Zygomatic Implant Placement in Conjunction with Sinus Bone Grafting: The “Extended Sinus Elevation Technique.” A Case-Cohort Study

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Purpose: The zygomatic implant is mainly indicated for the rehabilitation of extremely atrophied maxillae when bone augmentation should be avoided. One drawback of zygomatic implants, which typically pass through the sinus, is initial or late bone resorption around the implant neck, which can result in oroantral communications followed by possible infection of the sinus. To decrease the risk of sinus infection, a modified technique was developed to preserve the integrity of the sinus membrane and to regenerate bone around zygomatic implants using an extended sinus grafting approach. Materials and Methods: Patients with extremely atrophied maxillae were provided with one to four zygomatic implants in conjunction with sinus grafting, plus conventional auxiliary implants, for immediate support of a provisional full-arch maxillary prosthesis. Definitive prostheses were delivered at 6 months after implant placement. All patients underwent clinical and radiographic examinations at 6 months. Results: Twenty-two zygomatic and 23 conventional auxiliary implants were placed in 10 patients. The overall 6-month implant survival rate was 90.9\% for zygomatic implants and 100\% for auxiliary implants placed in the anterior area. Only two minor technical complications were seen, and clinical indicators (including probing pocket depth, keratinized tissue, and plaque and bleeding indices) were good in all patients. A substantial gain of radiographic bone around the zygomatic implants was observed. Conclusion: The proposed technique led to successful prosthetic function for all patients. With the described technique, exposed implant threads within the maxillary antrum are eliminated and the potential for biologic complications is minimized. Oral Craniofac Tissue Eng 2011;1:188–197

Key words: atrophic maxilla, dental implants, maxillary sinus, peri-implant bone loss, sinus elevation, zygomatic implant
The introduction of the zygomatic implant made it possible for clinicians to perform immediate implant placement without bone augmentation for the treatment of such patients. To date, several reports have described success with zygomatic implants supporting fixed prosthetic reconstructions. Even immediate provisionalization accompanied by immediate functional loading of zygomatic implants has shown promising results.

The survival of zygomatic implants is primarily based on adequate bone support derived from the zygomatic buttress. Because much of the implant is outside of the bone tissue and only a short part of it is supported by bone, mechanical and biologic stability would seem to be limited. Clinically, therefore, it is necessary to splint the zygomatic implants with other implants in a rigid reconstruction as the loading protocol begins.

To increase biomechanical stability over the long term, the development of an extended implant site surrounding the entire zygomatic implant seems to be favorable. Therefore, a treatment method to provide a bony housing around the zygomatic implant simultaneous with implant placement would be preferable. The purpose of the following cohort study is to introduce a modified surgical technique for the placement of zygomatic implants that aims to minimize the risk of biologic complications.

MATERIALS AND METHODS

This case cohort study was performed in a private dental clinic in southern Germany (Private Institute of Periodontology and Implantology). Patients over the age of 18 (of both sexes and any race) were recruited for maxillary reconstruction with an immediately loaded full-arch prosthesis. All patients had extremely atrophied maxillae and were planned to be treated with one to four zygomatic implants (Nobel Biocare) in conjunction with sinus bone grafting. To support the fixed prosthesis with a minimum of four implants, conventional auxiliary tilted implants (NobelActive, Nobel Biocare) were placed in the anterior maxilla, when necessary.

Other inclusion criteria were as follows:

- Patients had to be either edentulous in the maxilla or their remaining teeth had to be hopeless and planned for extraction.
- Atrophy of the maxilla had to be extreme enough to have required posterior bone augmentation, were it not for the placement of zygomatic and tilted implants.
- A decision had to have been previously made to use dental implants for rehabilitation with a fixed restoration.
- Patients had to be physically and psychologically able to tolerate conventional surgical and restorative procedures.
- Patients had to provide informed consent.

Exclusion criteria were as follows:

- Any general contraindications for implant surgery
- Any active infection or severe inflammation in the areas intended for implant placement
- The presence of systemic diseases such as uncontrolled diabetes
- Any treatment with therapeutic radiation to the head within the previous 12 months
- The presence of any previously unresorbed grafting material at the implant site
- Severe parafunctional habits such as bruxing and clenching
- Pregnancy at the time of the screening visit
- Poor oral hygiene and/or motivation

The nature of the study was explained to each patient before he or she provided written informed consent. Randomization of patients/procedures was not feasible given the specific treatment protocol.

Presurgical Evaluation

All patients underwent preoperative clinical and radiographic evaluation. To determine the residual bone volume and the desired prospective implant positions and lengths, a presurgical cone beam computed tomography (CBCT) scan was obtained. Consequently, a three-dimensional evaluation of the maxilla and the sinus cavity was performed. The width, density, and volume of the zygoma were determined to ensure that placement of a zygomatic implant was a feasible treatment approach (Figs 1 and 2). A provisional prosthesis was fabricated prior to surgery, in accordance with a diagnostic setup.

Surgical Procedure

Implant surgery was performed with patients under general anesthesia. One hour prior to surgery, antibiotic prophylaxis was administered as a single injection of clindamycin (600 mg), which was also prescribed postsurgically (300 mg orally administered three times daily for 7 days). Analgesics were prescribed postsurgically if needed for pain. Rinsing with 0.1% chlorhexidine was performed for up to 2 weeks after surgery.

After extraction of any remaining hopeless teeth, a muco-periosteal flap was raised from the maxillary crest to the zygomatic buttress (Fig 3). The suborbital nerve was identified and avoided to prevent paresthesia and other neural injuries. Corresponding to the sinus floor elevation technique, a lateral sinus window at the facial aspect of
the maxilla was prepared with rotating burs. The future entrance point of the zygomatic implant at the alveolar crest (ie, the first molar region) served as a starting point in the mesiodistal direction. Special care was given to prevent perforation of the sinus membrane. After the lateral window was established, the sinus membrane was precisely elevated toward the medial aspect of the maxillary antrum with sinus elevation instruments (Figs 4 and 5). To enable sinus bone grafting, the lateral window and the subsequent reflection of the sinus membrane were extended to the superolateral aspect of the maxilla to the proposed implant site(s) in the zygomatic bone (Figs 6 and 7). This prolonged lateral window was also helpful during surgery for determining the orientation of implants within the zygoma and the maxillary sinus.

After the sinus membrane was elevated adequately, initial access into the zygomatic bone was obtained with a round bur (Fig 8). Depending on the quantity and quality of existing bone, the optimal positions for
the implants in the regions of the second premolar and the first molar were defined. The angulations of the implants were checked to confirm that the implants fit within the provisional prosthesis. The exact position of the tip of the implant in the zygomatic arch was marked with a round bur after the sinus window had been prepared. Next, different drills with increasing diameters were used to prepare the sites for the insertion of one to four zygomatic implants (Nobel Biocare) in each patient. The precise implant lengths were determined by the use of a special depth gauge. With the objective of immediate loading, definitive abutments were connected to the zygomatic implants (Fig 9).

After the integrity of the sinus membrane was confirmed, the established sinus cavity was augmented with a bone graft material (Osteobiol mp3, ADSystems) corresponding to a traditional sinus elevation approach (Fig 10). The procedure was performed until the entire intrasinusal and lateral portions of the zygomatic implant as well as the exposed threads at the implant neck had been augmented.

The augmented area was covered with a resorbable barrier membrane (Osteobiol SoftCorticalLamina, ADSystems) to prevent soft tissue ingrowth into the sinus and to enable guided bone regeneration. Fixation pins (TitanPin, Geistlich) were used when collapse of the barrier membrane was expected (Fig 11). A second barrier membrane (Osteobiol Evolution, ADSystems) was applied on top of the first membrane to allow optimal soft tissue integration (Fig 12).

After implant placement and grafting, primary wound closure was obtained. A pickup impression of the implants was made at the conclusion of surgery, and interocclusal registration was performed using a prefabricated provisional prosthesis. Within 4 hours, a screw-retained full-arch acrylic resin provisional prosthesis was delivered to each patient (Fig 13). The prostheses were designed without cantilevers but with a minimum of 10 teeth because of the favorable support provided by the posterior zygomatic implants. Postoperatively, the positions of the implants and the amount of bone augmentation were checked radiographically (Fig 14).
Definitive Prosthetic Procedure

Definitive reconstructions were delivered to all patients 6 months postsurgery (Fig 15). Complete full-arch prostheses were supported by metal or zirconia frameworks combined with high-density acrylic resin. Cantilevers were extended up to the first molar regions to provide a greater occlusal surface area and improved functional capability. The definitive prostheses were fixed with titanium screws (Torqtite, Nobel Biocare) at 20 Ncm with a torque-control device.

Supportive Implant Therapy

All patients were given the opportunity to participate in an implant recall program. The supportive care was performed on an individual basis at 3- or 6-month intervals. The hour of therapy included removal, cleaning, and polishing of the fixed prosthesis; examination and reevaluation of the implants; motivation and re-instruction of the patient; and instrumentation of the implants using primarily a low abrasive air polishing powder (Clinpro Prophypowder, 3M ESPE). When this was completed, the prosthesis was seated with a torque-control device and the screw access holes were closed again.

Follow-up Protocol

Clinical Examinations. At 6 months after surgery at the time of definitive prosthesis placement, the following clinical parameters were checked at the implant level by an independent clinician.

- The stability of each implant was assessed by applying pressure with two opposing instruments after removal of the prostheses.
- The presence of plaque at six sites per implant was recorded as the percentage of total surfaces (FMPS).
- Bleeding on probing (BOP) was measured dichotomously at six sites per implant and was recorded as the percentage of total surfaces (FMBS).
- Pocket probing depth (PPD) was measured at six sites per zygomatic implant and recorded to the nearest millimeter.
The distance between the implant shoulder and the mucosal margin (DIM) in millimeters was measured at six sites per zygomatic implant.

The probing attachment level (PAL) in millimeters was calculated by subtracting PPD from DIM.

The height of the keratinized mucosa (KT) was measured at the buccal aspect of the zygomatic implants.

All clinical measurements were made by an independent examiner using a UNC-15 periodontal probe (Hu-Friedy), with readings recorded to the nearest millimeter.

Radiographic Examination. Radiographic assessment was done with CBCT scans obtained immediately after surgery and at the 6-month follow-up visit (i-CAT, Imaging Sciences) (exposure time: 20 seconds; tube voltage: 120 kV; tube current: 3 to 8 mA). Measurements were made using a software program (OsiriX 3.9 Imaging Software, Pixmeo SARL) (level = 1,500, window = 5,000, zoom = 400%).

To perform reproducible measurements at different time points, a multiplanar reconstruction running through the implant apex, the implant head, and the center of the abutment was created for each zygomatic implant at each time point. The implant access point of the sinus floor (Z1), the calculated implant center (Z2) (implant length/2), and the implant entrance point within the zygomatic buttress (Z3) served as reference levels. Linear radiographic bone height—the distance between the implant surface and the external border of the augmented area—was measured perpendicular to the implant axis within the created plane on the buccal and palatal aspects of each zygomatic implant (Fig 16).

Survival and Complications. For the purposes of this study, implant and prosthesis survival were defined as the implant and/or prosthesis remaining in situ throughout the observation period, with or without modification. All biologic complications were noted, including postoperative bruising, infection, neuropathy/paresthesia, and/or recurrent and persistent peri-implant infection. Technical complications to be noted included fracture of the implants, screws, or abutments; screw or abutment loosening; framework or veneer fractures; and loss of retention.

Data Analysis
Data were expressed as means ± standard deviations (SDs). The radiographic measurements at the 6-month follow-up were compared to the values obtained immediately after surgery by means of a paired t test (α = .05).

RESULTS

Between January 2010 and November 2010, 10 patients (three men and seven women) were reconstructed with immediately loaded complete full-arch prostheses, each supported by a minimum of four implants. The mean age at surgery was 61.5 years (range, 56 to 69 years). Three of the included patients were smokers (two were light smokers of < 10 cigarettes/day, and one was a heavy smoker of about 20 cigarettes/day).

In all, 22 zygomatic implants and 23 anterior auxiliary implants were placed. Each patient received zygomatic implants in conjunction with sinus bone grafting, as described.
Survival and Complications
One zygomatic implant had to be removed immediately after surgery, because the implant apex slightly perforated the orbital floor and was located within the orbital fat compartment, as detected in the postoperative CBCT scan. A second zygomatic implant was removed surgically after 6 months as a consequence of persistent idiopathic pain in the cheekbone. Both implants were removed without compromising prosthetic function. No implants were lost as a consequence of mobility. The overall 6-month implant survival rates were 90.9% for zygomatic implants and 100% for auxiliary implants. Extensive bruising was observed in two patients. No oroantral communications or infections of the sinus were observed within the observation time.

Technical complications included fracture of the acrylic veneer material in one provisional prosthesis and occlusal screw loosening in one case. All the technical complications were considered minor and could be resolved without detaching the prostheses, resulting in an overall prosthetic survival rate of 100%. Main characteristics of each patient are shown in Table 1.

Six-month Clinical Outcomes
The 10 patients presented at the 6-month follow-up examination with mean FMPS and FMBS of 18.3% ± 2.1% and 13.5% ± 2.1%, respectively. All implants were clinically stable. The 6-month mean PPD was 3.7 ± 0.3 mm. DIM of 3.3 ± 0.4 mm and PAL of 0.4 ± 0.3 mm on average were recorded. Mean KT height of 3.4 ± 0.2 mm was found. The 6-month outcome measures are displayed in Table 2.

Radiographic Observations
Linear measurements of the radiographic bone gain are shown in Table 3. In all treated sites, the grafting material could be visualized as a radiopaque structure in CBCT scans postsurgically and at the 6-month evaluation. The differences in average radiographic bone gain at reference level Z1 between baseline and 6 months were statistically significant (P < .0001 and P = .0023, respectively). For reference level Z2, the differences between baseline and 6 months were statistically significant (P = .0034 and P = .0022, respectively). For Z3 as well, the differences between baseline and 6 months were statistically significant (P = .0018 and P = .0002, respectively). Figure 17 shows new radiographic bone formation around a zygomatic implant after 6 months of healing.

DISCUSSION
This clinical cohort study demonstrates the procedure, the clinical outcomes, and the radiologic findings of a novel surgical approach to place zygomatic implants in conjunction with sinus bone grafting. The results preliminarily illustrate the potential benefits of this approach. In fact, a substantial gain of radiographic
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bone around the zygomatic implants (means of 1.4 ± 0.5 mm to 4.3 ± 0.4 mm) was observed at 6 months, accompanied by shallow PPDs (3.7 ± 0.3 mm) and minimal attachment loss (PAL = 0.4 ± 0.3 mm). During the observation period, no oroantral communications or infections of the sinus were observed. These outcomes were achieved using what the authors have termed the “extended sinus elevation technique.”

In general, for the reconstruction of the extremely atrophied maxilla, the zygomatic implant concept offers a very positive benefit. Avoiding bone augmentation procedures and graft maturation prior to implant placement, which eliminates time-consuming and repeated surgical interventions, is considered a major benefit of the traditional approach to zygomatic implant insertion. Additionally, shortening the treatment through immediate functional loading of zygomatic implants is regarded as an improved treatment modality, and not only for older patients with unfavorable medical conditions.

However, although zygomatic implant insertion has been shown to have a number of advantages, the conventional placement technique may have some limitations. Existing clinical data have shown that the placement of zygomatic implants increases the risk of postoperative complications related to the sinus.4–7,12–14 Aparicio et al15 reported that sinusitis occurred in 2.3% to 13.6% of cases; thus the risk for sinusitis should not be underestimated.

The fact that the zygomatic implant itself passes through the maxillary sinus cavity does not seem to result in any profound complications in the antrum. With the sinuscope technique, Petruson16 assessed the reaction of the sinus membrane to zygomatic implants penetrating the sinus cavity. During the healing process, the sinus mucosa covered the implants to some extent, and no signs of infection around the implants were observed visually. Davo et al17 followed a cohort receiving immediately loaded zygomatic implants clinically and radiologically. The authors stated that sinuses penetrated by zygomatic implants seemed to maintain a normal physiology. No clinical signs or symptoms of sinusitis could be found, despite the fact that in approximately 15% to 20% of patients, early radiologic findings of infection were observed.

Another possible explanation for the postoperative sinus infections frequently seen might be that oroantral communications provoke a severe reaction of the maxillary sinus mucosa. The mechanical and biologic stability of the zygomatic implant is almost exclusively limited to the short portion that is incorporated into the cheekbone, whereas the crestal bone, with its often thin sinus floor, displays the weakest point of implant-bone anchorage. Kahnberg and colleagues4 reported that the thin palatal bone, the widening of the drill hole during the surgical procedure, and possible micromovement of the zygomatic implants after loading, may together influence sinus-related symptoms and complications. Furthermore, the authors stated that the limited maxillary bone volume may have had an impact and could not be excluded as a possible cause of implant failure.

Table 2 Clinical Outcomes at the 6-month Follow-up Examination

<table>
<thead>
<tr>
<th>Variables</th>
<th>Mean ± SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>FMPS (%)</td>
<td>18.3 ± 2.1</td>
</tr>
<tr>
<td>FMBS (%)</td>
<td>13.5 ± 2.1</td>
</tr>
<tr>
<td>PPD (mm)</td>
<td>3.7 ± 0.3</td>
</tr>
<tr>
<td>DIM (mm)</td>
<td>3.3 ± 0.4</td>
</tr>
<tr>
<td>PAL (mm)</td>
<td>0.4 ± 0.3</td>
</tr>
<tr>
<td>KT (mm)</td>
<td>3.4 ± 0.2</td>
</tr>
</tbody>
</table>

Table 3 Radiographic Bone Gain Immediately After Surgery and at the 6-month Follow-up Examination

<table>
<thead>
<tr>
<th>Location</th>
<th>Baseline</th>
<th>6 mo</th>
<th>Difference</th>
<th>P*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Z1</td>
<td>Buccal</td>
<td>2.5 ± 0.2</td>
<td>1.6 ± 0.1</td>
<td>0.9 ± 0.2</td>
</tr>
<tr>
<td></td>
<td>Palatal</td>
<td>5.0 ± 0.6</td>
<td>4.2 ± 0.5</td>
<td>0.8 ± 0.2</td>
</tr>
<tr>
<td>Z2</td>
<td>Buccal</td>
<td>2.5 ± 0.4</td>
<td>1.4 ± 0.5</td>
<td>1.0 ± 0.3</td>
</tr>
<tr>
<td></td>
<td>Palatal</td>
<td>6.5 ± 0.7</td>
<td>4.3 ± 0.4</td>
<td>2.2 ± 0.5</td>
</tr>
<tr>
<td>Z3</td>
<td>Buccal</td>
<td>3.0 ± 0.3</td>
<td>2.4 ± 0.3</td>
<td>0.5 ± 0.2</td>
</tr>
<tr>
<td></td>
<td>Palatal</td>
<td>3.9 ± 0.5</td>
<td>2.9 ± 0.4</td>
<td>0.9 ± 0.2</td>
</tr>
</tbody>
</table>

*Paired t test.

Fig 17 CBCT scan 6 months after implant placement according to the modified technique. Note the bony housing that has developed around the entire zygomatic implant.
Becktor et al.\textsuperscript{14} observed a 9.7% implant failure rate because of recurrent sinusitis in spite of clinical stability of the implants. They proposed that lack of osseointegration occurred at the marginal bone level, resulting in transverse mobility of the zygomatic implant. The subsequent pump effect during function may have led, via oroantral communications, to the sinus infections.

Crestal bone level alterations, in conjunction with increased PPDs, caused either by the positioning of the zygomatic implant head and abutment or by peri-implant infections, may be another factor responsible for opening a passage between the oral cavity and implant infections. Regarding peri-implant infections, Al-Nawas and colleagues\textsuperscript{18} reported that, for 9 of 20 implants, both BOP and PPD ≥ 5 mm were seen, resulting in a success rate of only 55%. Where residual crestal bone height is minimal, these intraoral soft tissue problems might have the potential to cause severe infections of the sinus and, when present, may necessitate removal of the implant.

Therefore, to reduce the complication rate, the biomechanical stability of the entire zygomatic implant should be increased. In contrast to traditional zygomatic implant placement, the objectives of the proposed "extended sinus elevation technique" are: (1) to preserve the integrity of the sinus membrane when placing the zygomatic implant and (2) to regenerate bone around the implant, thereby increasing the bone-to-implant contact, while the new implant site is created, comparable to a sinus elevation procedure. With this technique, the advantages of the conventional zygomatic implant concept—namely, the immediate reconstruction of a severely atrophied maxilla and the benefits of a bone grafting procedure—are combined in a single step. It can be assumed that the simultaneous implant site development, by creating more bone volume and improving bone topography along the entire zygomatic implant, enhances biomechanical stability and minimizes any crestal transverse mobility. Communications between the oral cavity and the maxillary antrum can be avoided, while the surgical technique provides a stable bony housing around the implant. In addition, exposed implant threads within the maxillary antrum are eliminated through the development of a bony housing around the entire zygomatic implant by sinus bone grafting. Possible oroantral communications may be prevented by the grafting approach when little crestal bone remains or initial or late marginal bone loss occurs.

The traditional sinus elevation procedure is a predictable treatment method to augment the posterior maxilla and has been associated with high implant survival rates and a low incidence of surgical complications.\textsuperscript{19–21} The success of sinus bone grafting is attributable to the high osteogenic potential of the sinus membrane. Clinical studies have shown that elevation of the membrane, with or without placement of a grafting material, results in bone gain above the sinus floor.\textsuperscript{22–26} Therefore, maintenance of the integrity of the sinus membrane in conjunction with sinus bone grafting seems to have a high potential to create a bony housing, even around zygomatic implants.

To perform the proposed technique, the integrity of the sinus membrane must be maintained intrasurgically rather than penetrated during drilling. Therefore the "extended sinus elevation technique" is characterized by an enhanced lateral window that is large enough to allow controlled elevation of the maxillary sinus membrane prior to zygomatic implant placement. To precisely reflect the membrane beyond the intended implant site, it is of the utmost importance that the window of the lateral antral wall is extended to the superolateral aspect of the maxilla. According to Boyes-Varley et al.,\textsuperscript{26} preparation of a buccal access window allows direct visualization of the access point of the implant into the body of the zygoma, and perforation of the posterior antral wall can be avoided because of visual control. Hence, the extended lateral window minimizes the risk of operative complications and enhances intrasurgical control. Furthermore, the visually controlled implant placement facilitates easier and more reproducible implant positioning, enabling prosthetically ideal orientation of the implant platform.

**CONCLUSION**

The proposed "extended sinus elevation technique" to place zygomatic implants in conjunction with sinus bone grafting may decrease the risk of biologic complications, in contrast with traditional zygomatic implant placement, in the following aspects:

- Maintenance of the integrity of the sinus membrane may reduce sinus-related symptoms and complications.
- Exposed implant threads within the maxillary antrum are eliminated through the development of a bony housing around the entire zygomatic implant by sinus bone grafting. Possible oroantral communications may be prevented by the grafting approach when little crestal bone remains or initial or late marginal bone loss occurs.
- Biomechanical properties may be improved by increased bone-to-implant contact as a new implant site is developed.

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REFERENCES


