ZYGOMATIC IMPLANTS

A Retrospective Study of a Multi-Center Case Series of 452 Zygomatic Implants Placed Over 5 Years for Treatment of Severe Maxillary Atrophy

Paul S. Petrungaro, DDS, MS; Santiago Gonzales, DDS; Carlos Villegas, DDS; Jardin Yousef, BS; and Alejandro Arango, DDS

Abstract: ***Background:*** Treatment of the severely resorbed maxilla traditionally has been managed with such protocols as sinus elevation, bone and soft-tissue grafting, and osteotomy procedures. The use of zygomatic implants has made it possible to circumvent such procedures, allowing immediate loading of implants with fixed prostheses. ***Objective:*** This study reports the success rate of 452 zygomatic implants placed and restored in 249 patients over 5 years in a multi-center setting. Additionally, case examples are presented. ***Methods:*** The authors conducted a multi-center case series study. Inclusion criteria were ASA 1 or ASA 2, nonsmoking adults over age 30, fully or partially edentulous, with severely atrophic maxillae. These patients had zygomatic implants placed over a 5-year period with a follow-up of 5 years. The survival rate of these implants is described. ***Results:*** A total of 249 patients, aged 34 to 80, had 452 zygomatic implants placed. Survival rate was 95% for quad zygoma; 99.1% for unilateral zygoma with additional premaxillary implants; 98.7% for bilateral single zygoma with additional premaxillary implants; and 100% for unilateral zygoma as a distal extension in implant-supported fixed prostheses. Overall implant survival rate was 97.6%. ***Conclusion:*** This study supports reports of zygomatic implants having a high success rate while allowing an array of ancillary procedures to be avoided. ***Clinical Implications:*** The use of zygomatic implants in the atrophic maxilla has shown to be a reliable treatment option for patients selecting to not undergo advanced bone-replacing protocols.

Bone loss in the maxillary arch coupled with enlargement of the maxillary sinus cavities can significantly increase the complexity of the replacement of natural teeth with dental implants.[1] When appropriate volume and quality of the alveolar structures remain present after tooth loss, the options for implant-supported prostheses are numerous. However, once ridge resorption becomes significant and bone volume and quality are compromised, advanced bone regeneration options become necessary,[2-4] and these options may necessitate several bone replacement procedures prior to implant reconstruction.[5]

Treating these types of cases with subsequent implant procedures can be challenging, add significant healing times and costs, and introduce the potential for complications. The All-on-4® procedure presented a "graftless" option to treat patients seeking a fixed implant-supported prosthesis.[6] The success rates in the dental literature have been favorable.[7] However, a significant portion of patients have severe maxillary atrophy in both the anterior and posterior maxillae and/or enlarged sinus cavities that pneumatize into the canine region. This circumstance drastically reduces bone availability in the premaxillary region, limiting implant placement with regard to length, width, and appropriate anterior-posterior (A-P) spread to support a fixed implant-supported prosthesis.

Utilizing the zygomatic process for immediate implant placement and stabilization can enable immediate function to be achieved.[8-10] Zygomatic implants have been introduced into the

treatment planning phase of patients with advanced maxillary atrophy.[9,11,12] Their usage may eliminate the need for advanced grafting protocols and allow patients who otherwise would require multiple, potentially costly procedures to have a single surgical procedure to immediately support a fixed prosthesis.[13]

This article outlines the challenges associated with treatment of severe maxillary atrophy, previous techniques to manage this situation, and the incorporation of zygomatic implants into the treatment planning phase as an alternative approach to managing the complexities of advanced bone loss in the maxilla. Also, the success rates of 452 zygomatic implants placed and restored over a 5-year period in a multi-center setting are reported.

Maxillary Atrophy

Advanced atrophy of the alveolar ridge is a complex limitation to implant rehabilitation in the maxilla. Severe maxillary atrophy may be due to any number of reasons. Advanced periodontal destruction precipitated by extension of inflammation into the periodontal tissues, leading to loss of the dentition, is a common one. An association between extended use of dental prostheses, whether complete, fixed partial, removable partial, and/or implant-supported dentures, and loss of residual alveolar bone has been suggested; however, this correlation is difficult to prove because patients who wear these devices do so because of their edentulism, which is the primary reason for alveolar atrophy.

Loss of the alveolar structures resulting in premature tooth loss may also explain maxillary bone resorption; for example, in patients diagnosed with congenital adrenal hyperplasia, premature exfoliation of primary teeth and accelerated eruption of permanent teeth leads directly to bone destruction.[14] Similarly, in children affected by the rare autosomal recessive disorder Papillon-Lefèvre syndrome, aggressive periodontitis and premature loss of dentition that negatively influences bone width and height are significant characteristics.[15]

Excessive alveoloplasty for prosthetic considerations may make matters worse by enhancing bone resorption and accelerating maxillary atrophy. Likewise, loss of periodontal tissue due to peri-implantitis of failing implants may be responsible for atrophy of the maxilla.[16,17]

Conventional Surgical Protocols

Various surgical procedures and protocols have been suggested and implemented to correct severe maxillary atrophy.[18-21] Among these techniques is the Le Fort I osteotomy, a procedure that oral and maxillofacial surgeons use to correct a wide variety of midfacial deformities, and which can also be used to address maxillary atrophy.[22] This technique involves creating an incision on the maxillary buccal mucosa, exposing the maxilla, then performing an osteotomy molar to molar wrapping around the tuberosities to reposition the maxilla inferiorly and inserting interpositional bone grafts, allowing correction of maxillary atrophy.[23]

Bone augmentation following lifting of the Schneiderian membrane (sinus lift and sinus grafting protocols) is yet another technique used to achieve alveolar bone height for implant placement.[24-29] Although this surgical procedure may be effective, it has restrictions. Yu and Qiu explain that after execution of a lateral sinus window exposure and bone augmentation the amount of

bone obtained may range from as little as 5% to as much as 59% of the desired height, depending on factors such as grafting material and, more importantly, the preservation of the lateral wall of the sinus.[30] Achieving correction of the atrophy of the posterior maxilla and pneumatization of the sinus anteriorly and crestally could involve multiple surgical procedures and prolonged healing times.[31]

In patients where sinus lift and grafting is not indicated, advanced ridge augmentation procedures are another potential treatment option.[32] After their most recent review of the literature, Sakkas et al described reconstruction of alveolar ridge using autogenous bone in the form of a block as the "gold standard." They correlated the predictability of this method to autogenous bone having osteogenic, osteoinductive, and osteoconductive properties.[3] Autogenous block grafting in the atrophic maxillary ridge has been shown in the literature to result in increased bone volume and quality in the normal healing phase of 6 to 8 months; however, these block grafts are subject to resorption ranging from 10% to 60% when the block is obtained from the iliac crest and 0% to 15% when harvested from the calvarium.[4,5,33] Although sometimes effective, the harvesting of autogenous grafts has been associated with donor site morbidities. Harvests from extraoral sites such as the iliac crest can interfere with muscle insertions and disturb gait cycle.[34] On the other hand, intraoral autogenous grafts have shown to sometimes cause prolonged numbness of dentition and sensorial disturbances of the mucosa.[35] In addition to the aforementioned complications, these types of ridge augmentation protocols require multiple surgical procedures, necessitating more time, increased costs for hospitalization, postoperative pain, potential nerve injury, and delayed muscle motility.[32]

Non-absorbable membranes, such as expanded polytetrafluoroethylene with or without titanium reinforcement, titanium mesh, and other products, have been used to attempt to regenerate the

TABLE 1

Quad Zygoma Procedures

Gender	No. of Patients	Partially Edentulous	Edentulous	Initial Treatment	Revision Treatment	No. of Implants	Failed Implants	Success Rates
MALE	12	4	8	10	2	48	3	93.7%
FEMALE	28	7	21	18	10	112	5	95.5%

TABLE 2

Unilateral Zygoma in Conjunction With Additional Implants in the Premaxilla

Gender	No. of Patients	Partially Edentulous	Edentulous	Initial Treatment	Revision Treatment	No. of Implants	Failed Implants	Success Rates
MALE	49	43	6	36	13	49	0	100%
FEMALE	66	59	7	49	17	66	1	98.4%

TABLE 3

Bilateral Single Zygomatic Implants With Additional Implants in the Premaxilla

Gender	No. of Patients	Partially Edentulous	Edentulous	Initial Treatment	Revision Treatment	No. of Implants	Failed Implants	Success Rates
MALE	43	36	7	29	14	86	1	98.8%
FEMALE	36	21	15	27	9	72	1	98.6%

TABLE 4

Unilateral Zygomatic Implants Utilized as Additional Extension/Abutment Tooth for Fixed Prosthodontics*

Gender	No. of Patients	Partially Edentulous	Edentulous	Initial Treatment	Revision Treatment	No. of Implants	Failed Implants	Success Rates
MALE	6	6	-	1	5	9	0	100%
FEMALE	9	9	-	3	6	10	0	100%

**includes double zygoma unilateral*

severely resorbed posterior maxilla and to replace both horizontal and vertical ridge volume.[2,32,36] The success of these materials is associated with the ability to obtain primary closure and provide an uninterrupted healing phase, the expertise of the surgeon performing the regenerative procedure, and the patient's capacity to undergo an uneventful healing phase. Additional surgical procedures will be needed for membrane removal, implant placement, and possibly ancillary bone grafting.[30] Incorporation of the localized delivery of growth factors through stem cells,[37,38] platelet-rich plasma,[39,40] and autologous-platelet-rich fibrin (A-PRF)[41-43] to aid in the wound healing of the aforementioned protocols are more recent additions to original protocols to help prevent complications associated with the multiple surgical procedures generally related to advanced bone regeneration techniques.

Various complications are associated with vertical and horizontal bone augmentation procedures in the posterior maxilla, and their outcomes have been shown to be unpredictable, thus precluding them from being widely used for preparation of the severely atrophic maxilla for implant placement.[31,44,45] In addition to requiring multiple surgical procedures, such protocols are technique-sensitive and their healing period, which is critical, can take up to 8 months.[43] Multiple surgical procedures can increase the likelihood of complications and morbidities and decrease predictability of outcomes. Because of recent advancements in immediate tooth placement,[6,46,47] patients may be less likely to accept treatment plans that require lack of functional teeth for extended periods.

Tilted Implants

In light of the various complications associated with bone replacement procedures, Maló et al and Jensen et al each described the placement of implants in the posterior maxilla in a tilted fashion to avoid the variations of sinus pneumatization patterns and anatomical structures and eliminate the need for multiple grafting procedures.[6,48] The success rates reported for placement of tilted implants (ie, All-on-4 procedure) make this a successful treatment option for providing an immediate, fully functional implant-supported prosthesis. However, variations in patients' bone volume and quality in the critical position of the maxillary second premolar/first molar area can make it difficult to achieve initial torque values for immediate loading and ideal A-P spread for prosthetic success, thus limiting the range of patients that qualify for this type of procedure.[49] Additionally, implant failure is associated with marginal bone loss, which results in further alveolar atrophy, and when this failure involves distal tilted implants in an implant-supported prosthesis, it renders the prosthesis nonfunctional. With the progression of maxillary atrophy there may be insufficient bone for an All-on-4 procedure.[50]

Zygomatic Implants

Brånemark introduced zygomatic implants in 1988 as a treatment alternative for patients requiring multiple grafting procedures.[51] Initially, the use of single zygomatic fixtures unilaterally with several additional implant fixtures in the premaxillary region to support an immediate fixed functional prosthesis as a variation of the All-on-4 procedure was described.[52,53] Their use quickly expanded to include the quad zygoma procedure (two zygomatic implants placed in each zygomatic arch[54,55]), a single zygomatic implant used as a distal abutment in a partially edentulous maxilla, and various combinations of fixed partial and full-arch immediate-loading situations.[53]

Bedrossian and Sullivan et al presented a fixed-prosthetic implant restoration of the edentulous maxilla, a systematic pretreatment evaluation method in which the use of zygomatic implants was expanded.[56] In addition, Bedrossian and Stumpel described a classification technique in the treatment planning phase to incorporate zygomatic implants.[8] Aparicio described a classification system for zygomatic implant placement based on the anatomy of the zygomatic arch.[57] Additional authors have described the use of these implants in various clinical situations for treatment of the atrophic posterior maxilla.[54,55,58-63] Petrungaro et al recently described their use for single-tooth replacement in a maxillary first molar region.[9] Various researchers have reported the success rate of zygomatic implants to be 98% over a 15-year period.[10,11,62] The American College of Prosthodontists position statement in 2016 said, "the use of the zygomatic implant in various clinical scenarios with multiple configurations enables the dental team to restore quality of life and gives patients an expedited and predictable option."[64]

Various complications are associated with vertical and horizontal bone augmentation procedures in the posterior maxilla, and their outcomes have been shown to be unpredictable, thus precluding them from being widely used for preparation of the severely atrophic maxilla for implant placement.

The purpose of this study is to report the success rates of 452 zygomatic implants placed and restored in 249 patients over a period of 5 years in a multi-center setting. The study observed the following types of cases: quad zygoma; unilateral zygoma in conjunction with additional implants in the area of the premaxilla; bilateral single zygomatic implants in addition to implants in the premaxilla; and unilateral zygomatic implant placement used as a distal extension in an implant-supported fixed prosthetic reconstruction. All zygomatic implants in this study were functionally loaded immediately after placement. Additionally, clinical case examples are described and illustrated.

Methods

The authors conducted a multi-center, retrospective study of a case series of patients who ranged in age from 34 to 80 and were residents of Manizales and Medellin, Colombia, and the Chicago, Illinois, metropolitan area, United States. These patients had

zygomatic implants placed over a 5-year period, between 2008 and 2013, and data collection began after all the implants were placed. The follow-up period was 5 years. The data was collected from the private practices of three of the authors (Drs. Gonzalez [Manizales, Colombia], Villegas [Medellin, Colombia], and Petrungaro [Chicago area]).

The dependent variable of the study was to describe the survival rate of the implants placed. Independent variables were gender, age, type of edentulism (full versus partial), initial versus revision treatment, type of treatment (quad zygoma; unilateral zygoma; bilateral single zygoma; and unilateral zygomatic implants used as additional extension/abutment tooth for fixed prosthodontics, which includes double zygoma unilateral), and number of implants placed. The study used descriptive statistical methods.

Inclusion criteria were adults of both genders, at least 30 years old, fully or partially edentulous with severe maxillary atrophy, nonsmokers, American Society of Anesthesiologists (ASA) classification 1 or 2, who were candidates for placement of zygomatic implants either as initial or revision treatment. Exclusion criteria were smokers, patients with complex medical history, and ASA classification 3 and above. This study was self-funded by the authors.

Results

The study included 249 patients (139 women, 110 men) between the ages of 34 and 80, who were residents of Manizales and Medellin (Colombia), and the Chicago, Illinois, metropolitan area (United States). These patients had 452 zygomatic implants placed over 5 years between 2008 and 2013. Data collection began after all 452 implants were placed. The follow-up was 5 years.

Patients in the study received one of the following treatment types: quad zygoma; unilateral zygoma in conjunction with additional implants in the area of the premaxilla; bilateral single zygomatic implants in addition to implants in the premaxilla; or unilateral zygoma placement used as a distal extension in an implant-supported fixed prosthetic reconstruction. Table 1 through Table 4 outline each case type and the various parameters observed in the study.

As shown in Table 1, 40 patients, 12 male and 28 female, received quad zygoma implants, totaling 160 individual implants. In this group, eight implants failed, ie, 5% of implants placed. Of the quad zygomatic implants placed, 95% survived, with a higher survival rate in female patients, at 95.5%.

As can be seen in Table 2, 115 patients, 49 male and 66 female, underwent unilateral zygomatic implant placement in


Fig 1.

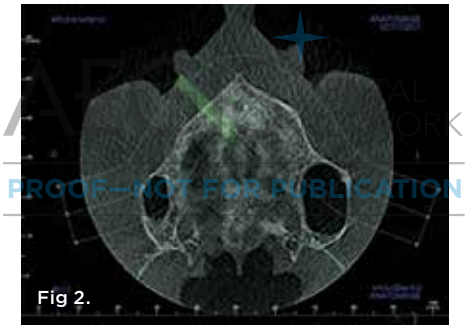
Fig 2.

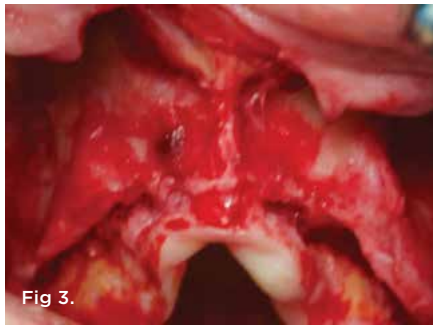
Fig 3.


Fig 4.

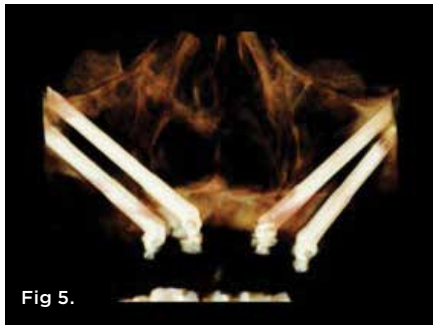
Fig 5.

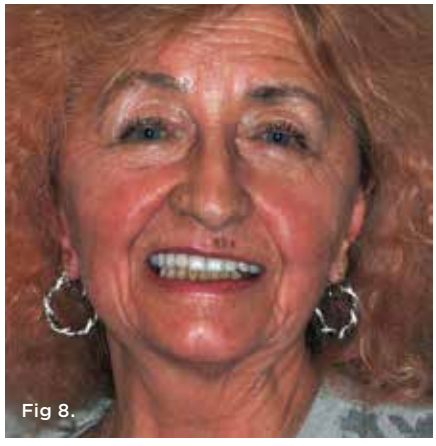
Fig 8.


Fig 6.


Fig 7.

Fig 1. Pretreatment clinical view, case 1. **Fig 2.** Pretreatment CBCT scan. **Fig 3.** Reflected maxillae. **Fig 4.** Quad zygomatic implant placement. **Fig 5.** Immediate postoperative CBCT scan, facial view. **Fig 6.** Case-complete definitive restoration, occlusal view. **Fig 7.** Case-complete CBCT scan, facial view. **Fig 8.** Case-complete patient facial view.

conjunction with additional implants in the premaxilla. In this group, 115 total implants were placed, one in each patient, and 114 of these implants survived, for a survival rate of 99.1%. The male group showed a 100% survival rate of the unilateral zygomatic implants placed.

In the third group (Table 3), 79 patients, 43 male and 36 female, had bilateral single zygomatic implants placed with additional implants in the premaxilla. A total of 158 implants were placed in this group, of which 156 survived, at a rate of 98.7%. Both female and male patients in this group showed similar success rates, at 98.8%.

Finally, as shown in Table 4, 15 patients, 6 male and 9 female, underwent unilateral zygomatic implant placement in which these implants were utilized as an additional extension/abutment tooth for fixed prosthodontics, including double zygomatic unilateral implants. In this group, all 15 implants placed survived, for a 100% survival rate.

Following the 452 zygomatic implants placed in the 249 patients in the study, 11 implants failed, for an overall survival rate of 97.6%. No patients had any signs or symptoms of a maxillary sinus infection.

Case Reports

The following case reports, which are examples from the case series, demonstrate the use of zygomatic implants in: a quad zygoma procedure (case 1), a case involving a failing maxillary implant-supported prosthesis treated by bilateral single zygomatic implants in addition to implants in the premaxilla (case 2), and a patient undergoing an All-on-4 procedure with an oro-antral complication and insufficient A-P spread treated by bilateral single zygomatic implants in addition to implants in the premaxilla (case 3). (*Editor's note:* Case 3 may be viewed online at compendiumlive.com/go/ccedxxxx.)

Case 1

A 72-year-old nonsmoking female patient presented for implant reconstruction of her totally edentulous maxilla (Figure 1). The patient could no longer tolerate her maxillary full denture and did not want to undergo extensive grafting procedures. Three-dimensional CBCT scanning demonstrated severe atrophy of ridge height and width in the premaxillary region, with advanced pneumatization of the sinus bilaterally (Figure 2). The patient also did not want treatment of her lower natural dentition supporting a removable partial denture.

After medical clearance and a thorough dental evaluation, the patient was scheduled for a quad zygomatic surgical and provisionalization procedure. She underwent outpatient general anesthesia with nasal intubation, and local anesthesia was administered intraorally throughout the maxillary arch and extraorally in the area of the zygomatic-facial nerve. After mid-crestal incision from the right to left tuberosity regions, vertical incisions were made in the area of the inferior portion of the zygomatic arch superiorly. Full-thickness mucoperiosteal reflection of the nasal floor, infraorbital foramen, infraorbital rim, and zygomatic arch was then completed (Figure 3). A significant knife ridge was present in the premaxillary region, continuing posteriorly (Figure 3).

An oval access opening was created at the superior aspect of the lateral wall of the maxilla, just inferior to the zygomatic bone, the buccal wall was fractured in a trap-door manner, and the sinus membrane was reflected superiorly and medially. This allowed for direct visualization of the most inferior portion of the zygomatic arch. Figure 4 shows the access opening into the sinus with two zygomatic implants placed in the arch.

After prosthodontic consultation and surgical guide insertion, initial site preparation into the zygomatic arch was initiated bilaterally. Four zygomatic implants (NobelZygoma 45°, Nobel Biocare, nobelbiocare.com), two 4 mm x 40 mm (posterior implants), one 4 mm x 50 mm, and one 4 mm x 52.5 mm, were inserted into the zygomatic bone bilaterally, achieving insertion torque values of at least 45 Ncm on each implant (Figure 4). Three 17-degree, 3 mm long multi-abutments and one straight, 3 mm long multi-abutment were seated and torqued initially to 10 Ncm (Figure 4).

Closure of the maxilla was completed with a bone-hole suture technique to stabilize buccal and palatal flaps with 4-0 monocryl suture (Ethicon, ethicon.com), followed by a continuous sling suturing technique for the rest of the wound closure. Conversion of the immediate temporary denture was then completed, and it was retrofitted to the multi-abutments placed. The immediate postoperative CBCT scan facial view is shown in Figure 5. Appropriate A-P spread was obtained with the successful placement of the zygomatic implants.

The patient was given instructions to manage the postoperative healing phase. After an uneventful 5-month healing and maturation phase, the restorative clinician initiated impression techniques to fabricate the final All-on-4 zygomatic acrylic prosthesis with a titanium bar support. Figure 6 shows the occlusal surface of the definitive prosthesis with the correct placement of the zygomatic implants 6.5 months post-placement, which resulted in minimal thickness of the palatal aspect of the final implant-supported denture. Figure 7 shows the case-complete CBCT scan facial view with the titanium bar evident, 6.5 months post-placement. The patient was quite pleased with her new smile (Figure 8).

Case 2

The patient was a healthy, nonsmoking 68-year-old woman who presented with failing implants in her maxillary arch that had been placed 3 years earlier (Figure 9). She was initially dentate and underwent an All-on-4 procedure in both arches simultaneously. The poor quality and low quantity of her remaining maxillary alveolar structures, along with the vertical placement of the posterior implants, contributed to the failure of the existing maxillary implants and definitive prosthesis.

Pretreatment planning with planning software (NobelClinician, Nobel Biocare) was accomplished prior to zygomatic surgical protocols (Figure 10). Figure 11 demonstrates the sagittal view of the presurgical treatment planning processes and the volume of the patient's right zygomatic arch, along with the planned positioning of the 45 mm zygomatic implant spatially to deliver the coronal aspect of the implant in the correct position of the arch to minimize prosthetic thickness of the interim definitive prosthesis. The patient was scheduled for maxillary revision surgery and placement of single zygomatic implants bilaterally, with evaluation of the remaining implants for either continued use or removal.

After outpatient administration of general anesthesia and delivery of local anesthetic, the maxillary prosthesis was removed along

with the posterior right implant. After full-thickness mucoperiosteal flap elevation, the abutments were removed from the remaining implants and a torque wrench was inserted into the implant bodies. All three remaining implants failed the negative torque test at less than 20 Ncm and thus were removed (Figure 12). Use of the previous definitive restoration as a surgical guide assisted in planning the trajectory of placement of the zygomatic implants. After a mid-crestal incision was created from the right to left tuberosity regions, vertical incisions were made in the area of the inferior portion of the zygomatic arch superiorly. Full-thickness mucoperiosteal reflection of the nasal floor, infraorbital foramen, infraorbital rim, and zygomatic arch was then completed, providing access to the zygomatic arch bilaterally. Two zygomatic implants were placed, a 4 mm x 45 mm implant in the right zygoma and a 4 mm x 40 mm implant in the left zygoma (Figure 13). Additionally, two 4.3 mm x 11.5 mm implants (NobelActive, Nobel Biocare) were placed in the premaxillary region following the "M" technique.[65] The placement of the implants and multi-abutments is demonstrated in Figure 13.

Closure was then obtained through combined use of bone-hole suturing and continuous sling suturing techniques using 4-0 monocryl sutures (Ethicon) (Figure 14). After an uneventful healing phase (typically 12 to 14 weeks), the definitive All-on-4 zygomatic prosthesis was constructed. Figure 15 shows a 3-year postoperative CBCT scan, facial view, of the revisional case management; the patient's 3-year postoperative full facial view is shown in Figure 16.

Discussion

This study demonstrates that zygomatic implants can be used to successfully treat an edentulous patient with atrophic maxillae. The concept was initially developed for the utilization of four zygomatic implants (quad zygoma) for a full-arch restoration. Different variations have since been utilized, with varying combinations and configurations of zygomatic implants being used in combination with conventional implants. The goal of these treatments is to obtain a fully functional restored maxilla with an implant-supported dentition. A study by Bedrossian found a high survival rate for zygomatic implants,[66] which was consistent with the findings of the present study (overall success rate of 97.6%).

Rehabilitation of the severely atrophic maxilla traditionally has been challenging, and multiple procedures/techniques have been developed over the years to regenerate the maxillary alveolar ridge


Fig 9.

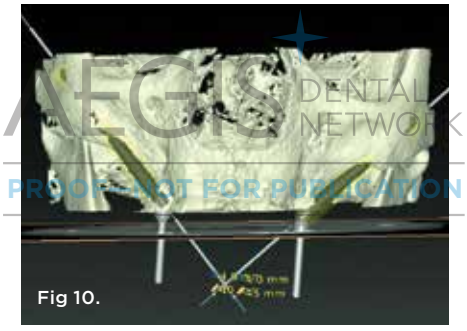
Fig 10.

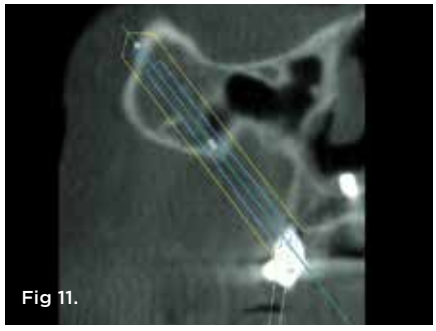
Fig 11.

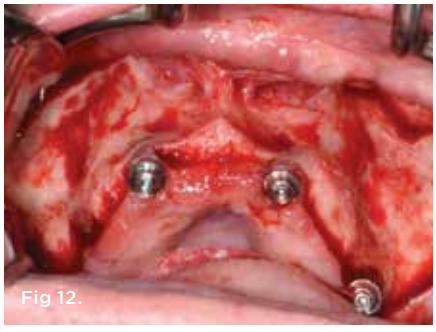
Fig 12.


Fig 13.


Fig 16.


Fig 14.

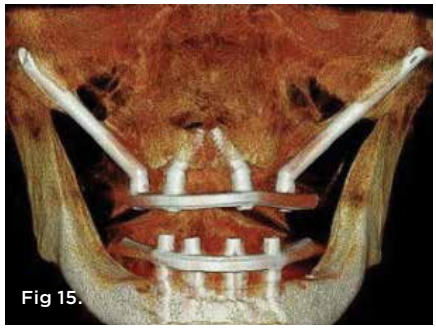
Fig 15.

Fig 9. Pretreatment clinical view, case 2. **Fig 10.** Pretreatment planning with software for correct size and placement of zygomatic implants. **Fig 11.** Software planning for zygomatic implant placement trajectory. **Fig 12.** Reflected maxillae prior to zygomatic implant placement. **Fig 13.** Zygomatic implants and additional implants placed in premaxillary region. **Fig 14.** Closure. **Fig 15.** Three-year post-treatment CBCT scan, facial view. **Fig 16.** Case-complete, 3-year, patient facial view.

to prepare it for implant placement. Although such procedures may be predictable, they sometimes can be cumbersome, leading to increased costs and time of treatment planning[2,4,5,18,23] and thus potentially making them unacceptable for some patients. Treatment of the atrophic maxilla with zygomatic implants has been widely reported in the literature and has shown to have high success rates[9-12] while avoiding an array of ancillary procedures, as the results of this study show.

A limitation of this study is that only patients who were seen in the private practices of the authors were included, and due to their level of expertise these practitioners have a very specific referral/patient base. Another limitation is that this was a retrospective study.

Conclusion

The use of zygomatic implants to aid in the support of immediate tooth replacement procedures in the atrophic posterior maxilla has been shown to be a reliable option for patients choosing not to undergo advanced bone-replacing protocols. Because the zygomatic arch provides a cortical bone volume and quality similar to that of the anterior mandible, its utilization to accept an implant fixture can provide a suitable initial torque implant index at fixture placement to support an immediate fixed, loaded prosthesis. Additional clinical trials are recommended to initiate the incorporation of zygomatic implants into initial treatment plants for patients requiring full or partial rehabilitation of their atrophic posterior maxilla as an alternative to advanced grafting procedures.

ABOUT THE AUTHORS

Paul S. Petrungaro, DDS, MS
Director, Start Smiling Dental Implant Centers, and Director and Founder, Implant Live, Northfield, Illinois; Diplomate, International Congress of Oral Implantologists

Santiago Gonzales, DDS
Private Practice, Oral Surgery, Manizales, Caldas, Colombia

Carlos Villegas, DDS
Private Practice, Oral Surgery, Medellín, Antioquia, Colombia

Jardin Yousef, BS
Pre-doctoral Student, College of Dental Medicine-Illinois, Midwestern University, Downers Grove, Illinois

Alejandro Arango, DDS
Clinical Assistant Professor, Oral and Maxillofacial Surgery, Medical College of Wisconsin, Milwaukee, Wisconsin

REFERENCES

1. Tasoulis G, Yao SG, Fine JB. The maxillary sinus: challenges and treatments for implant placement. *Compend Contin Educ Dent*. 2011;32 (1):10-19.
2. Rocchietta I, Simion M, Hoffmann M, et al. Vertical bone augmentation with an autogenous block or particles in combination with guided bone regeneration: a clinical and histological preliminary study in humans. *Clin Implant Dent Relat Res*. 2016;18(1):19-29.
3. Sakkas A, Wilde F, Heufelder M, et al. Autogenous bone grafts in oral implantology–is it still a "gold standard"? A consecutive review of 279 patients with 456 clinical procedures. *Int J Implant Dent*. 2017;3(1):23.
4. Schwartz-Arad D, Levin L, Sigal L. Surgical success of intraoral autogenous block onlay bone grafting for alveolar ridge augmentation. *Implant Dent*. 2005;14(2):131-138.
5. Chiapasco M, Casentini P, Zaniboni M. Bone augmentation procedures in implant dentistry. *Int J Oral Maxillofac Implants*. 2009;24(suppl):237-259.
6. Maló P, de Araújo Nobre M, Lopes A, et al. "All-on-4" immediate-function concept for completely edentulous maxillae: a clinical report on the medium (3 years) and long-term (5 years) outcomes. *Clin Implant Dent Relat Res*. 2012;14(suppl 1):e139-e150.
7. Maló P, de Araújo Nobre M, Lopes A, et al. A longitudinal study of the survival of All-on-4 implants in the mandible with up to 10 years of follow-up. *J Am Dent Assoc*. 2011;142(3):310-320.
8. Bedrossian E, Stumpel LJ 3rd. Immediate stabilization at stage II of zygomatic implants: rationale and technique. *J Prosthet Dent*. 2001;86 (1):10-14.
9. Petrungaro PS, Kurtzman GM, Gonzales S, Villegas C. Zygomatic implants for the management of severe alveolar atrophy in the partial or completely edentulous maxilla. *Compend Contin Educ Dent*. 2018;39(9):636-645.
10. Davó R, Malevez C, Rojas J, et al. Clinical outcome of 42 patients treated with 81 immediately loaded zygomatic implants: a 12- to 42-month retrospective study. *Eur J Oral Implantol*. 2008;9(suppl 1) (2):141-150.
11. Maló P, Nobre Mde A, Lopes I. A new approach to rehabilitate the severely atrophic maxilla using extramaxillary anchored implants in immediate function: a pilot study. *J Prosthet Dent*. 2008;100(5):354-366.
12. Aparicio C, Ouazzani W, Hatano N. The use of zygomatic implants for prosthetic rehabilitation of the severely resorbed maxilla. *Periodontol 2000*. 2008;47:162-171.
13. Balshi SF, Wolfinger GJ, Balshi TJ. A retrospective analysis of 110 zygomatic implants in a single-stage immediate loading protocol. *Int J Oral Maxillofac Implants*. 2009;24(2):335-341.
14. Angelopoulou MV, Kontogiorgos E, Emmanouil D. Congenital adrenal hyperplasia: a case report with premature teeth exfoliation and bone resorption. *Pediatrics*. 2015;135(6):e1524-e1529.
15. Gungor OE, Karayilmaz H, Yalcin H, Hatipoğlu M. Oro-dental characteristics of three siblings with Papillon-Lefevre syndrome. *Niger J Clin Pract*. 2017;20(2):256-260.
16. Berglundh T, Wennström JL, Lindhe J. Long-term outcome of surgical treatment of peri-implantitis. A 2-11-year retrospective study. *Clin Oral Implants Res*. 2018;29(4):404-410.
17. Carcuac O, Berglundh T. Composition of human peri-implantitis and periodontitis lesions. *J Dent Res*. 2014;93(11):1083-1088.
18. Misch CE. Maxillary sinus augmentation for endosteal implants: organized alternative treatment plans. *Int J Oral Implantol*. 1987;4(2):49-58.
19. Wessberg GA, Jacobs MK, Wolford LM, Walker RV. Preprosthetic management of severe alveolar ridge atrophy. *J Am Dent Assoc*. 1982;104(4):464-472.
20. Lamberti VS. Subantral graft: clinical application of the biological principles osseoinduction in the treatment of posterior maxillary atrophy [article in Spanish]. *Int J Dent Symp*. 1994;2(1):56-59.
21. Chanavaz M, Donazzan M, Ferri J, et al. Sinus augmentation. Statistical evaluation of 15 years of surgical experience (Manuel Chanavaz, 1979-1994) [article in French]. *Rev Stomatol Chir Maxillofac*. 1995;96(4):267-273.
22. Buchanan EP, Hyman CH. LeFort I Osteotomy. *Semin Plast Surg*. 2013;27(3):149-154.
23. Bell WH, Buche WA, Kennedy JW 3rd, Ampil JP. Surgical correction of the atrophic alveolar ridge. A preliminary report on a new concept of treatment. *Oral Surg Oral Med Oral Pathol*. 1977;43(4):485-498.
24. Avila-Ortiz G, Wang HL, Galindo-Moreno P, et al. Influence of lateral window dimensions on vital bone formation following maxillary sinus augmentation. *Int J Oral Maxillofac Implants*. 2012;27(5):1230-1238.
25. Smiler DG, Johnson PW, Lozada JL, et al. Sinus lift grafts and

endosseous implants. Treatment of the atrophic posterior maxilla. *Dent Clin North Am*. 1992;36(1):151-188.
26. Tatum OH, Lebowitz MS, Tatum CA, Borgner RA. Sinus augmentation. Rationale, development, long-term results. *N Y State Dent J*. 1993; 59(5):43-48.
27. Tatum H Jr. Maxillary and sinus implant reconstructions. *Dent Clin North Am*. 1986;30(2):207-229.
28. Peleg M, Chaushu G, Mazor Z, et al. Radiological findings of the post-sinus lift maxillary sinus: a computerized tomography follow-up. *J Periodontol*. 1999;70(12):1564-1573.
29. Block MS, Kent JN. Maxillary sinus grafting for totally and partially edentulous patients. *J Am Dent Assoc*. 1993;124(5):139-143.
30. Yu H, Qiu L. A prospective randomized controlled trial of two-window versus solo-window technique by lateral sinus floor elevation in atrophic posterior maxilla: results from a 1-year observational phase. *Clin Implant Dent Relat Res*. 2017;19(5):783-792.
31. Petrungaro PS. Reconstruction of severely resorbed atrophic maxillae and management with transitional implants. *Implant Dent*. 2000;9(3):271-277.
32. Garcia-Júnior IR, Souza FÁ, Figueiredo AAS, et al. Maxillary alveolar ridge atrophy reconstructed with autogenous bone graft harvested from the proximal ulna. *J Craniofac Surg*. 2018;29(8):2304-2306.
33. Cordaro L, Amadé DS, Cordaro M. Clinical results of alveolar ridge augmentation with mandibular block bone grafts in partially edentulous patients prior to implant placement. *Clin Oral Implants Res*. 2002;13(1):103-111.
34. Cricchio G, Lundgren S. Donor site morbidity in two different approaches to anterior iliac crest bone harvesting. *Clin Implant Dent Relat Res*. 2003;5(3):161-169.
35. Cordaro L, Torsello F, Miuccio MT, et al. Mandibular bone harvesting for alveolar reconstruction and implant placement: subjective and objective cross-sectional evaluation of donor and recipient site up to 4 years. *Clin Oral Implants Res*. 2011;22(11):1320-1326.
36. Sheikh Z, Qureshi J, Alshahrani AM, et al. Collagen based barrier membranes for periodontal guided bone regeneration applications. *Odontology*. 2017;105(1):1-12.
37. Sohn DS, Heo JU, Kwak DH, et al. Bone regeneration in the maxillary sinus using an autologous fibrin-rich block with concentrated growth factors alone. *Implant Dent*. 2011;20(5):389-395.
38. Zigdon-Giladi H, Khoury N, Evron A. Adult stem cells in the use of jaw bone regeneration: current and prospective research. *Quintessence Int*. 2015;46(2):125-131.
39. Wang X, Zhang Y, Choukroun J, et al. Effects of an injectable platelet-rich fibrin on osteoblast behavior and bone tissue formation in comparison to platelet-rich plasma. *Platelets*. 2018;29(1):48-55.
40. Lynch SE, ed. *Tissue Engineering: Applications in Oral and Maxillofacial Surgery and Periodontics*. 2nd ed. Chicago, IL: Quintessence Publishing; 2008.
41. Choukroun J, Diss A, Simonpieri A, et al. Platelet-rich fibrin (PRF): a second-generation platelet concentrate. Part IV: clinical effects on tissue healing. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod*. 2006;101(3):e56-e60.
42. Ghanaati S, Herrera-Vizcaino C, Al-Maawi S, et al. Fifteen years of platelet rich fibrin in dentistry and oromaxillofacial surgery: how high is the level of scientific evidence? *J Oral Implantol*. 2018;44(6):471-492.
43. Choukroun J, Diss A, Simonpieri A, et al. Platelet-rich fibrin (PRF): a second-generation platelet concentrate. Part V: histologic evaluations of PRF effects on bone allograft maturation in sinus lift. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod*. 2006;101(3):299-303.
44. Moreno Vazquez JC, Gonzalez de Rivera AS, Gil HS, Mifsut RS. Complication rate in 200 consecutive sinus lift procedures: guidelines for prevention and treatment. *J Oral Maxillofac Surg*. 2014;72(5):892-901.
45. Wallace SS, Froum SJ. Effect of maxillary sinus augmentation on the survival of endosseous dental implants. A systematic review. *Ann Periodontol*. 2003;8(1):328-343.
46. Petrungaro PS. Options for the esthetic zone using the immediate restoration procedure: observational data of 15 years and 5000 implants. *Compend Contin Educ Dent*. 2017;38(5):318-325.
47. Kan JYK, Rungcharassaeng K, Deflorian M, et al. Immediate implant placement and provisionalization of maxillary anterior single implants. *Periodontol 2000*. 2018;77(1):197-212.
48. Jensen OT, Cottam JR, Ringeman JL, et al. Angled dental implant placement into the vomer/nasal crest of atrophic maxillae for All-on-Four immediate function: a 2-year clinical study of 100 consecutive patients. *Int J Oral Maxillofac Implants*. 2014;29(1):e30-e35.
49. Jensen OT. Dental extraction, immediate placement of dental implants, and immediate function. *Oral Maxillofac Surg Clin North Am*. 2015;27(2):273-282.
50. Spencer KR. Implant based rehabilitation options for the atrophic edentulous jaw. *Aust Dent J*. 2018;63(suppl 1):S100-S107.
51. Brånemark P-I. *Surgery and Fixture Installation. Zygomaticus Fixture Clinical Procedures*. 1st ed. Gothenburg, Sweden: Nobel Biocare AB; 1998.
52. Brånemark P-I, Gröndahl K, Ohrnell LO, et al. Zygoma fixture in the management of advanced atrophy of the maxilla: technique and long-term results. *Scand J Plast Reconstr Surg Hand Surg*. 2004;38(2):70-85.
53. Gunaseelan R, Saravanakumar M, Hariharan R. Restoration of failing maxillary implant-supported fixed prosthesis with cross arch splinted unilateral zygomatic implant: a clinical report. *J Oral Implantol*. 2012;38(6):751-755.
54. Aboul-Hosn Centenero S, Lázaro A, Giralt-Hernando M, Hernández-Alfaro F. Zygoma quad compared with 2 zygomatic implants: a systematic review and meta-analysis. *Implant Dent*. 2018. doi: 10.1097/ID.0000000000000726.
55. Malevez C. Zygomatic anchorage concept in full edentulism [article in French]. *Rev Stomatol Chir Maxillofac*. 2012;113(4):299-306.
56. Bedrossian E, Sullivan RM, Fortin Y, et al. Fixed-prosthetic implant restoration of the edentulous maxilla: a systematic pretreatment evaluation method. *J Oral Maxillofac Surg*. 2008;66(1):112-122.
57. Aparicio C. A proposed classification for zygomatic implant patient based on the zygoma anatomy guided approach (ZAGA): a cross-sectional survey. *Eur J Oral Implantol*. 2011;4(3):269-275.
58. Chrcanovic BR, Abreu MH. Survival and complications of zygomatic implants: a systematic review. *Oral Maxillofac Surg*. 2013;17(2):81-93.
59. Esposito M, Worthington HV. Interventions for replacing missing teeth: dental implants in zygomatic bone for the rehabilitation of the severely deficient edentulous maxilla. *Cochrane Database Syst Rev*. 2013;(9):CD004151.
60. Molinero-Mourelle P, Baca-Gonzalez L, Gao B, et al. Surgical complications in zygomatic implants: a systematic review. *Med Oral Patol Oral Cir Bucal*. 2016;21(6):e751-e757.
61. Araújo RT, Sverzut AT, Trivellato AE, Sverzut CE. Retrospective analysis of 129 consecutive zygomatic implants used to rehabilitate severely resorbed maxillae in a two-stage protocol. *Int J Oral Maxillofac Implants*. 2017;32(2):377-384.
62. Fernández H, Gómez-Delgado A, Trujillo-Saldarriaga S, et al. Zygomatic implants for the management of the severely atrophied maxilla: a retrospective analysis of 244 implants. *J Oral Maxillofac Surg*. 2014;72(5):887-891.
63. Tzerbos F, Bountaniotis F, Theologie-Lygidakis N, et al. Complications of zygomatic implants: our clinical experience with 4 cases. *Acta Stomatol Croat*. 2016;50(3):251-257.
64. Tuminelli FJ, Balshi TJ. Zygomatic Implants. American College of Prosthodontists Position Statement. Chicago, IL: American College of Prosthodontists; February 2016. https://www.prosthodontics.org/assets/1/7/Zygomatic_Implants.pdf. Accessed February 13, 2020.
65. Jensen OT, Adams MW. The maxillary M-4: a technical and biomechanical note for all-on-4 management of severe maxillary atrophy—report of 3 cases. *J Oral Maxillofac Surg*. 2009;67(8):1739-1744.
66. Bedrossian E. Rehabilitation of the edentulous maxilla with the zygoma concept: a 7-year prospective study. *Int J Oral Maxillofac Implants*. 2010;25(6):1213-1221.