgical approach for the implant placement and survival rate of implants. This chapter provides sufficient information on the treatment of patient with severely atrophic posterior maxillae specifically via the use of nongrafting procedure, zygomatic implant. The application of zygomatic implant is gaining popularity over conventional bone augmentation procedure as a treatment modality.

Keywords Bone quality · Bone augmentation · Zygomatic implant · Edentulous jaw classification

2.1 Bone Quality

The success rate of osseointegrated implant in the maxilla especially in the posterior region is significantly lower when compared to the implant success rate in the mandible as witnessed in clinical situations [1–5]. The main factors contribute to the higher implant failure rates in the maxilla are due to poor quality and quantity of bone tissues [1]. Maxillary bone has a lower bone density than mandibular bone especially in the posterior region which makes it unfavourable for osseointegration [5–7]. Furthermore, the anatomy of edentulous maxilla in terms

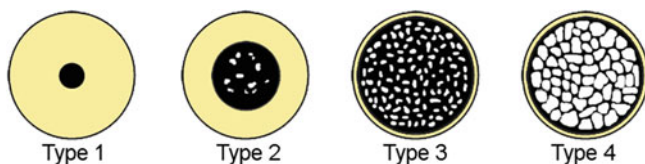


Fig. 2.1 Classification of bone quality

of morphology and configuration has shown limited survival rates for conventional implant placement [2, 6, 8].

Maxillary bone consists of two bone layers, cortical and cancellous bone layer [8, 9]. Cortical bone or also known as compact bone has a higher modulus of elasticity than cancellous bone [8, 10]. There is a higher tendency for better osseointegration process to occur in a higher bone density (cortical) compared to a low bone density (cancellous) [10]. This is likely due to an increase in bone-implant contact that generates a higher strength of anchorage leading to a more stable implant [10, 11]. According to Leckholm and Zarb, the quality of jaw bones can be classified into four main categories as configured in Fig. 2.1 [12].

Type 1 (D1) bone quality is defined as the bone jaws that comprised of homogenous compact bone. While for Type 2 (D2), the bone consists of a dense cancellous bone core surrounded by a 2 mm thick layer of cortical bone. Type 3 (D3) bone consists of a thin layer of cortical bone surrounding a core of dense cancellous bone and Type 4 (D4) bone characterized as a thin layer of cortical bone surrounding a core of low density cancellous bone of poor strength [5, 8, 11]. Generally, the anterior region of maxilla can be classified as Type 3 whilst the posterior region or specifically the molar region is classified as Type 4 [5, 8]. Mandibles are generally more densely corticated than maxillae and both jaws tend to have thinner cortical and increased cancellous porosity towards the posterior [5, 8]. It is important to note that there is a high correlation between implant failure and poor bone density.

2.2 Potential of the Zygoma for Implantation

There was a possibility of placing dental implants in the zygomatic bone as mentioned by Aparicio et al. [13] in 1993. Other than that, the use of zygomatic bone as a support structure for the patients who undergone maxillectomies had been cited by Weischer et al. through a study in 1997 [14]. The measurement of maxilla and zygoma for pre-surgical planning of implant fixation was conducted by Uchida et al. in 2001 using 12 cadavers. The results showed that an implant diameter of 3.75 mm requires a zygoma thickness of at least 5.75 mm [15]. They concluded that an angulation of 43.8° or less increases the risk of perforating the infratemporal fossa or the lateral area of the maxilla. However, an angulation of 50.6° or more increases the risk of perforating the orbital floor [15]. Due to the

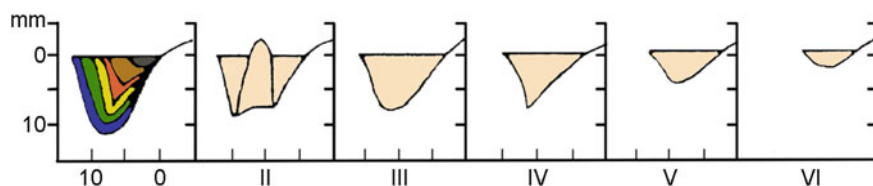


Fig. 2.2 Classification of jaw atrophy in posterior maxilla

curvy and complex shape of the zygoma, implants have to be placed at an appropriate angle with respect to the occlusal plane [16].

Another study done by Nkenke et al. determined the potential of zygomatic bone as a remote site for implant anchorage [17]. Computed tomography images and histomorphometry technique were used to examine 30 human zygomas. The authors revealed that zygoma consists of cancellous bone which is unfavourable for implant placement. Success of implants placed in the zygomatic bone could be achieved by crossing the implant through four cortical layers [17]. In contrast, Kato et al. investigated the internal structure of cadaveric edentulous zygomatic bone using micro-computed tomography and found the presence of wider and thicker cancellous bone at the apical end of the fixture that could be used to promote initial fixation [18].

2.3 Edentulous Jaw Classification

The classification of edentulous jaw is used in dentistry to identify the types of treatment suitable for patients. Jaw atrophy involves a reduction of alveolar height and width as well as bone remodelling that affects the external shape and the internal structure [19]. It occurs in chronic and irreversible fashion due to tooth extraction, trauma, infection, pneumatization of the maxillary sinus and ablative tumour surgery [17]. The pattern of alveolar ridge atrophy, however, is different between maxilla and mandible—maxilla exhibits centripetal resorption while mandible shows centrifugal resorption [20]. There is a higher tendency for bone resorption to occur at the edge of alveolar rather than at the bottom part of the socket after tooth extraction [8, 21]. Based on Tallgren's classic study, more than 2 mm vertical resorption was found in the anterior jawbone between the first year after teeth extraction and insertion of complete dentures. However, the resorption rate of alveolar edge reduced to 0.05 mm/year in the edentulous maxilla and 0.20 mm/year in the edentulous mandible [22].

The resorption of maxilla will move the residual alveolar bone superiorly and medially [8]. In the posterior region of maxilla, critical bone atrophy can result in Class VI thin bone layer with a characteristics of reduced cortical bone thickness, or in a more severe cases a total loss of bone as illustrated in Fig. 2.2 [5]. This is probably due to critical remodelling process which occurs within the cancellous

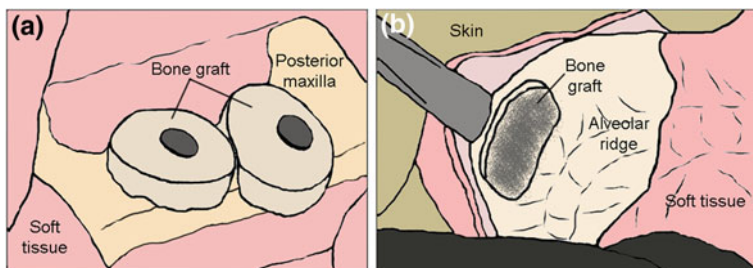


Fig. 2.3 a Onlay bone grafting in posterior maxilla [35] and (b) sinus lifting

bone itself after tooth extraction. The thinning of cortical bone layer reduced the implant anchorage strength, causing a potential failure of osseointegration [8]. The lack of sufficient bone quantity can be solved through various bone augmentation techniques to increase bone volume for dental implant placement in the posterior region of maxilla [2, 23].

2.4 Conventional Surgical Procedure by Using Bone Augmentation

Treatments for edentulous maxilla patients specifically with severe degree of resorption can be performed through several techniques—bone augmentation or grafting; using angled implants in parasinus region; placing implant in the pterygoid apophysis; using short and wide implants; or using zygomatic implants [24, 25]. Bone augmentation has been regarded as the gold standard procedure to treat atrophic maxilla, and the iliac crest is normally used as bone graft [24, 26]. Crestal onlay grafting, inlay grafting (maxillary antrum and nasal floor) or sinus lifting, Le Fort I osteotomy with interpositional grafting and distraction osteogenesis are among augmentation procedures performed to restore the lost bone (Fig. 2.3) [26, 27]. However, this procedure is resource demanding and requires a relatively longer time of treatment and a longer healing period for the patients [26]. In addition, harvesting of bone grafts could cause morbidity or infection of the donor site [17, 26–29].

Based on literature reviews, the survival rate of implant is lower for grafted maxillae compared to non-grafted maxillae especially in the posterior region [27, 28, 30]. It was reported that the use of autogenous drafts lead to a success rate of 87–95 % [27]. Keller et al. conducted a follow-up study of 248 implants placed in grafted maxillae using inlay autogenous bone grafts and reported a success rate of 87 % within a period of 57.1 months [31]. Another study reported by Branemark et al. in 2001 showed 80 % implants with favourable outcome within 2–15 years follow-up using the autogenous onlay bone grafting and simultaneous endosseous

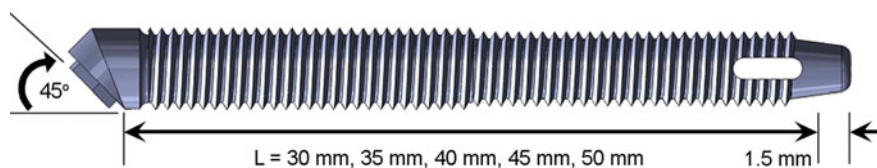


Fig. 2.4 Zygomatic implant specifications

implant placement [32]. Similar results were reported by Lekholm et al. using the same technique of onlay bone grafting with a slightly lower success rate of 75 % [33, 34]. These results were true with the notion that implants placed in native bone has a greater probability of success compared to those implanted in grafted bone [27, 30]. In a comparative study by Widmark et al., a higher success rate was found for implants placed in native bone (96) compared to those using bone graft (82 %) after 1 year follow-up [27]. At 3–5 years follow-up, the success rate of corresponding implants reduced to 87 and 74 %. The nongrafting surgical procedures are therefore preferable for the edentulous atrophic maxilla as the bone augmentation technique resulted in less effective outcomes.

2.5 Advanced Surgical Procedure by Zygomatic Implant Application

Brånemark introduced an alternative system utilising zygomatic implants to overcome complications related to bone augmentation technique [24, 25, 27, 28, 34, 36, 37]. Zygomatic implants were previously utilised to rehabilitate patients who had undergone maxillectomy due to tumour resection, trauma or congenital defect [17, 28, 38]. However, the function of this implant had been extended for rehabilitation of edentulous atrophic maxilla patients. This implant had been introduced to obtain a steady anchorage in zygomatic bone where placement of standard implants would not be possible in the posterior region of maxilla [39].

Zygomatic implant used for the treatment of edentulous atrophic maxillae comes in various dimensions in terms of length, diameter, thread distribution and other features (Fig. 2.4) [40]. Two treatment plans are currently used, either two or more zygomatic implants placed bilaterally without conventional implants support [27, 39], or one zygomatic implant placed bilaterally together with at least two conventional implants placed at the anterior region of maxilla [39, 41–43]. The selection of treatment plan depends on the degree of bone resorption in maxilla. The insertion path of zygomatic implant is usually from the alveolar ridge bone in second premolar or first molar region, going through maxillary sinus or its wall into zygomatic bone [24, 28, 40, 44]. The apical part of implant body will be directed or inserted into the wider and thicker cancellous bone of the zygoma [45].

2.5.1 Advantages and Disadvantages of Zygomatic Implants

The use of zygomatic implants to treat edentulous atrophic maxillae has a lot of advantages over the use of bone graft augmentation incorporation with conventional implants placement in the posterior region. The most prominent advantage is by not using the bone graft itself which is associated with donor site morbidity in the respective region [24, 27, 39, 43, 46]. The total treatment time also reduced as bone grafting procedure requires three to 6 months to heal before the bone can be loaded with traditional dental implants [39, 43, 46, 47]. An additional 6 months are then required to complete the whole process. In the case of immediate implant stabilisation through simultaneous loading and bone grafting, the whole process of prosthetic restoration will therefore take about 6 months to complete. However, this type of treatment is not suitable for patients with sufficient posterior bone volume [27]. The existing patient's maxillary denture can be used as a temporary removable prosthesis prior to the actual prosthesis after soft tissue reline [27, 48]. Treatment using zygomatic implants also requires less hospitalization as the bone grafting technique needs 6 months for bone formation before the actual implant placement. Zygomatic implant approach could also reduce the number of supporting implants at the anterior region due to a steady implant anchorage is achievable in the zygoma, thus, reducing a potential complications [27, 48]. In terms of cost, treatment via zygomatic implant is almost similar to bone grafting.

The main disadvantages of zygomatic implant application are the complexity of implant installation as well as the emergence of implant head in palatal region resulting in an excess bulk of prosthesis causing discomfort. The difficulties to articulate and to perform oral hygiene are some of the common problems caused by the excess protrusion of the implant head. Placement of the zygomatic fixture also requires a well-trained surgeon and restorative dentist has to properly plan the fabrication of a full arch implant-supported prosthesis. Due to the limitation and intricacies of zygoma anatomy, it is difficult to treat patients pronounced concavity of the maxillary lateral wall. Among reported complications associated with zygomatic implants are sinusitis, oroantral fistula formation, periorbital and conjunctiva hematoma or edema, lip lacerations, pain, facial edema, temporary paresthesia, epistaxis, gingival inflammation and orbital injury [27]. Limited intraoperative visibility, complexity of anatomical structures and intricacies of zygoma curve has made this procedure a demanding task [36].

2.5.2 Indications and Contraindications

The role of the zygoma as an implant support structure is indicated in both partial and total maxillary edentulism with a high degree of resorption in the sinus area [49, 50]. Patients with systemic diseases associated with atrophy of the posterior

maxilla are also an indication for the use of zygomatic implants. Balshi and Wolfinger [51], reported a case of congenital ectodermal dysplasia successfully treated with bilateral zygomatic implants in combination with four conventional implants in the anterior region and two pterygoid implants. Peñarrocha et al. [44] published a case of ectodermal dysplasia, where two zygomatic fixtures were placed together with three implants in the anterior maxillary region. An upper complete prosthesis was screwed onto the implants and after 18 months of follow-up, the patient reported significant improvement in oral function and self-esteem.

The reconstruction of maxillary defects following tumour resection or due to maxillectomy is another situation where zygomatic implants have been applied [50]. In this particular case, zygomatic implants are used to anchor an obturator [14] and has been reported to provide increased prosthetic stability, thus improving the life quality of patients. There are several advantages when using zygomatic implants for maxillectomy. Firstly, early detection of postoperative recurrence is easier compared to the one with closed flap. Secondly, when a maxillary prosthesis is supposed to be placed at the midfacial region, zygomatic bone is generally preferred because of its thickness. This could also avoid contracture of the facial soft tissues in the early stages.

Schmidt et al. [52] carried out a retrospective analysis of patients rehabilitated with zygomatic implants following maxillary resection, and presented nine cases of partial or total maxillectomies rehabilitated using 28 zygomatic and 10 conventional implants. Although six zygomatic and three standard implants failed, they concluded that the combination of conventional and zygomatic implants could be used in patients with extensive resection of the maxilla. Landes [53] evaluated the level of satisfaction and indications for zygomatic implants in patients undergoing maxillary resection for various defects. Twelve patients received 28 zygomatic implants and 23 dental implants with a follow-up of 14–53 months. The success rate was 71 % and the quality of life was comparable to those with fixed prostheses over natural dentition.

There are also references to nasomaxillary reconstructions with the aid of zygomatic implants in patients with serious oronasal communications originating from tumour surgery. Bowden et al. [54] presented two cases of nasal reconstruction using implants anchored in the zygoma.

Contraindications of the treatment using zygomatic implants are similar to those applied in the placement of conventional dental implants [13]. Although the intervention in the maxillary sinus cavity could be noted, however, it is not significant to cause local infection. Patients with zygomatic implants may contract an upper respiratory tract infection, which might close to the maxillary ostium, resulting in sinusitis. When this occurs, the sinusitis can become chronic and it is necessary to surgically restore ventilation to the sinuses. There seems to be no increased risk of inflammatory reactions in normal nasal and maxillary mucosa in the regions where titanium implants passed through the mucosa [55].

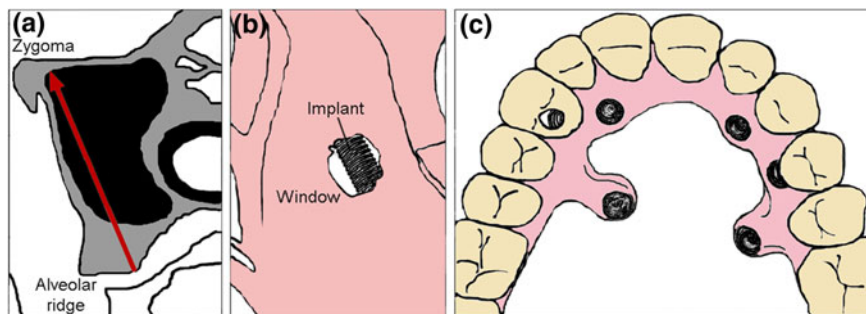


Fig. 2.5 **a** The intrasinus path of zygomatic implant. **b** Lateral window of the maxillary sinus for visual control of implant insertion. **c** Final prosthesis of a patient treated with intrasinus approach. The emergence of implant head is in palatal area

2.5.3 Types of Surgical Approach

There are various types of surgical approach applicable in practice for the placement of zygomatic implants to treat severe edentulous maxilla patients such as intrasinus, sinus slot (Stella), extrasinus and extramaxillary approach since the zygomatic bone has been accepted as a possible implant-anchoring structure. The choice of the surgical technique is determined by the patient's bone anatomy as well as technical skill of the clinician. The original surgical approach of intrasinus was defined by Brånemark System® in 1988, which involved the insertion of a long implant (between 35 and 55 mm) anchored to the zygomatic bone, following an intra-sinus trajectory [56]. The intrasinus has been well-known as a traditional and the most common approach applied to treat atrophic maxillae associated with the use of zygomatic implants posteriorly, with or without additional retentions by conventional dental implants anteriorly.

In the intrasinus approach, the position of zygomatic implant body has to be maintained at the boundaries of the maxillary sinus causing the implant head to emerge in a more palatal aspect resulting in a bulky dental prosthesis (Fig. 2.5a) [27–29, 57]. Patients complaints regarding discomfort should be a cause for concern as this could be due to mechanical resistance of the prosthesis and may affect oral hygiene. Moreover, the penetration of implant body through the maxillary sinus needs to be considered as the condition of the soft tissues will be affected [41]. To perform the surgery via this approach, several protocols have to be followed as described by Brånemark System®. The following descriptions explain the procedures involved for the installation of zygomatic implant via intrasinus approach [58]:

1. The incision of gingival soft tissue is made on the crest or 10 mm palatally to the crest based on Standard Le Fort 1 incision. The purpose of this procedure is to expose the lateral surface of the maxilla up to the zygoma. The location of the infraorbital foramen is identified for anatomic orientation.

2. The alveolar crest including the palatal side is exposed for the drilling purpose.
3. A window with a size of 10×5 mm is made on the lateral wall of the sinus close to the infrazygomatic crest, for observation during implant insertion (Fig. 2.5b). An advanced surgical procedure will eliminate the realization of window opening by the use of surgical drill guide.
4. The sinus mucosa is dissected from the interior sinus wall to ensure that the implant will not pass through the sinus. The sinus mucosa is lifted starting from the floor to the roof of the sinus wall.
5. The zygomatic implant body is planned to be placed as posteriorly as possible. The implant should preferably pass through the sinus close to the incisura point and perforates the cortical layer of the zygomatic bone.
6. The exact point on the alveolar crest is determined to start the drilling sequence. A reactor is placed at the incisura to facilitate the correct 3D orientation of the implant into bone site. The drill guard is used to prevent contact between rotating drill shaft and soft tissue.
7. After the drilling process, the straight depth indicator is utilised to determine the required length of zygomatic implant.
8. To place the zygomatic implant into the prepared bone site, the drilling unit is used with a low speed level. At this stage, the angulation of implant body has to be confirmed until the apical part of implant body reaches the cortical layer of the zygoma.
9. The handle is used to rotate the implant body so that the desired depth and implant head position are achieved.
10. After the implant body has been well-positioned, a cover screw is connected to the head of implant (Fig. 2.5c) to prevent any ingrowth of bone in the internal threads (two-stage procedure).
11. The wound is closed by suturing procedure to minimize post-surgical bleeding.

Stella and Wagner described a variant of the technique, in which the implant is positioned through the sinus via a narrow slot, following the contour of the malar bone and introducing the implant in the zygomatic process [59, 60]. In this way, the need for penetration of the maxillary sinus is avoided, and the implant will emerge over the alveolar crest at the first molar level, with a more vertical angulation. This technique is better than the intrasinus because the flap is more conservative, causing less trauma and improving the postoperative course. The outcome of prosthesis is also improved aesthetically and functionally without hybrid rehabilitation [34].

The surgical procedure is initially started by a crestal incision from one maxillary tuberosity to another in the opposite side. At the end of incision, 1 cm additional vertical releasing incision is made bilaterally [60]. Similar with intrasinus approach, the traditional Le Fort 1 standard can be performed to expose the base of piriform rim, up to the inferior aspect of infraorbital nerves, and around the inferior half of zygoma body bilaterally. The flap is considerably simpler

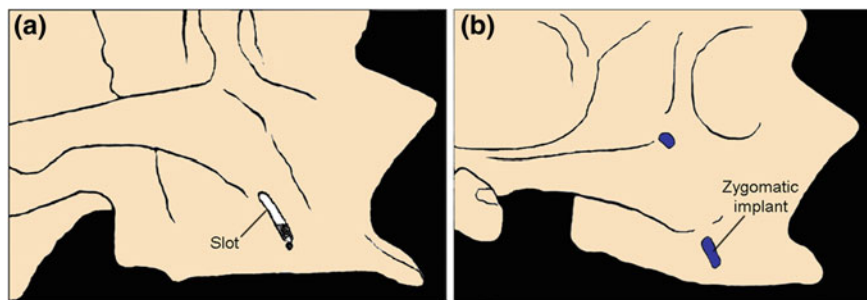


Fig. 2.6 **a** Preparation of sinus slot in bone. **b** Complete operative site preparation together with the placement of zygomatic implant

compared to the traditional approach, which covers the level of infraorbital rim and the superior aspect of the zygomatic arch [60]. Two burr holes are created; one at the superior aspect of the height of zygomatic buttress contour and the second hole 5 mm above the crest of alveolar bone. Zygomatic implant depth gauge is used to prepare the holes and used to simulate the angulation of implant placement during drilling process. Both holes are then connected by drilling a slot from the buttress wall to the floor of maxillary sinus (Fig. 2.6a) [60]. The slot preparation will not affect the sinus membrane.

The 2.9 mm zygomatic implant twist drill is used and placed over the alveolar crest bone. It is directed through the center of sinus slot towards the junction of orbital rim and zygomatic arch (Fig. 2.6b). The drilling process is repeated with a 3.5 mm pilot and twist drill to widen the inferior aspect. The depth gauge is used again to reconfirm the preparation of implant depth. In order to ensure a proper angulation of the implant platform, a hexagonal machine screwdriver (DIA 186) is placed on the implant mount screw. It should be allowed to rotate in proper position when the implant is turned with the hand wrench [60]. Peñarrocha et al. [61] detailed the use of this technique, presented five clinical cases and discussed the advantages of the Stella and Wagner system over the original Brånemark technique. Boyes-Varley et al. disagree with the sinus slot technique since perforation of the posterior antral wall is possible due to lack of visibility [62].

Extrasinus or also known as exteriorized approach, on the other hand, is mainly used to treat patients pronounced with buccal concavities at the maxillary sinus lateral wall [28]. It is impossible to install the fixtures using the intrasinus approach particularly for this type of patients. By using this approach, the zygomatic implant head could be positioned closer to the alveolar crest bone, and therefore, the size of prosthesis could be reduced (Fig. 2.7). One of the most important inclusion criteria to perform this approach is the presence of buccal concavity at the maxillary sinus wall that precluded intrasinus placement with the implant head emergence within a distance of 10 mm medial from the top of the alveolar crest [28]. The general and local health of patients that prevent the use of general anesthesia and intraoral surgery are the exclusion criteria for this approach.

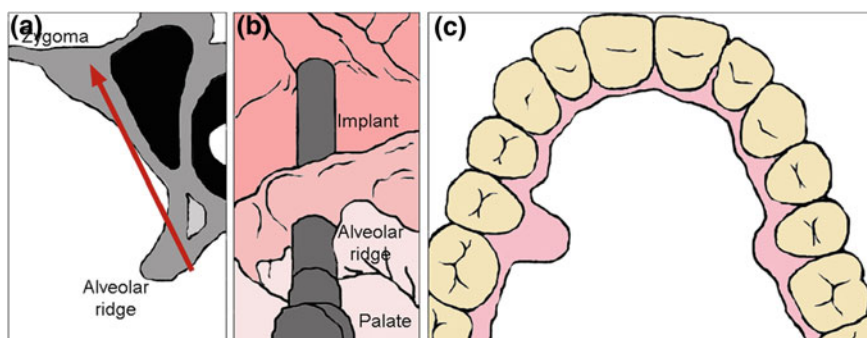


Fig. 2.7 **a** The extrasinus path of zygomatic implant. **b** The zygomatic implant pass through the extreme buccal concavity from the alveolar crest to the zygoma. **c** Final prosthesis of a patient treated with extrasinus approach. The emergence of implant head is slightly in the palatal area

Most of the surgical procedures involved are similar to that of intrasinus approach, except for the opening window creation to the maxillary sinus wall and sinus membrane integrity consideration. Moreover, the path of implant insertion is also different, in which the implant body anchors in an extrasinus path, and it should preferably engage the lateral wall of maxillary sinus before penetrating the zygoma arch [28]. The implant body could be completely or partially outside the sinus cavity. Aparicio et al. reported a mean distance of 3.8 mm from the zygomatic implant head to the central part of alveolar crest using extrasinus approach, which was less than 11.2 mm, recorded by the control group through intrasinus approach. This could prove that the approach results in less bulky of prosthesis construction that beneficial for cleaning purpose and providing better comfort to the patients.

Extramaxillary is the latest surgical technique for the treatment of edentulous atrophic maxillae. It was introduced to simplify the earlier surgical approaches of zygomatic fixtures and to improve the quality of rehabilitation in terms of aesthetics, function and comfort for patients. This technique is significantly different to the other approaches because only the implant body anchored in the zygomatic arch (Figs. 2.8a and 2.8b) [41]. The crestal part of implant body only accommodates at the maxilla externally using a zygomatic implant with different thread distribution and covered with soft tissue. Hence, the emergence of the implant head will be more prosthetically correct in comparison to the other classical approaches (Fig. 2.8c) [41]. This approach could also avoid the introduction of foreign object into sinus cavity that could initiate sinusitis to patients [39]. In real clinical situation, surgeons will start the surgery by performing mucoperiosteal incision on the maxillary arch from molar to molar to allow flap reflection. The incision is also made on the zygomatic process by having two vertical-releasing to expose the inferior edge of the zygomatic bone, similar with other approaches. A distance of 3 mm from the vertical edge of the zygoma is kept in order to place the extramaxillary implant within bone as posteriorly as possible. This is done to

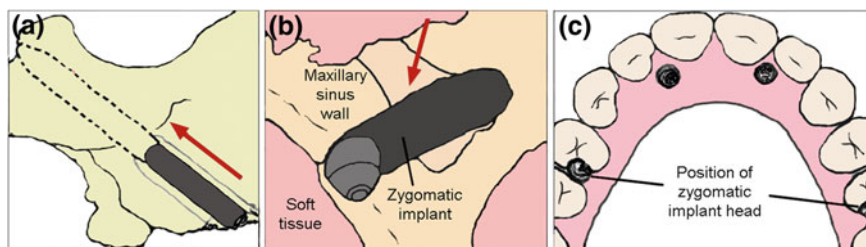


Fig. 2.8 **a** The extramaxillary path of zygomatic implant. **b** The zygomatic implant accommodates the maxillary and anchors in the zygoma. Arrow marks the intact maxillary sinus membrane. **c** Final prosthesis of a patient treated with extramaxillary approach. The emergence of implant head in the posterior region is slightly in the maxillary arch

reduce the cantilever effects of the fixed implant-supported prosthesis as well as to allow for the placement of additional zygomatic implants if needed in future. A round bur is used to create a path from the maxillary bone to the zygoma inferior edge, followed by the drilling process. During this process, surgeons will feel the preparation of the external cortical bone by placing the thumb at that area. In addition, the soft tissues need to be protected by using retractor and drilling guard. Any possibility of damage of the infraorbital nerve can be avoided since a direct observation of anatomical structures is achieved. Moreover, the penetration of maxillary sinus medial wall and its sinus membrane could be avoided through this approach in most patients' cases. However, in particular cases, the sinus mucosa can still be perforated by the implant body because the position of the soft tissue is in the pathway of drill direction [41].

In the classical surgical approaches either intrasinus, sinus slot or extrasinus, the zygomatic implant body is installed to a depth of 18.2 in the zygomatic bone whilst 6.2 mm in the posterior region of maxilla [42]. However, according to some authors, the implant can also be fixed 8–10 mm in the zygomatic bone [40]. The head of implant body was designed in specific angles such as 25, 45 and 55° respected to the occlusal plane to make it easier to establish a common path of implant insertion. Generally, the 45° implant head is mostly utilised since there is no restriction by the sinus or alveolar bone.

2.5.4 Survival Rate of Zygomatic Implants

It can be concluded that zygomatic implants recorded a high survival rate which is about 98.4–100 % based on 20 clinical follow-up studies [24]. Most of the studies have involved the use of conventional dental implants that placed in the anterior maxilla to support the prosthesis. Figures 2.9 and 2.10 depict the failure rates of the zygomatic and conventional dental implants, respectively, reported by several authors from 2001–2008.

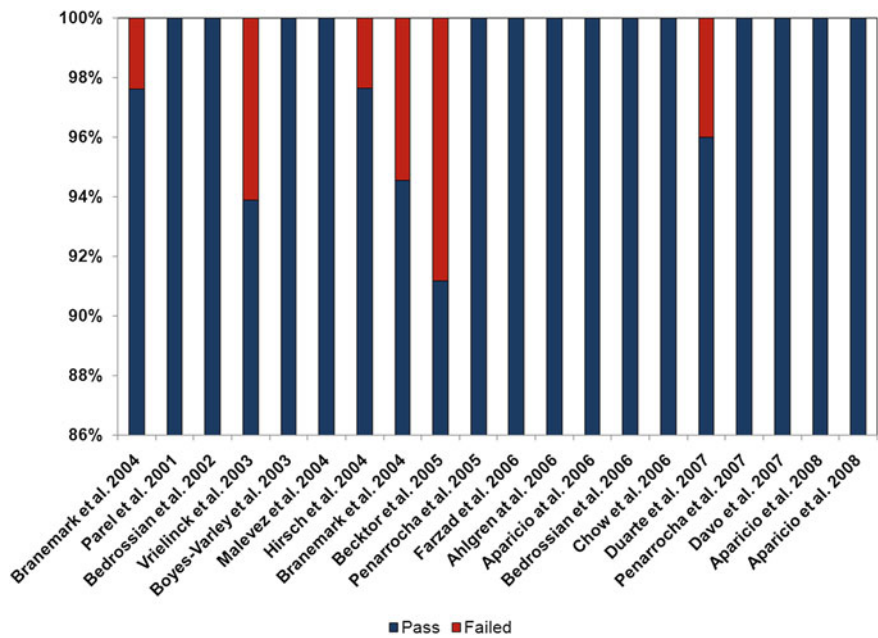


Fig. 2.9 Zygomatic implant failure rates based on 20 clinical follow-up studies

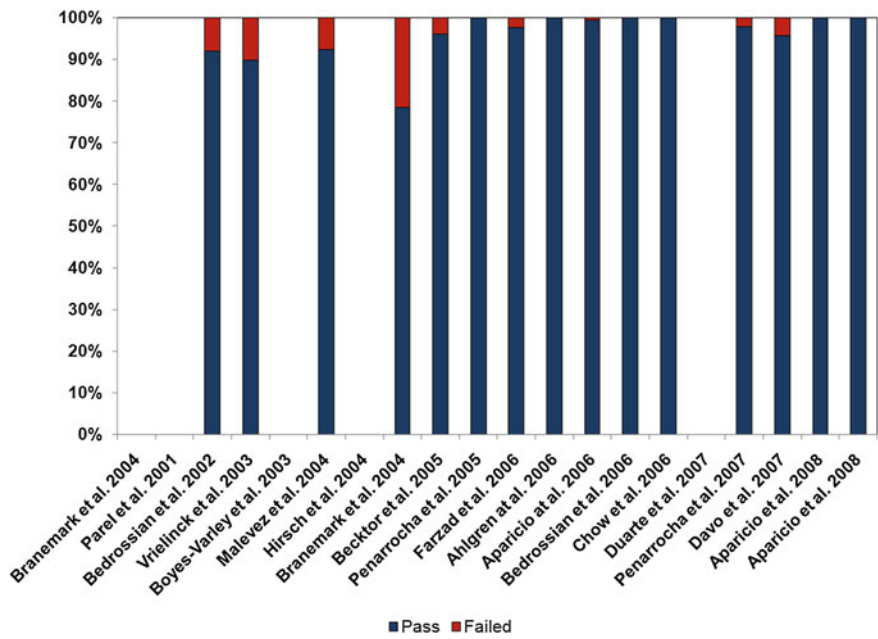


Fig. 2.10 Conventional dental implant failure rates based on 20 clinical follow-up studies

There were more than 1,000 zygomatic and conventional implants placed in more than 500 patients with a total of follow-up study of 6 months to 12 years. The primary inclusion criteria for this survey are the placement of zygomatic implants for the treatment of severely atrophic posterior maxillae and also maxillary defects. The zygomatic implants were placed through the classical intrasinus approach for the treatment of atrophic maxillae. According to Aparicio et al. the cumulative failure rates of zygomatic implants and conventional dental implants were 1.6 and 5.2 %, respectively. Most of the treatments involved the use of one zygomatic implant installed bilaterally in conjunction with conventional dental implants support in the premaxillary region. There was only one case of two zygomatic implants placed bilaterally without additional retentions by conventional implants. Out of 48 zygomatic implants, two implants had failed with a follow-up of 30 months. Besides, five studies were conducted under immediate loading function. According to Block et al. there was no significant effects on the complications or implant failure rates caused by smoking [27]. This was supported by Ahlgren et al., who reported 100 % success rate of zygomatic implants achieved under a follow-up study of 11–49 months [63]. Another study by Aparicio et al. in 2006 found the similar result when 69 patients (27 smoked) treated with 131 zygomatic implants within a period of 6 months to 5 years follow-up [27].

Although the route of zygomatic fixtures has concerned the intrasinus trajectory, it did not seem to provoke any biological or soft tissue complications. However, a few studies have had highlighted this issue. In a study of 1–6 year's follow-up, Becktor et al. investigated 31 zygomatic implants placed in 16 patients. Three zygomatic implants failed (9.7 %) and had to be removed due to recurrent sinusitis in spite of successful osseointegration. The causative factors of sinusitis could be because of a communication created from oral cavity into maxillary sinus or mobility of the implant during function, which caused by the lack of osseointegration at the marginal bone around the neck of implant. Some other studies also reported on similar complication of sinusitis with 2.3–13.6 % occurrence [24]. Through a study in 2006, Becktor had summarised that the sinusitis occurrence is not related to the stability of implants and prosthesis [64]. Other than that, intra-oral infections were among complications seemed to occur for about 3.8–31.8 %. One study reported that out of 20 zygomatic implants, nine of them failed as observed by bleeding of periimplant soft tissue and increasing of probing depth. These problems could be caused by inappropriate position of zygomatic implant body and abutment due to the chosen surgical approach. In addition, the design of prosthesis itself also plays an essential role for successful clinical outcomes [24].

The performance of zygomatic implants via the extrasinus approach also achieves an excellent survival rate. According to Aparicio et al. who has first experienced with the technique, 36 zygomatic fixtures were used to treat 20 patients pronounced with buccal concavities within a period of 12 months follow-up. The finding showed that none of the implants failed. It was also supported by no pain, discomfort or complications recorded up to 18 months follow-up. The convincing and encouraging outcomes showed by this approach have made it as an

appropriate treatment option to place the zygomatic implants in patients pronounced with buccal concavities in the posterior maxilla.

Malo et al. reported 98.5 and 100 % cumulative survival rates for implants (conventional and zygomatic) and prosthetics, respectively in 1 year period follow-up study [17]. The study investigated the application of the extramaxillary approach in the treatment of atrophic maxillae using a new zygomatic implant design in immediate function. The results found that one zygomatic implant failure was observed caused by implant mobility where there was disconnection between implant and prosthesis. The occurrence of sinus soft tissue infection was also detected, as the patients had experienced in diagnosis of maxillary sinusitis prior to the surgery that could be associated with the rupture of sinus membrane during surgical phase.

References

1. Meyer U, Vollmer D, Runte C, Bourauel C, Joos U (2001) Bone loading pattern around implants in average and atrophic edentulous maxillae: a finite-element analysis. *J Cranio Maxill Surg* 29(2):100–105
2. Huang HL, Hsu JT, Fuh LJ, Tu MG, Ko CC, Shen YW (2008) Bone stress and interfacial sliding analysis of implant designs on an immediately loaded maxillary implant: a non-linear finite element study. *J Dent* 36(6):409–417
3. Baggi L, Cappelloni I, Maceri F, Vairo G (2008) Stress-based performance evaluation of osseointegrated dental implants by finite-element simulation. *Simul Modell Pract Theory* 16(8):971–987
4. Baggi L, Cappelloni I, Di Girolamo M, Maceri F, Vairo G (2008) The influence of implant diameter and length on stress distribution of osseointegrated implants related to crestal bone geometry: A three-dimensional finite element analysis. *J Prosthet Dent* 100(6):422–431
5. Li T, Kong L, Wang Y, Hu K, Song L, Liu B, Li D, Shao J, Ding Y (2009) Selection of optimal dental implant diameter and length in type IV bone: a three-dimensional finite element analysis. *Int J Oral Maxillofac Surg* 38(10):1077–1083
6. Devlin H, Horner K, Ledgerton D (1998) A comparison of maxillary and mandibular bone mineral densities. *J Prosthet Dent* 79(3):323–327
7. Seong WJ, Kim UK, Swift JQ, Hodges JS, Ko CC (2009) Correlations between physical properties of jawbone and dental implant initial stability. *J Prosthet Dent* 101(5):306–318
8. Rohlig BG (2004) The use of angulated implants in the maxillary tuberosity region. Dissertation. University of Marburg, Istanbul
9. Nomoto S, Matsunaga S, Ide Y, Abe S, Takahashi T, Saito F, Sato T (2006) Stress distribution in maxillary alveolar ridge according to finite element analysis using micro-CT. *Bull Tokyo Dent Coll* 47(4):149–156
10. Danza M, Zollino I, Paracchini L, Riccardo G, Fanali S, Carinci F (2009) 3D finite element analysis to detect stress distribution: spiral family implants. *J Maxillofac Oral Surg* 8(4):334–339
11. Sevimey M, Turhan F, Kiliçarslan MA, Eskitascioglu G (2005) Three-dimensional finite element analysis of the effect of different bone quality on stress distribution in an implant-supported crown. *J Prosthet Dent* 93(3):227–234
12. Lekholm U, Zarb GA (1985) Tissue-integrated prostheses. In: Branemark PI, Zarb GA, Albrektsson T. *Tissue-integrated prosthesis*. Quintessence, Chicago

13. Aparicio C, Branemark PI, Keller EE, Olive J (1993) Reconstruction of the premaxilla with autogenous iliac bone in combination with osseointegrated. *Int J Oral Maxillofac Implants* 8:61–67
14. Weischer T, Schettler D, Mohr C (1997) Titanium implants in the zygoma as retaining elements after hemimaxillectomy. *Int J Oral Maxillofac Implants* 12:211–214
15. Uchida Y, Goto M, Katsuki T, Akiyoshi T (2001) Measurement of the maxilla and zygoma as an aid in installing zygomatic implant. *J Oral Maxillofac Surg* 59:1193–1198
16. Miyamoto S, Ujigawa K, Kizu Y, Tonogi M, Yamane GY (2010) Biomechanical three-dimensional finite-element analysis of maxillary prostheses with implants. Design of number and position of implants for maxillary prostheses after hemimaxillectomy. *Int J Oral Maxillofac Surg* 39(11):1120–1126
17. Nkenke E, Hahn M, Lell M, Wiltfang J, Schultze Mosgau S, Stech B et al (2003) Anatomic site evaluation of the zygomatic bone for dental implant placement. *Clin Oral Impl Res* 14:72–79
18. Kato Y, Kizu Y, Tonogi M, Ide Y, Yamane G (2005) Internal structure of zygomatic bone related to zygomatic fixture. *J Oral Maxillofac Surg* 63:1325–1329
19. Cawood JJ, Stoelinga PJW, Blackburn TK (2007) The evolution of preimplant surgery from preprosthetic surgery. *Int J Oral Maxillofac Surg* 36(5):377–385
20. Eufinger H, Gellrich NC, Sandmann D, Dieckmann J (1997) Descriptive and metric classification of jaw atrophy: An evaluation of 104 mandibles and 96 maxillae of dried skulls. *Int J Oral Maxillofac Surg* 26(1):23–28
21. Misch CE (2008) Contemporary implant dentistry, 3rd edn. Mosby Elsevier, Canada
22. Bryant SR, Zarb GA (2002) Outcomes of implant prosthodontic treatment in older adults. *J Can Dent Assoc* 68(2):97–102
23. de Cos Juez FJ, Sánchez Lasheras F, García Nieto PJ, Álvarez-Arenal A (2008) Non-linear numerical analysis of a double-threaded titanium alloy dental implant by FEM. *Appl Math Comput* 206(2):952–967
24. Aparicio C, Ouazzani W, Hatano N (2008) The use of zygomatic implants for prosthetic rehabilitation of the severely resorbed maxilla. *Periodontol* 2000 47(1):162–171
25. Davo R, Malevez C, Rojas J, Rodríguez J, Regolf J (2008) Clinical outcome of 42 patients treated with 81 immediately loaded zygomatic implants: a 12- to 42-month retrospective study. *Eur J Oral Implantol* 1(1):1–10
26. Farzad P, Andersson L, Gunnarsson S, Johansson B (2006) Rehabilitation of severely resorbed maxillae with zygomatic implants: an evaluation of implant stability, tissue conditions, and patients' opinion before and after treatment. *Int J Oral Maxillofac Implants* 21(3):399–404
27. Block MS, Haggerty CJ, Fisher GR (2009) Nongrafting implant options for restoration of the edentulous maxilla. *J Oral Maxillofac Surg* 67:872–881
28. Aparicio C, Ouazzani W, Aparicio A, Fortes V, Muela R, Pascual A, Codesal M, Barluenga N, Manresa C, Franch M (2010) Extrasinus zygomatic implants: Three year experience from a new surgical approach for patients with pronounced buccal concavities in the edentulous maxilla. *Clin Implant Dent Relat Res* 12(1):55–61
29. Aparicio C, Ouazzani W, Garcia R, Arevalo X, Muela R, Fortes V (2006) A prospective clinical study on titanium implants in the zygomatic arch for prosthetic rehabilitation of the atrophic edentulous maxilla with a follow-up of 6 months to 5 years. *Clin Implant Dent Relat Res* 8(3):114–122
30. Widmark G, Andersson B, Carlsson GE, Ivanoff CJ (2001) Rehabilitation of patients with severely resorbed maxillae by means of implants with or without bone grafts: A 3- to 5-year follow-up clinical report. *Int J Oral Maxillofac Implants* 16(1):73–79
31. Keller EE, Tolman DE, Eckert SE (1999) Maxillary antral-nasal inlay autogenous bone graft reconstruction of compromised maxilla: A 12-year retrospective study. *Int J Oral Maxillofac Implants* 14(5):707–721
32. Branemark PI, Grondahl K, Worthington P (2001) Osseointegration and autogenous onlay bone grafts: reconstruction of the edentulous atrophic maxilla. Quintessence, Chicago

33. Lekholm U, Wannfors K, Isaksson S, Adielsson B (1999) Oral implants in combination with bone grafts: A 3-year retrospective multicenter study using the Brånemark implant system. *Int J Oral Maxillofac Surg* 28(3):181–187
34. Peñarrocha-Diago M, Boronat A, Cervera R, Garcia B (2006) Fixed ceramometallic prostheses over anterior and transzygomatic implants by using the sinus slot technique-Report of a case. *J Oral Implantol* 32(1):38–40
35. Cordaro L, Torsello F, Accorsi Ribeiro C, Liberatore M, Mirisola di Torresanto V (2010) Inlay-onlay grafting for three-dimensional reconstruction of the posterior atrophic maxilla with mandibular bone. *Int J Oral Maxillofac Surg* 39(4):350–357
36. Chen X, Wu Y, Wang C (2009) Application of a surgical navigation system for zygoma implant surgery. In: 4th European conference of the international federation for medical and biological engineering, pp 940–943
37. Al-Nawas B, Wegener J, Bender C, Wagner W (2004) Critical soft tissue parameters of the zygomatic implant. *J Clin Periodontol* 31(7):497–500
38. Aparicio C, Ouazzani W, Aparicio A, Fortes V, Muela R, Pascual A, Codesal M, Barluenga N, Franch M (2010) Immediate/early loading of zygomatic implants: clinical experiences after 2 to 5 years of follow-up. *Clin Implant Dent Relat Res* 12:77–82
39. Stiévenart M, Malevez C (2010) Rehabilitation of totally atrophied maxilla by means of four zygomatic implants and fixed prosthesis: A 6–40-month follow-up. *Int J Oral Maxillofac Surg* 39(4):358–363
40. Bedrossian E, Stumpel LJ (2001) Immediate stabilization at stage II of zygomatic implants: rationale and technique. *J Prosthet Dent* 86(1):10–14
41. Maló P, de Araujo Nobre M, Lopes I (2008) A new approach to rehabilitate the severely atrophic maxilla using extramaxillary anchored implants in immediate function: a pilot study. *J Prosthet Dent* 100(5):354–366
42. Ujigawa K, Kato Y, Kizu Y, Tonogi M, Yamane GY (2007) Three-dimensional finite elemental analysis of zygomatic implants in craniofacial structures. *Int J Oral Maxillofac Surg* 36(7):620–625
43. Watanabe I, Hildebrand S, Woody RD, Talwar R (2005) Zygoma fixtures for a patient with a severely atrophic maxilla: a clinical report. *Int Chin J Dent* 5:71–74
44. Peñarrocha-Diago M, Uribe-Origone R, Rambla-Ferrer J, Guarinos-Carbó J (2004) Fixed rehabilitation of a patient with hypohidrotic ectodermal dysplasia using zygomatic implants. *Oral Surg Oral Med O* 98(2):161–165
45. Davo R, Malevez C, Rojas J (2007) Immediate function in the atrophic maxilla using zygoma implants: a preliminary study. *J Prosthet Dent* 97(6, Supplement 1):44–51
46. Hirsch JM, Ohnrell LO, Henry PJ, Andreasson L, Branemark PI, Chiapasco M, Gynther G, Finne K, Higuchi KW, Isaksson S, Kahnberg KE, Malevez C, Neukam FW, Sevetz E, Urgell JP, Widmark G, Bolind P (2004) A clinical evaluation of the zygoma fixture: one year of follow-up at 16 clinics. *J Oral Maxillofac Surg* 62(9 Suppl 2):22–29
47. Ferreira EJ, Kuabara MR, Gulinelli JL (2010) “All-on-four” concept and immediate loading for simultaneous rehabilitation of the atrophic maxilla and mandible with conventional and zygomatic implants. *Brit J Oral Max Surg* 48(3):218–220
48. Thomas J, Balshi GJW, Petropoulos Vicki C (2003) Quadruple zygomatic implant support for retreatment of resorbed iliac crest bone graft transplant. *Implant Dent* 12(1):47–51
49. Stevenson AR, Austin BW (2000) Zygomaticus fixtures: the Sidney experience. *Ann R Australas Coll Dent Surg* 15:337–339
50. Tamura H, Sasaki K, Watahiki R (2000) Primary insertion of implants in the zygomatic bone following subtotal maxillectomy. *Bull Tokyo Dent Coll* 41:21–24
51. Balshi TJ, Wolfinger GJ (2002) Treatment of congenital ectodermal dysplasia with zygomatic implants: a case report. *Int J Oral Maxillofac Implants* 17:277–281
52. Schmidt BL, Pogrel MA, Young CW, Sharma A (2004) Reconstruction of extensive maxillary defects using zygomaticus implants. *J Oral Maxillofac Surg* 62:82–89
53. Landes CA (2005) Zygoma implant-supported midfacial prosthetic rehabilitation: a 4-year follow-up study including assessment of quality of life. *Clin Oral Impl Res* 16:313–325

54. Bowden JR, Flood TR, Downie IP (2006) Zygomaticus implants for retention of nasal prostheses after rhinectomy. *Brit J Oral Max Surg* 44(1):54–56
55. Petruson B (2004) Sinuscopy in patients with titanium implants in the nose and sinuses. *Scand J Plast Reconstr Surg Hand Surg* 38:86–93
56. Branemark PI (1998) Surgery and fixture installation. Zygomaticus fixture clinical procedures, 1 edn. Nobel Biocare AB, Goteborg, Sweden
57. Zwahlen RA, Gratz KW, Oechslin CK, Studer SP (2006) Survival rate of zygomatic implants in atrophic or partially resected maxillae prior to functional loading: a retrospective clinical report. *Int J Oral Maxillofac Implants* 21(3):413–420
58. Zygoma Implant Placement and Prosthetic Procedure (2004) Branemark System, vol 12. Nobel Biocare, Sweden
59. Penarrocha M, Garcia B, Marti E, Boronat A (2007) Rehabilitation of severely atrophic maxillae with fixed implant-supported prostheses using zygomatic implants placed using the sinus slot technique: Clinical report on a series of 21 patients. *Int J Oral Maxillofac Implants* 22(4):645–650
60. Stella J, Warner M (2000) Sinus slot technique for simplification and improved orientation of zygomaticus dental implants: a technical note. *Int J Oral Maxillofac Implants* 15:889–893
61. Peñarrocha M, Uribe R, García B, Martí E (2005) Zygomatic implants using the sinus slot technique: clinical report of a patient series. *Int J Oral Maxillofac Implants* 20:788–792
62. Boyes Varley J, Howes D, Lownie J, Blackbeard G (2003) Surgical modifications to the Branemark zygomaticus protocol in the treatment of the severely resorbed maxilla: a clinical report. *Int J Oral Maxillofac Implants* 18:232–237
63. Ahlgren F, Storksén K, Tornes K (2006) A study of 25 zygomatic dental implants with 11 to 49 months' follow-up after loading. *Int J Oral Maxillofac Implants* 21(6):421–425
64. Becktor JP (2006) On factors influencing the outcome of various methods using endosseous implants for reconstruction of the atrophic edentulous and partially dentate maxilla. Dissertation. Göteborg University, Sweden

Biomechanics in Dentistry: Evaluation of Different
Surgical Approaches to Treat Atrophic Maxilla Patients

Ishak, M.I.; Abdul Kadir, M.R.

2013, XIII, 91 p. 72 illus., Softcover

ISBN: 978-3-642-32602-8