

The use of zygomatic implants for prosthetic rehabilitation of the severely resorbed maxilla

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In many patients conventional implant treatment cannot be performed in the edentulous maxilla because of extensive bone resorption and the presence of extensive maxillary sinuses, leading to inadequate amounts of bone tissue for anchorage of the implants. The treatment option for these patients has often been some type of bone-augmentation procedure in order to increase the volume of load-bearing bone. Traditionally, the atrophic maxilla has been treated with large bone grafts from the iliac crest, a procedure that requires general anesthesia. The bone grafts have been used as onlays, in combination with a Le Fort I osteotomy, or as maxillary sinus inlays. Implants have been inserted simultaneously or after an initial healing period. Long-term follow-up studies have shown varying degrees of implant survival in grafted bone. A recent literature review based on 23 publications revealed an overall survival rate of 82–84% after a follow-up time from 12 to 60 months (38). A 10% higher survival rate was seen for implants placed after initial healing of the bone graft than if the implants were placed simultaneously with the bone graft. It can be argued that bone-augmentation procedures are resource demanding, take a long time and may present risks for morbidity of the donor site of the bone graft. It is also obvious that failure rates are higher in grafted than in nongrafted maxillae (17). One alternative to bone grafting that has been considered in the atrophied maxilla is the use of the zygomatic fixture (3, 12, 17). The Brånemark zygomatic fixture is the result of developments of reconstructive techniques for prosthetic rehabilitation of patients with extensive defects of the maxilla caused by tumor resections, trauma and congenital defects (22, 26). The bone of the zygomatic arch was used for anchorage of a long fixture, which, together with ordinary fixtures, could be used as an anchor for epis-

theses, prostheses and obturators. The technique has enabled sufficient rehabilitation of these patients, with restored function and improved esthetics as a result, and thus has given many patients back a normal social life.

The purpose of the present article is to describe the surgical and prosthetic technique, new developments and the clinical outcome zygomatic implantology, based on the literature and on our own experience.

Indications and pre-surgical evaluation

In general, zygomatic fixtures can be used in patients with a totally and partially edentulous maxillary who have insufficient bone volume for placement of regular implants posterior to the canines (Figs 1 and 2). Together with conventional implants in the anterior region, the zygomatic fixture offers anchorage for a fixed bridge using less invasive surgery compared with bone-augmentation procedures. It is most suitable in patients presenting with severe resorption of the posterior maxilla (i.e. <4 mm bone height distal to the canines) but with sufficient amounts of bone in the anterior region, so at least three implants per quadrant can be placed. In patients with small bone volumes also in the anterior part of the maxilla, the zygomatic implant can be used in conjunction with a bone-augmentation procedure of the anterior segment. In this way, fewer bone grafts are needed for the augmentation procedure. Zygomatic implants are also indicated when contraindications exist for harvesting of the iliac crest bone graft. As discussed later, one advantage with the technique is that it can be performed as an outpatient procedure under local anesthesia and conscious sedation. However, for

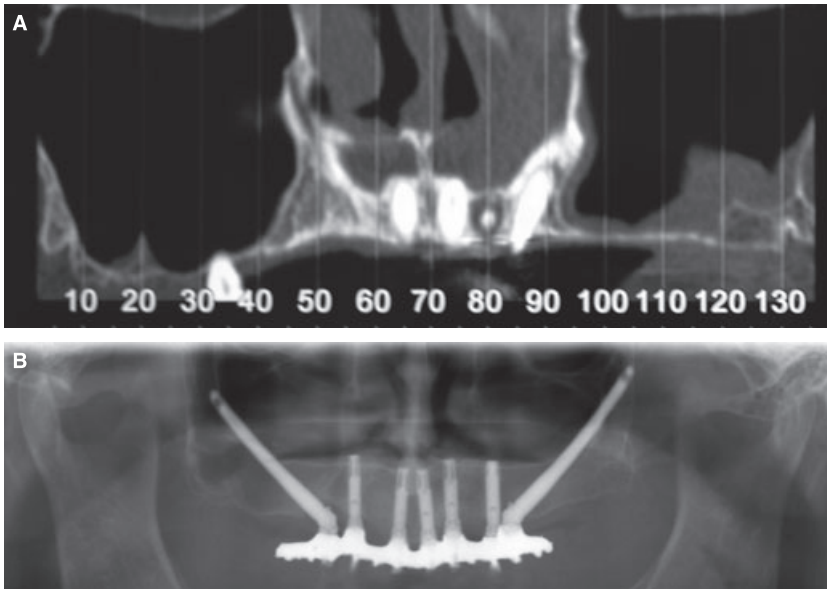


Fig. 1. (A) Pre-operative and (B) post-operative radiographs showing a typical totally edentulous patient treated with two zygomatic implants and five standard implants in the premaxilla.

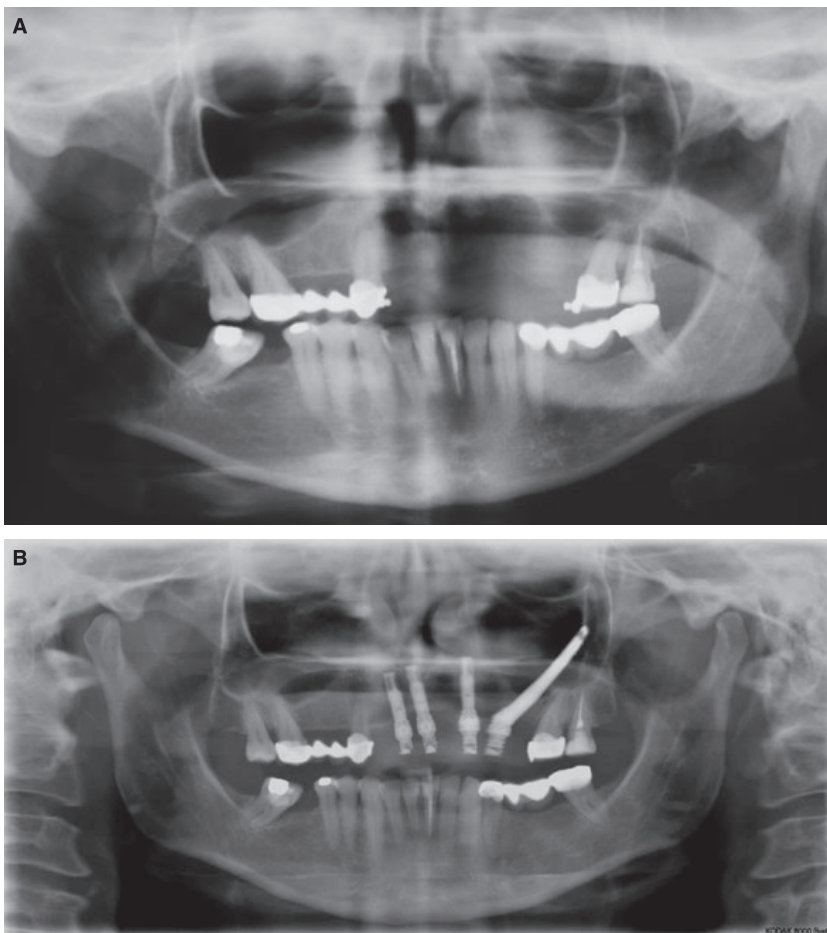


Fig. 2. (A) Pre-operative and (B) post-operative radiographs of a patient treated with one zygomatic and three standard implants in the partially edentulous maxilla.

better comfort for the patient, the routine procedure is usually performed under general anesthesia.

The zygomatic bone has a pyramidal shape and contains dense cortical and trabecular bone (29, 30, 41). According to a cadaver study, the mean length of

available bone in this region is about 14 mm (30). Computed tomography is needed for evaluation of the zygomatic implant site. The amount of bone in the zygomatic arch and in the residual alveolar crest has to be evaluated. The angulation, expected emergence

site and the relationship of the implant body to the maxillary sinus and lateral wall should be evaluated. With the original technique, the path of the zygomatic fixture is inside the maxillary sinus. The emergence of the head of the implant in relation to the alveolar crest, typically in the palatal aspect of the second premolar region, is therefore dependent on the spatial relationship between the zygomatic bone, the maxillary sinus and the alveolar crest. As will be discussed later, a new technique, including extrasinus passage of the implant, has been evaluated with promising results. This facilitates an optimal positioning of the zygomatic fixture head in relation to the alveolar crest and the occlusal table of the prosthetic construction. Any pathosis of the maxillary sinus should preferably be treated prior to installation of the zygomatic fixture.

Fixture designs

The original zygomatic fixture is a self-tapping titanium implant with a machined surface and is available in lengths from 30 to 52.5 mm. The threaded apical part has a diameter of 4 mm and the crestal part has a diameter of 4.5 mm. The implant head has an angulation of 45° and an inner thread for connection of Brånemark System abutments. Zygomatic fixtures are currently commercially available from at least three different companies that offer implants with an oxidized rough surface, a smooth midimplant body, a wider neck at the alveolar crest and a 55° angulation of the implant head.

Surgical technique

Surgery is usually carried out under general anesthesia. In those patients, local anesthesia is infiltrated in the maxillary vestibulum, in the area of the zygomatic bone and 1 cm palatal to the bone crest. The area is exposed via a midcrestal incision and vertical releasing incisions along the posterior part of the infrazygomatic crest and anterior to the surgical site. The vertical ridge/anterior border of the zygomatic arch is identified. A second landmark is the lateral orbital border. Mucoperiosteal flap elevation and exposure of the central/posterior part of the zygomatic complex, avoiding interference with the orbita, the lateral wall of the maxillary sinus and the alveolar crest, are carried out. A retractor is positioned for visibility and to protect the soft tissues. An indicator is used to determine the drilling direction and the starting point at the crest, usually

in the second premolar/first molar region. A bone window, some 10 mm wide, is created at the lateral aspect of the maxillary sinus following the desired path of the zygomatic implant from the sinus floor to the top of the sinus cavity. The sinus membrane is carefully dissected free from the sinus walls into the sinus cavity. A series of drills is used to penetrate the alveolar process and the zygomatic bone. The estimated length of the zygomatic implant is selected using a depth gauge. The self-tapping zygomatic implant is placed with the aid of a motor or manually using a fixture mount (Fig. 3A–C). Care should be taken not to enlarge the palatal hole at the rest during insertion, which is especially important in cases of thin alveolar/basal bone. If needed, bone particles harvested locally can be packed around the zygomatic implant. A cover screw is placed on the implant and the mucoperiosteal flap is closed.

Abutment connection is usually made after a healing period of 6 months following the procedures for the Brånemark System using standard or straight/angulated multiunit Brånemark abutments.

Prosthetic procedure

The prosthetic procedure follows conventional protocols for cemented or screw-retained implant-supported dental bridges (Fig. 3D–E). As the emergence of the zygomatic implant is often some 10–15 mm medial to the ridge, the bridge should be designed to enable proper oral hygiene in the area.

Clinical outcome of using the zygomatic implant

Reported zygomatic implant outcomes

In a literature review of English-written scientific journals, 20 studies presenting clinical outcomes with the zygomatic fixture were found (Table 1). The publications included 582 patients and 1143 zygomatic implants with a follow-up of 6 months–12 years. A total of 18 implants were reported as failures, giving an overall survival rate of 98.4%. However, it should be noted that some studies in part cover the same patient groups and therefore the true numbers of unique patients and implants are not known in detail. Nevertheless, the data show that the zygomatic implant technique is highly predictable

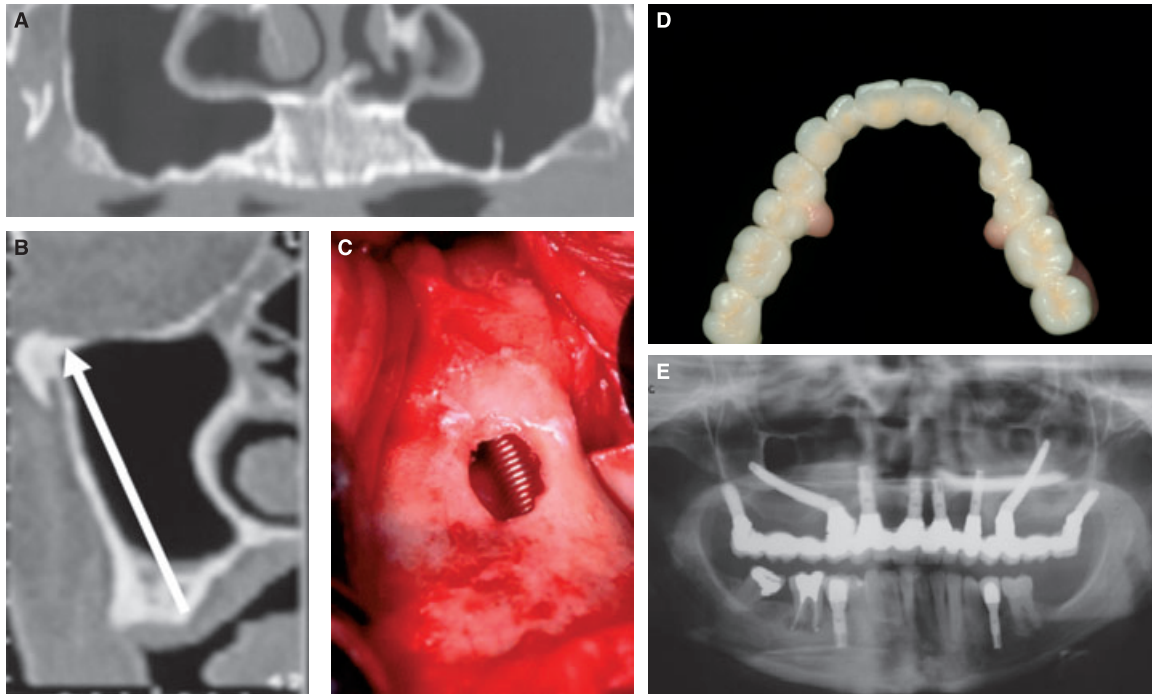


Fig. 3. (A) Pre-operative radiograph of a totally edentulous maxilla. (B) Tomographic section showing the intra-sinus path of the zygomatic implant (arrow). (C) Clinical photograph showing a lateral window of the maxillary sinus for visual control of implant insertion. (D) Clinical

photograph showing the final prosthetic construction. (E) Radiograph of the completed procedure showing two zygomatic implants and six standard implants, where two are in the tuber area and four are in the premaxilla.

and results in good clinical outcomes. In comparison, the additional 1388 conventional implants, placed in the anterior region, showed a survival rate of 94.8%.

Although the zygomatic fixture was introduced by Brånemark and coworkers during the 1990s, the first scientific publication from the group was presented in 2001 (33). None of 65 zygomatic implants placed in 27 patients with maxillary defects had been lost over 1–12 years of follow-up. In a more recent study from the group, 5–10-year data from 28 patients treated with 52 zygomatic implants and 106 regular implants were reported (12). Three zygomatic (6%) and 29 regular (27%) implants were lost during the follow-up. In a multicenter study that included 16 centers, the 1-year results of 66 patients treated with 124 zygomatic implants showed a survival rate of 98% with few complications (23). In a study on 131 zygomatic implants in 69 patients, no implant was lost during a follow-up period from 6 months to 5 years (3, 20). Beक्टर et al. (7) evaluated 31 zygomatic fixtures in 16 patients after an average follow-up period of 46 months. They experienced problems with recurrent sinusitis in three patients, which resulted in removal of three zygomatic implants in spite of successful osseointegration. Penarrocha et al. (36) reported that patient satisfaction with zygomatic implant-supported fixed prostheses was

similar to that for fixed prostheses supported by conventional implants.

Soft tissue complications

The zygomatic implant prosthesis system is complex from the biologic point of view as a result of the interfaces towards different tissues such as bone, oral mucosa and sinus mucosa. The passage of the fixture itself through the sinus cavity does not seem to provoke any severe negative soft tissue reactions, as evaluated by sinuscopy of 14 patients (37). However, few clinical follow-up studies on zygomatic implants report on soft tissue complications intra-orally or in the maxillary sinus. As mentioned in the previous paragraph, Beक्टर et al. (7) had to remove three of 31 implants because of recurrent sinusitis, in spite of the implants being clinically stable. They proposed two explanations for their problems: either the internal threaded abutment screw chamber of the zygomatic implant created a communication from the oral cavity into the maxillary sinus, which may have resulted in sinusitis, or a lack of osseointegration occurred at the marginal level in the palatal area, which resulted in transversal mobility of the zygomatic implant and a pump effect during function (7). Other researchers have reported sinusitis

Table 1. Results from follow-up studies on zygomatic implants

Study	Reference no.	Patients (n)	Follow-up	Zygomatic implants	Failed	Additional implants	Failed
Branemark et al. 2004*	12	81	1–10 years	164	4	?	?
Parel et al. 2001	33	27	1–12 years	65	0	?	?
Bedrossian et al. 2002	8	22	34 months	44	0	80	7
Vrielinck et al. 2003	43	29	<2 years	46	3	80	9
Boyes-Varley et al. 2003	11	45	6–30 months	77	0	?	?
Malevez et al. 2004	27	55	0.5–4 years	103	0	194	16
Hirsch et al. 2004	23	66	1 years	124	3	?	?
Brånemark et al. 2004	12	28	5–10 years	52	3	106	29
Becktor et al. 2005	7	16	1–6 years	31	3	74	3
Penarrocha et al. 2005	34	5	1–1.5 years	10	0	16	0
Farzad et al. 2006	18	11	1.5–4 years	22	0	42	1
Ahlgren et al. 2006	1	13	1–4 years	25	0	46	0
Aparicio et al. 2006	3	69	0.5–5 years	131	0	304	2
Bedrossian et al. 2006**	9	14	>12 months	28	0	55	0
Chow et al. 2006**	13	5	10 months	10	0	20	0
Duarte et al. 2007***	16	12	30 months	48	2	–	–
Penarrocha et al. 2007	35	21	12–45 months	40	0	89	2
Davo et al. 2007**	15	18	6–29 months	36	0	68	3
Aparicio et al. 2008**	5	25	7–38 months	46	0	127	0
Aparicio et al. 2008**	6	20	6–18 months	41	0	87	0
Total		582		1143	18 (1.6%)	1388	72 (5.2%)

*From Darle 2000 (14).

**Immediate loading.

***Immediate loading on four zygomatic implants.

to occur in 2.3–13.6% of the sinuses treated (4, 12, 18, 23, 27). Intra-oral infections seem to occur at a similar rate (i.e. from 3.8 to 6.5%) (2, 4, 12, 23), except in the studies carried out by Becktor et al. (29%) and Farzad et al. (31.8%) (7, 19). Another study reported that nine of 20 zygomatic implants were associated with periimplant bleeding and increased probing depths, possibly caused by difficulties in implementing appropriate hygiene because of the positioning of the zygomatic implant head and abutment, and the design of the prosthesis (2). Thus, the risk of soft tissue problems and sinusitis should not be underestimated.

Recent developments of the zygomatic fixture technique

Placement in local anaesthesia

One further simplification of the technique is the use of local anesthesia and oral or intravenous sedation, as developed by the second author (NH).

This procedure is recommended if the surgeon is experienced and the procedure takes less than 1.5 h. The local anesthetic procedure includes the use of four different local anesthetic approaches simultaneously.

- normal infiltration anesthesia in the buccal sulcus from the central incisor tooth to the third molar tooth using lidocaine with epinephrine (about 3.6 ml). Block of the posterior superior alveolar nerve about 1 cm palatal to the bone crest.
- infra-orbital nerve block by an oral approach using lidocaine with epinephrine or felypressine with about 1.8 ml of prilocaine.
- block of the sphenopalatine ganglion through the greater palatine foramen using lidocaine with epinephrine or felypressine with about 1.8 ml of prilocaine.
- infiltration anesthesia around the zygoma area through the skin using about 3.6 ml of lidocaine with epinephrine.

The authors' experience is that the procedure is well tolerated by the patient and that the surgery is facilitated by working on a conscious patient.

Immediate loading

Numerous clinical follow-up studies have reported good short-term results with immediate/early loading protocols in the maxilla. In pioneering studies, Tarnow and colleagues (40) reported no losses of 14 immediately loaded implants in two patients, and Horiuchi and colleagues (24) lost two of 36 (5.6%) implants in five patients. In a 1-year study on immediate loading using turned implants, Glauser and colleagues (21) lost two of 18 (11.1%) implants in the totally edentulous maxilla. Olsson and colleagues (30) treated 10 consecutive edentulous patients with oxidized titanium implants connected by a provisional bridge in the maxilla. Nine patients received six implants each and one patient received eight implants. After 1 year of loading, four implants (6.6%) in one patient were lost owing to infection. The losses were not considered to be caused by the immediate loading per se, and no implants were lost in the remaining nine patients. Östman et al. (31) treated 20 patients with 123 oxidized implants for loading with a provisional fixed bridge in the totally edentulous maxilla within 12 h. They reported the loss of one (0.8%) of the 123 implants in the study group after 1 year of loading. A similarly good outcome was reported by van Steenberghe et al. (42) and by Fischer & Stenberg (19). The reasons for the successful outcome may be a result of careful patient selection and concern about primary stability, bearing in mind that bone density is often low in the posterior maxilla. The good results can also be attributed to the fact that the implants can be placed in an arch form, which counteracts bending forces. According to the present authors' experiences, high primary stability can also be achieved with zygomatic implants, and the possibility of using an early loading protocol has been evaluated. In essence, the same surgical technique is used as for a two-stage procedure but abutments are connected to the implants together with sterile impression copings. Impressions of both jaws and bite registration are made immediately following surgery in order to manufacture a provisional fixed bridge that is delivered within 24 h. Some patients received the definitive metal-resin bridge within 5 days. For the former group, the definitive metal-resin bridge is usually delivered 4–6 months after surgery. The patients are instructed to eat a diet of soft food for 4 months. In a recent study (5), the outcome of immediate/early loading was reported for 25 patients, who were treated with 46 zygomatic implants and 127 conventional implants and followed for at least 1 year. No implant losses

and few complications were experienced in this patient group. This is in agreement with the experiences of other authors using zygomatic implants with immediate loading (8, 13, 15, 16, 28).

The use of multiple zygomatic implants

The use of multiple zygomatic implants (i.e. two to three in each side) was suggested by Bothur et al. (10) (Fig. 4A–E). In a recent study, Duarte et al. (16) used four zygomatic implants and no premaxillary conventional implants in the prosthetic rehabilitation of 12 patients with edentulous and severely resorbed maxillas. A fixed bridge of a gold framework and acrylic teeth was fabricated and delivered shortly after implant surgery. The patients were evaluated after 6 and 30 months when the bridges were removed for individual testing of implant stability. One zygomatic implant was found to be loose at the 6-month follow-up and another one was found to be loose at the 30-month check-up. Thus, the overall survival rate was 95.8% after 30 months of follow-up. No severe complications relating to the sinus or the soft tissues were reported.

Extrasinus placement

One drawback with the zygomatic implant technique is the palatal emergence of the implant head, which is often the case because of the desire to maintain the implant body within the boundaries of the maxillary sinus (Fig. 5A,B). This commonly results in a bulky dental bridge at the palatal aspect, which sometimes leads to discomfort and problems with oral hygiene. Zygomatic implant placement with an intrasinus path may even be impossible in patients with pronounced buccal concavities at the lateral aspect of the maxillary sinus. Therefore, an extrasinusal approach to placement of zygomatic implants has been developed to obtain the implant head emergence at or near the top of the residual alveolar crest, usually in the second premolar/first molar regions. Moreover, the implant body should preferably engage the lateral bone wall of the maxillary sinus while entering the zygomatic bone (Fig. 6A). The implant site is prepared without making an opening to the maxillary sinus and otherwise follows the standard drilling steps for zygomatic implants (Fig. 6B).

This leading author has experience with the extrasinus technique in 20 patients with pronounced buccal concavities in whom 36 zygomatic implants and 104 conventional implants were placed (6, 32)

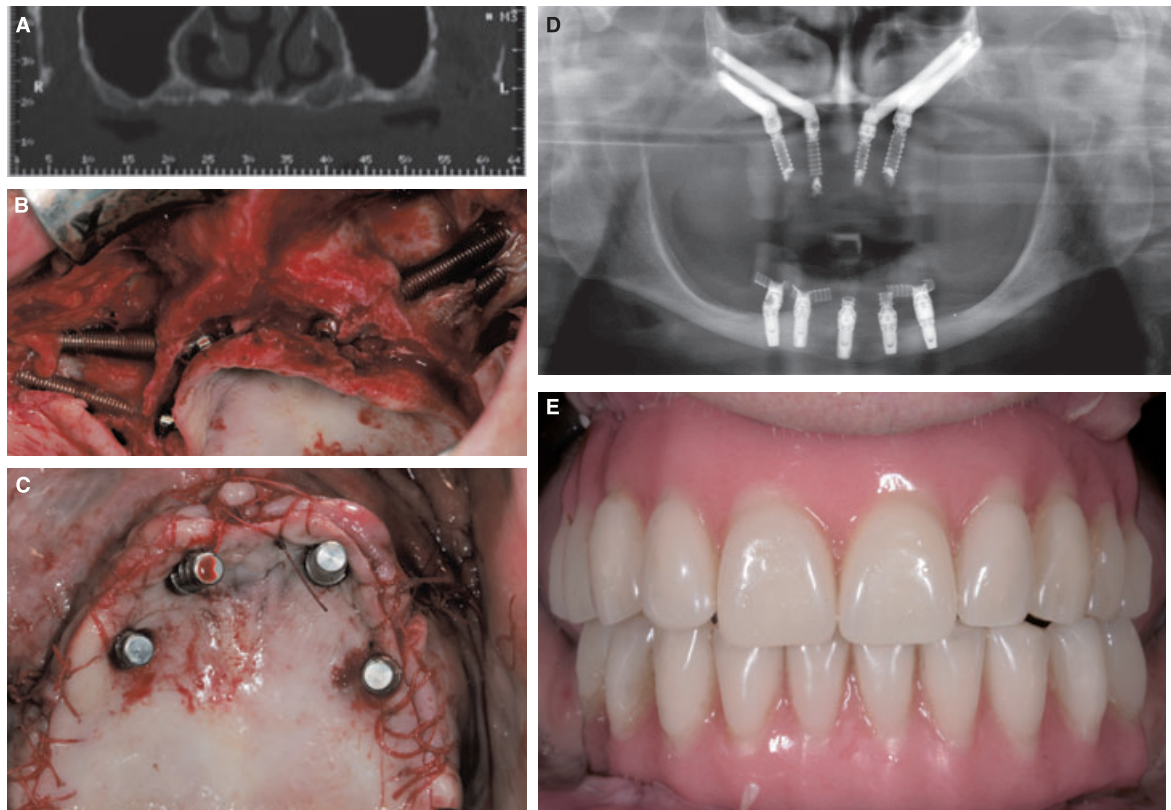


Fig. 4. (A) Radiographs of a totally edentulous maxilla with extreme resorption. (B) The case is solved by the use of four zygomatic implants. (C) Clinical photographs showing the emergence of the four implants. (D) Post-

operative radiograph. (E) Clinical photograph showing the final prosthetic result. The patient has fixed implant-supported metal acrylic bridges in both jaws.

(Fig. 7A–C). Eighteen patients were treated bilaterally and two patients were treated unilaterally. After a mean follow-up of 12 months (range 6–18 months) after occlusal loading, no implants were lost. The post-operative phase included sequels similar to that occurring after the standard zygomatic technique (i.e. some haematoma, swelling and pain). However, no pain, discomfort or complications related to the extrasinus path of the zygomatic implants were recorded after the initial healing period and up to 18-month follow-up. The initial outcomes are encouraging and indicate that an extrasinus approach can be utilized to place zygomatic implants in patients with pronounced buccal concavities in the posterior maxilla.

Concluding remarks

According to the original zygomatic implant protocol, surgery was carried out under general anesthesia and an intrasinus path of the zygomatic implant was prescribed. New developments, as discussed in this article, include the use of local anesthesia and

sedation, the immediate loading of the zygomatic implants, as well as extrasinus placement of the implant, which further simplifies the surgical technique and reduces patient discomfort. Previous authors have described simplified surgical protocols with regard to opening of the sinus cavity. Stella & Warner (39) described a technique where a minimal opening of the sinus wall was used. The technique was later criticized by Boyes-Varley et al. (10), who argued that visualization of the entrance of the implant into the zygomatic bone is important to avoid complications. With the extrasinus approach (6), no opening of the sinus wall is made. Because the implant path is along or lateral to the sinus wall, the engagement of the zygomatic bone is visualized. One concern with the extrasinus technique may be the long-term effect of exposed threads towards the soft tissue at the lateral aspect of the zygomatic implants. However, Lekholm and coworkers (25) did not observe any increased marginal bone loss or failure rate for machined implants with exposed threads at implant surgery compared with fully submerged implants, both of which were followed for 5 years. Moreover, Petruson (37) examined the maxillary sinuses of 14 patients

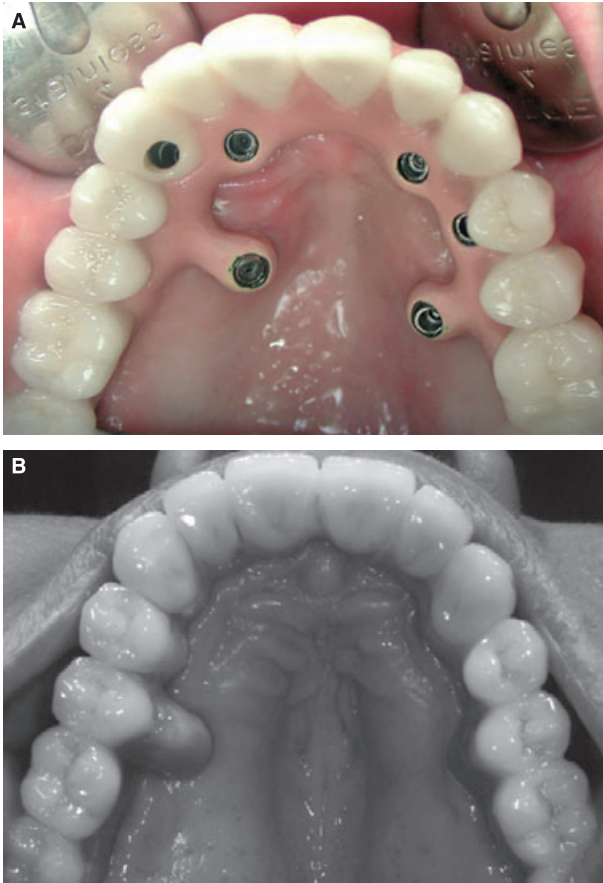


Fig. 5. (A) Final fixed bridge in a patient treated with intrasinus zygomatic implants. Note the emergence of the implants in the palate. (B) Final fixed bridge in a patient treated with extrasinus zygomatic implants. The emergence of the implants is at (right) and slightly palatal (left) to the top of the alveolar crest.

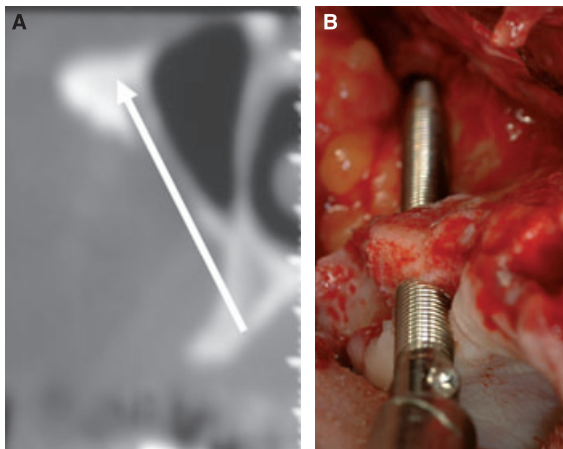


Fig. 6. (A) Tomographic section showing pre-operative planning of an extrasinus zygomatic implant. (B) Clinical photograph showing a zygomatic implant passing through an extreme buccal concavity from the alveolar crest (bottom) to the zygoma (top).

with zygomatic implants using sinuscopy and found no signs of adverse reactions. As discussed by Becktor et al. (7), it is likely that problems with sinusitis are

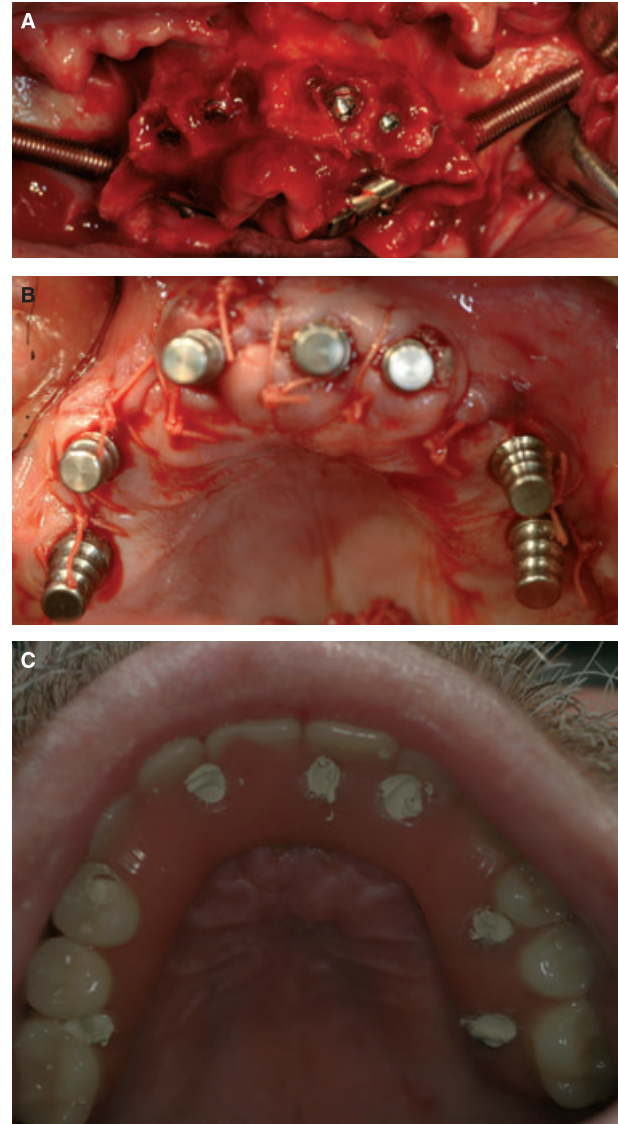


Fig. 7. (A) Clinical photograph of a totally edentulous maxilla with pronounced buccal concavities after placement of two extrasinus zygomatic implants and five standard implants. (B) Emergence of the implants after suturing. (C) In this case, the patient's removable denture has been transformed to a provisional bridge, which was connected to the implants on the same day.

related more to oro-antro communications than to exposed implant threads per se. None of the patients presented above showed any adverse sensations or reactions from the region of the zygomatic implants. It should be stressed that the implants of the present study had a machined surface. At present, zygomatic implants with a roughened oxidized surface are commercially available. However, the change from a machined surface to a roughened oxidized surface must be considered as a major modification and therefore new studies on the long-term performance of implants with this surface are necessary. Considering the complex interface between implant and

bone, oral and sinus mucosa, the use of a rough implant surface may be questioned. Although the bone integration of surface-modified implants seems to be facilitated by a rough surface, the nonsubmerged rough surfaces may attract plaque formation. Moreover, the compilation of reported outcomes showed good results (i.e. a failure rate of 1.6% for more than 1143 machined zygomatic implants).

In conclusion, zygomatic implants are very useful in the prosthetic rehabilitation of the severely resorbed maxilla, regardless of whether it is totally edentulous or partially edentulous individuals. A literature survey, as well as the experience of the present authors, showed that good clinical outcome can be achieved. The zygomatic implant technique should be regarded as a major surgical procedure and proper training is, of course, needed. However, in comparison with bone grafting procedures, the technique is less invasive and complicated and has a lower risk of morbidity because of the fact that harvesting of bone graft is usually not needed. In patients with insufficient bone volume in the anterior region, bone grafting may be required in order to enable placement of conventional implants. However, fewer bone grafts are needed because the posterior maxilla does not need any augmentation procedure. Bone grafting should still be regarded as one option for reconstruction of the severely resorbed maxilla and is necessary in patients where reconstruction of the facial morphology and correction of the intermaxillary relation is desired. Yet, the patient selected for bone grafting reconstruction should know that the clinical outcome of immediate loading is not completely documented.

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