Rehabilitation of the Edentulous Maxilla with the Zygoma Concept: A 7-year Prospective Study

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Purpose: The success of zygomatic implants following the two-stage, as well as the immediate loading, concept has been well documented. This graftless approach for the treatment of the completely edentulous resorbed maxilla allows for rehabilitation with an implant-supported fixed prosthesis. The purpose of this prospective study is to report on the 7-year follow-up of patients treated with zygomatic implants in conjunction with two to four anterior maxillary implants placed into immediate function and restored with a definitive fixed prosthesis. Materials and Methods: This prospective study involved 36 patients treated with 74 zygomatic implants and 98 anterior maxillary implants supporting fixed prostheses between 2003 and 2005. Results: Two zygomatic implants in two patients were identified as mobile at stage-two surgery; replacement implants resulted in successful osseointegration. All anterior maxillary implants were determined as osseointegrated at stage two. Three patients experienced unilateral maxillary sinus infections that were refractory to oral antibiotics and were treated with functional endoscopic sinus surgery, which resolved the infections. All patients treated with the immediate loading concept were restored with definitive fixed profile prostheses as planned. Conclusion: The high survival rate, reduced morbidity, and high rate of patient acceptance for the zygomatic implant concept allowed the rehabilitation of the resorbed edentulous maxilla with fixed implant-supported prosthesis, rendering this procedure a viable and a predictable treatment option. Int J Oral Maxillofac Implants 2010;25:1213-1221

Key words: atrophied maxilla, edentulous maxilla, fixed maxillary prosthesis, immediate load, zygoma

Physiologic treatment planning refers to the execution of a surgical and prosthetic treatment protocol that biomechanically mimics the conditions prior to tooth loss. The existence of the alveolar bone depends largely on internal loading, such as that provided by tooth roots or oral endosseous implants (Fig 1). The external pressure placed on the residual alveolar bone by a denture increases the rate of jawbone atrophy. Fixed implant-supported restorations help to prevent or minimize the resorption associated with tissue-supported prostheses.

Treatment of moderately to severely resorbed maxillae presents a challenge for the implant surgical-restorative team. The large pneumatized sinuses that are typical of this group of patients often necessitate extensive bone grafting if conventional implant placement is envisioned. Various procedures have been available for treatment of the resorbed maxilla. Adell et al2 and Breine and Brånemark3 used composite grafts to provide implant anchorage. Le Fort I osteotomy4 and iliac block grafts5,6 have also been used to reestablish a bone volume that will allow the placement of implants. To create sufficient bone mass in the posterior maxilla, sinus grafting procedures5,6 have been performed. Survival of implants placed in elevated sinuses was studied at the Sinus Consensus Conference.7 The conclusion reached by the participants was similar to the report published by Tolman in 1995: the material was so “multivariate and multifactorial that it was difficult to draw definitive conclusions; these must await controlled prospective studies.”8 Grafting of the maxilla with delayed implant placement has also been described in the literature.9 Rasmusson et al experienced success with autogenous grafting to establish a favorable topography of the resorbed maxilla for implant placement using inlay, onlay, and/or Le Fort I procedures.10 An implant success rate of 80% was reported for grafting with delayed implant placement, and 77% success was observed for grafting with simultaneous implant placement, compared to 89% in nongrafted bone. Keller et al, who used inlay grafts in their report on the reconstruction of the compromised maxilla,9

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reported 87% and 95% survival rates for implants and prostheses, respectively. However, the somewhat limited success with these adjunctive procedures has deterred patients from seeking them. An alternative is the zygomatic implant, which was introduced by P-I Brånemark in 1988.

**OVERVIEW OF ZYGOMATIC IMPLANTS**

In the reconstruction of the edentulous maxilla with zygomatic implants, either the traditional two-stage protocol\(^{11,12}\) or an immediate loading protocol\(^{13-16}\) may be considered. The two-stage protocol requires immediate cross-arch splinting of the zygomatic implants at the time of implant uncovering. Uncovered zygomatic implants with healing abutments should not be placed under occlusal loads without cross-arch stabilization. Cross-arch stabilization at stage-two surgery can be accomplished efficiently with the Cal technique. To facilitate the timely fabrication of this bar, fixture level impression of the implants are taken prior to placement of the cover screws and closure of the soft tissues. During the 6 months of the osseointegration, Cal cylinders are placed onto the fixture level model of the patient’s maxilla, and a custom cross arch bar is fabricated with a spacer placed between the Cal cylinder and the bar. At stage-two surgery, the Cal cylinders are secured to the uncovered implants and the bar is directly, intraorally, luted to the Cal cylinders. This technique allows for the fabrication of a passive bar (Fig 2) prior to the uncovering procedure.\(^{17}\) For the immediate loading technique used in the present study, conversion of the patient’s existing denture into a fixed provisional prosthesis is used to ensure cross-arch splinting of the zygomatic implants. Immediate loading of zygomatic implants is the focus of this study and has been reported in the literature, with favorable results.\(^{13-16}\)

**Regional Anatomy: Os Zygomaticus**

The quantity and quality of zygomatic bone were studied and reported by Nkenke et al.\(^{18}\) The morphology and microstructure of the os zygomaticus were assessed by quantitative computed tomography and histomorphometry. The bone mineral density of 30 human zygomatic bone specimens was studied. The trabecular bone mineral density, the trabecular bone volume, and the trabecular bone pattern were correlated with each other. The authors concluded that the trabecular bone of the os zygomaticus was not a favorable site for implant placement. However, Nkenke et al further suggested that the success seen with the zygomatic implant is a result of the engagement of four cortices by the implants. The lingual cortex of the maxillary alveolus, along with the cortical floor of the maxillary sinus, provides bicortical stabilization at the crestal portion of the implant. The superolateral portion of the roof of the maxillary sinus is formed by the inferior portion of the zygomatic bone. This portion of the zygoma, along with its lateral superior cortical covering, provides bicortical stabilization at the apical portion of the zygomatic implant. Better understanding and treatment planning for the placement of the zygomatic implant are possible when the findings of Nkenke et al are kept in mind.

**Radiographic Evaluation**

In the present study, as well as in previous reports,\(^{11,15,19}\) the use of computed tomography as well as panoramic radiographs was critical in the initial evaluation of the patient. Axial computed tomographic scans as well as cone beam technology can provide detailed information on the maxillary sinus. The width of the residual alveolar bone as well as the width and height of the zygomatic body can be visualized in frontal (Fig 3) or axial reformatted sections (Fig 4).

Further evaluation of the zygomatic bone has also been described.\(^5\) Although they are not absolutely necessary, reformatted frontal images in 0.5- to 1.0-mm
slices can provide the less-experienced surgeon with more information for planning the surgery. The presence of sinus pathology, including but not limited to thickening of the sinus membrane and the presence of air–fluid levels, can be ruled out with both panoramic and tomographic imaging (Fig 5). The ability to manipulate the cone beam images to demonstrate the position of the apex of the zygomatic implant within the body of the zygoma as well as the relationship of the platform of the zygomatic implant to the crestal portion of the alveolus leads to a better understanding of the surgical technique.

**Surgical Protocol**

The surgical procedure can be performed in an outpatient setting under intravenous sedation, although the procedure is usually performed under local anesthesia or general anesthesia in an operating room. The proper administration of sufficient local anesthesia is critical in the management of patients under intravenous sedation. The various infiltrations and nerve blocks include circumvestibular infiltration of the maxilla, greater palatine nerve blocks, and bilateral transcutaneous infiltration of the temporal areas over the zygomatic body. Bilateral inferior alveolar nerve blocks should be considered to allow retraction of the mandible during surgery without undue stimulation of the sedated patient. It is recommended that direct visualization of the path of the implant from the premolar area to the base of the zygoma be obtained whenever possible. Direct visualization of the base of the zygoma body has also been advocated by clinicians who have used computer-assisted treatment planning and surgical templates for placement of zygomatic implants. A clear view of the path of the instruments is needed to establish the osteotomy as well as visualize the path of the implant during its insertion, thereby avoiding disorientation and potential complications associated with placement of the zygomatic implant. Generally, three potential axes for the insertion of the implants are possible. The proper axis is a path that extends from the premolar region through the maxillary sinus, entering the midportion of the zygomatic body. If the entry point in the zygomatic body is anterior to this path, potential for penetration into the orbit exists. However, if the axis is posterior to this path, the implant may be at risk of entering the infratemporal fossa, leading to soft tissue embedment and a subsequent lack of osseointegration; an increased potential for unexpected hemorrhage also exists (Fig 6). The armamentarium for placement of the zygomatic implant is specific. The zygomatic implant has two diameters along its length. The diameter at the apical
two thirds of the implant is 4.0 mm, and the implant widens at its alveolar third to a diameter of 5.0 mm. Zygomatic implants are available in lengths ranging from 30 to 52.5 mm, and a specialized series of long zygomatic drills is used to prepare the osteotomy.

Provisional Prosthetic Conversion Technique
To provide the patient with a fixed provisional prosthesis immediately following the surgical procedure, conversion of the patient’s existing complete denture or fabrication of a new immediate denture is undertaken. The denture should have the proper vertical dimension of occlusion as well as proper tooth positions,10–22 as reported in previous publications.13,23

Fabrication of the Definitive Prosthesis
After 6 months of osseointegration, the prosthesis is removed and the stability of the implants is checked. Osseointegration is confirmed by a lack of mobility of the implants and the absence of sensitivity during percussion. Farzad et al24 measured implant stability using the Ostell device (Integration Diagnostics). This method of resonance frequency analysis showed mean implant stability quotients for anterior maxillary and zygomatic implants of 61.6 (range, 48 to 71) and 65.9 (range, 42 to 100), respectively. Olive and Aparicio25 used the Periotest (Siemens), the values of which compared favorably with previously reported measurements of osseointegrated implant stability. Zwahlen et al26 used the reverse-torque technique (10 Ncm) at stage-two surgery 6 months after placement of the implants to determine osseointegration. After osseointegration is confirmed, the patient is ready for either an acrylic resin profile prosthesis27 or a metal-based acrylic resin profile prosthesis with acrylic resin teeth.

Oral Hygiene
Long-term maintenance of soft tissue health around the fixed prosthesis is essential. Proper contouring of the intaglio surface of the prosthesis by the restorative clinician is therefore crucial. The relationship of the base of the prosthesis to the crest of the ridge is identical in contour to the pontic contours in fixed prostheses (Fig 7). Patients can clean the undersurface of the profile prosthesis easily. In older patients or patients with limited dexterity, channels can be created in the bulk of the acrylic resin to guide dental floss between the implants (Fig 8). A properly fabricated implant-supported fixed maxillary prosthesis is a functional, well-tolerated appliance for this group of patients.

MATERIALS AND METHODS

Patient Selection
The inclusion criteria for the present study included patients with 7 to 10 mm of bone in zone I of the anterior maxilla; less than 2 mm of bone in zone II and 0 to 2 mm of bone in zone III (Fig 9 and Table 1). Patients with active sinus pathology, or those presenting with greater than 3 mm of bone in zone II, were excluded. All included patients therefore had clear maxillary sinuses, as documented clinically and by panoramic and three-dimensional imaging.

In the anterior maxilla, double-threaded MK IV 4.0-mm implants (Nobel Biocare) were used, along with NobelSpeedy 4.0-mm implants (Nobel Biocare). The posterior implants were machined zygomatic implants. Chairside conversion of the patients’ dentures was performed using Multiunit abutments (Nobel Biocare), which were also used as the abutments for the definitive profile prosthesis. The immediately loaded provi-
sional prosthesis was replaced with the definitive metal-framework profile prosthesis 6 months after stage-one surgery in all patients. Panoramic radiographs were taken at stage-one surgery to ensure complete seating of all prosthetic components of the immediately loaded prosthesis. Radiographic and clinical examinations, along with patients’ self-reports, confirmed the absence of sinus pathologies prior to fabrication of the definitive prosthesis.

**Implant Treatment**

In this study, all patients were treated using Valium (Hoffmann La Roche) and Demerol (Sanofi-Aventis) under intravenous sedation. All patients were premedicated with 2 g penicillin or 600 mg clindamycin 1 hour prior to surgery. Thirty-six patients (14 men and 22 women) were treated between 2003 and 2005 in a prospective study. Thirteen patients had four anterior maxillary implants placed and 23 patients had two anterior maxillary implants placed, all in conjunction with two posterior maxillary zygomatic implants. In all patients, the implants were loaded immediately through conversion of their maxillary denture into a fixed provisional profile prosthesis (Fig 10).

**Implant Survival Criteria**

Six months after implant placement, an implant was classified as surviving if it fulfilled its supportive function and was stable when tested individually after removal of the provisional prosthesis. Lack of mobility, resistance to reverse torque, an absence of pain upon percussion, and the absence of signs of peri-implant pathology meant that the implant could be classified as surviving.

**RESULTS**

**Clinical Outcomes**

No patients withdrew from the study. Seventy-four zygomatic implants and 98 anterior maxillary implants were immediately loaded and followed for 7 years (Table 2). At the 6-month follow-up visit, all but two zygomatic implants were identified as osseointegrated. The two failed zygomatic implants were removed and new zygomatic implants were inserted and placed into immediate function by connecting them to the existing provisional prosthesis. After an additional 6 months of osseointegration, both implants were stable, without any symptoms or mobility, and both patients received their definitive profile prosthesis.

Thirteen patients received four implants in the canine and central incisor positions. Twenty-three patients had two implants placed in the lateral incisor positions. All received two zygomatic implants in the positions of the right second premolar and the left first premolar. A total of 54 Brånemark

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<th>Table 1 Treatment Concept Recommendations Based on the Zones of the Maxilla</th>
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<td>Presence of bone</td>
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<td>Zone I, II, III</td>
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<td>Zone I, II</td>
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<td>Zone I only</td>
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<td>Insufficient bone</td>
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<th>Table 2 Implant Life Table</th>
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<td>Time period</td>
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<td>Loading to 5 y</td>
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<td>Loading to 6 y</td>
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<td>97.2/100**</td>
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*One zygomatic implant in two different patients was replaced and subsequently osseointegrated prior to fabrication of the definitive prosthesis.
**Prior to replacement of the two failed implants, a 97.2% success rate was seen for the zygomatic implants. Both of the replaced implants osseointegrated after replacement, for an overall success rate of 100%.
System TiUnite MK IV (4-mm diameter) and 44 NobelSpeedy (4-mm diameter) implants were placed in the anterior maxilla. Abutment selection included straight or angulated (17 degrees) Multiunit abutments (Nobel Biocare) secured to each implant to allow connection of the provisional and ultimately the definitive fixed profile prosthesis.

Standard implants placed in the anterior maxilla had the following lengths: 7 mm (n = 3), 8.5 mm (n = 5), 10 mm (n = 36), 11.5 mm (n = 9), and 13 mm (n = 45). The zygomatic implants used had the following lengths: 30 mm (n = 4), 35 mm (n = 8), 40 mm (n = 26), 42.5 mm (n = 13), 45 mm (n = 11), 50 mm (n = 7), and 52.5 mm (n = 3). The two replacement implants were both 42.5 mm in length and replaced failed 45-mm and 40-mm implants.

The abutments placed on the standard anterior implants were straight and 17-degree angulated Multiunit abutments (Nobel Biocare). The straight abutments used were 1 mm (n = 12), 2 mm (n = 42), and 3-mm (n = 6) long. Angled abutments were 2 mm (n = 33) or 3-mm (n = 5) long. For the zygomatic implants, straight Multiunit abutments with lengths of 1 mm (n = 9), 2 mm (n = 44), and 3 mm (n = 19) were used.

Marginal Bone Levels
The radiographic findings immediately postoperatively were consistent with the applied surgical technique, which placed the anterior maxillary implants flush with the bone. It was not possible to judge the change in marginal bone level at the zygomatic implants, as proper placement of these implants oriented the platform slightly palatal to the crest, so that the marginal bone was superimposed over the implant platform in the radiographs. However, the anterior maxillary implants were clearly visible on periapical radiographs and the marginal bone loss at 5 years was between 0 and 2 mm, with an estimated average of less than 1 mm. Intraoral and panoramic radiographic examinations were performed immediately postoperatively as well as at quarterly visits for the first year after placement and annually thereafter. For the intraoral radiographs, a conventional film holder was used, and its position was used as the reference point for bone level measurements. When sinus infections were suspected, cone beam images were performed to evaluate the maxillary, ethmoid, and frontal sinuses in detail.

DISCUSSION
Reported complications with the zygomatic implant include sinus infections, transient neurosensory disturbances, difficulties with speech, and implant failure. Although the use of the zygomatic implant to provide posterior implant support in the treatment of the edentulous maxilla has been proven predictable, with minimal postoperative complications, discussion of complications related to this procedure is warranted.

Sinus Infections
Several authors have reported on complications with zygomatic implants and their management. Potential complications include soft tissue irritations around the abutment connection with the zygomatic implant, which can be corrected by minor soft tissue procedures. Delayed acute sinusitis was reported by Aparicio et al at 14, 23, and 27 months postplacement. These infections were resolved following the administration of oral antibiotics, without further complications.

At times, delayed unilateral infection of the maxillary sinus is apparent after the placement of zygomatic implants and immediate loading. If the infection does not resolve with one or two rounds of oral antibiotic therapy, there may be concern that the implant is acting as a foreign body and is responsible in part for the persistence of the infection, and its removal may be indicated. Petrusson reported on “foreign bodies” in the maxillary sinus by reviewing patients 1 year after the placement of zygomatic implants. The 1-year follow up of 14 patients using an endoscope for rhinoscopy and sinuscopy (Fig 11) observed no signs of infection or inflammation in the mucosa around the implants. Therefore, the presence of unilateral infection in lieu of the presence of bilateral zygomatic implants suggests that other causes should be considered.
For the maxillary sinus to drain, a patent osteomeatal complex is necessary (Figs 12a and 12b). If congenital or traumatic deformities of the osteomeatal complex constrict this passage, then a slight swelling of the overlying soft tissues may completely block the drainage of the maxillary sinus and perhaps also the ethmoid and sphenoid sinuses (Fig 13). Physical blockage of the maxillary ostium with postsurgical debris left inside the sinus may also contribute to postsurgical maxillary sinus infection without involvement of the ethmoid or sphenoid sinuses.

Failure of conservative treatment to resolve these infections with antibiotics warrants consideration of functional endoscopic sinus surgery (FESS) to establish a patent osteomeatal complex allowing the drainage of the maxillary, ethmoid, and sphenoid sinuses. FESS involves the removal of the middle turbinate, bulla, and uncinate process. The ethmoid air cells are opened to allow passive drainage (Figs 14a and 14b). Upon completion of FESS, a patent osteomeatal complex is created, allowing passive drainage. Postoperative oral antibiotic treatment can help to completely resolve any remaining infection.

In this study, three patients, each with unilateral persistent sinus infections refractory to oral antibiotic treatments, responded favorably to the FESS procedure, with complete resolution of their sinus infections. A comprehensive discussion with an otolaryngologist for consideration of the FESS procedure is strongly recommended if oral antibiotic treatments do not resolve the maxillary sinus infections.
Neurosensory Disturbances
Neurosensory disturbance of the zygomaticofacial nerve has been reported, as this nerve is commonly encountered during reflection of the soft tissue over the lateral aspect of the zygomatic body.29 Transient paresthesia was also experienced in four patients in this study. The paresthesias all resolved within 7 weeks of surgery, and the etiology was attributed to soft tissue dissection and retraction during the surgical procedure.

Difficulty with Speech
Because the resorption pattern of the posterior maxilla is toward the palate (Fig 15), the platform of the zygomatic implant is generally placed in intimate contact with the lingual plate of the resorbed posterior maxillary alveolar ridge. In some cases, the prominence of the implant platform may be identifiable by the patient’s tongue. Adaptation to the lingual contours of the zygomatic prosthesis is well tolerated by most patients, with only transient or minimal disruption of their speech.27

Implant Failure
High survival rates have been reported in the literature for zygomatic implants.13–16 In the present study, two immediately loaded zygomatic implants failed. The failed zygomatic implants were noted at initiation of the fabrication process for the definitive prosthesis, as they rotated during a reverse-torque test. This problem was corrected by removal of the failed zygomatic implants and placement of new zygomatic implants immediately above the failed implant sites. The new zygomatic implants were immediately loaded by connection to the existing provisional prosthesis (Fig 16). After an additional 6-month osseointegration period, all implants were stable and the definitive profile prosthesis was completed.

CONCLUSION
The zygomatic implant is a predictable means of establishing posterior maxillary support for a fixed implant-supported maxillary prosthesis without the
need for bone grafting. This paper reviews the 7-year experience of the use of the zygomatic implant, including the management of its complications. Implant failure was limited to two patients, each of whom showed nonintegration of one of their zygomatic implants at stage-two evaluation. The failed implants were removed and immediately replaced. At the end of the study, all implants had osseointegrated and were restored with the intended fixed definitive prostheses. In the hands of experienced surgical and prosthetic teams, the zygomatic implant is a viable addition to existing treatment modalities. The implant may be used with an immediate loading protocol with favorable long-term outcomes.

REFERENCES