Outcomes of Calvarial Bone Grafting for Alveolar Ridge Reconstruction

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Purpose: *This article describes a series of patients who underwent calvarial bone grafting (CBG) for reconstruction of extremely edentulous jaws for the purpose of implant placement.* ***Materials and Methods:*** *A retrospective review was conducted of all patients treated with split CBGs to the atrophic maxilla or mandible between 1999 and 2006. All patients were monitored for signs of infection, dehiscence, or other complications. The amount of augmentation was measured on panoramic radiographs.* ***Results:*** *A total of 15 reconstructed sites (eight maxillary, seven mandibular) in 13 consecutive patients with a mean preoperative height of 6 mm (range, 3 to 9 mm) were included in the study and followed for a mean of 32 months. Ten women and three men aged 40 to 88 years (mean, 63 years) underwent surgery. There were no complications associated with the bone harvesting technique, and all implants had primary stability at the time of placement. Two patients had graft exposure in the maxilla. Two implants were removed in one patient. On average, the gain in ridge height was 15 mm (range, 10 to 19 mm). A total of 53 implants were placed, with an average of four implants per patient.* ***Conclusion:*** *Split CBGs to the atrophic maxilla and mandible can restore optimal height to support and facilitate implant-based restorations. A prospective study with a longer follow-up period is required to evaluate the rate of resorption associated with split CBG. Immediate placement of implants at the time of grafting in the mandible shortens the treatment time.* Int J Oral Maxillofac Implants 2009;24:131–136

Key words: *alveolar ridge resorption, cranial bone grafting, implant reconstruction*

Alveolar bone loss with edentulism is a common finding and is often a sequela of edentulism.[1] The loss of alveolar bone is accentuated over a period of time, and conventional techniques of prosthetic restoration may hasten bone loss.[2] Endosseous implants can slow or prevent bone mineral loss.[3] However, to achieve a predictable long-term outcome for osseointegrated implants, a sufficient volume and quality of alveolar bone must be present at implant recipient sites. Augmentation of the resorbed alveolar crest can be achieved with bone grafts, guided bone regeneration, sinus floor augmentation, split osteotomy, nerve transposition, and distraction osteogenesis.[4–8] Results after treatment of severe maxillary and mandibular atrophy (Cawood classes V and VI) are often unsatisfactory and unpredictable[9]; thus, reconstruction of such severely resorbed edentulous jaws represents a challenge. Free autogenous iliac bone is the most commonly used graft material for an extensive alveolar ridge reconstruction. The application of iliac bone, however, is associated with problems such as unpredictable bone resorption.[10]

In maxillofacial surgery, calvarial bone grafts (CBG) are commonly used for reconstruction of large bone defects of the midface.[11,12] Dandy performed the first human autogenous CBG.[13] Since then, abundant evidence has accumulated indicating the excellence of the calvarium as a source of autogenous bone for the craniofacial area.[14–17] In the 1990s, various authors

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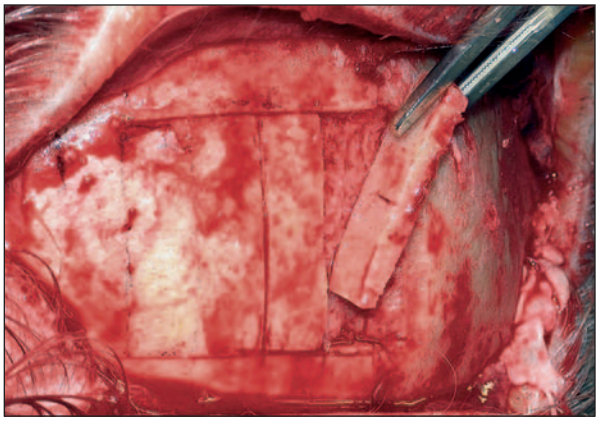

Fig 1 Harvesting the outer table of cranium in strips.

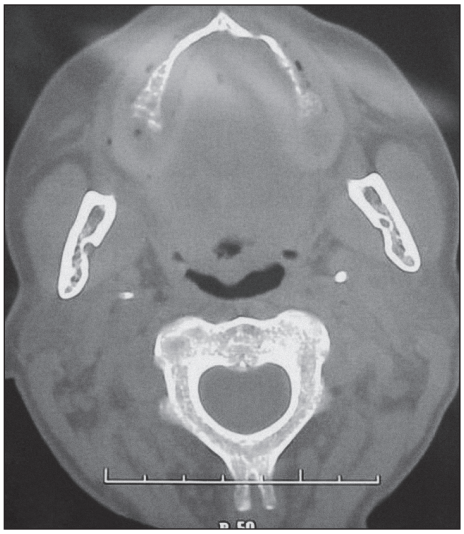

Fig 2 Axial computerized tomogram revealing extreme atrophy of the maxillary alveolus.

reported alveolar ridge augmentation using CBGs.[18–21] Although there have been several reports on CBGs for ridge augmentation, to date there have been no reports on the magnitude of augmentation. This paper describes a series of patients who underwent alveolar ridge reconstruction using split CBGs to facilitate the placement of dental implants. To the authors' knowledge, this is the first study to evaluate the magnitude of ridge augmentation, associated complications, and implant survival.

MATERIALS AND METHODS

This is a retrospective study involving patients who underwent split CBG for the purpose of alveolar ridge reconstruction secondary to severe atrophy. Only those patients who consecutively underwent CBG between 1999 and 2006 to augment the atrophic alveolar ridge were included in the study. Patients with incomplete medical records were excluded from the study. As part of this study, either the maxilla or the mandible was considered as a recipient site. During the postoperative period, both donor and recipient sites were monitored for signs of infection, dehiscence, or other complications. In all patients, preoperative and postoperative alveolar ridge heights were compared. The measurements were initially performed by one of the authors (RG) and were confirmed by another individual not related to the study. All the measurements were taken from patients' panoramic radiographs, all of which were performed on the same machine. The radiographic exposure parameters remained constant for all the patients. Standardized structures such as dental implants or natural teeth were used as references. An assumed magnification factor of 25% was taken into consideration for all images. Postoperative radiographs were made at the initial follow-up visit after surgery.

Split-thickness calvarial bone was harvested in a standard fashion, as described in the literature.[22] Several outer cortical strips (generally five or six for each site) measuring 3 cm × 8 mm were harvested and stored in saline (Fig 1). When augmenting the extremely atrophic maxilla (Fig 2), a high buccal incision was made. A full-thickness mucoperiosteal flap was elevated on both the facial and palatal aspects. Sinus inlay grafting was performed by raising the sinus membrane and the cortical blocks were placed beneath the membrane. A resorbable membrane was used whenever a tear in the sinus membrane was noted. Next, the cortical strips were secured in the form of an onlay graft to the facial aspect of the resorbed alveolar ridge (Figs 3 and 4). The grafts were rigidly fixed using titanium screws. To achieve a uniform and smooth shape, the defects between the grafts were filled with synthetic bone. After 4 to 6 months of healing, dental implants were placed (Figs 5 and 6).

To reconstruct the atrophic mandible, a submental incision was made along the natural resting lines of the skin. The anterior portion of the mandible was exposed via careful dissection. The inferior border was exposed and the periosteum was lifted off the superior aspect of the mandible. The mental nerve was identified bilaterally and protected. Four pieces of the harvested cranial bone strips were placed on the superior and inferior borders of the anterior mandible. The cortical strips were rigidly secured with bicortical titanium screws. To facilitate implant placement, sequential osteotomies were made into

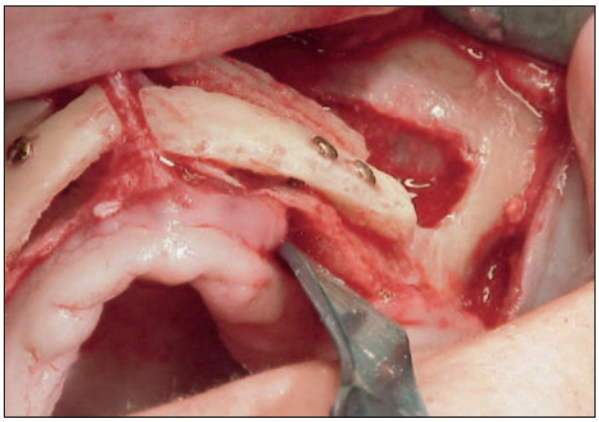

Fig 3 Cranial bone strips are used to augment an extremely atrophic maxillary ridge, along with sinus inlay grafting.

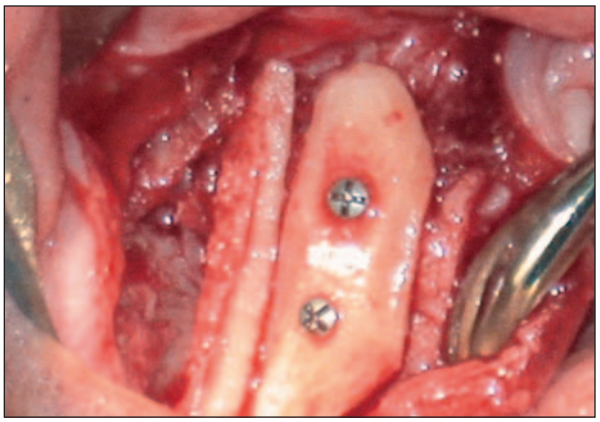

Fig 4 Onlay grafting to the facial and alveolar ridge.

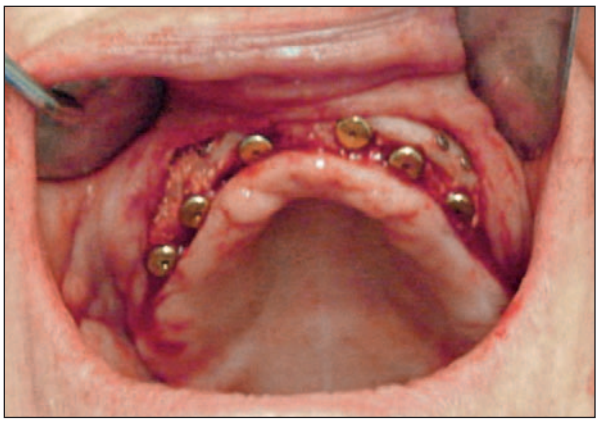

Fig 5 Implant placement after 4 months of healing.

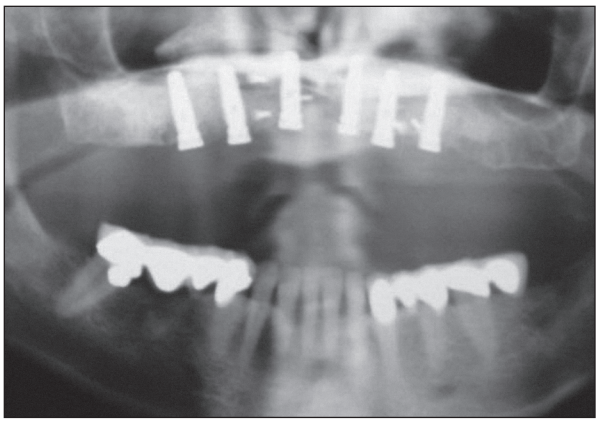

Fig 6 Six months after implant placement.

the reconstructed mandible under copious irrigation. Four dental implants (Nobel Biocare, Yorba Linda, CA) measuring 4.3 × 13 mm were then placed onto the anterior mandible and primary stability was achieved. The incision was then closed in layers with 2-0 Vicryl and 5-0 nylon on the skin. The implants were allowed to osseointegrate for a period of 4 months. Subsequently, patients were restored with implant-supported overdentures.

RESULTS

A total of 15 sites were reconstructed with CBGs in 10 women and three men. The mean age was 63 years, with a range of 40 to 88 years. The mean follow-up period was 32 months (range, 5 to 82 months) after the restoration. Twelve patients underwent this procedure secondary to severe atrophy. One patient had loss of basal bone structure because of trauma. Two patients underwent reconstruction of both the maxilla and mandible simultaneously. There were eight recipient sites in the maxilla (two sites with partial maxillary defects) and seven in the mandible. Because of the extent of bone loss, four patients underwent sinus inlay and onlay procedures simultaneously.

The mean preoperative height in the maxilla was 4.7 ± 2.3 mm (range, 3 to 9 mm). The mean postoperative height of the maxilla was 14.6 ± 3.5 mm (range, 10 to 19 mm). In the mandible, the mean preoperative height was 6.5 ± 1.5 mm (range, 5 to 9 mm). The mean height achieved in the mandible after augmentation was 15.4 ± 2.29 mm (range, 13 to 17 mm). The bone grafts were left for a mean consolidation period of 6 months. However, in five patients, implants were placed at the time of bone grafting in the mandible. A total of 53 implants were placed. On average, four implants were placed in each patient. Two patients had exposure of the bone graft in the maxilla without loss of graft material. One patient

had two implants removed secondary to dislodgement of an implant into the maxillary antrum. The same patient also developed local infection secondary to a previously infected oroantral fistula. Local infection was managed conservatively with chlorhexidine oral rinse and systemic antibiotics. No neurosensory disturbances were noted in any of the patients, and all grafts showed good stability.

DISCUSSION

This report describes the clinical outcome of 13 consecutive patients who underwent CBG for the purpose of implant placement. Preferred donor sites for reconstruction of the extremely atrophic maxilla or mandible are generally the anterior or posterior iliac crest and the calvarium. Although iliac crest bone grafting has been used for many years, it is associated with complications and unpredictable resorption.[10] Because of its dense cortical bone and limited resorption over the years, calvarium is a reliable source. In a report on a series of patients who received CBGs, Iizuka et al reported 0.16 to 1.50 mm of graft resorption after implant placement.[23] The mean follow-up in that study was 19.6 months, and four patients with dehiscence were reported. In one patient the dehiscence was associated with infection. In another study, Iturriaga and Ruiz reported crestal bone loss between 1.5 and 2.5 mm after 1 year.[24] However, there was no further bone loss during the follow-up period (2 to 8 years). Three patients had dural tears during CBG harvest. Two patients experienced intraoral dehiscence, graft failure, and oroantral fistula. One patient had major intraoral bleeding. Smolka et al reported a 95% implant survival in a series of CBGs to the atrophic mandible.[25] The grafted height of the mandible ranged from 9 to 14 mm. In that report, two cases of dehiscence, one patient with infection, and two patients with graft loss were noted. In a recent series, Gleizal and Beziat reported on 73 patients that had undergone CBG for alveolar ridge augmentation.[26] These authors had used bicortical CBGs for ridge augmentation. The majority of the reconstructions (78%) were performed in the maxilla, and the reported success rate was only 89%. The authors had also reported fracture of outer and inner tables after implant placement and dural tears.

In contrast, the present series of patients did not have major complications. The amount of augmentation (10 to 19 mm) in this series is significantly higher than that reported in the literature. No major bleeding or dural tears were noted in this series. Two patients developed soft tissue dehiscence at the recipient site in the maxilla. One patient developed infection and subsequent graft loss. However, this patient previously had an oroantral fistula secondary to trauma. In the same patient, two implants were removed secondary to displacement into the maxillary antrum because of chronic sinus infection. A major finding in this series was the simultaneous placement of implants in the mandible after CBG. This has not been reported in the literature previously.

Because of the thickness of cortical bone, the monocortical parietal portion of the cranium can be harvested. Tessier stated that the parietal area provided bone of the appropriate shape for most facial applications.[16] Pensler and McCarthy demonstrated consistently adequate thickness of the calvarium (7.45 ± 1.03 mm) in this area.[27] Small outer table segments of bone are preferred and easily removed with a small osteotome (Dautrey curved chisel osteotome). A narrow osteotome of 8 to 12 mm is recommended. Similarly, a flexible osteotome may be helpful because of its tendency to follow the curvature of the diploe. The main disadvantage of these techniques is that in inexperienced hands there is more of a tendency toward fracture of the inner cortex. This is rare, and the technique is particularly useful for harvesting smaller grafts. The first segment of cortical bone should be small (5 to 6 mm in width), which improves access for the subsequent segments. Generally, it is prudent to harvest one to two strips more. These can help to add volume and to close any residual bony defects.

Ozaki and Buchman noted that cortical bone grafts resorbed significantly less than cancellous bone grafts.[28] Several others had stated that membranous bone resists resorption to a much greater degree than endochondral bone.[28–30] Lenzen et al had reported a 10% resorption rate at 1 year after CBG.[21] However, the initial healing of cortical bone grafts is slower compared to that of cancellous bone grafts. Hammack and Enneking found that cortical grafts were not penetrated by blood vessels for at least 6 days and that complete vascularization occurred by approximately 1 to 2 months—taking twice as long as vascularization of cancellous grafts.[32] However, calvarial bone grafts showed mature and compact osseous tissue after a healing period of 4 months.[32] Also, rigid fixation of the bone graft blocks is critical to the success of the procedure. Movement of the graft tends to decrease viability, and it is believed that rigid fixation of onlay bone grafts will decrease resorption.[33–37] Postoperative resorption of bone grafts was minimal, even when the grafts were not fully covered by adjacent soft tissue on the inner side.

In the maxilla, onlay bone grafting is indicated primarily when there is severe resorption of the

maxillary alveolus that results in the absence of a clinical alveolar ridge and loss of adequate palatal vault form. Consistent with buccal and labial resorption, the bone graft should be positioned more buccally. This will increase the width and height of the atrophic alveolar ridge. As an indication for bone grafting prior to implant placement in the atrophic mandible, Keller and Tolman stated a minimum mandibular height of 4 to 5 mm and a minimum width of 6 mm.[39] However, major disadvantages are associated with using short implants in a severely atrophic mandible. Stress fractures of the mandible might develop, along with pathologic fracture because of peri-implantitis.[38,40] Anteroposterior and transverse discrepancies between the maxilla and mandible can also be corrected by combining interpositional bone-grafting techniques and lateral ridge grafting, as described in this article.

There are several advantages in using the cranium as a source of bone graft. No visible scar, minimal secondary deformity at the donor site, and less postoperative pain are associated with this procedure. The procedure does not affect respiration or ambulation and therefore involves shortened hospitalization in comparison to costochondral and iliac crest bone grafting. The potential complications of CBG include scalp seroma, hematoma, alopecia, wound infection, paresthesia, bone contour irregularities, dural tear, intracranial hemorrhage, brain injury, cerebrospinal fluid leak, meningitis, air embolism, and death. Scalp seroma is the most common minor complication, but this is prevented by drain placement. Major complication rates range from 0% to 12%, with most authors citing rates of 0% to 2%.[15,41–44]

CONCLUSION

The cranium serves as an excellent source of cortical bone grafts. Based on the results of this study, suitable height can be reconstructed, allowing for placement of dental implants. Immediate placement of the implants in the mandible can be achieved and is a major advantage of using cranial bone grafts. This is a relatively easy procedure to perform if planned properly, and the use of suitable instruments is also key to its success. Although the number of cases reported in this article is limited, there were no complications at the donor sites, correlating to earlier findings. A long-term study with a mean follow-up of 60 months is planned to evaluate the rate of graft resorption.

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