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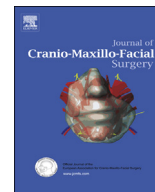
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Immediate dental implant placement in calvarial bone grafts to rehabilitate the severely resorbed edentulous maxilla: A prospective pilot study

Thomas F. Putters^a, Gerry M. Raghoebar^b, Jenneke Klein-Nulend^c, Arjan Vissink^b,
Jurjen Schortinghuis^{a,*}

^a Department of Oral and Maxillofacial Surgery (Head Dr. Jurjen Schortinghuis), Treant Hospital, Emmen-Stadskanaal, The Netherlands

^b Department of Oral and Maxillofacial Surgery (Head Prof. Dr. Fred KL Spijkervet), University of Groningen, University Medical Center Groningen (UMCG), Groningen, The Netherlands

^c Department of Oral Cell Biology, Academic Centre for Dentistry Amsterdam (ACTA) (Head Prof. Dr. Cees Kleverlaan), University of Amsterdam and Vrije Universiteit Amsterdam, Amsterdam Movement Sciences, Amsterdam, The Netherlands

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ABSTRACT

Purpose: The aim of this study was to describe the surgical technique of immediate dental implant placement in calvarial grafts for augmentation of the severely resorbed maxilla and to assess the treatment results.

Methods: In 13 patients the maxilla was augmented with calvarial bone followed by simultaneous dental implant placement (total: 68 implants). In the frontal “knife edge” region, implants were inserted in the buccal plated area. In the maxillary sinus area, implants were inserted into alveolar bone that was plated buccally or palatally through the sinus window. After 4 months, the implants were retrieved and subsequently loaded. Per-operative and post-operative variables were scored. One bone biopsy sample was taken for histological analysis.

Results: The surgical procedure and wound healing was uneventful. During abutment connection after 4 months, all implants were fully osseointegrated with no signs of graft resorption. Radiographically, the mean (\pm SD) peri-implant bone loss after 1 year of functional loading was 0.23 ± 0.44 mm. No implants were lost. Histological examination revealed vital calvarial and maxillary bone with active remodeling.

Conclusion: Immediate dental implant placement in calvarial bone grafts to rehabilitate severely resorbed maxilla is technically feasible and seems to have a high success rate.

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1. Introduction

Placement of dental implants in the severely atrophied maxilla can be a challenge due to the limited amount of bone available. To ensure enough bone to place the dental implants with reliable stability, autogenous bone needs to be transplanted to the maxilla. To create sufficient bone volume in the extremely resorbed maxilla, the floor of the maxillary sinus is usually augmented with anterior iliac crest grafts, combined with buccal plating (Raghoebar, 2001).

After a healing period of 3–6 months, dental implants can be placed in the grafted maxilla. The implants then need to osseointegrate for another 3 months, after which the denture can be made. This rather long treatment period of approximately 8 months can be bothersome to the patient.

Since 2010, we use calvarial bone for the augmentation of the maxilla (Schortinghuis et al., 2012). After a period of 4 months, the dental implants were placed, which in turn, needed to osseointegrate for another 3 months. However, due to the limited resorption that was clinically observed at the time the implants were placed (Putters et al., 2015), we explored whether the dental implants could be placed simultaneously with the augmentation in a prospective pilot study. By combining the time needed for healing of the graft with the osseointegration of the implants, a reduction in

* Corresponding author. Department of Oral and Maxillofacial Surgery, Treant Hospital, Boermarkeweg 60, 7824 AA Emmen, The Netherlands. Fax: +31 (0) 591691932.

E-mail address: j.schortinghuis@treant.nl (J. Schortinghuis).

total treatment time to 4 months would be obtained. Here, we present our experience and clinical and radiographic results of 13 patients in whom a maxilla augmentation with calvarial bone was performed and the implants were placed at the same time. To assess the results of the augmentation at the microscopic level, a bone biopsy sample of one healed grafted maxilla was taken for histological evaluation at 4 months, at the time the dental implants were retrieved.

2. Materials and methods

2.1. Ethical considerations

This study was in accordance with the Medical Ethical Committee guidelines of The University Medical Centre Groningen (approval M14157).

2.2. Inclusion criteria

In 2013 and 2014, a total of 13 consecutive patients with a severely resorbed maxilla and problems wearing dentures were identified to be included in the study. Inclusion criteria were the inability to wear dentures due to retention problems caused by maxillary atrophy, less than 3 mm bone width of the alveolar process in the frontal region, and less than 4 mm bone height under the maxillary sinus as measured using computed tomography (CT). Exclusion criteria were smoking, immunosuppressive medication, and use of bisphosphonates and/or chemotherapeutic agents.

2.3. Surgical procedure

Under general anesthesia, calvarial bone was harvested using a standard technique as described earlier (Schortinghuis et al., 2012), to remove 4–6 outer table calvarial bone blocks measuring approximately 1.5 × 1.0 × 0.3 cm (length × width × height) each (Fig. 1a).

Intraorally, after reflection of the mucoperiosteum, a sinus augmentation procedure was first performed on both sides. An oval bone window was prepared at each sinus location, leaving the sinus membrane intact. After reflexion of the Schneiderian membrane, calvarial bone mass was used to fill up the space created. After this, the calvarial bone blocks could be fixed buccally with 1.3 mm diameter microscrews (Synthes, Wolhusen, Switzerland). The implant was inserted on top to achieve primary stability. When the thickness of the alveolar process in the maxillary sinus region was only as thin as an egg shell, a calvarial graft was placed onto the palatal wall via the sinus window, and fixed by microosteosynthesis screws inserted palatally.

In the frontal knife edge region, the calvarial bone blocks were fixed onto the buccal side. Before fixation, possible soft tissue remnants were meticulously removed from the alveolar process. Care was taken to ensure that the bone blocks had a nice “fit” onto the alveolar process, i.e. the bone graft was in full contact with the remaining process. When needed, the grafts were contoured and/or “hollowed” in the center area (removing part of the diploe) using pliers. During fixation of the graft, the screws were inserted mesially and distally near the edges, allowing dental implant placement between the screws (Fig. 1b).

When needed, grafts were placed on both the buccal and the palatal side (Fig. 2). At least 2, but mostly 3 or 4 screws were used per bone block for fixation. After fixation of the grafts, the sharp edges along the entire calvarial grafts were carefully rounded with a round carbide burr to prevent mucosal perforation due to sharp graft edges. Thereafter, the implant bed was drilled. The location of the start of the pilot drill was usually on top of the knife edge ridge

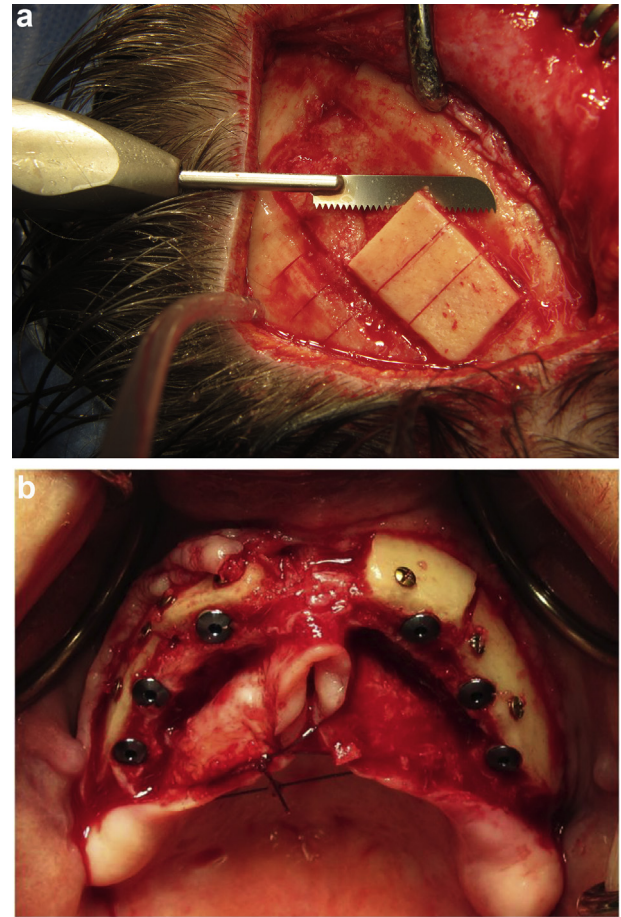


Fig. 1. Immediate dental implant placement in calvarial bone grafts. The calvarial bone blocks were harvested from the tabula externa (a) and fixed onto the alveolar process (buccal plating) with microscrews (b). Between the screws, the dental implants were placed.

or at the interface of the graft and the ridge. The drill was carefully but firmly stabilized during preparation of the implant bed to ensure that the drill moved only vertically, and to prevent tilting of the drill as a result of a lack of stabilization. When drilling the implant bed, the buccal plates did not come loose when properly fixed.

After drilling the implant beds, the bone level dental implants were placed manually. The holes were not tapped. Four or 6 implants (diameter 4.0 mm, length 11.5 mm; Biomet Nanotite Certain Tapered Implant, Biomet 3i, Dordrecht, The Netherlands) were placed in the grafted maxilla (Figs. 1b and 2). After ensuring primary stability, healing caps were placed, and the remaining bone mass was placed around the grafts. After periosteal release, the mucosa was closed tensionless using resorbable 4-0 mattress sutures. No membrane was used.

After 4 months, the implants were uncovered using the same incision as during the augmentation, the microscrews removed, and the healing abutments placed. In 1 patient a 1-mm-wide slice-biopsy sample was taken of the alveolar process (Fig. 3).

After dehydration of the bone biopsy in descending alcohol series, the tissue was embedded without prior decalcification in low-temperature polymerizing methylmethacrylate (MMA, Merck Schuchardt OHG, Hohenbrunn, Germany). Histological sections of 4 µm thickness were prepared using a Jung K microtome (R. Jung, Heidelberg, Germany). Sections were stained with Goldner's Trichrome method to distinguish mineralized bone tissue (green) and

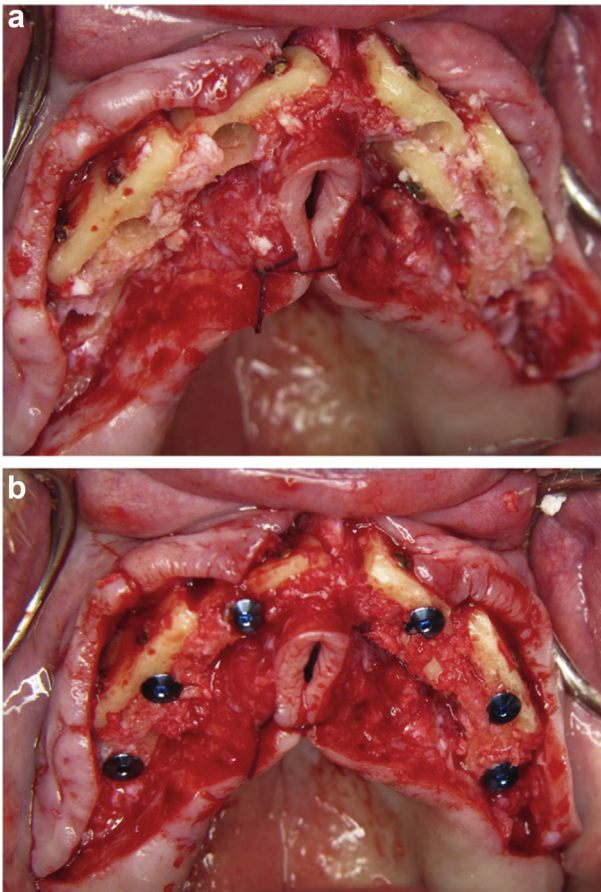


Fig. 2. An extremely thin knife edge was double plated with calvarial bone. (a) Just before implant insertion. The implant bed consisted mostly of calvarial bone. (b) After placement of implants. Scraped calvarial bone mass was used to fill up the gaps.

unmineralized osteoid (red). When the palatal mucosa was very thick, thinning of the mucosa was performed to prevent pseudo pocket formation around the suprastructure. After healing of the gingiva, the suprastructure and denture were made.

During follow-up patients were instructed to visit the dental hygienist and to visit control appointments.

2.4. Follow-up

Per-operatively, perforation of sinus mucosa and primary stability of implants were scored.

Post-operatively, the patients were asked to monitor pain levels daily for both the scalp and intraoral wound using a 10-cm visual analogue scale (VAS), which ranges from 0 (no pain) until 10 (worst pain ever experienced). Clinical and radiological follow-up was at least 1 year in all patients. During regular follow up visits the following items were scored: intraoral wound dehiscence, and signs of infection (swelling, redness, fistulae).

During implant retrieval at 4 months, the following items were scored: signs of peri-implant bone loss, signs of resorption around screw heads, and signs of inflammation (granulomatous tissue, bone graft loss). In one patient without signs of bone loss or resorption, a 1.5-mm-thick bone biopsy sample of the maxilla was taken and fixed in buffered formalin for further histological processing.

After retrieval of the implants, the following items were scored: peri-implant mucositis, peri-implantitis, loss of implants, gingival

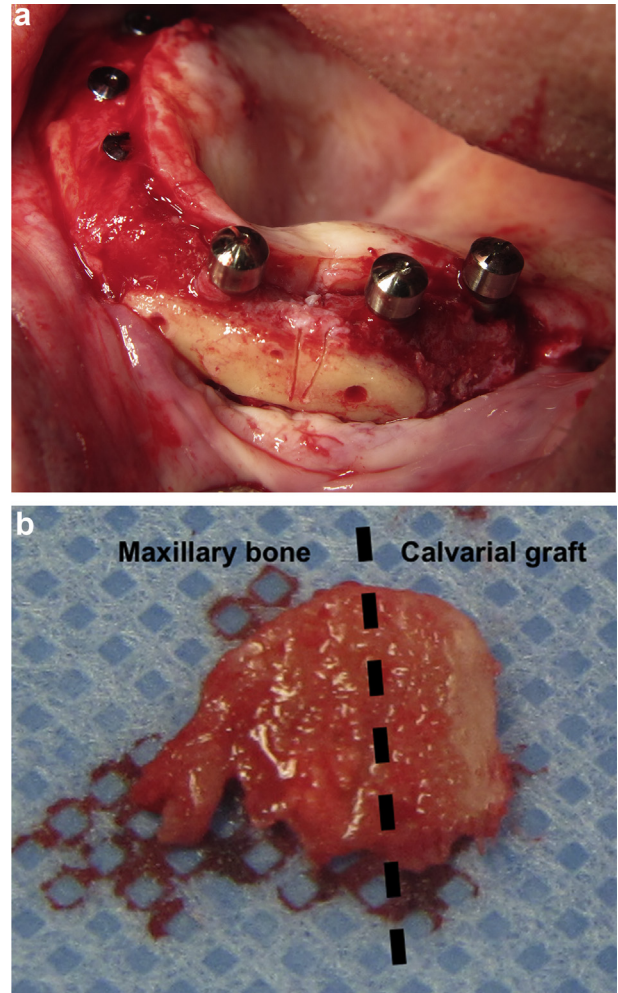


Fig. 3. At 4 months, when the implants were retrieved, the healing abutments were placed and a bone slice biopsy was taken of the augmented maxilla in which calvarial graft as well as a native maxillary bone was present. (a) The calvarial graft seemed well integrated with the alveolar bone and did not show signs of resorption. (b) Biopsy sample on the table. The right side consisted of calvarial graft.

hyperplasia under the bar construction, additional surgical procedures (correction hyperplasias, bone recontouring, removal of implants).

Peri-implant mucositis and peri-implantitis were scored at patient level. As a definition for peri-implant mucositis and peri-implantitis, the consensus reached at the Seventh European Workshop on Periodontology was used (Lang and Berglundh, 2011), i.e. peri-implant mucositis (radiographic bone loss < 2 mm) with bleeding on probing and/or suppuration, and peri-implantitis with bleeding on probing and/or suppuration in combination with marginal bone loss of at least 2 mm.

2.5. Radiographic follow-up

Peri-implant bone levels were measured radiologically on orthopantomograms at the time of implant retrieval just before the denture was made, and after 1 year of functional loading. The orthopantomograms were made using a planmeca device (Planmeca Promax, Planmeca, Helsinki, Sweden), in which the head of the patient was positioned using laser guidance beams. Using calibrated imaging software (Planmeca Romexis, version 4.2.1, Helsinki, Sweden) implant bone levels were measured from the

implant margin to the bone level both mesial and distal of the implant. The average values of the implants were calculated in millimeters.

3. Results

A total of 13 patients (4 male, 9 female, mean age 68 ± 9 years) were included in the study. All patients were operated on by J.S. and T.P.

3.1. Peri-operative course

Augmentation of the maxilla (Schortinghuis et al., 2012; Putters et al., 2015) with calvarial bone was uneventful in all patients. A total of 68 implants were placed. In 5 patients, 4 implants were placed, and in 8 patients 6 implants. In 2 patients it was necessary to double plate the very thin knife edge in the frontal region (Fig. 2). There were no significant perioperative complications, i.e. no sinus membrane perforations were observed, calvarial bone blocks could be fixed properly, and all implants could be inserted with primary stability.

During surgery, the following experiences are of note. First, the calvarial bone pieces can be handled easily and contoured to fit the alveolar process. Microscrews can be inserted into the calvarial bone with ease, and a remarkable tight “fit” onto the remaining alveolar process can be obtained. During drilling of the implant bed, the calvarial graft remains in place and does not become dislodged due to the pressure of the drill or the implant insertion.

All patients were dismissed from the hospital the next day, except 1 patient with a hypersensitivity reaction to the antibiotics used. This patient was dismissed after 2 days.

3.2. Post-operative course

The average intraoral pain levels were low. At the first post-operative day, the average score on the VAS was 0.3 ± 0.8 (mean \pm SD). After 6 days, all patients were pain-free. The mean (\pm SD) follow-up was 30 ± 11 months. During the first 4 months after augmentation, no wound dehiscences occurred. Four months postoperatively, the implants were retrieved. The calvarial bone did not show signs of resorption. The implants were all covered with bone, and no signs of peri-implant bone loss were observed. The calvarial bone around the screw heads did not show resorption. After placing the healing abutments on the implants and subsequent healing of the mucosa, the suprastructures were placed and the dentures made. During further follow-up, no implants were lost. In 5 patients, progressive gingival hyperplasia under the suprastructure limited dental hygiene and resulted in peri-implant mucositis. This was resolved by diathermic correction of the gingiva and extra visits to a dental hygienist.

Radiographically, the average peri-implant bone loss was 0.23 ± 0.44 mm (mean \pm SD) from the time of retrieval of the implants until 1 year of functional loading.

The bone biopsy sample was taken at 4 months between two retrieved implants (Fig. 3). On this biopsy sample, the calvarial graft could be clearly identified by eye. Histologically both the calvarial graft and the remaining alveolar bone showed signs of active remodeling, as could be observed by the presence of non-mineralized (red) areas of newly deposited osteoid. The calvarial bone part was vital, as assessed by the presence of living osteocytes. Osseous contact was observed between the graft and the alveolar bone (Fig. 4).

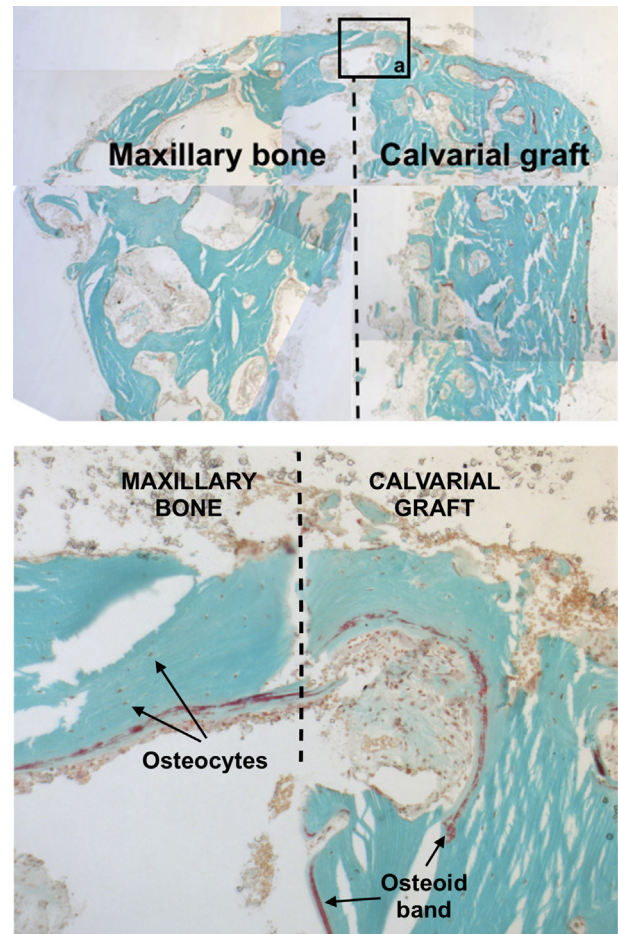


Fig. 4. Histological section of a biopsy of the healed grafted maxilla. Combined image, Goldner's Trichrome stain, magnification $\times 25$. Histology shows the presence of mineralized bone tissue throughout the biopsy (green). The right side represents calvarial graft, the left side maxillary bone (dotted line). Insert (a). Detailed image of the healed grafted maxilla. Goldner Trichrome stain, magnification $\times 100$. Interface between calvarial graft (right) and maxillary bone (left). An osseous bridge is present indicating osseous integration of the calvarial bone (dotted line). Both the maxillary bone as well as the calvarial bone are vital, as indicated by the presence of osteocytes (visible as tiny black “dots” inside the green mineralized tissue), and by the presence of osteoid bands (red).

4. Discussion

In this pilot study, we describe and evaluate an alternative approach to rehabilitate the severely resorbed maxilla with dental implants. The results in this study indicated that it was technically possible to place dental implants in the same procedure as the augmentation of the maxilla with calvarial bone. In addition, the results showed that the dental implants will osseointegrate during the same time period in which the integration of the calvarial bone graft with the maxillary bone takes place.

The concept of augmenting and placement of implants at the same time is not new; it has been, and still is, current practice in sinus lift procedures in which dental implants are placed in the remaining maxillary bone (Ting et al., 2017). This concept is also performed in cases in which implants are placed in combination with guided bone regeneration techniques, for example in single tooth replacement situations (Jung et al., 2017). Here, the implants are placed first, and then they are covered with bone mass. Presumably these techniques are successful, since the implants receive

their primary stability from the tight anchorage in the vital bone of the alveolar process.

An important difference with our study is that we placed implants that received their primary stability by anchorage in the calvarial bone graft, and less in the thin alveolar process. In our patients, it would not be possible to place the implants in the remaining alveolar bone first, and then cover the dental implant with bone.

The implant surface is mostly surrounded by calvarial bone graft. It seems therefore that osseointegration of implants and healing of calvarial grafts occurs simultaneously and successfully.

Augmentation of the maxilla with calvarial bone and simultaneous placement of implants has been performed by others (Lenssen et al., 2011). In one study, 6 temporary implants were placed simultaneously with the augmentation to provide a base for a fixed resin denture. After 6 months, the temporary implants were removed and the definitive dental implants were placed. A high success rate of the temporary implants placed at the time of augmentation was found, which is in accordance with our findings.

In contrast to anterior iliac crest bone, the calvarial bone seems to resorb only to a minimal extent during the healing phase (Mertens et al., 2013). Calvarial bone is much denser than iliac crest bone as graft (Monje et al., 2014), and this may explain why we

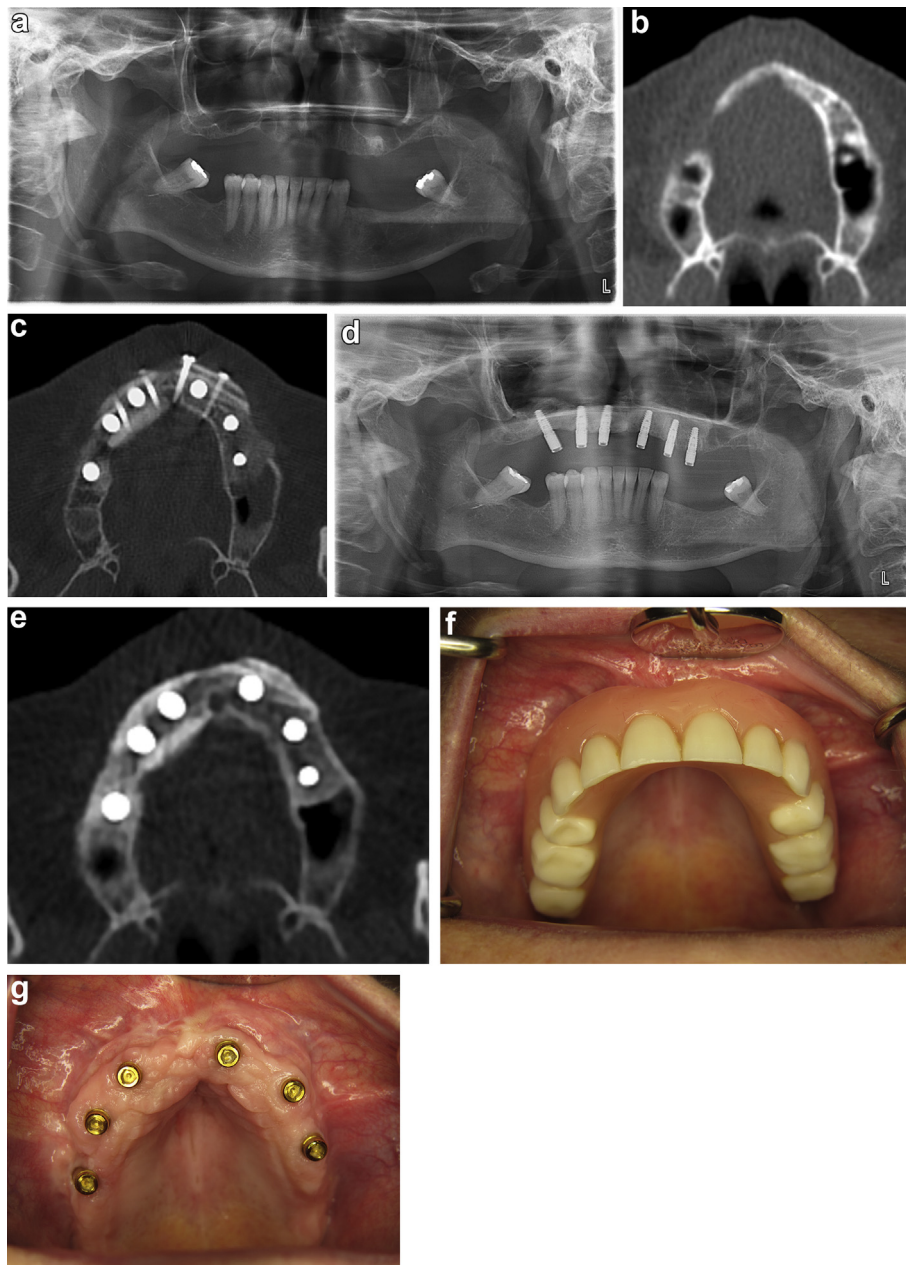


Fig. 5. Illustration of preoperative situation and postoperative result after 4 years and 10 months of functional loading. (a, b) Preoperative OPG (a) and CT scan (b) demonstrating a severely resorbed irregular maxilla. (c) Postoperative CT scan of a grafted maxilla with placed implants. The right side of the maxilla is plated with calvarial bone on the buccal and palatal side. The implants are placed between the osteosynthesis screws. (d, e) OPG (d) and CT scan (e) after 4 years and 10 months of follow-up indicating successful osseointegration of both the calvarial grafts and the implants. (f, g) Final prosthetic result after 4 years of functional loading (f). No signs of peri-implant inflammation or bone loss are present (g).

observed no signs of bone resorption at the time of implant retrieval.

The average peri-implant bone loss in our pilot study was limited, suggesting that the calvarial bone graft functioned well as implant supportive bone. By using calvarial bone and simultaneous placement of implants, we reduced the total treatment time with approximately 4 months by combining the healing period of the grafts with the duration of osseointegration of the implants. Usually, dental implants are placed after the graft has healed. In case of iliac crest bone, this process takes about 3–6 months. Then the implants are placed, which in turn need to osseointegrate for an additional period of 3 months, before the suprastructure can be made.

As compared to anterior iliac crest grafts, calvarial bone grafts seem to have long-term low morbidity, and less pain post-operatively in the short term (Kuik et al., 2016).

The bone biopsy revealed vital bone with active remodeling and close contact between the graft and the alveolar process. This indicates that the graft was healing well and that a “new,” vital maxillary process was formed. This is in accordance with results by others who performed histological evaluation of calvarial bone grafts for intraoral grafting (Orsini et al., 2003; Vinci et al., 2011). During osseointegration, vital bone is formed around the implant. It seems that the calvarial bone graft has become vital within a period of 4 months, enabling osseointegration. However, a more elaborate study involving more bone biopsy samples is needed to make a more evidence-based assessment of the bone density, vitality and remodeling of the calvarial bone graft.

A limitation of this study is the radiographic evaluation. We only measured mesial and distal bone loss around the implant, and not on the buccal or palatal side. However the clinical evaluation (bleeding on probing, bone loss) did not indicate progressive bone loss on the buccal or palatal sides. In one patient, CT scans were made of the grafted maxilla postoperatively and 4 years and 10 months afterward for evaluation of sinus complaints. No peri-implant bone loss was present, and there were no signs of resorption of the calvarial grafts (Fig. 5).

In this pilot study, a small number of patients have been evaluated. The results obtained were positive, i.e., an uneventful surgical procedure and high implant survival rate, and provide an incentive to study a larger series of patients to reproduce and confirm our results in the near future.

5. Conclusion

This prospective pilot study reveals that immediate placement of dental implants in calvarial bone grafts to rehabilitate a severely

resorbed maxilla is technically feasible, seems to have a high success rate, and may reduce total treatment time.

Conflicts of interest

The authors declare that they have no conflict of interest.

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