Rehabilitation of atrophic maxilla: A review of 101 zygomatic implants

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Abstract

Introduction: Zygomatic implants are a good rehabilitation alternative for upper maxilla with severe bone reabsorption. These implants reduce the need for onlay-type bone grafting in the posterior sectors and for maxillary sinus lift procedures - limiting the use of bone grafts to the anterior zone of the upper jaw in those cases where grafting is considered necessary.

Objective: To evaluate the survival of 101 zygomatic implants placed in upper maxilla presenting important bone reabsorption, with a follow-up of 1-72 months.

Patients and methods: A retrospective study was made of 101 Zygoma® implants (Nobel Biocare, Göteborg, Sweden) placed in 54 patients with totally edentulous and atrophic upper maxilla, in the period between 1998-2004. There were 35 women and 19 men, subjected to rehabilitation in the form of fixed prostheses and overdentures using 1-2 zygomatic implants and 2-7 implants in the anterior maxillary zone. The principal study variables were smoking, a history of sinusitis, the degree of bone reabsorption, and peri-implant bone loss, among others.

Results: The descriptive analysis of the 101 zygomatic implants placed in 54 patients with a mean age of 56 years (range 38-75) yielded a percentage survival of 96.04%, with four failed implants that were removed (two before and two after prosthetic loading). Nine patients were smokers, and none of the 54 subjects reported a history of sinus disorders.

Discussion and conclusions: Zygomatic implants are designed for use in compromised upper maxilla. They allow the clinician to shorten the treatment time, affording an interesting alternative for fixed prosthetic rehabilitation. This study confirms that zygomatic bone offers predictable anchorage and acceptable support function for prostheses in atrophic jaws. However, these implants are not without complications. Longer-term evaluations are needed of zygomatic implant survival in order to establish a correct clinical prognosis.

Key words: *Zygomatic implants, atrophic upper maxilla, edentulism, dental implants.*

Introduction

Introduced by Brånemark in 1988, zygomatic implants were designed to rehabilitate atrophic upper maxilla, or upper jaws subjected to resection for oncological reasons, or with bone loss secondary to trauma. Their use has made it possible to reduce bone grafting procedures in patients seeking a permanent solution with a minimum number of surgical operations and the shortest treatment time possible - without losing the expectations for successful treatment.

The insertion of standard dental implants and the preparation of a prosthesis are limited in patients with atrophic upper jaws, due to the limited amount and quality of the available bone, as well as because of the presence of highly pneumatized maxillary sinuses. In these cases it is necessary to resort to advanced bone graft surgery, such as the bloc iliac crest Le Fort I osteotomy, onlay-type bone grafting techniques, or maxillary sinus lift procedures in the posterior sectors of the maxilla (1-4). These techniques pose a series of inconveniences, such as the need for multiple surgical interventions, the use of extraoral bone donor sites (e.g., iliac crest or skull) - with the morbidity involved in surgery of these zones - and the long time for which patients remain without rehabilitation during the graft consolidation and healing interval (5). These factors complicate patient acceptance of the restorative treatment and limit the number of procedures carried out.

Zygomatic implants are an effective treatment alternative that reduces the use of bone graft procedures, employing the zygomatic bone as anchorage. When contemplating zygomatic implant rehabilitation, the patient must present not only posterior alveolar crest reabsorption precluding the placement of additional fixations for supporting the prosthesis, but also sufficient bone volume in the anterior zone of the upper jaw - with a minimum height of 10 mm and a width of 4 mm - to allow the placement of 2-4 conventional fixations. If the bone volume in the anterior upper maxillary zone is insufficient, there must be ideal conditions for onlay-type bone grafting and guided bone regeneration (GBR) techniques.

Different therapeutic options are available for the rehabilitation of atrophic upper maxilla (6). Maxillary sinus lift procedures are accepted and are predictable for implant placement. In order to apply this technique, a bone donor site must be available. This site can be intraoral (chin, ascending mandibular ramus, retromolar trigone, etc.) or extraoral (iliac crest, skull, tibia, etc.), depending on the size of the maxillary sinus and on whether sinus lifting is to be uni- or bilateral. Depending on the remnant bone volume and quality as established by the classification of Lekholm and Zarb 1985 (7), maxillary sinus lift and implant placement are carried out in one or two phases. When the bone height is insufficient to secure the necessary primary implant stability (type 4 bone with type D or E reabsorption), bone grafting is performed in a first phase, followed 6 months later by implant placement (2).

Lekholm et al. (8)conducted a multicenter retrospective study with a follow-up period of three years, involving 150 patients with edentulous upper jaws that were treated with different bone grafting techniques (onlay, inlay, or using the Le fort I osteotomy plus bone grafting). These authors reported a 23% failure rate when placing the implants in the same surgical step as bone grafting, and a 10% failure rate when two surgical phases were used. The success rate of prosthetic rehabilitation in the patients was 85%. Keller et al. (9) presented the long-term results (with 12 years of follow-up) corresponding to 118 inlay autologous bone grafts placed in the nasal and sinusal zones in patients with compromised upper maxilla. The survival rate was 87%, while the correct prosthetic function rate was 95%. These procedures may require several surgical interventions, and the duration of treatment associated with such bone grafting procedures, plus the time needed to prepare the definitive dental rehabilitation, is considerable. Nevertheless, the end results usually offer high percentage success rates.

Zygomatic implants have been proposed to facilitate the treatment of atrophic upper maxilla, since they reduce the need for a range of surgical interventions, and moreover shorten the overall treatment time (10,11).

Different authors (12-15) have described the use of zygomatic implants for the functional and esthetic reconstruction of palatal deformities, post-maxillectomy defects or other mutilating disorders, and in developmental anomalies of the craniofacial skeletal components (e.g., ectodermal dysplasia) - with satisfactory results in all cases.

The present study evaluates the survival of 101 zygomatic implants placed in upper maxilla presenting important bone reabsorption, with a follow-up period of 1-72 months.

Patients and Methods

The 54 patients included in the present study were treated in the Branemark Osseointegration Center (BOC) of Barcelona (Spain) between February 1998 and January 2004. All were totally edentulous in the upper maxilla, with important bone reabsorption of the latter, and required a solution due to the lack of stability of the full dentures. In all patients the remnant bone was insufficient to allow conventional implant-based rehabilitation (Figure 1).

The preoperative protocol comprised a blood test, en electrocardiogram and chest X-ray study to evaluate the general health of the patient. A clinical intraoral examination was carried out to discard infectious or inflammatory processes of the soft tissues (mucosa and gums). After evaluating the posterior region of the upper maxilla, 10 patients were seen to present type IV maxillary bone reabsorption, while 34 had type V reabsorption according to the classification of Cawood and Howell (16).

The radiological study included a panoramic X-ray study and high-resolution computed tomography scan (HRTC) to assess the size and conformation of the zygomatic and

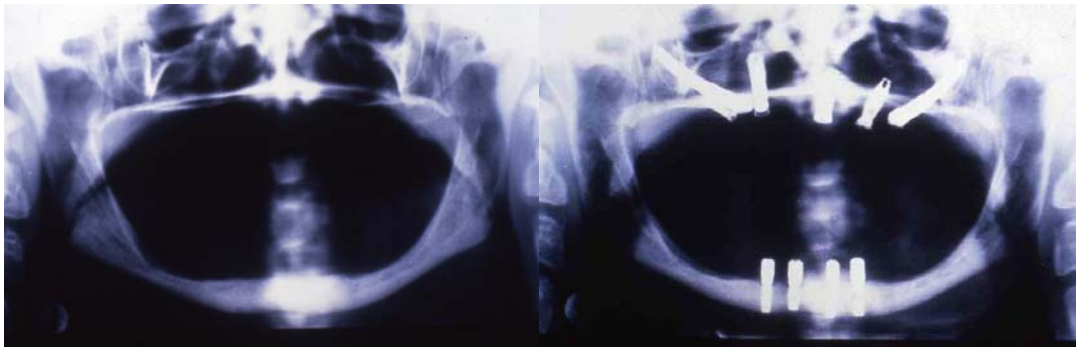

Fig. 1. A) Preoperative panoramic X-ray view of a patient with maxillary atrophy. B) Postoperative panoramic X-ray view of rehabilitation with two zygomatic implants and three standard implants in the anterior zone of the upper maxilla.

maxillary bone, and to discard possible maxillary sinus pathology.

The information collected from the clinical histories and radiological studies of all patients comprised age, sex, smoking, antecedents of systemic disease, the degree of maxillary atrophy, the type of bone graft placed in the anterior maxillary sector, and the lengths of the zygomatic and standard implants, the type of prosthesis placed, the duration of postoperative follow-up, and the complications recorded over a period of 1-72 months.

The included patients were required to present reabsorption of the posterior sector of the upper jaw, though with sufficient bone in the anterior region to allow the placement of at least two standard implants. Alternatively, the patients were required to present severe bone reabsorption amenable to simultaneous placement of bone grafts in the anterior zone.

A total of 101 Zygoma® implants (Nobel Biocare, Götenborg, Sweden) were used, together with 221 Brånemark System® standard implants (Nobel Biocare, Götenborg, Sweden). The Zygoma® implants were made of titanium with a self-threading machined surface, available in 8 different lengths of between 30 and 52.5 mm. The implant diameter varied according to the portion close to the maxillary alveolar ridge (diameter = 4.5 mm) or the apical portion of the implant inserted in the zygomatic bone (diameter = 4 mm). In order to compensate the inclination of implant insertion with respect to the zygoma, the implant head was angled 45º (Figure 2).

The 221 standard implants placed in the anterior zone of the upper jaw were inserted following the protocol described by Brånemark et al. (7) A total of 219 regular platform (RP) and two wide platform (WP) conventional implants were used.

The patients were operated upon under inhalatory general anesthesia using sevoflurane (Sevorane®, Abbott, Madrid, Spain), with intravenous fentanyl (Fentanest® Kern Pharma, Barcelona, Spain). In addition, use was made of local anesthesia (4% articaine with 1:100.000 adrenaline) to block the superior alveolar nerves (posterior, middle and anterior), and the palatal nerves (posterior and nasopalatal). The upper maxilla was reached through a crestal incision allowing improved palatal access for implant placement. After raising the mucoperiosteal flap, soft tissue dissection was extended along the inferior and frontal lateral surfaces of the zygomatic bone, with identification of the infraorbital foramen. Special care was taken to avoid invading the orbit or sectioning the insertion of the masseter muscles in excess - as important bleeding could result. Following zygomatic dissection, the maxillary sinus was fenestrated, creating a 10 x 5 mm infrazygomatic window, while keeping the Schneider membrane intact. This window should allow visualization of drill entry to the zygomatic bone and the implant bed at the time of implant placement. The palatal mucosa was then detached, visualizing the insertion trajectory from the zone of the second premolar / first molar to reach the zygomatic bone traversing the maxillary sinus. To avoid penetration of the

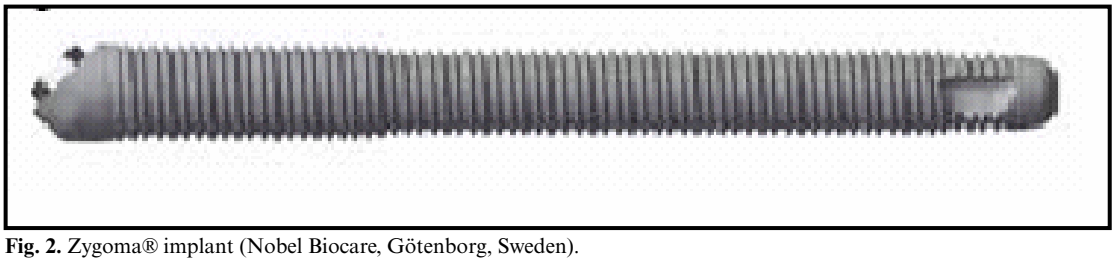

Fig. 2. Zygoma® implant (Nobel Biocare, Götenborg, Sweden).

orbit, a soft tissue retractor was placed in the zygomatic angle. This retractor was used to indicate direction and moreover served as a stop. The drilling sequence started with a rounded drill or guide penetrating at palatine level. The trajectory through the maxillary sinus was followed, allowing visual control of the drill through the infrazygomatic window, with insertion in the zygomatic bone until the superior cortical layer was perforated. The drill was directed towards the Brånemark retractor previously positioned at a 90º angle with respect to the zygomatic bone. The drilling sequence was continued using a 2.9 mm helicoid drill, 2.9 and 3.5 mm pilot drills, and a 3.5 mm helicoid drill. Working of the alveolar portion was completed with a 4 mm countersink drill, which is not advisable if very fine or fragile palatine bone is found. During drilling, and because of the length of the drills, the lower lip required protection in order to avoid possible injury or burns. Finally, the bed was measured, followed by implant placement until exceeding the upper cortical layer (17)(Figure 3).

The zygomatic implants in the totally edentulous patients were always accompanied by standard implant placement in the anterior sector of the upper jaw - surgical insertion depending on the available bone volume. In those cases where bone volume was considered insufficient, the process was accompanied by bone graft placement.

Simple sutures were placed, with horizontal mattress sutures to ensure correct flap closure, using reabsorbable 4/0 polyglactin 910 suture material (Vicryl®, Johnson & Johnson, St. Stevens-Woluwe, Belgium).

Antibiotic (amoxicillin 750 mg, Normon®, Madrid, Spain, 1 tablet every 8 hours for 10 days), antiinflammatory (diclofenac 50 mg, Normon®, Madrid, Spain, 1 tablet every 8 hours for 3 days) and analgesic medication was prescribed (metamizol 575 mg, Normon®, Madrid, Spain, 2 capsules every 8 hours), together with rinses (0.12% chlorhexidine gluconate, Lacer®, Barcelona, Spain, twice daily for 15 days).

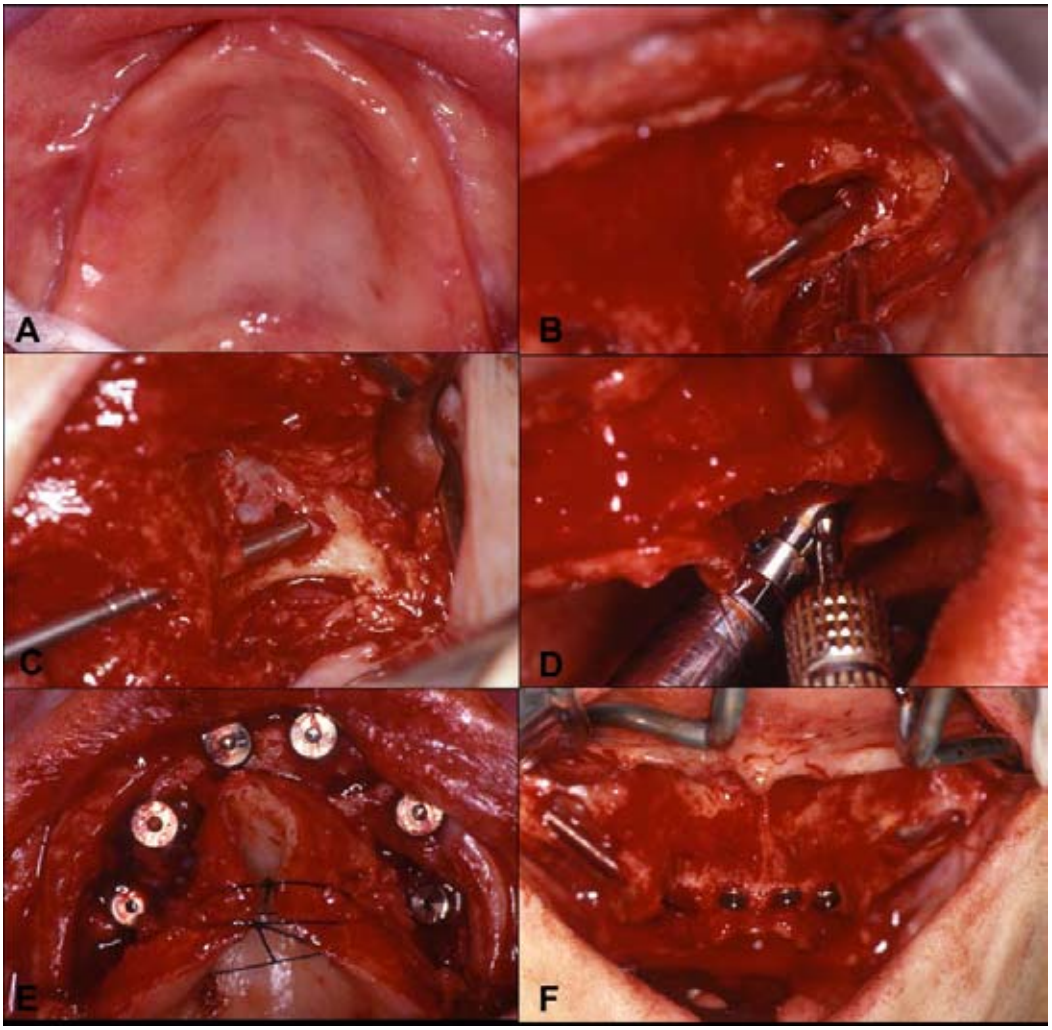

Fig. 3. Surgical sequence. A) Edentulous alveolar ridge. B) Drilling through the maxillary sinus under visual control. C) Insertion of the 2.5 mm drill. D) Placement of the zygomatic implant and angulation of the implant head to correct its palatine emergence. E) Occlusal view with the dental implants in place. F) Frontal view of the first surgical phase.

In all cases the sutures were removed one week after the operation. Posteriorly, clinical controls were made after 1, 3 and 6 months, in preparation of the second phase of implant surgery, with panoramic X-ray control.

Following placement of the definitive prosthesis, the patients were seen yearly to assess soft tissue condition, perform a panoramic X-ray control, and evaluate occlusion.

Zygomatic implant success was defined by the following criteria: clinical stability without signs of mobility; the absence of pain, infection or any other implant-related pathology; the absence of peri-implant radiotransparencies; and a prosthetically favorable implant position.

In turn, zygomatic implant failure was defined as: evidence of implant osteointegration loss; implant fracture; and failure to meet the aforementioned success criteria.

The results were analyzed using the SPSS version 12.0 statistical package for Microsoft Windows (license of the University of Barcelona, Spain).

Results

A total of 101 zygomatic implants were placed in 54 patients (35 women and 19 men), with a mean age of 56 years (range 38-75). All patients were completely edentulous in the upper jaw. Eight patients smoked over 10 cigarettes/day, while one patient smoked fewer than 10 cigarettes/day. As regards the systemic disease antecedents of interest, three patients had suffered hepatitis C, two were hypercholesterolemic, one was HIV-positive, another had high blood pressure, and one patient had undergone surgical resection due to squamous cell carcinoma.

In 25 of the 54 patients, the combination of zygomatic implants with onlay- or inlay-type bone grafting and guided bone regeneration (GBR) in the same surgical step proved necessary (Table 1). In the remaining 29 patients we placed the zygomatic implants and the standard implants in the anterior zone of the upper maxilla.

During the postoperative period, swelling in the infraorbital region with bruising were recorded in some cases. Pain proved mild to moderate, and was effectively treated with conventional analgesics.

The number of standard implants placed in the anterior sector of the jaw varied according to the anatomical characteristics of the patient, and in all cases placement was made in seek of adequate mechanical stability for the prosthesis. In addition to the zygomatic implants, 2 standard dental implants were placed in 5 patients, 3 in 5 patients, 4 in 32 patients, 5 and 5 patients, 6 in 6 patients, and 7 in one patient - yielding a total of 221 conventional implants. In 7 cases we placed a single zygomatic implant, with conventional-technique implants on the contralateral side. The remaining 47 patients received bilateral zygomatic implants. Table 2 shows the distribution of zygomatic implant lengths.

Table 1. Bone grafting technique used in the anterior zone of the upper maxilla and donor zones.

Premaxillary bone grafting technique	Iliac crest	Skull	Chin	Bovine bone + autologous bone	Total
Vestibular onlay	5	2	1	0	8
Crestal onlay	2	0	0	0	2
Vestibular + crestal onlay	4	2	0	0	6
Vestibular onlay + nasal inlay	1	0	0	0	1
Crestal onlay + nasal inlay	1	0	0	0	1
Vestibular onlay + crestal onlay + nasal inlay	3	0	0	0	3
GBR	0	0	0	4	4
Total	16	4	1	4	25

Table 2. Distribution of the zygomatic implants used, according to length.

Length	30 mm	35 mm	40 mm	42.5 mm	45 mm	47.5 mm	50 mm	52.5 mm	Total
No. implants	0	10	27	16	8	24	16	0	101

All the zygomatic implants were placed using the two-phase procedure. The mean osteointegration time was 7.83 months (range 6-12). The 221 conventional implants placed in the maxilla (with a minimum of 2 and a maximum of 7 per patient) yielded a 93.22% success rate, with 15 implant failures that did not adversely affect prosthesis design or stability.

In 25 cases a fixed prosthesis was placed, with hybrid prostheses in 20 cases. Nine patients in turn received overdentures supported by a bar joining the zygomatic implants with the implants located in the anterior sector.

All patients were subjected to the established controls from the first surgical phase onwards. During the follow-up period (Table 3), we recorded a total of four zygomatic implant failures in female patients, together with one complication that caused important sinus infection episodes that were resolved by antibiotic treatment. Two of the failures occurred at the time of the second surgical phase, before prosthesis loading, as a result of a lack of bone integration. After 18 months of prosthetic loading, one smoker of over 10 cigarettes/day with a fixed prosthesis supported by 6 standard implants suffered peri-implantitis affecting one of the zygomatic implants. Posteriorly, after 43 months of loading, the fracture of one of the zygomatic implants was recorded in a patient with overdentures on three standard fixations. The four failures in four patients were regarded as implant failures, since the established success criteria were not met, and the zygomatic implants were removed without replacement. These patients retained a single zygomatic implant that proved able to support the prosthetic rehabilitation in combination with the fixations in the anterior sector of the maxilla. Patient reported satisfaction with the treatment was high from both the surgical and prosthetic perspective, with no discomfort attributable to the palatine emergence of the zygomatic implants.

Discussion

Our study yielded a zygomatic implant survival rate of 96.04%, comparable to the results published by other authors such as Brånemark et al. (18), Hirsch et al. (10), Malevez et al. (19), Vrielinck et al. (20), Bedrossian et al. (21) and Nakai et al. (22). In effect, Brånemark et al. (18) recorded a survival rate of 94.2% with 52 Zygoma® implants over a follow-up period of 5-10 years, in 28 patients with atrophic upper maxilla. Of the 106 conventional implants placed, a total of 29 failed (27%), and 17 patients required premaxillary bone grafting. Two of the three zygomatic implant failures occurred at the time of fitting of the prosthesis, and the other after 6 years of loading. In our series, four zygomatic implants failed and were removed. Malevez et al. (19) published a retrospective study with a follow-up duration of 6-48 months of prosthetic loading, evaluating the survival rate of 103 zygomatic implants placed in 55 edentulous and severely reabsorbed upper maxilla. These authors reported a 100% zygomatic implant survival rate, with a single complication prior to prosthetic loading (severe sinus infection successfully treated with antibiotics). Bedrossian et al. (21) in turn reported 100% survival in a series of 44 zygomatic implants in 22 patients, with a 91.25% survival rate for the 80 standard implants placed in the anterior sector of the upper jaw. The observation period was 34 months, i.e., shorter than in our study. The authors reported that all patients underwent a postoperative period similar to that of patients subjected to conventional implant surgery (15).

Bothur et al. (23) described a modification of the standard zygomatic implant placement technique, using more than three implants on each side of the upper maxilla to support the dental prosthesis, and thus obviating the bone graft procedures in the premaxillary zone. It would be interesting to know the long-term results in order to define the prognosis associated with this technique.

Table 3. Follow-up of the patients in the series.

First surgical phase	Patients treated	Zygomatic implants placed	Failures	Time of failure
1998	3	6	0	----
1999	5	9	1	43 months post-loading
2000	9	16		----
2001	17	32	1	Second phase
2002	14	27	2	Second phase and 18 months post-loading
2003	5	10	0	----
2004	1	1	0	----
Total	54	101	4	----

There have been reports of speech alterations and problems for maintaining correct hygiene of the dental prostheses, largely as a result of the palatine emergence of the platform of the zygomatic implant (22). Boyes-Varley et al. (24) placed 30 zygomatic implants in 18 patients, modifying the angulation of the implant head 55º in order to position emergence at alveolar crest level. According to the authors, this angulation of the implant head affords a cantilever reduction of over 20%, which in addition to improving the space required for tongue movement allows the patient better access for adequate maintenance of the dental prosthesis.

Nkenke et al. (25) studied the dimensions and characteristics of the bone using computed tomography and histomorphometry - assessing mineral density, volume and the trabecular network of 30 human zygomatic bones. The results showed that zygomatic bone is composed of abundant trabecular bone, with bone density parameters that are not optimum for implant placement. In coincidence with Rigolizzo et al. (26), they concluded that implant anchoring success in zygomatic bone is afforded by the great stability resulting from contact with at least four cortical layers (27).

A surgical splint can be used for placement of the Zygoma® implants. Van Steenberghe et al. (28) evaluated the accuracy of surgical perforation guides in placing implants within zygomatic bone. They placed 6 fixations measuring 45 mm in length in three human cadavers, employing three-dimensional planning software that uses the images obtained by computed tomography and simulates the position of the zygomatic implants. The surgical guides were custom manufactured based on three-dimensional reconstructions of the zygomatic-maxillary complex. On comparing the pre- and postoperative tomographic sections, the authors found the deviation to be less than 3º in 4 of the 6 cases. Vrielinck et al. (20), in 29 patients used surgical guides obtained by stereolithography, for placing 67 zygomatic implants. They reported a 93% success rate with two failures attributable to apical excess emergence of the implants. In addition, one patient developed a buccosinusal fistula secondary to defective surgical closure, and two patients suffered chronic gingivitis around the two zygomatic implants. These complications were not considered failures, since the implants remained functional. This study showed a mean deviation in implant inclination of 2.7 mm, and of 5.14º for the zygomatic implants in their apical portion. The authors recommended using surgical perforation guides for zygomatic implant placement, due to the long lengths of these implants and the anatomical peculiarities of the receptor zone (14).

Al-Nawas et al. (29) investigated the peri-implant soft tissue alterations of 37 zygomatic implants placed in 24 patients between 1998-2001. The evaluation was made over an average of 598 days. Periodontal colonization by pathogenic microorganisms was detected in 20 implants. Nine of the 20 implants showed bleeding in response to probing, and four of these 9 implants yielded positive microbiological results. The mean probing depth was 1 mm greater palatine and mesial compared with the vestibular and distal aspects. Another 9 implants showed bleeding and pockets of 5 mm or more - this resulting in a reduction of the implant success rate to 55%. Such potential peri-implant soft tissue alterations must be taken into account when deciding to use zygomatic implants as a management alternative in patients with atrophic maxilla.

Esposito et al. (30) conducted a review of the literature to compare the results of zygomatic implant placement without bone augmentation techniques versus conventional dental implants placed after bone augmentation, in patients with severe maxillary reabsorption and a minimum follow-up of one year. They found no randomized study contrasting these two procedures; as a result, no conclusions could be drawn based on the scientific evidence. The authors likewise indicated that the studies advocating zygomatic implants as treatment alternative for upper jaws with bone deficiencies are not long-term surveys, since the technique is relatively new. However, zygomatic implants appear to offer high percentage survival over the short term in severely reabsorbed bone, as reflected by the reviewed series that point to the need for long-term multicenter studies.

In our series the zygomatic implant survival rate was 96.04%, comparable to the results published in the literature. The use of these implants lessened the need for extensive bone grafting, shortened hospital stay, and reduced postoperative morbidity and pain. It is important to note that this procedure is not without complications, and requires thorough knowledge of the technique and great surgical skill. The advantages seen in clinical practice define zygomatic implants as an effective treatment alternative for the management of patients with atrophic upper maxilla.

References

1. Astrand P, Nord PG, Branemark PI. Titanium implants and onlay bone graft to the atrophic edentulous maxilla: a 3-year longitudinal study. Int J Oral Maxillofac Surg. 1996 Feb;25(1):25-9.

2. Wannfors K, Johansson B, Hallman M, Strandkvist T. A prospective randomized study of 1- and 2-stage sinus inlay bone grafts: 1-year follow-up. Int J Oral Maxillofac Implants. 2000 Sep-Oct;15(5):625-32.

3. Wiltfang J, Schultze-Mosgau S, Nkenke E, Thorwarth M, Neukam FW, Schlegel KA. Onlay augmentation versus sinuslift procedure in the treatment of the severely resorbed maxilla: a 5-year comparative longitudinal study. Int J Oral Maxillofac Surg. 2005 Dec;34(8):885-9. Epub 2005 Jun 22.

4. Sorní M, Guarinós J, García O, Peñarrocha M. Implant rehabilitation of the atrophic upper jaw: a review of the literature since 1999. Med Oral Patol Oral Cir Bucal. 2005 Apr 1;10 Suppl 1:E45-56.

5. Iturriaga MT, Ruiz CC. Maxillary sinus reconstruction with calvarium bone grafts and endosseous implants. J Oral Maxillofac Surg. 2004 Mar;62(3):344-7.

6. Sorní M, Guarinos J, Peñarrocha M. Implants in anatomical buttresses of the upper jaw. Med Oral Patol Oral Cir Bucal. 2005 Mar-Apr;10(2):163-8.

7. Brånemark P-I, Zarb G, Albrektsson T. Tissue-integrated Prosthesis. Chicago: Quintessence; 1985.
8. Lekholm U, Wannfors K, Isaksson S, Adielsson B. Oral implants in combination with bone grafts. A 3-year retrospective multicenter study using the Brånemark implant system. Int J Oral Maxillofac Surg. 1999 Jun;28(3):181-7.
9.Keller EE, Tolman DE, Eckert SE. Maxillary antral-nasal inlay autogenous bone graft reconstruction of compromised maxilla: a 12-year retrospective study. Int J Oral Maxillofac Implants. 1999 Sep-Oct;14(5):707-21.
10. Hirsch JM, Ohrnell LO, Henry PJ, Andreasson L, Brånemark PI, Chiapasco M, et al. A clinical evaluation of the Zygoma fixture: one year of follow-up at 16 clinics.
J Oral Maxillofac Surg. 2004 Sep;62(9 Suppl 2):22-9.
11. Fernández-Ateca B, Colorado-Bonin M, Gay-Escoda C. Implantes transcigomáticos. Av Periodon Implantol 2004;16:129-41.
12. Parel SM, Brånemark PI, Ohrnell LO, Svensson B. Remote implant anchorage for the rehabilitation of maxillary defects. J Prosthet Dent. 2001 Oct;86(4):377-81.
13. Balshi TJ, Wolfinger GJ. Treatment of congenital ectodermal dysplasia with zygomatic implants: a case report. Int J Oral Maxillofac Implants. 2002 Mar Apr;17(2):277-81.
14. Pham AV, Abarca M, De Mey A, Malevez C. Rehabilitation of a patient with cleft lip and palate with an extremely edentulous atrophied posterior maxilla using zygomatic implants: case report. Cleft Palate Craniofac J. 2004 Sep;41(5):571-4.
15. Peñarrocha-Diago M, Uribe-Origone R, Rambla-Ferrer J, Guarinos-Carbó J. Fixed rehabilitation of a patient with hypohidrotic ectodermal dysplasia using zygomatic implants. Oral Surg Oral Med Oral Pathol Oral Radiol Endod. 2004 Aug;98(2):161-5.
16. Cawood JI, Howell RA. A classification of the edentulous jaws. Int J Oral Maxillofac Surg. 1988 Aug;17(4):232-6.
17. Malevez C, Daelemans P, Adriaenssens P, Durdu F. Use of zygomatic implants to deal with resorbed posterior maxillae. Periodontol 2000. 2003;33:82-9.
18. Brånemark PI, Gröndahl K, Ohrnell LO, Nilsson P, Petruson B, Svensson B, 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.
19. Malevez C, Abarca M, Durdu F, Daelemans P. Clinical outcome of 103 consecutive zygomatic implants: a 6-48 months follow-up study. Clin Oral Implants Res. 2004 Feb;15(1):18-22.
20. Vrielinck L, Politis C, Schepers S, Pauwels M, Naert I. Image-based planning and clinical validation of zygoma and pterygoid implant placement in patients with severe bone atrophy using customized drill guides. Preliminary results from a prospective clinical follow-up study. Int J Oral Maxillofac Surg. 2003 Feb;32(1):7-14.
21.Bedrossian E, Stumpel L 3rd, Beckely ML, Indresano T. The zygomatic implant: preliminary data on treatment of severely resorbed maxillae. A clinical report. Int J Oral Maxillofac Implants. 2002 Nov-Dec;17(6):861-5. Erratum in: Int J Oral Maxillofac Implants. 2003 Mar-Apr;18(2):292. Indersano, T [corrected to Indresano, T].
22. Nakai H, Okazaki Y, Ueda M. Clinical application of zygomatic implants for rehabilitation of the severely resorbed maxilla: a clinical report. Int J Oral Maxillofac Implants. 2003 Jul-Aug;18(4):566-70.
23. Bothur S, Jonsson G, Sandahl L. Modified technique using multiple zygomatic implants in reconstruction of the atrophic maxilla: a technical note. Int J Oral Maxillofac Implants. 2003 Nov-Dec;18(6):902-4.
24. Boyes-Varley JG, Howes DG, Lownie JF, Blackbeard GA. Surgical modifications to the Brånemark zygomaticus protocol in the treatment of the severely resorbed maxilla: a clinical report. Int J Oral Maxillofac Implants. 2003 Mar-Apr;18(2):232-7.
25. Nkenke E, Hahn M, Lell M, Wiltfang J, Schultze-Mosgau S, Stech B, et al. Anatomic site evaluation of the zygomatic bone for dental implant placement. Clin Oral Implants Res. 2003 Feb;14(1):72-9.
26. Rigolizzo MB, Camilli JA, Francischone CE, Padovani CR, Brånemark PI. Zygomatic bone: anatomic bases for osseointegrated implant anchorage. Int J Oral Maxillofac Implants. 2005 May-Jun;20(3):441-7.
27. Ivanoff CJ, Gröndahl K, Bergström C, Lekholm U, Brånemark PI. Influence of bicortical or monocortical anchorage on maxillary implant stability: a 15-year retrospective study of Brånemark System implants. Int J Oral Maxillofac Implants. 2000 Jan-Feb;15(1):103-10.
28. Van Steenberghe D, Malevez C, Van Cleynenbreugel J, Bou Serhal C, Dhoore E, Schutyser F, et al. Accuracy of drilling guides for transfer from three-dimensional CT-based planning to placement of zygoma implants in human cadavers. Clin Oral Implants Res. 2003 Feb;14(1):131-6.
29. Al-Nawas B, Wegener J, Bender C, Wagner W. Critical soft tissue parameters of the zygomatic implant. J Clin Periodontol. 2004 Jul;31(7):497-500.
30. Esposito M, Grusovin MG, Worthington HV, Coulthard P. Interventions for replacing missing teeth: bone augmentation techniques for dental implant treatment. Cochrane Database Syst Rev. 2006 Jan 25;(1):CD003607