Reconstruction of Severely Atrophied Alveolar Ridges with Calvarial Onlay Bone Grafts and Dental Implants

Christian Mertens, DDS;* Helmut G. Steveling, DDS;† Robin Seeberger, MD, DDS;*
Jürgen Hoffmann, MD, DDS, PhD;‡ Kolja Freier, MD, DDS, PhD§

ABSTRACT

Objective: Severely atrophied alveolar ridges are most commonly reconstructed with free autologous bone grafts from the iliac crest. The use of these grafts, however, is frequently associated with bone resorption as possible late complication after implant surgery and prosthetic loading. Other donor sites, especially intraoral donor sites, show limited availability. The aim of this present study was to evaluate the clinical and radiographical outcome of alveolar ridge reconstruction with bone from the calvarium and subsequent implant rehabilitation.

Patients and Methods: Reconstruction was performed by using calvarial split grafts in case of severe and complex alveolar ridge defects induced by trauma or bone atrophy. Fifteen patients were treated at 19 different intraoral recipient sites (15 sites in the maxilla, four in the mandible). Autologous block grafts were used for combined vertical and horizontal grafting. After a 3-month healing period, patients received dental implants. A total of 99 dental implants (OsseoSpeed™, Astra Tech AB, Mölndal, Sweden) were inserted and left to heal in a submerged position for 3 months before the prosthetic implant-based rehabilitation was performed.

Results: No donor site complications occurred during or after surgery. At the intraoral recipient sites two infections occurred, leading to partial loss of the grafts. Implant placement, however, was possible in all cases. Two of 99 implants were lost in two patients prior to prosthetic loading. Patients were followed up clinically and radiographically for an average observation period of 28 months. Implant survival rate and success rates were 97.85 and 95.7%, respectively, and a minimal marginal bone loss was documented.

Discussion: The low morbidity at the donor sites and the good marginal bone stability in the reconstructed regions indicate that calvarial bone grafts represent a viable treatment alternative to grafts from the iliac crest.

KEY WORDS: bone grafting, calvarial bone, dental implants, implant survival, marginal bone loss

INTRODUCTION AND OBJECTIVE

For reconstructions of severe alveolar ridge defects, caused by extensive bone atrophy or trauma, bone grafting procedures with autologous block grafts are necessary to allow for a subsequent rehabilitation with dental implants. The use of intraoral donor sites, however, is restricted because of the limited availability of bone volume. The most common donor site for extended augmentation procedures is the iliac crest. However, major concerns are graft resorption and donor site morbidity occurring after transplantation and implant surgery. These observations have been confirmed by several studies.[1–4]

*Senior resident, Department of Oral and Maxillofacial Surgery, University Hospital Heidelberg, Heidelberg, Germany; †private practice, Gernsbach, Germany; ‡chairman, Department of Oral and Maxillofacial Surgery, University Hospital Heidelberg, Heidelberg, Germany; §vice chairman, Department of Oral and Maxillofacial Surgery, University Hospital Heidelberg, Heidelberg, Germany

Reprint requests: Dr. Christian Mertens, DDS, Department of Oral and Maxillofacial Surgery, University Hospital Heidelberg, Im Neuenheimer Feld 400, Heidelberg 69120, Germany; e-mail: christian.mertens@med.uni-heidelberg.de

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Bone resorption of almost 50% is depicted after half a year following grafting with free bone transplants from the iliac crest. With respect to calvarial bone, resorption is reported to be minimal.[5–7] Smolka and colleagues reported a volumetric bone reduction of 19.2% after 1 year.[7]

The use of calvarial bone grafts was first described as an osteocutaneous vascularized flap in 1890.[8] Smith and Abramson[9] and Tessier[10] popularized the use of free outer table calvarial bone grafts. Current applications mainly range from the repair of traumatic defects to the correction of congenital deformities of the midface.[11] For this indication, bone harvesting from the calvarium is quite common. The calvarium is composed of two parallel layers of cortical bone separated by a thin layer of cancellous bone. The mean thickness of the adult skull ranges from 6.80 mm to 7.72 mm but can also deviate between 3 mm and 12 mm.[12]

For maxillary and mandibular reconstructions with calvarial bone grafts literature mainly focuses on unicortical grafts[5,13], however, bicortical calvarial bone grafts are described occasionally as well.[14]

Studies on this technique often lack clear evaluation and success parameters.[15] This makes a comparison with other implant-related studies difficult.

The aim of this study was to evaluate implant survival, implant success, graft survival, graft success, marginal bone loss, implant specific clinical parameters at the recipient site as well as complications and morbidity at the donor site.

PATIENTS AND METHODS

Patients

The study was conducted in accordance with the principles of the Declaration of Helsinki. Prior to the start of the study, the study protocol had been reviewed and approved by the Ethics committee for clinical studies of the Medical Faculty of the Heidelberg University.

For inclusion in this study, patients could only be considered when meeting the following inclusion criteria:

- severe and complex alveolar ridge defects in the maxilla or mandible induced by trauma or bone atrophy
- insufficient amount of horizontal and/or vertical alveolar bone (class V and VI according to Cawood and Howell classification)[16] not permitting conventional implant placement and subsequent implant-retained rehabilitation
- patients' demand of an implant-retained rehabilitation

Exclusion criteria were as follows:

- extensive sagittal misrelationship between maxilla and mandible, which can not be compensated by calvarial bone grafts because of the limited thickness of such grafts and thus requiring other surgical procedures (e.g., onlay grafting with thicker iliac bone grafts or le fort I osteotomy)
- extensive vertical misrelationship between maxilla and mandible, which can not be compensated by calvarial bone grafts because of the limited thickness of the grafts and thus requiring other surgical procedures (e.g., distraction osteogenesis)
- defects resulting from oral cancer treatment (radical surgery in the head and neck region)
- patients with thin calvaria (<5 mm)

Fifteen patients satisfying the inclusion and exclusion criteria were treated in the Department of Oral and Maxillofacial Surgery of the University Hospital Heidelberg between 2007 and 2009.

Of the 15 patients included in this study, 11 were female and four were male. Mean age was 54 years (range 30–71 years). Twelve patients were treated for atrophy and three had alveolar ridge defects caused by trauma. Of the 15 patients treated, all 15 underwent augmentation procedures in the maxilla and four patients were operated on both jaws.

Donor Site Procedure

Presurgical planning consisted of preoperative panoramic radiographs and cone beam computed tomography (CT) in order to evaluate the amount of residual maxillary or mandibular bone. To asses the donor sites, skull radiographs were taken to determine the thickness and density of the parietal bone. Donor site surgery and alveolar ridge reconstructions were performed under general anesthesia.

At the respective donor site, a vertical hemicoronal incision in craniocaudal direction was made on the parietal scalp. The length of the incision was dependent upon the quantity of bone needed and was to allow for good visibility onto the donor site. In this study, only

bone blocks from the outer cortex were harvested (calvarial split bone grafts). The desired dimension of the graft block was outlined with round burs under constant irrigation. A distance of at least 3 cm from the median line was kept to avoid contact with the sagittal sinus in cases of elevation of the inner cortex. The bur should reach the cancellous bone, indicated by bleeding, but should not penetrate the inner side of the cortical bone, preventing contact to the meninges. The block grafts were then segmented in smaller grafts, to facilitate harvesting, and removed using curved chisels. Finally, the peripheral edges of the donor sites were beveled and smoothed with a large bur, and the donor site was closed with multilayered sutures.

Augmentation Procedure

At the recipient site, onlay bone grafting was performed laterally and vertically. Bone-graft layers were placed laterally to increase the bone width and in anterior regions to compensate for sagittal misrelation between maxilla and mandible. To compensate for vertical bone loss and to achieve a sufficient height of the alveolar ridge, bone grafts were inserted using an onlay technique. The grafts were apposed to the native bone surface. All block grafts were rigidly fixated to the residual bone with titanium miniscrews (Modus® System, Medartis, Basel, Switzerland). Small bone segments were placed at transition zones and edges to achieve good bone remodeling.

If additionally sinus lift surgery was necessary, the lateral method described by Tatum[17] was applied. The integrity of the sinus membrane was always respected. As graft material small bone particles or particulated calvarial block grafts were used. Primary wound closure was obtained after periosteal releasing incisions.

Prophylactic antibiotics were applied intravenously until discharge and then continued orally for a total period of 7 days. Sutures were removed after 10 days; patients were not permitted to wear their prostheses for 3 weeks. After this time the prostheses were adapted and relined with soft material.

Graft success was assessed 3 months after surgery (i.e., at implant placement) applying the criteria by Barone and colleagues[18] These criteria are absence of exposure and infection of the graft in the postoperative period, incorporation of the graft to the receptor bed, absence of radiolucent areas, bleeding of the grafted bone when removing the fixation screws, and sufficient bone to place the dental implants.

Implant Therapy

After 3 months of graft healing, patients were scheduled for implant surgery, which was either performed under general (eight patients) or local anesthesia (seven patients). Patients were operated as outpatients and received 99 dental implants (OsseoSpeed™, Astra Tech AB, Mölndal, Sweden). An alveolar crest incision was made and mucoperiosteal flaps were elevated to expose the sites for implant placement. Fixation screws used for stabilization of the bone grafts were removed prior to implant placement. Adequate bone height and width were achieved in all cases and allowed for implant placement. The drilling protocol was performed according to the manufacturer's specification and was adapted to the bone quality. Bone quantity and quality were determined and recorded in accordance with the Lekholm and Zarb classification.[19] The insertion depth of the respective implant was determined by the surrounding bone, ensuring that implant neck and alveolar ridge were at the same level.

Sutures were removed 7 days after surgery. After additional 3 months of submerged implant healing, patients received their implant-retained prosthetic restorations (Figures 1 and 2).

Follow-Up Procedure

Patients were followed up and evaluated by the same single investigator with clinical examinations being scheduled 6 and 12 months after prosthetic loading and on an annual basis thereafter. Clinical parameters, such as Mombelli's modified plaque index and sulcus bleeding index were determined.[20] The peri-implant pocket depths were measured at mesial, distal, vestibular, and oral positions of the implant and the deepest value was recorded. In cases of screw-retained suprastructures, the mobility of each individual implant was tested manually after removing the screw-retained restorations. Occlusion was monitored and hygiene instructions were given to the patients.

For the assessment of marginal bone loss, patients were investigated radiographically from preoperative planning throughout the follow-ups. Radiographic follow-ups were performed using panoramic and intraoral radiographs. Panoramic radiographs were taken prior to the augmentation procedure, immediately after the reconstructive procedure, prior to implant placement, immediately after implant placement and after the completion of prosthetic rehabilitation.

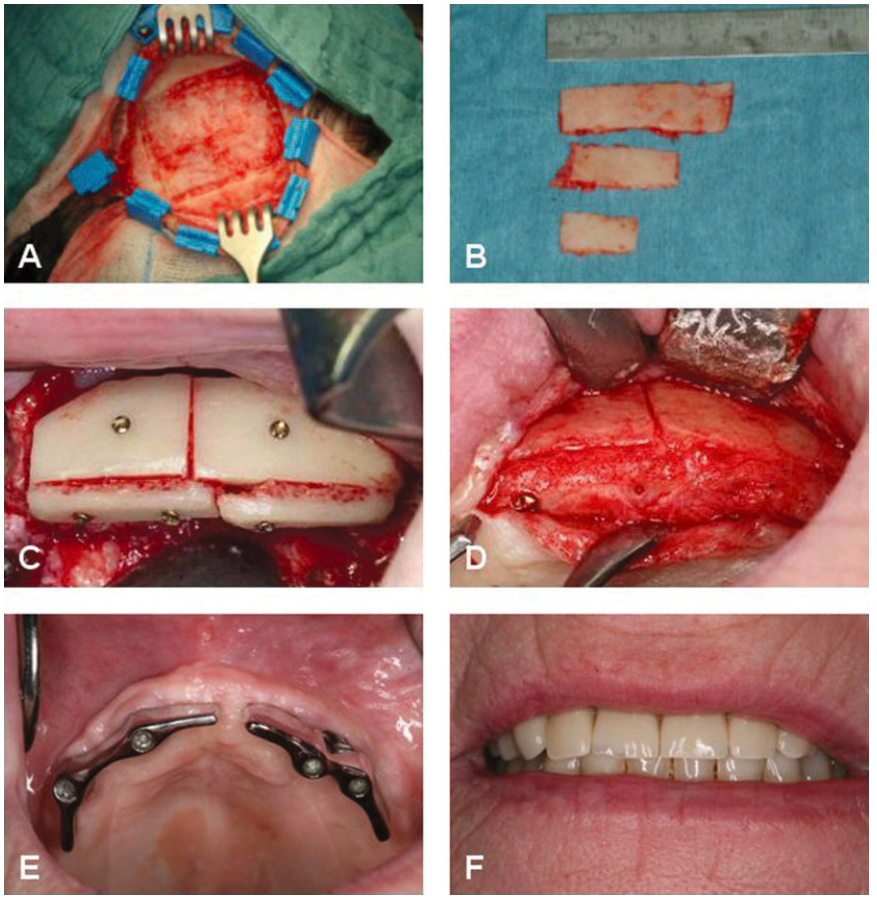

Figure 1 (A) Intraoperative view of donor side surgery after bone harvesting. (B) Harvested pieces of calvarial bone grafts. (C) Intraoperative view of vertical and lateral onlay grafts in the anterior maxilla. (D) Intraoperative view after 3 months of healing before implant placement. (E,F) Removable prosthodontic denture at follow-up visit.

Intraoral radiographs were taken at prosthetic loading and annually thereafter to evaluate marginal bone loss around the dental implants. The distance between the implant reference point (implant shoulder) and the first visible bone to implant contact was measured. Bone level was measured mesially and distally for each implant. Mesial and distal values were analyzed individually and calculated as a combined mean value. To correct dimensional distortion, the apparent dimension of each implant was measured on the radiograph and compared with the actual implant size. To ensure reproducibility between examinations, intraoral radiographs were taken, applying the paralleling technique using film holders. All radiographs were analyzed by the same independent radiologist, who had not previously been actively involved in this study.

Implant success was evaluated according to Albrektsson and colleagues[21] success criteria. Successful implants were characterized by the following criteria: (1) absence of persistent pain or dysesthesia; (2) absence of peri-implant infection with suppuration; (3) absence of mobility; (4) absence of continuous peri-implant radiolucency; and (5) peri-implant bone resorption less than 1.5 mm in the first year of function and less than 0.2 mm in the following years.

Patient Satisfaction

At the last follow-up, patients were asked to fill in questionnaires related to satisfaction concerning donor site surgery and implant-retained prostheses.

For the donor site, assessment the following parameters were analyzed: discomfort at donor side, pain, meteorosensivity, and paresthesia. Concerning the recipient site, the following parameters were recorded: evaluation of function (chewing and phonetics), aesthetics, and overall satisfaction. Response alternatives for patients were as follows: 1 = very satisfied, 2 = satisfied, 3 = neutral, 4 = dissatisfied, and 5 = very dissatisfied. In addition, patients were asked whether they

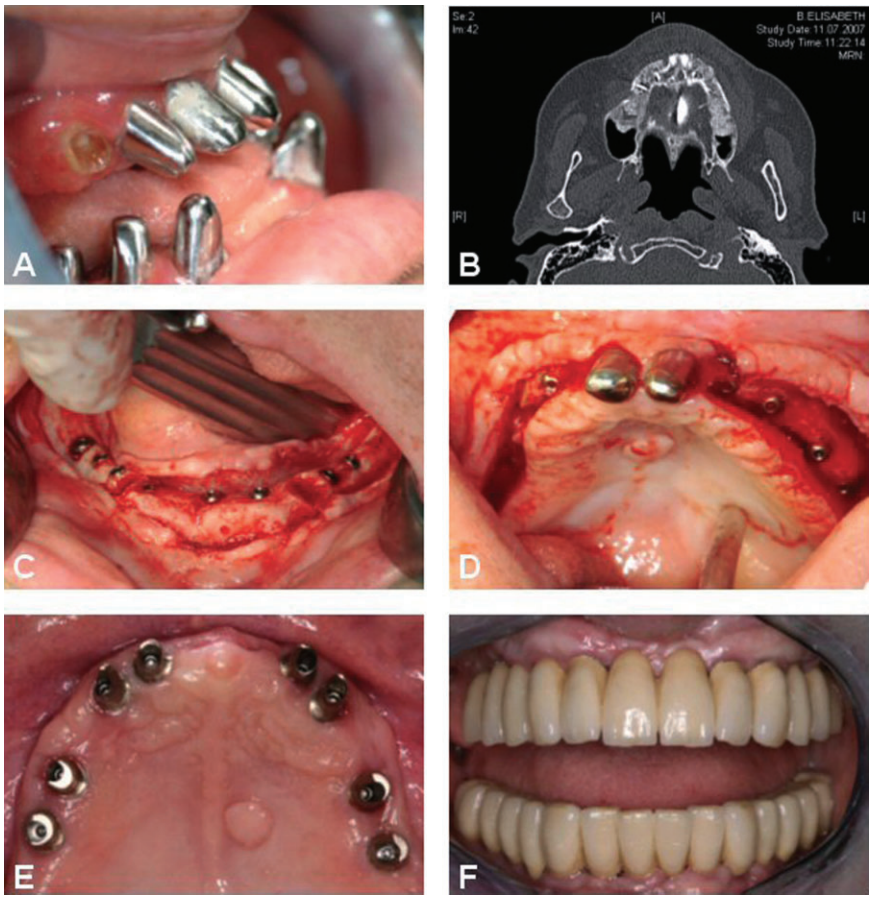

Figure 2 (A) Clinical situation prior to treatment. (B) Postoperative computed tomography scan after onlay grafting. (C,D) Intraoperative view after 3 months of healing after implant placement in the mandible and maxilla. (E) Fixed prosthetic rehabilitation on 16 implants. (F) Prosthetic denture at 3-year follow-up.

would undergo the same procedure again and would recommend the treatment to a friend with similar problems.

Statistical Method

The results of the measurements were then evaluated statistically, using SPSS® Software (SPSS Inc., Chicago, IL, USA). For descriptive purposes, arithmetic mean values, standard deviations, median and percentile values, and cumulative frequencies were calculated.

RESULTS

Bone Stability

In the early graft healing phase, two of the vertical grafts partially failed at the receptor site because of postoperative infection, resulting in a partial dehiscence of the grafted site. After local wound treatment of the infection, the graft was partially removed and the wound could be revised without any further complications.

At the time of implant insertion, there were no signs of graft exposure or infection at the recipient sites. All grafts showed good incorporation into the receptor bed, bleeding of the grafted bone when removing the fixation screws and good bone stability allowing for placement of dental implants (see Figures 1 and 2). No transplant loss or bone-graft resorption was to be documented. All 15 patients received dental implants. Radiographically, there were no signs of radiolucent areas. Using the graft success criteria established by Barone and colleagues, the graft success rate is 100%.[18]

To quantify resorptive changes in the height of bone grafts, measurements were performed using radiographs. The radiographic follow-up showed good stability of the bone dimension and good mean marginal bone stability of 0.5 mm (standard deviation [SD]: 0.6 mm, minimum: 0 mm, maximum: 2.6 mm;

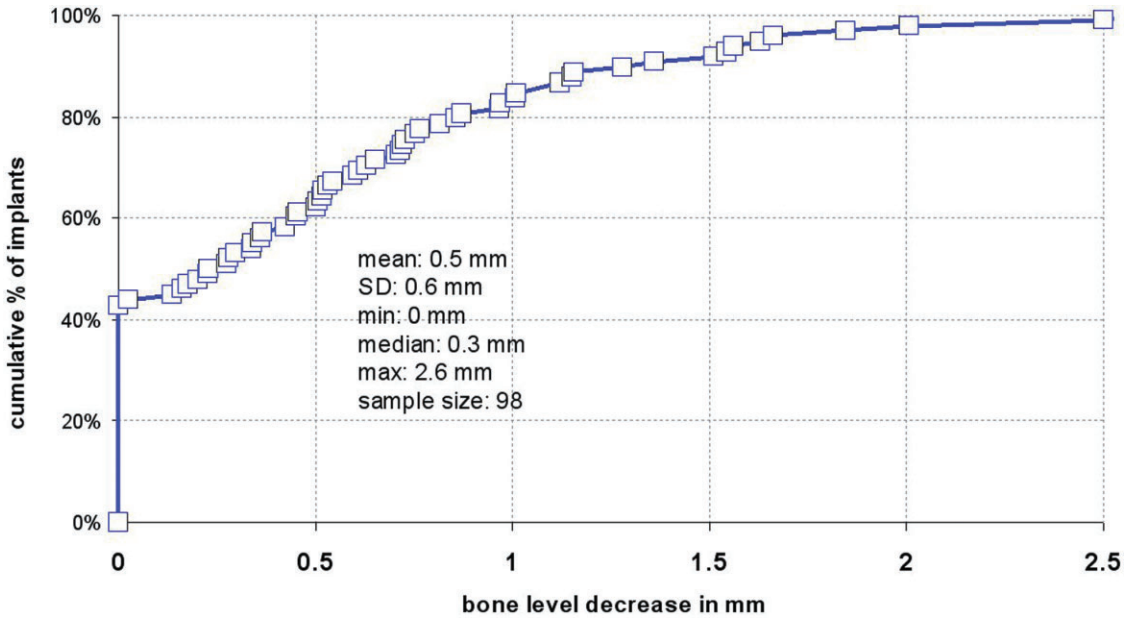

Figure 3 Cumulative distribution function of marginal bone level changes. SD = standard deviation.

Figures 3 and 4). All implants were free from radiolucent zones around them and all implants were functionally loaded. There were no clinical or radiological signs of suppuration, pain, or ongoing pathologic processes.

Implant Therapy

All 15 patients received dental implants. All 99 implants were placed in a two-stage procedure and could be inserted with primary stability and insertion torques >35 Ncm at the time of placement.

The distribution of implant positions and implant dimension is displayed in Tables 1 and 2. In summary, 75 implants were placed in maxillae and 24 implants in mandibles.

Of the 99 implants placed, two maxillary implants in two patients failed osseointegration prior to prosthetic loading and had to be removed. One implant was replaced. The other loss was not replaced. The cumulative implant survival rate was 98.02%. Five implants did not fulfill the Albrektsson implant success criteria,

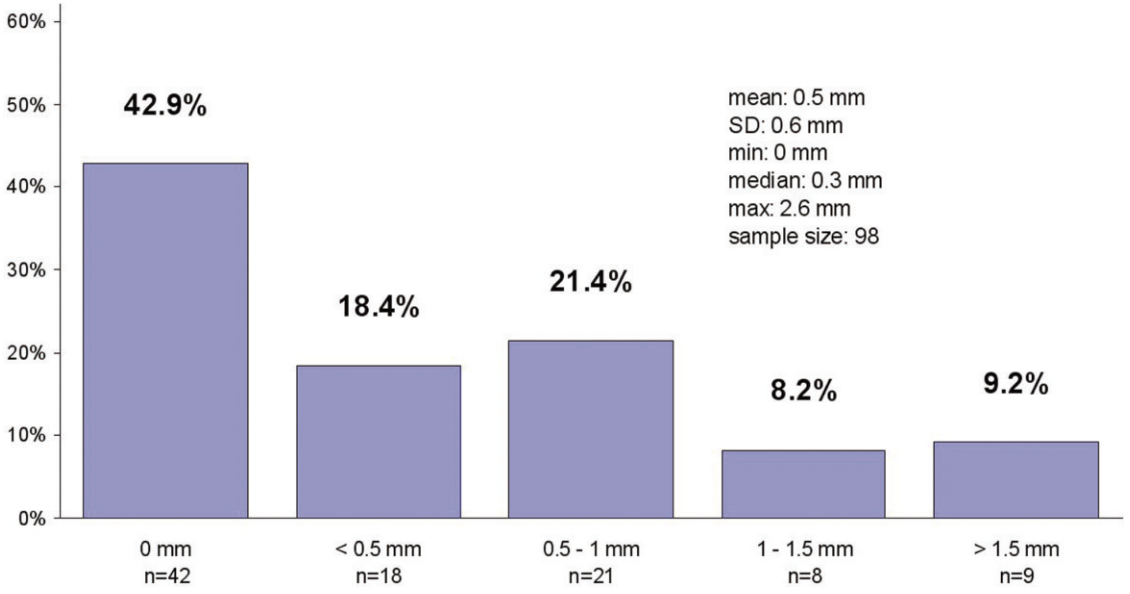

Figure 4 Frequency distribution including descriptive statistics of marginal bone loss. SD = standard deviation.

TABLE 1 Diameter by Length, Implant Frequencies

	Diameter				
Length	3.5 mm	4.0 mm	4.5 mm	5.0 mm	Total
9 mm	11	5	10	3	29
11 mm	22	23	8	1	54
13 mm	10	3	3		16
Total	43	31	21	4	99

concerning marginal bone loss, at the last follow-up, resulting in a success rate of 95.05%.

Ten patients received fixed restorations and nine patients received removable restorations. Fifteen prosthetic restorations were located in the upper jaw and four in the lower jaw. All patients had opposing dentitions at prosthetic loading, which were either tooth or implant retained. No prosthetic or technical complications were observed during the study. The survival rate of the prosthetic reconstruction was 100% because the two lost implants failed osseointegration prior to prosthetic loading.

Clinical and radiographical examinations were performed on an annual basis with a mean follow-up time of 28 months (SD: 9.72 months, minimum: 19 months, maximum: 46 months). At the last follow-up visit, the peri-implant plaque index showed a good oral hygiene for 78.9% of the implants (grades 0 and 1). In 16.9% of all implants, a provocation of peri-implantary bleeding could be induced. A mean peri-implant probing depths of 3.03 mm was recorded (SD: 0.91 mm, minimum: 2 mm, maximum: 7 mm). Occlusion was monitored and hygiene instructions were given to the patients.

TABLE 2 Distribution of Placed Implants according to the Position in the Jaw

Tooth Region	Mandibula	Maxilla	Total
1	2	7	9
2	6	10	16
3	3	15	18
4	4	10	14
5	4	18	22
6	3	15	18
7	2	0	2
Total	24	75	99

There were no further appointments for additional maintenance programs between the scheduled visits.

Donor Site Morbidity

There were no intraoperative complications associated with the bone harvesting technique, such as dura exposure, cerebral injury, or signs of hematoma. Additionally, there were no postoperative complications like postoperative infection or dehiscence. At the last follow-up visit no patient showed signs of keloid, differences in pigment coating or alopecia at the donor site. No patient reported any symptoms of discomfort at the former donor site or pain or paresthesia. With respect to aspects of meteorosensivity, one patient reported a possible sensitivity; however, the patient was suffering from a 30-year history of migraine and was not sure if the reaction was related to the bone harvesting or to the migraine. Directly after the grafting procedure, the patients reported to have no or minimal pain at the donor site.

Patient Satisfaction

Concerning the implant treatment, all patients were very satisfied considering the aspects function, aesthetics, and overall satisfaction. All patients would undergo the same procedure again and would also recommend the treatment to patients with similar problems.

DISCUSSION

For successful osseointegration of implants, a sufficient quantity and quality of bone is indispensable. Thus, in cases of severe and complex alveolar ridge defects, induced by trauma or bone atrophy, bone grafting procedures are essential. Results from extensive augmentation procedures of severe maxillary and mandibular atrophy (Cawood classes V and VI) are often unsatisfactory, unpredictable, and frequently result in higher implant loss rates.

Generally, iliac bone grafts are the gold standard because these grafts can be used for a wide indication of augmentation procedures. But in literature, iliac bone grafts for alveolar ridge reconstructions are associated with higher bone resorption rates than bone from the calvaria.[5–7,22]

In a comparative animal study by Donovan and colleagues, the average bone volumes of calvarial and iliac onlay bone transplants in mini pigs were analyzed after 12 months.[23] The remaining iliac bone was at

52.5%, while the remaining calvarial bone transplant was at 91.2%. Histological analysis showed a higher osteoblastic and lower osteoclastic activity in calvarial grafts. Similar results were reported in another animal study on rabbits by Chen and colleagues[24] For calvarial bone grafts, a resorption of 28% was reported, while iliac bone grafts showed a resorption of 68% after 70 days in a rabbit model. Smith and Abramson reported in their study on rabbits that only 25% of the augmented iliac bone graft remained after 1 year. In contrast, the calvarial bone grafts showed an increased volume.[9]

In a study on humans, a mean three-dimensional volume reduction of 19.2% was determined by using CT scans in five patients with calvarial bone grafts after 1 year.[7] Three further studies analyzed marginal bone resorption of calvarial bone grafts.[5,6] Iizuka and colleagues reported resorption of less than 0.5 mm in 12 of 13 patients after a mean observation period of 19.6 months.[5] The marginal bone resorption observed by Chiapasco and colleagues was between 0.3 mm and 1.2 mm after a mean observation period of 24 months.[22] A histomorphologic study showed that calvarial bone grafts used for sinus augmentation resulted in significantly higher degree of bone volume and vital bone than iliac crest bone grafts.[25]

For iliac bone grafts, on the contrary, a total bone volume reduction of 47–49.5% is reported using CT scans after half a year.[26] Chiapasco and colleagues reported resorption rates of 12 to 60% for iliac grafts in a review.[27] They concluded that the site of bone harvesting is a factor influencing graft resorption rates. In a longitudinal study of Nyström and colleagues, patients had reconstructive surgery with onlay grafts from the iliac crest. After 6 months a mean marginal bone loss of 1.98 mm was reported and after 3 years the bone loss amounted 4.67 mm.[28]

In our study, 15 patients were reconstructed with calvarial bone grafts, dental implants, and prosthetic reconstruction. Patients were followed up for a mean observation period of 28 months. The findings of this study are in accordance with survival rates and marginal bone loss values of other studies evaluating calvarial bone grafts.[22] Considering that vertical bone augmentation procedures are usually associated with higher bone resorption rates,[27] results concerning marginal bone stability (0.5 mm) are quite promising. The implant survival rate in this study is 98.02%. Despite, using calvarial bone grafts, survival rates are comparable with studies analyzing implants inserted in native bone.

One must keep in mind, however, that implants were mostly not solely inserted in the calvarial bone grafts only but were often retained by a combination of native bone and bone graft because of the limited thickness of the graft. This technique is comparable with bone grafting with cortical bone harvested from intraoral donor sites. The limited thickness of the calvarial bone grafts also limits the indications for augmenting bone with these kinds of grafts in a single layer technique. If patients suffer from an extensive vertical or sagittal misrelationship of maxilla and mandible, which can not be compensated by calvarial bone grafts because of their limited thickness, other donor sides with a higher graft thickness (e.g., iliac bone) or other surgical procedures (e.g., le fort I osteotomy with interpositional grafts) have to considered.

The described technique is difficult to compare directly with implants inserted in iliac bone augmentations. Because of their larger dimension, iliac bone grafts often retain the major part of an implant and consequently less implant retention is achieved by the native bone.

Additionally, postoperative morbidity for calvarial bone grafts at the donor site is extremely low with little or no discomfort for the patients.[13,29]

During the observation period of this study, no intra- or postoperative complications had to be reported. These findings are in accordance with several other studies, as reported in a review by Chiapasco and colleagues[27] A multicenter study reported only three cases of temporary neurological complications in 12,672 cranial bone-graft harvestings.[30] The potential complications of outer table calvarial bone graft include alopecia, scalp seroma, or hematoma, dural exposure, intracranial hemorrhage, cerebrospinal fluid leak, meningitis, and brain injuries. A study by Tessier and colleagues reported an overall complication rate of 0.25%.[31] Bone harvesting from the iliac crest is associated with significantly higher morbidity of the patient and the probability of complications is higher. Arrington and colleagues[32] analyzed complications of iliac crest bone harvesting and reported as minor complications superficial infections, superficial seromas, and minor hematomas. Major complications were herniation of abdominal contents through massive bone-graft donor sites, vascular injuries, deep infections at the

donor site, neurological injuries, deep hematoma formation requiring surgical intervention, and iliac wing fractures. Furthermore, pain and walking difficulties are described, which were generally slight and transitory.[18,33]

While calvarial bone harvesting is a safe procedure if performed by an experienced surgical team, potential complications, although quite seldom, can be more severe than in cases of bone harvesting from the iliac crest. Intracranial hemorrhage, cerebrospinal fluid leak, meningitis, and brain injuries would require neurosurgical treatment.

Certain aspects should be considered when performing bone harvesting from the calvaria. The varying mean thickness of the adult skull generally ranges from 6.80 mm to 7.72 mm but can also deviate between 3 mm and 12 mm, which can increase the risk for dural exposure.[12] Because of this reason, it is of utmost importance to harvest bone only from the parietal region where the highest thickness is found, thus reducing the risk of damaging the inner cortex.[34] Furthermore, the thickness of the cancellous layer between inner and outer cortex can decrease with the age of the patient and may even disappear completely.[14] This can increase the risk of penetrating the inner side of the cortical bone. Moreover, a distance of at least 3 cm from the midline of the skull must be respected to avoid sagittal sinus lacerations.[35]

Respecting these aspects risks can be significantly reduced with complication rates range from 0% to 12% with most authors citing rates of 2%.[36–38]

When using calvarial bone grafts, the cortical structure of these grafts must be considered. Grafts are not penetrated by blood vessels for at least 6 days and that complete vascularization takes approximately 1 to 2 months. This is twice as long for vascularization of cancellous grafts.[39] This could also potentially increase the risks for dehiscences. Exposure of bone grafts had to be reported in this study; however, calvarial bone grafts showed mature and compact osseous tissue after a 4-month healing period.[39]

In this study, the bone stability of the augmented bone was analyzed using conventional radiographs only. No three-dimensional radiographic evaluation was performed after implant placement or prosthetic loading to avoid unnecessary radiation of the patient. The applied radiological method allows for good assessment of vertical bone stability; however, it does not give sufficient information as far as horizontal bone resorption or total bone reduction is concerned. However, a reason for the use of this radiographic evaluation method is the possibility to compare the results with other studies evaluating marginal bone stability in native bone. Additionally, the measurement technique used in this study is identical to that in most investigations analyzing marginal bone resorption after implant placement in calvarial bone grafts.[5]

Finally, not only radiographic parameters but also clinical parameters were recorded to assess the implantologic outcome of this treatment procedure, showing stable conditions at the follow-up appointments.

With respect to discomfort and pain for the patient at the donor site, the results of the patient questionnaires are in accordance to the findings of Donovan and colleagues, showing high satisfaction and minimal to no postoperative discomfort following bone harvesting from the outer table of the calvaria and bone augmentation in the maxilla or mandible.[13] Severe bone atrophy or trauma induced bone loss can often result in functional and aesthetic problems. These problems include insufficient retention of the prosthesis, difficulties with speech and eating, loss of soft-tissue support, loss of facial vertical dimension, and an aged face. Such limitations can negatively affect a patient's quality of life and daily activities. Because of the performed treatment, the condition of all patients significantly improved concerning aesthetic and functional aspects. This could be the main reason for the high satisfaction rate of patients included in this study.

CONCLUSION

The results of this study reveal that with the correct indication alveolar ridge reconstructions, using calvarial bone grafts, represent a reliable grafting method that can be a treatment alternative to iliac bone grafts, with a low complication rate at the donor site and with low bone resorption and high implant survival at the recipient side.

The incorporated bone grafts allowed for implant placement with high primary stability. After implant placement and prosthetic loading, follow-ups showed overall stable clinical parameters.

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