Int. J. Oral Maxillofac. Surg. 2014; 43: 748–757
http://dx.doi.org/10.1016/j.ijom.2014.01.004, available online at http://www.sciencedirect.com

International Journal of Oral & Maxillofacial Surgery

Systematic Review
Dental Implants

Implants in the zygomatic bone for maxillary prosthetic rehabilitation: a systematic review

M. C. Goiato[1], E. P. Pellizzer[1], A. Moreno[1], H. Gennari-Filho[1], D. M. dos Santos[1], J. F. Santiago Jr.[1], E. G. dos Santos[2]

[1]Department of Dental Materials and Prosthodontics, Araçatuba Dental School, UNESP, Araçatuba, São Paulo, Brazil; [2]Department of Production Engineering, Polytechnic School, USP, São Paulo, Brazil

M.C. Goiato, E.P. Pellizzer, A. Moreno, H. Gennari-Filho D.M. dos Santos, J.F. Santiago Jr., E.G. dos Santos: Implants in the zygomatic bone for maxillary prosthetic rehabilitation: a systematic review. Int. J. Oral Maxillofac. Surg. 2014; 43: 748–757.

Abstract. The purpose of this systematic review was to evaluate clinical studies on the follow-up survival of implants inserted in the zygomatic bone for maxillary rehabilitation. A comprehensive search of studies published from 2000 to July 2012 and listed in the PubMed/MEDLINE, Embase, and Cochrane Library databases was performed in accordance with the PRISMA statement. Relevant studies were selected according to predetermined inclusion and exclusion criteria. The initial database search yielded 751 titles. After filtering, 313 abstracts were selected, culminating in 42 full text articles. Application of eligibility criteria led to the elimination of 17 articles. Hence 25 full-text articles were considered clinically relevant and were included. Calculations of the interval survival rates and cumulative survival rates of implants could be carried out on the data extracted from the final list of included studies for the different time intervals. These studies reported the insertion of a total of 1541 zygomatic implants and 33 implant failures. Failure generally occurred during the first year interval and was related to clinical complications, such as recurrent acute and chronic sinusitis. After a 36-month follow-up, the survival rate was 97.86%. Additional studies with longer follow-up periods, including the number of zygomatic implants inserted and details of the variations in the surgical techniques used and the impact of the maxillary morphology are still required.

Key words: zygomatic implants; follow-up; dental implants; edentulous maxilla.

Accepted for publication 9 January 2014
Available online 14 February 2014

Brånemark et al.[1] and others[2–6] have suggested that oral implants may be fixed in the zygomatic bone, alone or in combination with conventional implants, for the rehabilitation of an atrophic maxilla, or as an attachment system after a hemimaxillectomy. The zygomatic bone allows anchoring far from the occlusal level and presents regular and compact trabecular bone with 98% of bone density.[7,8] For these reasons, some have suggested that zygomatic implants could be used as an alternative for fixed rehabilitation in edentulous patients.[9–11] The use of zygomatic implants increases treatment success and decreases the use of bone grafts, the number of surgical steps, and the length of treatment.[4,11] However, there are factors that are important to consider during the surgical–prosthetic planning of zygomatic implants, such as the size and

0901-5027/060748 + 010 $36.00/0

extension of the nasal cavities, bone quantity, number and size of the implants, and the surgical technique.[12–14] Clinical complications have been reported after implant insertion, including fracture of the prosthetic veneer and maxillary sinus infections requiring removal of the zygomatic implant.[4,15–17]

The aim of this systematic literature review was to identify relevant clinical studies on zygomatic implants regarding their failure and clinical complications during follow-up. Two hypotheses were tested: (1) implant survival is reduced during the first year, and (2) the failure rate is not influenced by the number of zygomatic implants.

Methods

Search strategy

This systematic review was performed in accordance with the PRISMA statement[18] and Cochrane guidelines. PubMed/MEDLINE, Embase, and Cochrane Library databases were searched for relevant articles published in English from 2000 to July 2011. The studies were grouped according to whether they evaluated zygomatic implants for maxillary rehabilitation. The search was updated in July 2012. A broad search strategy was pursued to capture relevant studies on zygomatic implants, grafting, bone resorption, techniques for the insertion of zygomatic implants, implant complications and failures, and patient satisfaction. The keywords 'zygomatic implants', 'follow-up', 'clinical study', 'dental implants', and 'edentulous maxilla' were used. Data from longitudinal studies were included, and article references were searched to identify additional relevant studies.

Study selection

The literature search was conducted by two independent individuals (AM and DMS). Studies were selected on the basis of their titles and abstracts according to the exclusion criteria for abstracts and full-text articles. Agreement between the readers was determined statistically, and any conflict was resolved by discussion or the analysis of a third reader (MCG). This procedure was applied at all selection stages. The full-text articles were evaluated by the readers using a pilot test form.

Inclusion and exclusion criteria

The inclusion criteria were: studies reporting clinical series of zygomatic implants with a follow-up period of at least 2 years; studies including patients with severely deficient edentulous maxillas, oro-nasal communication, and cases of tumour resection of the maxilla that could not be rehabilitated except with conventional dental implants due to a lack of bone; partially or totally edentulous patients; studies in which immediate or late function protocols were applied. Randomized controlled clinical trials (RCTs), cohort studies, case–control studies, and cross-sectional studies were included.

The exclusion criteria were: studies without an initial evaluation at 6–12 months after implant/prosthesis loading; case reports, comments, systematic reviews, and animal studies; non-oral implants (hip/knee). If necessary, the exclusion criteria were reviewed and the abstracts were reassessed until a complete definition of the exclusion criteria was determined.

Outcomes and variables

For each study included, the following information was extracted: year of publication; number of patients in whom zygomatic implants were placed; setting and country of the study; whether the patients used partial or complete dentures; implant manufacturer and instruments for measuring failure; whether the implant had a treated surface; type of implant loading; type of prosthesis installed; clinical complications reported before and after insertion of the final prosthesis, including other prosthetic complications reported during the follow-up period; whether the zygomatic/conventional implant was removed; length of the zygomatic implant; surgical protocol used; number of zygomatic implants placed and failed; number of conventional implants placed and failed; follow-up period range; and survival rate of the zygomatic implants.

Data synthesis

For selection of the references, the titles were evaluated and the kappa statistic was calculated to define agreement between the answers. Studies were evaluated regarding feasibility of data synthesis (qualitative and quantitative). All implants were classified into failure and survival groups. Failures included implants removed regardless of the cause, and survivals represented stable implants without signs of pathology, mobility, resistance to removal torque, pain, and peri-implantitis. Clinical and radiographic examinations evaluating peri-implant bone loss or a residual sinus disease, as well as the use of instruments for measuring zygomatic implant integrity, were also recorded. The results were summarized in tables and charts.

The survival of zygomatic implants was calculated by Kaplan–Meier method. The failure rate was determined as the percentage of implants lost relative to the number of implants inserted for each study. The statistical analysis was performed using IBM SPSS version 19.0 statistical software (IBM Corp., Armonk, NY, USA).

Results

Study selection and characteristics

The search retrieved 751 references, including 382 from Medline, 264 from PubMed, 91 from Embase, and 14 from the Cochrane Library. After duplicate references had been removed, 292 studies were selected for the data synthesis (Fig. 1). The search update resulted in 21 additional abstracts. After the 292 abstracts and 21 additional abstracts had been analyzed, 38 studies were selected (inter-reader agreement, kappa = 0.84). Reference tracking revealed an additional four papers, for a total of 42 full-text papers in the eligibility assessment. After the full-texts of these articles had been examined, 25 studies were included in the final review (inter-reader agreement, kappa = 0.70).[4,5,7,11,16,19–38] The content of the articles is summarized for comparison in Tables 1–3.

Qualitative analyses

Table 1 presents the sample size and implant characteristics of the 25 selected studies. The number of patients with zygomatic implants ranged from 4 to 76, with a mean of 29.9 patients; there was a predominance of female patients. Most studies were conducted in Europe, most implants were fabricated by Nobel Biocare (Sweden), and there was only one multicenter study. Patients were usually completely edentulous or individuals with a partially edentulous maxilla. The implants exhibited different surface treatments. Fifteen studies conducted late loading (prosthesis insertion at 4–6 months after initial implant loading), whereas 10 studies reported immediate loading. Fixed dentures and overdentures were fabricated, and crowns were veneered with acrylic resin and ceramic.

Some clinical complications and causes of implant loss were reported (Table 2).

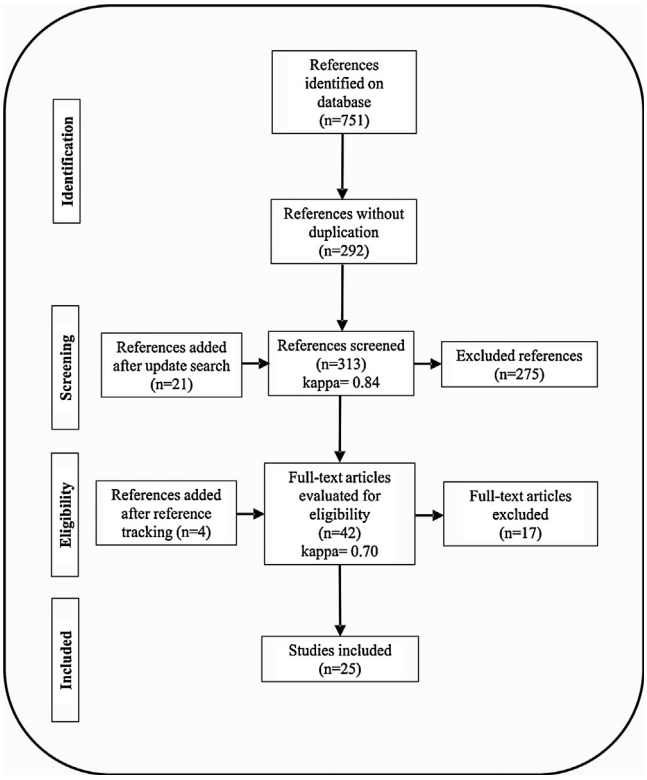

Fig. 1. Literature search and results.

Recurrent acute and chronic sinusitis was reported before and after prosthesis insertion. In eight studies, some of the zygomatic implants were removed from the infected area. Prosthetic complications included fracture of the artificial teeth, removal of a fixed denture or overdenture, and allergy to the metal framework. The zygomatic implant length ranged from 25 to 60 mm. The main surgical protocols applied were the Le Fort I, crestal, and palatal incisions.

The studies reviewed showed limitations in terms of poor clinical evaluation of the zygomatic implants during follow-up. Some studies used conventional radiography instead of computed tomography (CT) scans as additional resources for verifying whether the implants had failed. CT scans offer three-dimensional images that allow the surgeon to evaluate the zygomatic/bone interface in more detail and to measure the peri-implant bone density. Studies using CT scans may have more reliable results. In addition, during normal function, oral prostheses are exposed to humidity and food, and the bone tissue is submitted to occlusal forces that may affect osseointegration.

The assessment of the methodological quality performed in this study included some specific aspects of the selected studies. Unfortunately, there was no sample size calculation in any of these studies. The studies were grouped according to resemblances in their methodology, such as sample size (mean), number of zygomatic implants inserted, periods of follow-up, surgical protocol, and zygomatic implants removed; these are summarized in Table 4. Group A represents the eight studies that had the smallest sample size; only group D had zygomatic implants removed. In a detailed analysis, 13 studies showed failures of zygomatic implants with the loss of 33 zygomatic implants that would have supported the prosthesis. However only eight studies reported removal of these zygomatic implants; the others studies did not provide this information. Half of the studies (groups A and B) had shorter periods of follow-up compared to the other half (groups C and D). Most of the studies (groups B, C, and D) showed around 60–80 zygomatic implants inserted, and 12 studies (groups A and D) used the crestal incision as the surgical protocol (Table 4). In addition some studies showed different periods of follow-up for the same sample.

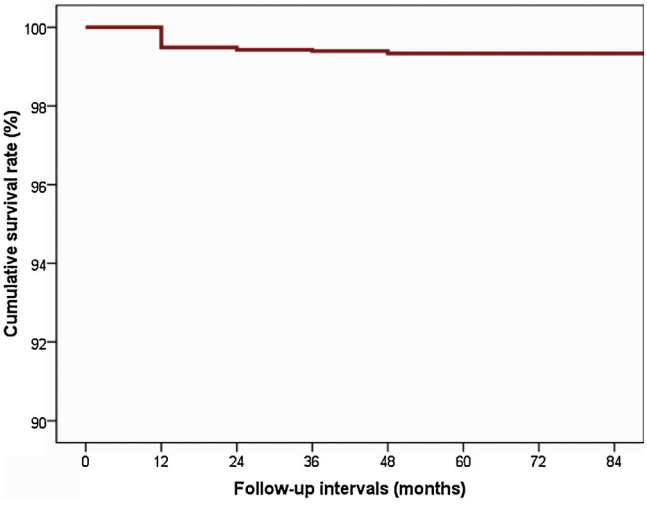

Fig. 2. Kaplan–Meier survival curve for zygomatic implants in the 15 studies selected with late loading.

Quantitative analyses

The 25 studies reported a mean follow-up of 42.2 months (range 0–144 months). A total of 1541 zygomatic implants were inserted, and 33 failures/losses were reported. Among the 25 studies, 14 showed a cumulative survival rate of 100% (Table 3).

The survival rate of zygomatic implants for the 25 studies was 97.86% after 36 months (Table 5). This value remained constant up to the last follow-up period. Loading decreased the survival of implants after 12 months for late implants and after 24 months for immediate implants (Table 5, Figs. 2 and 3).

Fig. 4 shows the studies ordered by the number of zygomatic implants and their respective failure rates. No relationship was observed between the failure rate and the number of implants. No statistical test was conducted to show the significance of such a relationship. However, one study presented a higher failure rate (21.43%) compared to the others.

Table 1. Summary of the sample sizes and characteristics of the implants inserted in the 25 selected studies.

Study	Number (% female)	Setting/country	PE or CE maxilla	Implant manufacturer*/ postoperative exams	Surface type	Type of implant loading	Type of prosthesis
Parel et al.[19] (2001)	27 (–)	Local/Sweden	CE	–	–	Late	FP or OVD
Bedrossian and Stumpel[7] (2002)	22 (–)	Local/USA	CE	Nobel Biocare/C&R exams	–	Late	PP/FP or OVD
Boyes-Varley et al.[20] (2003)	45 (–)	Local/South Africa	PE and CE	Nobel Biocare/C&R examinations	SLA	Late	FP or OVD
Vrielinck et al.[21] (2003)	29 (69.0)	Local/Belgium	PE and CE	Nobel Biocare/clinical and CT scan	–	Late	FP or OVD
Al-Nawas et al.[22] (2004)	24 (–)	Local/Germany	CE	–/Clinical exam and microbial analysis	–	Late	–
Malevez et al.[4] (2004)	55 (74.5)	Local/Belgium	CE	Nobel Biocare/C&R exams	–	Late	FP
Schmidt et al.[23] (2004)	9 (–)	Local/USA	CE	–/Clinical examination and microbial analysis	–	Late	OVD
Becktor et al.[24] (2005)	16 (62.5)	Local/Sweden	CE	Nobel Biocare/C&R exams	–	Late	PP/FP
Aparicio et al.[16] (2006)	69 (68.1)	Local/Spain	CE	Nobel Biocare/C&R exams	–	Late	FP
Ahlgren et al.[25] (2006)	13 (–)	Local/Norway	CE	Nobel Biocare/C&R exams	–	Late	FP or OVD
Bedrossian et al.[26] (2006)	14 (–)	Local/USA	CE	Nobel Biocare/C&R exams	Oxidized	Immediate	PP/FP
Aghabeigi and Bousdras[27] (2007)	4 (–)	Local/England	CE	Nobel Biocare/clinical and cranial radiographs	Machined	Late	FP or OVD
Davo et al.[28] (2007)	18 (66.7)	Local/Spain	CE	Nobel Biocare/clinical and resonance frequency analysis	Machined	Immediate	PP/FP
Duarte et al.[29] (2007)	12 (–)	Local/Brazil	CE	Nobel Biocare/orthopantomographic and Waters' view posterior–anterior radiographs	Machined	Immediate	PP/FP
Peñarrocha et al.[30] (2007)	21 (52.4)	Local/Spain	CE	Straumann/C&R exams	–	Late	FP
Kahnberg et al.[31] (2007)	76 (75.0)	Multicenter/Sweden, Australia, Italy, Finland, USA, Belgium, Germany, Spain	PE and CE	Nobel Biocare/clinical evaluation	–	Late	FP or OVD
Davó et al.[32] (2008)	42 (54.8)	Local/Spain	PE and CE	Nobel Biocare/C&R exams	–	Immediate	PP/FP
Mozzati et al.[33] (2008)	7 (42.9)	Local/Italy	CE	Nobel Biocare/C&R exams	Oxidized (TiUnite)	Immediate	PP/FP
Pi Urgell et al.[11] (2008)	54 (64.8)	Local/Spain	CE	Nobel Biocare/C&R exams	Machined	Late	FP or OVD
Balshi et al.[5] (2009)	56 (51.8)	Local/USA	CE	Nobel Biocare/C&R exams	Oxidized (TiUnite)	Immediate	PP/FP
Davó[34] (2009)	24 (66.7)	Local/Spain	CE	Nobel Biocare/C&R exams	Machined	Late	FP or OVD
Bedrossian[35] (2010)	36 (61.1)	Local/USA	CE	Nobel Biocare/C&R exams	Oxidized (TiUnite)	Immediate	PP/FP
Chow et al.[36] (2010)	16 (56.3)	Local/China	CE	Nobel Biocare/clinical and CT scan	Oxidized	Immediate	PP/FP
Stievenart and Malevez[37] (2010)	20 (95.0)	Local/Belgium	CE	Nobel Biocare/C&R exams	–	Immediate	PP/FP
Maló et al.[38] (2012)	39 (76.9)	Local/Portugal	CE	Nobel Biocare/C&R exams	Oxidized (TiUnite)	Immediate	PP/FP

–, Condition not reported in the study; C&R exams, clinical and radiographic examinations; CE, completely edentulous; CT, computed tomography; FP, fixed prosthesis; PE, partially edentulous; OVD, overdenture; PP, provisional prosthesis; SLA, sandblasted, large-grit, acid-etched technique.

* Nobel Biocare: Nobel Biocare, Sweden; Straumann: Straumann, Basel, Switzerland.

Table 2. Summary of clinical complications and causes of implant loss in the 25 selected studies.

Study	Clinical complications (*n*)					ZI length (mm)	Surgical protocol
	Before FP insertion	After FP insertion	Prosthetic complications	Removal of ZI/CVIs	Other complications		
Parel et al.[19] (2001)	–	–	–	No/–	–	25–60	Trans-sinus incision
Bedrossian and Stumpel[7] (2002)	–	–	–	–	–	30–52.5	CI
Boyes-Varley et al.[20] (2003)	–	–	–	No/–	–	30–50	LFI
Vrielinck et al.[21] (2003)	Sinusitis (2); bucco-sinus fistula (1); chronic gingivitis around ZI abutments (2)	–	–	–	Facial oedema; infra-orbital swelling and discomfort or pain symptoms in the zygoma	30–50	CI
Al-Nawas et al.[22] (2004)	–	OA fistula (1)	–	–	Colonization with periodontal pathogens; colonization of corresponding cheek pouch; ZI bleeding on probing	–	–
Malevez et al.[4] (2004)	Sinusitis (1)	Sinusitis (5)	Wearing removable denture (3)	No/yes	–	30–52.5	PI/LFI
Schmidt et al.[23] (2004)	–	–	–	–	–	–	–
Becktor et al.[24] (2005)	Sinusitis (6)	Sinusitis (1)	–	Yes/yes	Gingivitis; poor oral hygiene; fistulas and local infection surrounding the implant	30–50	Mucoperiosteal elevation
Aparicio et al.[16] (2006)	–	Sinusitis (3)	Tooth fraction in incisal aspect in metal/resin (4)	No/yes	Facial oedema; moderate nasal bleeding	35–52.5	Trans-zygomatic incision
Ahlgren et al.[25] (2006)	–	Allergy to gold alloy	Allergy to OVD gold bar supported by 4 implants (1)	No/yes	Facial haematoma/lip burning	11–50	PI/CI
Bedrossian et al.[26] (2006)	–	–	Partial fracture on surrounding denture (2)	No/no	–	35–52.5	CI
Aghabeigi and Bousdras[27] (2007)	–	–	–	No/no	–	30–52.5	Mucoperiosteal elevation
Davo et al.[28] (2007)	Sinusitis (1)	–	–	No/yes	Slight discomfort at the palatal aspect of the ZI (1)	30–52.5	CI
Duarte et al.[29] (2007)	–	Peri-implant inflammation	Changed prosthesis due to ZI loss (1)	Yes/–	–	–	CI
Peñarrocha et al.[30] (2007)	Sinusitis (2)	–	–	No/yes	–	30–42.5	Sinus slot technique
Kahnberg et al.[31] (2007)	–	Fistula formation, sinus-related complications; sinusitis (1); paresthesia of the right infra-orbital nerve (1)	Repair of fractured tooth and modification of prosthesis due to failed CVIs	Yes/yes	Inflammatory hyperplasia, infection, redness, and swelling tissue around the ZI abutments; pain at night; tenderness; symptoms in relation to cold, rhinitis, and in the sinus area	–	CI
Davó et al.[32] (2008)	Sinusitis and intraoral fistula (1)	–	–	No/yes	Soft tissue oedema and pain in the zygomatic region	40–52	PI/LFI
Mozzati et al.[33] (2008)	–	–	–	No/no	Slight difficulty pronouncing the letter ‘S’ with the PP (1)	35–50	CI
Pi Urgell et al.[11] (2008)	–	Sinusitis (4)	–	Yes/yes	Oedema and haematoma in the infra-orbital area	30–52.5	CI
Balshi et al.[5] (2009)	–	–	–	Yes/yes	–	30–52.5	CI
Davó[34] (2009)	Sinusitis (5)	–	OVD removal after 1 year of function (1)	Yes/yes	–	30–52.5	PI/LFI

Bedrossian[35] (2010)	Sinusitis (3)	–	–	Yes/no	–	30–52.5	Mucoperiosteal elevation
Chow et al.[36] (2010)	–	–	–	No/–	–	–	CI
Stievenart and Malevez[37] (2010)	–	–	Fixed denture loss due to loss of 3 implants (1)	Yes/–	Soft tissue inflammation, poor oral hygiene	30–52.5	CI
Maló et al.[38] (2012)	Sinusitis (3)	Sinusitis (2); OA communication (1)	–	No/no	–	–	Extra-maxillary and extra-sinusal

–, Condition not reported in the study; CVI, conventional implant; CI, crestal incision; FP, final prosthesis; LFI, Le Fort I incision; OA, oro-antral; OVD, overdenture; PI, palatal incision; PP, provisional prosthesis; ZI, zygomatic implant.

Fig. 3. Kaplan–Meier survival curve for zygomatic implants in the 10 studies selected with immediate loading.

Discussion

The data in this study suggest that zygomatic implants may be used as an alternative for patients with severe maxillary resorption. Both hypotheses were accepted: the survival rate decreased considerably after the first year of implant insertion (98.12%), and the results were similar regardless of the loading type. After the first year of loading, the survival rate continued to decrease, and then remained constant from 36 months until the last follow-up period (>84 months). Previous studies have indicated that the insertion of implants in the four regions of the zygomatic cortical bone with thick trabeculae provides anchoring that is resistant to the distribution of occlusal forces.[7,37,39–42] This fact may explain the good long-term results for these implants.

Studies have suggested that zygomatic implants may be used as an alternative to bone grafts in patients with severe maxillary resorption[43,44] because the insertion of zygomatic implants does not require additional grafting.[4,5,17,24,25] The surgical protocol is less invasive and more predictable.[16] In the present study, the Le Fort I, crestal, and palatal incisions were the most commonly applied approaches (Table 2). The Le Fort incision provides oral access to the nasal and lateral zygoma opening, whereas the crestal incision allows the insertion of a unilateral zygomatic implant.[20,23] Such techniques provide excellent prosthetic stabilization.

Complications in the soft tissues and sinusitis may occur with zygomatic implants, which should be treated with medicine or surgery.[5,11,16,21,22,24,28,30,32,34,35,38] If the infection is not resolved with antibiotics, then the implant may prolong the infection and require removal.[35,45] Some adverse complications were reported to have occurred in the initial months after prosthesis insertion or surgery. Cases of sinusitis and other pathological infections caused failure/loss of the zygomatic implants. These sinus complications may have been related to a combination of the extreme thinness of the palatal bone tissue, the surgical procedure, and the micro-movement of the functioning zygomatic implant.[31,36]

Complications may result from the loss of osseointegration and inflammation of the soft tissues surrounding the abutments (zygomatic implants have deeper pockets compared to those of conventional implants).[22,37] This situation can lead to contamination and communication between the implant screw and mouth. Some authors have treated the implant surface in the maxillary sinus to avoid biofilm formation and tissue accumulation.[25,46,47] Most studies that have used zygomatic implants with immediate loading have used modified implant surfaces to maintain the primary stability.[5,26,28,29,33,35,36,38] Furthermore, frequent and correct oral hygiene to avoid peri-implant inflammation was suggested in all studies.

The failure rate was not related to the number of zygomatic implants (Fig. 4). Schmidt et al.[23] and Becktor et al.[24] obtained higher failure rates compared to the other studies. This result may be related to poor oral hygiene and soft tissue contamination surrounding the abutments. The presence of Gram-negative anaerobic

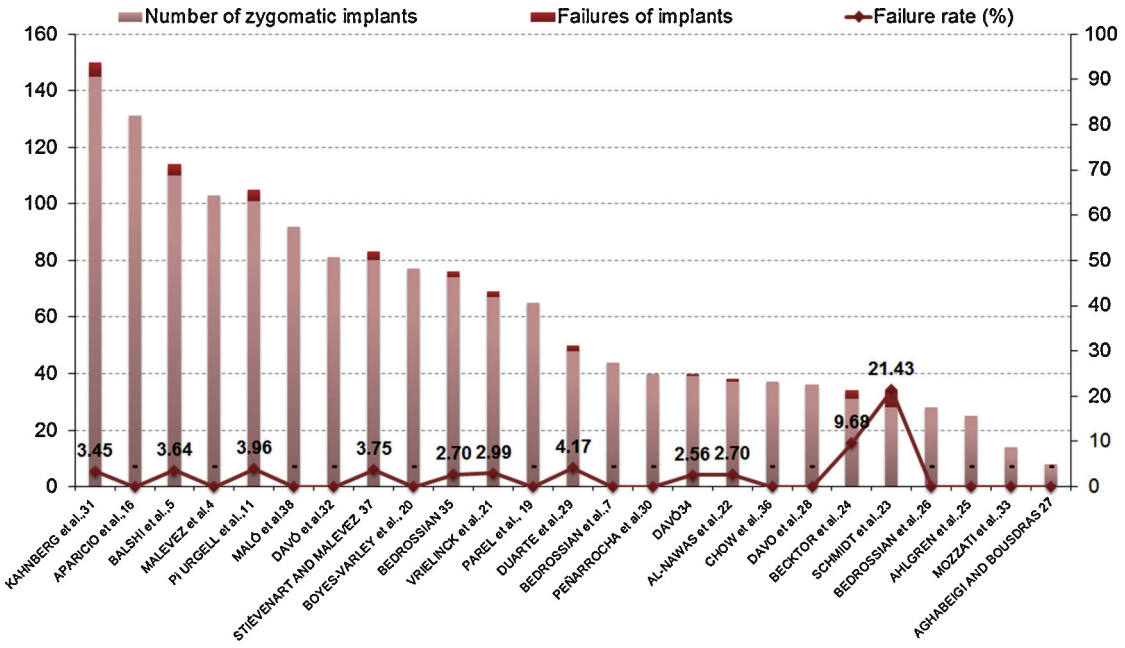

Fig. 4. Number of zygomatic implants at each follow-up interval according to the implant failures for the 25 selected studies.

and facultative anaerobic bacteria in peri-implantitis, such as *Prevotella* spp, *Porphyromonas gingivalis*, *Fusobacterium* spp., and *Actinomyces* spp., has been reported.[22,48] Thus, oral hygiene is important because the soft tissues may act as a bacterial reservoir.[22]

In some studies, the implants failed because initial stability was not present in the low-quality bone during insertion. This situation may be due to the rotating of the apical part of the implant to a more lateral position compared to the initial drilling.[21] In the study of Schmidt et al.[23], two of the three patients who experienced zygomatic implant failure had received radiation therapy. The long-term sequelae and risks of radiation therapy, including decreased vascular supply to the bone, altered processes of cellular division, cellular damage, and

Table 3. Summary of implant failures and follow-up intervals in the 25 selected studies.

Study	Follow-up intervals of the study (months)	No. of zygomatic/ conventional implants	Failures of zygomatic implants	Survival rate (%) of zygomatic implants	Failures of conventional implants
Parel et al.[19] (2001)	12–144	65/–	0	100	–
Bedrossian and Stumpel[7] (2002)	0–34	44/80	0	100	7
Boyes-Varley et al.[20] (2003)	6–30	77/–	0	100	–
Vrielinck et al.[21] (2003)	3–24	67/71	2	93.0	6
Al-Nawas et al.[22] (2004)	11–30.5	37/–	1	97.0	–
Malevez et al.[4] (2004)	6–48	103/194	0	100	16
Schmidt et al.[23] (2004)	0–84	28/10	6	78.6	3
Becktor et al.[24] (2005)	9–69	31/74	3	94.30	3
Aparicio et al.[16] (2006)	6–60	131/304	0	100	2
Ahlgren et al.[25] (2006)	11–49	25/30	0	100	5
Bedrossian et al.[26] (2006)	12–34	28/55	0	100	0
Aghabeigi and Bousdras[27] (2007)	9–24	8/14	0	100	0
Davo et al.[28] (2007)	6–29	36/68	0	100	3
Duarte et al.[29] (2007)	6–30	48/–	2	95.8	–
Peñarrocha et al.[30] (2007)	12–45	40/89	0	100	2
Kahnberg et al.[31] (2007)	1–36	145/–	5	96.3	–
Davó et al.[32] (2008)	12–42	81/140	0	100	4
Mozzati et al.[33] (2008)	1–24	14/34	0	100	0
Pi Urgell et al.[11] (2008)	1–72	101/221	4	96.04	15
Balshi et al.[5] (2009)	9–60	110/391	4	96.37	11
Davó[34] (2009)	6–60	39/109	1	97.40	11
Bedrossian [35] (2010)	6–84	74/98	2	97.2	0
Chow et al.[36] (2010)	6–24	37/–	0	100	–
Stievenart and Malevez[37] (2010)	6–40	80/–	3	96.0	–
Maló et al.[38] (2012)	1–36	92/77	0	100	0

–, Condition not reported in the study.

Table 4. Comparative assessment of the methodological quality for the 25 studies selected.

Studies*	Sample size (mean)	No. of zygomatic implants	Periods of follow-up	Surgical protocol	Zygomatic implants removed
(A)[7,21–23,26,28,33,36]	17.4	36.4	30.6	75% of the studies used CI	No
(B)[4,25,32,38]	37.3	75.3	36.3	More than one	No
(C)[16,19,20,27,30]	33.2	64.2	51.6	Other technique	No
(D)[5,11,24,29,31,34,35,37]	36.8	78.5	50.9	75% of the studies used CI	Yes

CI, crestal incision.
* Studies grouped according to resemblances in their methodology.

Table 5. Life-table survival analysis showing the cumulative survival rate of zygomatic implants for the 25 selected studies.

Follow-up intervals of the study (months)	No. of implants in each interval	No. of failures in each interval	Survival rate within each interval (%)	Cumulative survival rate (%)
0–12	1541	27	98.25	98.25
12–24	1398	2	99.86	98.12
24–36	1068	2	99.81	97.99
36–48	533	2	99.62	97.86
48–60	432	0	100.0	97.86
60–72	215	0	100.0	97.86
72–84	51	0	100.0	97.86
>84	4	0	100.0	97.86

reduced cell life, may contraindicate the use of osseointegrated implants.[49] Fracture of the artificial teeth and removal of the fixed denture or overdenture were also observed as consequences of occlusal instability due to bruxism or failure during surgical–prosthetic planning.[25,27] These failures were corrected after insertion of a new implant or replacement of the prosthesis.[23,29]

The length of the zygomatic implants ranged from 25 to 60 mm. The zygomatic implants were typically associated with conventional implants for posterior prosthetic rehabilitation. The main stress in the zygomatic implant is distributed at the confines of the lateral wall of the maxillary sinus and the fixture–abutment joint.[50] There is a significant biomechanical disadvantage regarding the long lever arm and the small amount of bone integration. The biomechanics of the zygomatic implant could be improved by inserting angled implants connected to conventional fixtures.[51,52] The reduction of the cantilever by zygomatic implants may also result in long-term positive effects in terms of the distribution of the load on the conventional implants.[33] In this situation, the occlusal forces are directly transferred to the zygomatic bone instead of the anterior or posterior atrophic maxilla.[32,50] Although there have been few studies on the biomechanics of zygomatic implants, previous studies with conventional implants have shown that the transmission of mastication forces can create a lever arm that is larger in inclined than in straight implants, causing secondary forces and a significant moment of force on the bone.[53–55] However, the angled head of the zygomatic implant is designed to allow the placement of the prosthesis at 45° to the long axis of the implant, providing an excellent ability to retain, support, and stabilize the jaw prosthesis, minimizing the lever effect.[7,19]

For severe resorption, the insertion of four zygomatic implants (anterior and posterior) is an alternative to grafting. The zygomatic implants can be placed in an arch form, to counteract the bending forces.[56] The anterior implants restore the incisor–canine region, whereas the posterior implants are used to rehabilitate the second premolar/first molar.[29,37,41] Seven of the 25 studies used zygomatic implants without association with conventional implants. Only three of these studies[19,20,36] exhibited a survival rate of 100%. Similar results were observed for the loading of the zygomatic implants. Immediate loading may allow the primary stabilization of the implant, reducing the treatment length and increasing the comfort of the patient.[28,29] Studies that used immediate implant loading reported decreased treatment times and increased acceptance of the treatment by the patient.[5,26,28,35,36,38] Finally, an excellent survival rate was observed for zygomatic implants in cases of prosthetic rehabilitation of patients with maxillary resorption.

In conclusion, zygomatic implants appear to be an effective alternative for the treatment of an atrophic maxilla. The survival rate decreases during the first year after surgery and is more related to local infection than to the number of zygomatic implants. The survival of osseointegrated implants may also be related to the use of suitable presurgical examinations and the parameters used during the surgical procedures.

Funding

None.

Competing interests

None declared.

Ethical approval

Not required.

References

1. Brånemark PI. *Surgery and fixture installation: zygomaticus fixture clinical procedures*. Göteborg, Sweden: Nobel Biocare; 1998: 1.
2. Aparicio C, Branemark PI, Keller EE, Olive J. Reconstruction of the premaxilla with autogenous iliac bone in combination with osseointegrated implants. *Int J Oral Maxillofac Implants* 1993;**8**:61–7.
3. Weischer T, Schettler D, Mohr CH. Titanium implants in the zygoma as retaining elements after hemimaxillectomy. *Int J Oral Maxillofac Implants* 1997;**12**:211–21.
4. Malevez C, Abarca M, Durdu F, Daelemans P. Clinical outcome of 103 consecutive zygomatic implants: a 6–8 months follow-up study. *Clin Oral Implants Res* 2004;**15**:18–22.

5. 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**:335–41.
6. Sartori EM, Padovan LE, de Mattias Sartori IA, Ribeiro Jr PD, Gomes de Souza Carvalho AC, Goiato MC. Evaluation of satisfaction of patients rehabilitated with zygomatic fixtures. *J Oral Maxillofac Surg* 2012;**70**:314–9.
7. Bedrossian E, Stumpel LJ. The zygomatic implant; preliminary data on treatment of severely resorbed maxillae. A clinical report. *Int J Oral Maxillofac Implants* 2002;**17**:861–5.
8. 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;**41**:571–4.
9. Esposito M, Worthington HV, Coulthard P. Interventions for replacing missing teeth: dental implants in zygomatic bone for the rehabilitation of the severely deficient edentulous maxilla. *Cochrane Database Syst Rev* 2005;**19**:CD004151.
10. Higuchi KW. The zygomaticus fixture: an alternative approach for implant anchorage in the posterior maxilla. *Ann R Australas Coll Dent Surg* 2000;**15**:28–33.
11. Pi Urgell J, Revilla Gutiérrez V, Gay Escoda CG. Rehabilitation of atrophic maxilla: a review of 101 zygomatic implants. *Med Oral Patol Oral Cir Bucal* 2008;**13**:E363–70.
12. Chanavaz M. Maxillary sinus: anatomy, physiology, surgery, and bone grafting related to implantology – Eleven years of surgical experience (1979–1990). *J Oral Implantol* 1990;**16**:199–209.
13. Esposito M, Hirsch JM, Lekholm U, Thomsen P. Biological factors contributing to failures of osseointegrated oral implants. (I). Success criteria and epidemiology. *Eur J Oral Sci* 1998;**106**:527–51.
14. Sjöström M, Sennerby L, Nilson H, Lundgren S. Reconstruction of the atrophic edentulous maxilla with free iliac crest grafts and implants: a 3-year report of a prospective clinical study. *Clin Implant Dent Relat Res* 2007;**9**:46–59.
15. Aparicio C, Malevez CH. El implante transzigomático. Consejo General de Colegios y Odontólogos y Estomatólogos de España. *Revista del Ilustre Consejo General de Colegios de Odontólogos y Estomatólogos de España (RCOE)* 1999;**4**:171–84.
16. Aparicio C, Ouazzani W, Garcia R, Arevalo X, Muela R, Fortes V. A prospective clinical study on titanium implants in the zygomatic arch for prosthetic rehabilitation of the atrophic edentulous maxilla with a follow-up of 6 months to 5 years. *Clin Implant Dent Relat Res* 2006;**8**:114–22.
17. Farzad P, Andersson L, Gunnarsson S, Johansson B. Rehabilitation of severely resorbed maxillae with zygomatic implants: an evaluation of implant stability, tissue conditions, and patients' opinion before and after treatment. *Int J Oral Maxillofac Implants* 2006;**21**:399–404.
18. Moher D, Liberati A, Tetzlaff J, Altman DG, PRISMA Group. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. *Int J Surg* 2010;**8**:336–41.
19. Parel SM, Brånemark PI, Ohrnell LO, Svensson B. Remote implant anchorage for the rehabilitation of maxillary defects. *J Prosthet Dent* 2001;**86**:377–81.
20. 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;**18**:232–7.
21. 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;**32**:7–14.
22. Al-Nawas B, Wegener J, Bender C, Wagner W. Critical soft tissue parameters of the zygomatic implant. *J Clin Periodontol* 2004;**31**:497–500.
23. Schmidt BL, Pogrel MA, Young CW, Sharma A. Reconstruction of extensive maxillary defects using zygomaticus implants. *J Oral Maxillofac Surg* 2004;**62**:82–9.
24. Becktor JP, Isaksson S, Abrahamsson P, Sennerby L. Evaluation of 31 zygomatic implants and 74 regular dental implants used in 16 patients for prosthetic reconstruction of the atrophic maxilla with cross-arch fixed bridges. *Clin Implant Dent Relat Res* 2005;**7**:159–65.
25. Ahlgren F, Størksen K, Tornes K. A study of 25 zygomatic dental implants with 11 to 49 months' follow-up after loading. *Int J Oral Maxillofac Implants* 2006;**21**:421–5.
26. Bedrossian E, Rangert B, Stumpel L, Indresano T. Immediate function with the zygomatic implant: a graftless solution for the patient with mild to advanced atrophy of the maxilla. *Int J Oral Maxillofac Implants* 2006;**21**:937–42.
27. Aghabeigi B, Bousdras VA. Rehabilitation of severe maxillary atrophy with zygomatic implants. Clinical report of four cases. *Br Dent J* 2007;**202**:669–75.
28. Davo R, Malevez C, Rojas J. Immediate function in the atrophic maxilla using zygoma implants: a preliminary study. *J Prosthet Dent* 2007;**97**(Suppl. 6):S44–51.
29. Duarte LR, Filho HN, Francischone CE, Peredo LG, Brånemark PI. The establishment of a protocol for the total rehabilitation of atrophic maxillae employing four zygomatic fixtures in an immediate loading system – a 30-month clinical and radiographic follow-up. *Clin Implant Dent Relat Res* 2007;**9**:186–96.
30. Peñarrocha M, García B, Martí E, Boronat A. Rehabilitation of severely atrophic maxillae with fixed implant-supported prostheses using zygomatic implants placed using the sinus slot technique: clinical report on a series of 21 patients. *Int J Oral Maxillofac Implants* 2007;**22**:645–50.
31. Kahnberg KE, Henry PJ, Hirsch JM, Ohrnell LO, Andreasson L, Brånemark PI, Chiapasco M, Gynther G, Finne K, Higuchi KW, Isaksson S, Malevez C, Neukam FW, Sevetz Jr E, Urgell JP, Widmark G, Bolind P. Clinical evaluation of the zygoma implant: 3-year follow-up at 16 clinics. *J Oral Maxillofac Surg* 2007;**65**:2033–8.
32. Davó R, Malevez C, Rojas J, Rodríguez J, Regolf J. Clinical outcome of 42 patients treated with 81 immediately loaded zygomatic implants: a 12- to 42-month retrospective study. *Eur J Oral Implantol* 2008;**1**:141–50.
33. Mozzati M, Monfrin SB, Pedretti G, Schierano G, Bassi F. Immediate loading of maxillary fixed prostheses retained by zygomatic and conventional implants: 24-month preliminary data for a series of clinical case reports. *Int J Oral Maxillofac Implants* 2008;**23**:308–14.
34. Davó R. Zygomatic implants placed with a two-stage procedure: a 5-year retrospective study. *Eur J Oral Implantol* 2009;**2**:115–24.
35. Bedrossian E. Rehabilitation of the edentulous maxilla with the zygoma concept: a 7-year prospective study. *Int J Oral Maxillofac Implants* 2010;**25**:1213–21.
36. Chow J, Wat P, Hui E, Lee P, Li W. A new method to eliminate the risk of maxillary sinusitis with zygomatic implants. *Int J Oral Maxillofac Implants* 2010;**25**:1233–40.
37. Stiévenart M, Malevez C. Rehabilitation of totally atrophied maxilla by means of four zygomatic implants and fixed prosthesis: a 6–40-month follow-up. *Int J Oral Maxillofac Surg* 2010;**39**:358–63.
38. Maló P, Nobre Md, Lopes A, Francischone C, Rigolizzo M. Three-year outcome of a retrospective cohort study on the rehabilitation of completely edentulous atrophic maxillae with immediately loaded extramaxillary zygomatic implants. *Eur J Oral Implantol* 2012;**5**:37–46.
39. Aparicio C, Ouazzani W, Hatano N. The use of zygomatic implants for prosthetic rehabilitation of the severely resorbed maxilla. *Periodontol 2000* 2008;**47**:162–71.
40. Malevez C, Daelemans P, Adriaenssens P, Durdu F. Use of zygomatic implants to deal with resorbed posterior maxillae. *Periodontol 2000* 2003;**33**:82–9.
41. Nkenke E, Hahn M, Lell M, Wiltfang J, Schultze-Mosgau S, Stech B, Radespiel-Tröger M, Neukam FW. Anatomic site evaluation of the zygomatic bone for dental

implant placement. *Clin Oral Implants Res* 2003;**14**:72–9.
42. Kato Y, Kizu Y, Tonga M, Ide Y, Yamane GY. Internal structure of zygomatic bone related to zygomatic fixture. *J Oral Maxillofac Surg* 2005;**63**:1325–9.
43. Keller E, Tolman D, Eckert S. Surgical–prosthodontic reconstruction of advanced maxillary bone compromise with autogenous onlay block bone grafts and osseointegrated implants: a 12-year study of 32 consecutive patients. *Int J Oral Maxillofac Implants* 1999;**14**:197–209.
44. Brånemark PI, Gröndahl K, Ohrnell LO, Nilsson P, Petruson B, Svensson B, Engstrand P, Nannmark U. 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**:70–85.
45. Petruson B. Sinuscopy in patients with titanium implants in the nose and sinuses. *Scand J Plast Reconstr Surg Hand Surg* 2004; **38**:86–93.
46. Aparicio C, Ouazzani W, Aparicio A, Fortes V, Muela R, Pascual A, Codesal M, Barluenga N, Manresa C, Franch M. Extrasinus zygomatic implants: three year experience from a new surgical approach for patients with pronounced buccal concavities in the edentulous maxilla. *Clin Implant Dent Relat Res* 2010;**12**:55–61.
47. Iezzi G, Vantaggiato G, Shibli JA, Fiera E, Falco A, Piattelli A, Perrotti V. Machined and sandblasted human dental implants retrieved after 5 years: a histologic and histomorphometric analysis of three cases. *Quintessence Int* 2012;**43**:287–92.
48. Mombelli A, Lang NP. The diagnosis and treatment of peri-implantitis. *Periodontol 2000* 1998;**17**:63–76.
49. Granstrom G. Placement of dental implants in irradiated bone: the case using hyperbaric oxygen. *J Oral Maxillofac Surg* 2006; **64**:812–8.
50. Ujigawa K, Kato Y, Kizu Y, Tonogi M, Yamane GY. Three dimensional finite elemental analysis of zygomatic implants in craniofacial structures. *Int J Oral Maxillofac Surg* 2007;**36**:620–5.
51. Celletti R, Pameijer CH, Bracchetti G, Donath K, Persichetti G, Visani Y. Histologic evaluation of osseointegrated implants restored in nonaxial functional occlusion with preangled abutments. *Int J Periodontics Restorative Dent* 1995;**15**:563–73.
52. Calandriello R, Tomatis M. Simplified treatment of the atrophic posterior maxilla via immediate/early function and tilted implants: a prospective 1-year clinical study. *Clin Implant Dent Relat Res* 2005;**7**(Suppl. 1):S1–2.
53. Satoh T, Maeda Y, Komiyama Y. Biomechanical rationale for intentionally inclined implants in the posterior mandible using 3D finite element analysis. *Int J Oral Maxillofac Implants* 2005;**20**:533–9.
54. Çaglar A, Aydin C, Ozen J, Yilmaz C, Korkmaz T. Effects of mesiodistal inclination of implants on stress distribution in implant-supported fixed prostheses. *Int J Oral Maxillofac Implants* 2006;**21**:36–44.
55. Korkmaz FM, Korkmaz YT, Yaluğ S, Korkmaz T. Impact of dental and zygomatic implants on stress distribution in maxillary defects: a 3-dimensional finite element analysis study. *J Oral Implantol* 2012;**38**: 557–67.
56. Aparicio C, Ouazzani W, Aparicio A, Fortes V, Muela R, Pascual A, Codesal M, Barluenga N, Franch M. Immediate/early loading of zygomatic implants: clinical experiences after 2 to 5 years of follow-up. *Clin Implant Dent Relat Res* 2010;**12**(Suppl. 1): e77–82.

Address:
Marcelo Coelho Goiato
Department of Dental Materials and Prosthodontics
Araçatuba Dental School
UNESP
José Bonifácio
1193
Araçatuba
São Paulo 16015-050
Brazil.
Tel: +55 18 36363287
Fax: +55 18 36363245.
E-mail: goiato@foa.unesp.br