Osseous resorption and enlargement of the maxillary sinus can complicate treatment of edentulous areas of the posterior maxilla. Treating such cases with traditional dental implants can be challenging, and treatment time, morbidity, and costs may significantly increase for the patient. Treatment planning options for the management of these types of severely resorbed partially or completely edentulous maxillae have been expanded to include the use of the zygomatic process for immediate implant fixation and stabilization with immediate function. This approach may alleviate the need for significant grafting to enable implant placement in the posterior maxilla and allow implants to be placed into denser, more stable bone. Zygomatic implants, which have been used clinically for the past 20 years in the treatment of the severely resorbed maxilla, allow implant placement to support fixed prosthetics. Their usage can potentially shorten treatment time and reduce costs, as the need to wait for osseous graft maturation is eliminated. Guided surgical approaches are being utilized to maximize placement of the prosthetic platform of these implants.

Zygomatic implants have been used for the past two decades to treat patients with severely resorbed maxillae. They allow implant placement to support fixed prosthetics. Brånemark introduced the first zygomatic implants in 1988, and they became available to the profession 10 years later after their viability was proven in clinical use. Initially, the protocol involved placing two zygomatic implants with additional root-form implants placed in the anterior maxilla, which were splinted together to support a screw-retained fixed prosthesis. Frequently, this may have resulted in the zygomatic implants being placed palatal to the alveolar ridge, leading to complications related to speech, hygiene, and comfort. Implant placement was done essentially freehand during surgery, which led to many of the common complications with this type of implant. Updated protocols and changes to the zygomatic implants themselves and their parts have largely resolved these types of complications.

Guided surgical approaches are being utilized to maximize placement of the prosthetic platform of these implants. The implant team (including surgeon, prosthetic dentist, and laboratory technician) uses a 3-dimensional (3D) computed tomography (CT) scan, ie, cone-beam CT (CBCT), to determine the available bone mass present in the severely resorbed maxilla, which will help dictate whether successful rehabilitation can be achieved through multiple grafting procedures, a conventional All-on-4® (Nobel Biocare, nobelbiocare.com) or similar procedure may be performed, or zygomatic implants will be required to restore the patient’s arch. Each of these procedures has benefits and drawbacks associated with it, as discussed below.

Grafting Procedures
Enlargement of the maxillary sinus related to tooth loss and periodontal disease frequently requires sinus augmentation, ie, elevation of the maxillary sinus and placement of osseous grafting, to allow implant placement in molar sites (Figure 1). Over the past 20 years multiple bone grafting procedures used in the reconstruction

Abstract: Treatment of severely resorbed partially or completely edentulous maxillae can include the utilization of the zygomatic process for immediate implant fixation and stabilization with immediate function. This approach may alleviate the need for significant grafting to enable implant placement in the posterior maxilla and allow implants to be placed into denser, more stable bone. Zygomatic implants, which have been used clinically for the past 20 years in the treatment of the severely resorbed maxilla, allow implant placement to support fixed prosthetics. Their usage can potentially shorten treatment time and reduce costs, as the need to wait for osseous graft maturation is eliminated. Guided surgical approaches are being utilized to maximize placement of the prosthetic platform of these implants.
of partially or completely edentulous maxillae have been described and well-documented in the dental literature. Understanding the prosthetic requirements needed to provide dentition to these patients, as well as the limitations involved, is paramount to the overall success of the grafting procedures performed. Sinus elevation and grafting, horizontal/vertical ridge augmentation, onlay grafting, LeFort osteotomy/sandwich grafting are just several of the options available for reconstruction of the severely resorbed maxilla.

Though all of these options have been shown to have a variety of success rates long term they usually require multiple surgeries, and the patient is unable to wear a prosthesis for at least the initial healing phase. Additionally, these techniques lengthen the treatment time before the final prosthetics can be initiated; cases of complex or multiple grafting procedures may stretch to a year or more. Frequently, in such cases involving severe resorption, implants cannot be placed at the time of initial grafting, potentially increasing treatment time further.

**Angled Dental Implant Placement/Immediate Function**

The severely resorbed maxilla and associated enlarged sinus can also be managed through the use of angled dental implant placement to avoid interfering with the medial aspect of the maxillary sinus, the lateral pyriform nasal plate, and the nasal floor (Figure 2). The All-on-4 treatment concept originally described by Maló allows for a non-grafting, immediate function option for patients who are partially or completely edentulous or in “terminal dentitions”; an immediate, fixed, maxillary palate-less prosthesis can be realized in a single procedure.

However, if the available residual bone does not allow for the implants to be placed with sufficient insertion torque, anterior-posterior (A-P) spread (ie, A-P distance between implants), or presence of bone in the anterior at the lateral nasal wall, the procedure is not possible for immediate implant fixation and loading, and long-term success may be compromised. In these situations a delayed approach may be taken, allowing implants to integrate prior to loading. Jensen et al described the use of the vomer/nasal crest in such atrophic cases as another option to engage dense cortical bone and achieve immediate implant stabilization. However, this does not address the handling of the posterior implants that are required.

**Zygomatic Implants**

In cases where the residual maxillary bone is insufficient, especially in the paranasal region or lateral pyriform rim and when the sinus pneumatization is anterior to the canine region, and multiple grafting procedures are contraindicated, the use of zygomatic implants may be an option (Figure 3). This may allow for immediate stabilization of the dental implants and immediate function of a stable fixed prosthesis. Brånemark initially described using the zygomatic process to allow longer implants (30-mm to 55-mm length) to be placed and achieve a higher insertion torque. Multiple authors have published on the use of zygomatic implants for the immediate stabilization and loading of a full-arch fixed prosthesis in the severely resorbed maxilla.

To engage the zygomatic bone, zygomatic implants require substantially longer lengths than traditional implants and are available in lengths ranging from 30 mm to 60 mm. Widths typically are in the 3.5-mm to 4.5-mm diameter range. These implants are available in various designs to accommodate different types of bone that may be present, as per the Aparicio classification. For example, one manufacturer (Southern Implants, southernimplants.com) offers designs that feature an apical diameter of 3.5 mm and other models that are 4.3 mm in apical diameter (Figure 4). Because the implant will be placed at an angle that skirts or has a trajectory through the
maxillary sinus so it can engage the zygoma with its apical end, the implant has an angled correction at its platform. Nobel Biocare, for example, provides zygomatic implants with a 45-degree correction, while Southern Implants manufactures them with a 55-degree correction. This angled correction is illustrated in Figure 5. This allows the prosthetic axis to more effectively approach a vertical inclination, but multi-abutments are added to further enable the platform to be brought into the appropriate position.

Anatomically, patients vary with regard to the position of the lateral wall of the sinus and the zygoma in relation to the ridge crest. Classifications of zygomatic implants according to Aparicio present as five different types based on where the zygomatic implant will lie in relation to the lateral wall of the sinus (Figure 6). In each classification the implant is fixated at the crest inferiorly and at the zygoma superiorly, but will traverse through part of the maxillary sinus. A portion of the body of the implant where it traverses through the sinus will not be encased in bone, and in some clinical situations part of the implant will not be in bone as it lies on the exterior of the lateral wall of the sinus. Anatomical variations aside, these implants are very long (30 mm to 60 mm) so that stability can be achieved at the apical portion, in the dense bone of the zygoma.

Variations of incorporating zygomatic implants into the severely resorbed maxilla may be part of a conventional type of All-on-4 treatment procedure when sufficient bone exists in the paranasal region for the placement of anterior implant fixtures (Figure 7 through Figure 10). When the paranasal region will not accommodate implant placement, this approach can be expanded to the quad zygoma procedure where two zygomatic implants are inserted in each upper quadrant bilaterally (Figure 11 through Figure 16).

Zygomatic implants are not limited to use in fully edentulous cases. Options exist for partially edentulous patients exhibiting multiple posterior tooth loss with both horizontal and vertical bone loss volume in the ridge crest. The implants may be used in the partially edentulous maxilla when insufficient volume of bone is present as an alternative to osseous grafting of the sinus or crest to enable implant placement in the posterior (Figure 17 through Figure 19). The incorporation of sinus grafting will lengthen treatment time, as the graft will need to mature prior to implant loading if the implant is able to be placed at the time of sinus augmentation. Should the implant not be able to be placed when sinus augmentation is

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**Fig 4.** Examples of zygomatic implants available in lengths up to 60 mm and in different styles based on the Aparicio classification present in the patient. Apical diameters could range from 3.5 mm, as shown in the two middle implants, to 4.3 mm, as shown in the two outer implants.

**Fig 5.** Zygomatic implants have a correction at the platform (yellow line) that may place the prosthetic axis (P) at an angle of 45° (left) or 55° (right) degrees from the implant axis (I) to allow restoration of the implant, which is placed at a significant angle compared to an axial implant position.

**Fig 6.** Classification (Aparicio) of zygomatic implants based on orientation to the lateral wall of the maxillary sinus.
performed, treatment time is further increased and restoration may not be possible for up to 1-year post initial surgery.

Discussion
Bone resorption combined with increased maxillary sinus enlargement and poor bone quality often makes it impossible to execute conventional implant placement in the posterior maxilla without extensive osseous grafting. Various bone augmentation techniques have been described for increasing the volume of bone to accommodate conventional implants. These techniques include sinus augmentation via lateral and crestal approaches and onlay grafting. Efforts have pursued alternatives to grafting procedures in the atrophic maxilla, both to decrease treatment time and lower the costs associated with bone grafting. Zygomatic implants have been in clinical use for 20 years and are utilized for treatment of patients with severely resorbed fully or partially edentulous maxillary arches.

Use of zygomatic implants, however, is not without risks; therefore, surgical experience is needed when placing them.20 Of the complications reported in the literature, sinusitis is the most common.21 Because a portion of the implant will traverse through the maxillary sinus, depending on which classification the patient falls into (Figure 6), sinus issues may potentially be expected. The incidence of sinusitis reported after zygomatic implant placement is as high as 26.6%.22-24 Sinusitis may develop several years after implant placement. The literature indicates that placement of zygomatic implants does not seem to be associated with severe sinusitis complications.25 D’Agostino reported that in a considerable number of patients with zygomatic implants asymptomatic radiologic alterations of the paranasal sinuses were observed.26 Asymptomatic chronic sinusitis with osteitis and a gradual collapse of the maxillary sinus cavity can be anticipated but does not appear to affect the high success rates being reported for these implants.27 Other potential complications that have been reported include oroantral fistula formation, temporary deficit of sensory nerves, vestibular cortical fenestration, postoperative peri-orbital/subconjunctival hematoma or edema, and moderate nasal bleeding for 1 to 3 days.28 Patients with pronounced...
success rate of 100% in 34 patients identified with a total of 220 implants placed. In yet another study, 49 patients received bilateral zygomatic implants and nine patients received unilateral zygomatic implants, with 107 zygomatic implants reported. All patients observed had supplemental anterior implants with a follow-up of 5 to 13 years and a mean follow-up time of 8.4 years per zygomatic implant. No losses of zygomatic implants were reported, and no major surgical or restorative complications were observed.

In 2014, a systematic review of studies of zygomatic implant survival published from 2000 to 2012 culminated in 25 full-text articles considered clinically relevant. These studies reported the insertion of a total of 1541 zygomatic implants, of which 33 failed. These failures generally occurred during the first year and related to clinical complications, such as recurrent acute and chronic sinusitis. The survival rate after a 36-month follow-up was 97.86%.

The American College of Prosthodontists’ position on these implants states, “the use of the zygomatic implant in various clinical scenarios with multiple configurations enables the dental team to

buccal concavities of the lateral aspect of the maxillary sinus may be more prone to such complications especially when a non-guided surgical approach is used. The limited intraoperative visibility along with the anatomical complexity of the structures and intricacies of the zygoma make this surgical procedure clinically demanding. Increased availability of CBCT, virtual implant planning, and CAD/CAM surgical guide fabrication may potentially greatly decrease complications and make placement less stressful.

Despite these potential complications, multiple authors have reported success rates with zygomatic implants. After observation of 92 zygomatic implant rehabilitations over 5 years performed on patients with completely edentulous, severely atrophic maxillae supported by immediately loaded zygomatic implants alone or in combination with conventional implants, Maló et al reported long-term outcome was satisfactory with cumulative success rates of 97% and 98.8% as related to patient and implant, respectively. Another study supported Maló’s findings wherein the authors observed at 10 years a zygomatic implant success rate of 100% in 34 patients identified with a total of 220 implants placed. In yet another study, 49 patients received bilateral zygomatic implants and nine patients received unilateral zygomatic implants, with 107 zygomatic implants reported. All patients observed had supplemental anterior implants with a follow-up of 5 to 13 years and a mean follow-up time of 8.4 years per zygomatic implant. No losses of zygomatic implants were reported, and no major surgical or restorative complications were observed.

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restore quality of life and gives patients an expedited and predictable option.”33

Conclusion
The use of zygomatic implants, either in combination with or without conventional implants in the anterior, may be considered in the atrophic fully or partially edentulous maxilla as an alternative treatment option to osseous grafting, which may be required to provide bone for conventional implant placement. Success and survival rates of zygomatic implants have been reported to be equal to conventional implants. Use of zygomatic implants may shorten the treatment time that would normally be required for osseous graft maturation and subsequently delay implant placement until such maturation occurs. Additionally, treatment costs may be lowered due to the elimination of complex grafting procedures. As the use of CBCT, virtual planning, and surgical guides progresses, it is anticipated that these implants may be more readily utilized and potential complications that had been associated with prior placement techniques will be reduced.

5. Combination with sinus augmentation: a case series with 1 to 15 years of loading. Paul S. Petrungaro, DDS, MS

6. Sinus enlargement in the left posterior maxilla limited implant placement distal to the existing implants at the premolar sites, and osseous grafting would be required for implant placement. Fig 18 and Fig 19. A zygomatic implant was instead placed into the posterior left, allowing the grafting would be required for implant placement. This enables a shortened treatment time prior to implant loading and reduces costs as grafting of the sinus is unnecessary.


