Application of cranial bone grafts for reconstruction of maxillofacial deformities

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This retrospective study evaluated outcomes with the use of calvarial bone grafts (CBGs) in maxillofacial reconstruction as well as donor and recipient site complications. The records of 50 consecutive patients from a private practice were reviewed; there were 34 women and 16 men, with an average age of 32.4 years (range 16 to 66 years). Among the 50 patients, CBGs were placed in 63 sites: the ramus (10), nasal dorsum (14), maxilla/alveolar ridge (12), glenoid fossa/temporal bone (14), mandibular body/symphysis (3), and orbitozygomatic complex (10). The longest follow-up averaged 22.4 months (range 12 to 48 months). An outer-table CBG harvest technique was utilized. All subjects were evaluated for infection, dehiscence, loss of graft, and any other complications. Three complications occurred (5%) at the recipient sites. Two grafts became infected requiring removal, and one nasal dorsal graft was mobile but remained in position. At 50 donor sites, 2 complications (4%) occurred, resulting in dural tears in two patients that were immediately repaired with no untoward consequence. In conclusion, CBGs are an effective bone source for maxillofacial reconstruction with low donor and recipient site complications.

Autogenous bone grafts are the gold standard for reconstruction of maxillofacial defects. Autogenous bone becomes osseointegrated and vascularized at its site of implantation, which decreases the chances of infection, displacement, and foreign body reaction compared with alloplastic implants. The drawbacks are the harvest time, donor site morbidity, graft resorption, modeling changes, and harvest volume limitations (1).

The clinician has to choose the site of bone harvest wisely, taking into account the nature of the reconstruction and volume requirements. Autogenous bone can be harvested from multiple sites, including the calvarium, tibia, anterior ileum, posterior ileum, rib, sternoclavicle, zygoma, mandible, and so forth. The use of calvarial bone grafts (CBGs) was first reported in 1670, when Van Meekren reconstructed a Russian soldier's calvarial defect utilizing a CBG from a dog (2). Other early contributors were Konig (3) and Muller (4) in 1890, reporting on human CBGs for the correction of posttraumatic craniomaxillofacial defects. In the 1980s, Tessier popularized the technique as an aid in the correction of craniofacial deformities (5). Pensler and McCarthy (6) published a study on the thickness and specific anatomy of the calvarium for safe and predictable harvesting.

CBGs have been utilized in reconstruction of the mandible (7), maxilla (8, 9), orbital floor (10, 11), orbital roof (12), malar region (13), and as a strut for nasal reconstruction (14). In craniofacial surgery, the CBG can be used to reconstruct advancement gaps resulting from Lefort I, II, and III procedures.

Outer-table CBGs can be taken from the parietal region of the skull, posterior to the coronal suture, where the skull is the thickest. CBGs can usually be harvested with minimal morbidity at the donor site, with a scar hidden in the hair-bearing region. The geometry and convexity of the CBG makes it suitable for most maxillofacial reconstructions. Due to its cortical nature, the CBG can be rigidly fixated, providing a stable platform for revascularization and osseointegration. In maxillofacial reconstruction, the proximity of the CBG donor site to the surgical site avoids the need for a second distant surgical field, but may preclude simultaneous bone graft harvest and recipient site preparation. Postoperative complications are few, and recovery is relatively painless. The donor site defect of the outer table can be reconstructed with a bone cement that solidifies with endothermic reaction. The graft should not be harvested in the midline because of the risk of injuring the sagittal sinus.

METHODS

This retrospective study consisted of 50 consecutive patients (34 women and 16 men), treated from 1996 to 2010 by a single private practice, in whom only cranial bone grafts were used to reconstruct maxillofacial defects *(Figures 1–2)*. This study was exempt from institutional review board approval. Records were reviewed, including operative reports, discharge summaries, progress notes, radiographs, and photographs. Subjects were excluded from the study if they had less than 12 months of follow up or inadequate records.

All subjects underwent bone harvesting and grafting by the same surgeon (Wolford). The outer-table CBG harvest technique

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Figure 1. Loss of left maxillary alveolar ridge secondary to trauma, reconstructed with layered calvarial bone grafts.

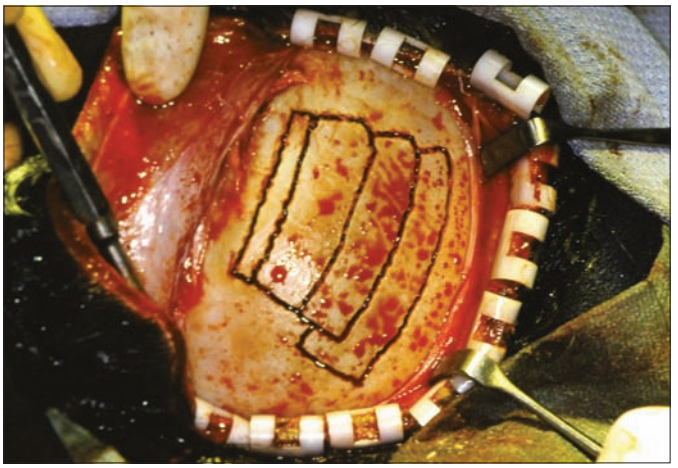

Figure 3. Surgical approach for harvesting of calvarial bone grafts.

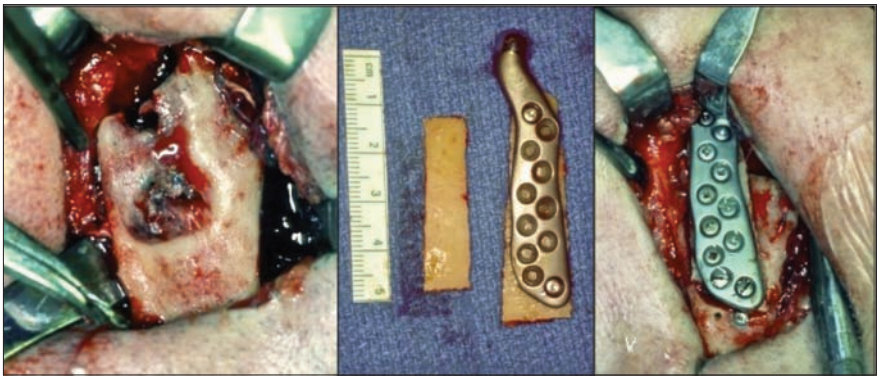

Figure 2. Reconstruction of right ramus and temporomandibular joint with calvarial bone grafts and TMJ Concepts prosthesis (previously Techmedica Inc, Camarillo, CA), following removal of Vitek total joint prosthesis (Vitek Inc, Houston, TX), containing Proplast/Teflon that destroyed the ramus. One calvarial bone graft was attached to the prosthesis to replace the lateral cortical bone, and the second piece was placed on the medial side of the ramus to replace the medial cortex.

was utilized in all patients, and the volume of the bone was harvested according to the recipient site defect. The harvest of the CBG was performed following completion of the recipient site preparation. The initial incision was made 2 cm posterior to the hair line and 2 cm lateral to the midline. The incision was made in a curvilinear fashion, superior to the temporalis muscle attachment *(Figure 3)*. Using a #10 scalpel, the incision was carried down to the cranium. Raney clips were placed at the edges of the incision. Minimal use of Bovie cautery and minimized harvest time decreased damage to the hair follicles. The bone to be harvested was outlined using a 701 burr, to correlate to the amount of bone necessary for the recipient site. The site of harvest was usually 2 cm lateral to the sagittal and squamoparietal sutures. The unicortical osteotomies of outer cortex bone to be harvested were connected. The inferior or superior edge of the donor site was beveled using a pineapple burr in order to access the diploë, deep to the outer cortex. Using a combination of slightly curved and straight osteotomies, the bone grafts were dislodged from the diploë. The bone was kept in saline and placed on ice for preservation. Hemostasis was achieved. The Raney clips were removed, and the incision was closed in a single layer using a 2.0 or 3.0 Prolene suture. A compression dressing was placed for prevention of hematoma. Sutures were removed 7 to 10 days after surgery.

The evaluation consisted of the clinical description of any complication at the donor or recipient site during the procedure, immediately after surgery, and at longest follow-up. The healing and integration of grafts were evaluated clinically and radiographically.

RESULTS

Fifty patients with 63 grafted areas were evaluated. The distribution of grafted areas is shown in the *Table*. The six grafted areas included mandibular body/symphysis, ramus, nasal dorsum, maxilla/alveolar ridge, glenoid fossa, and orbitozygomatic complex. Patients' average age was 32.4 years (range 16 to 66 years), and the longest follow-up averaged 22.4 months (range 12 to 48 months).

The percentage of complications associated with the recipient sites was calculated from the total number of grafted anatomical locations, while the percentage of complications associated with the donor site was calculated using the total number of patients, since there was a single donor site per patient. At the recipient sites, three complications were noted (4.8%). In one case of a maxillary ridge augmentation with simultaneous osseointegrated dental implants, the graft was lost secondary to infection. The second patient had facial congenital infiltrating lipomatosis and received a unilateral orbitozygomatic reconstruction with a CBG, following extensive resection of the tumor, which involved the orbit, zygoma, and associated soft tissue. There was partial loss of the graft secondary to infection, related to the poorly vascularized recipient bed. In the third case a nasal dorsal reconstruction graft became mobile, failing to integrate and fuse to the nasal bony structure, but it remained in place 3 years after surgery. The rest of the grafts healed uneventfully and at the radiographic evaluation appeared to demonstrate adequate integration between the graft and the host bone at long-term follow-up.

At the donor sites, two complications were identified (4.0%). A dural tear occurred on a 16-year-old patient who had only one cortical plate of the parietal bone. The tear was primarily

Table. Distribution of grafts and outcome

Reconstruction area	Number of grafts	Complications at recipient site	Complications at donor site
Mandibular ramus	10	None	2 dural tears; repaired
Nasal dorsum	14	1 mobile graft, in proper anatomical position	None
Maxilla/alveolar ridge	12	1 infection; graft loss	None
Glenoid fossa/ temporal bone	14	None	None
Mandible	3	None	None
Orbitozygomatic complex	10	1 infection; partial graft loss	None
Total	63	3/63 sites (4.8%)	2/50 subjects (4.0%)

repaired. In the second patient the dura tear was also closed primarily. Both patients healed uneventfully.

DISCUSSION

CBGs are used for a multitude of maxillofacial reconstructions, with low complication rates (15). The literature has reported clinical observation of minimal to no resorption of the CBG at short-term follow-up (16, 17).

The reconstruction, although technique sensitive in its adaptation to the recipient site, is safer and more cost-effective than alloplastic grafting (18–20). CBGs can be considered the material of choice for maxillofacial reconstruction due to their histocompatibility, anatomofunction, and mechanical properties (21). Additionally, CBGs are fresh live tissue that will revascularize and osseointegrate to adjacent bone, having a low rate of infection (22).

Although CBGs require time for harvest, unlike alloplastic graft materials, the disadvantages associated with CBGs are few. When large bone grafts are harvested, the donor defect can be reconstructed with synthetic substitutes, which have been reported to result in infections and inflammatory reactions (23). The chance of dural tear exists with outer-table CBG harvesting if the inner table is penetrated (24). In harvesting outer CBGs, the possible complications are intracerebral hematoma, subarachnoid hemorrhage, and cerebrospinal fluid leaks (25), none of which were encountered in this study. Additionally, the volume of graft to be harvested could be a limiting factor for large defects requiring reconstruction (24). Removal of the outer table where the residual defect is inadequately filled can result in a cosmetic defect in the skull.

Although no controlled human studies have measured the exact rate of resorption and retained volume of CBGs, the clinical studies support stable outcomes (26–28). DeLuca et al reported an animal study, where the CBGs had a volume retention rate of 85.1%, and recommended CBGs as the gold standard for craniofacial reconstruction (29).

In our retrospective study, the complication rates at the donor site (4.0%) and the recipient site (4.8%) were relatively low. The outer-table CBG harvest technique is a time-consuming procedure compared with use of alloplastic and tissue-engineered materials. In comparison to bone grafts obtained from other anatomical sites, CBGs benefit the operator with one field of surgical access, eliminating the preparation of a distant second site. The reported complication rates are low. This bone grafting procedure is an effective technique for reconstruction of maxillofacial defects.

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