Use of a customized 3D “basket” to create a solitary split-thickness cranial graft from numerous split fragments in an infant

Technical note

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While autologous split calvaria remains the preferred material for use in pediatric cranioplasty, it may be difficult to split the bone neatly into two distinct pieces, especially in infants and young children. In this paper, the authors present a technique in which numerous split pieces of bone can be readily joined together and conformed to the shape of the specific defect using a customized template and 3D trellis-like basket. (http://thejns.org/doi/abs/10.3171/2014.5.PEDS1420)

KEY WORDS • cranioplasty • 3D • basket • split-thickness • autograft • technique

The illustrative case

This 18-month-old girl was mauled by a dog when she was 11 months old, which resulted in a near complete amputation of the left ear, a comminuted, depressed, left parietal skull fracture, a left parietal subdural hematoma, and an intraparenchymal contusion. These injuries were treated at an outside institution with a craniectomy for elevation of the skull fracture, evacuation of the hematoma, and debridement of the overlying soft tissues. The bone defect was repaired using titanium mesh. The patient’s course was complicated by recurrent otorrhea and meningitis, ultimately necessitating the placement of a ventricular shunt. She was transferred to our institution (Albert Einstein College of Medicine of Yeshiva University/Montefiore Medical Center) with fevers and persistent leakage of CSF from the scalp. Magnetic resonance imaging revealed a large enhancing collection draining from the scalp to the subdural space. Ultimately, an explantation of the mesh implant, evacuation of the collection, removal of the shunt with placement of an external ventricular drain, and further debridement of the scalp was required. The patient convalesced and the infections cleared without incident.
“Basket” cranioplasty

Six months after removal of the mesh implant the patient was brought back to the hospital electively for a definitive repair of the 5.4- × 4.4-cm left parietooccipital defect (Fig. 1A). A split-thickness skull graft was planned. Given the size of the defect and the thinness of the remaining parietal calvaria (in some areas less than 3 mm), we anticipated that splitting the skull graft into 2 pieces might prove difficult. Therefore, a 3D model of the skull was developed from a CT scan (Fig. 1B). A custom-made, 3D contoured “osteotomy guide” (VSP Reconstruction) that matched the defect was created to serve as a template to assist in harvesting the calvarial graft (Fig. 1C). Additionally, a unique 3D “positioning guide” (VSP Reconstruction) that also matched the shape and contour of the defect (as well as the osteotomy guide) was created (Fig. 1D). The positioning guide possessed a flat base so it would rest on the sterile working table (back table) and serve as a collection basket in which fragments of split bone could be placed and affixed together to form 1 graft (Fig. 2A). Like a basket, the positioning guide possessed a trellis-like base so that small screws could be placed in the split bone from above and below.

Operative Technique

A segment of the skull anterior to the defect was chosen, and a craniectomy conforming to, but slightly larger than, the custom osteotomy guide was performed. Next, as described by Steinbok et al., Tessier bone benders were used to create a shearing space within the craniectomised bone.10 The small, thin, straight osteotomes and a 3-mm sagittal saw were used to split the graft in two. The bone flap was particularly thin and brittle; instead of a single

![Fig. 1. A: Three-dimensional CT reconstruction of the left parietooccipital skull defect in the patient. B: An image generated by the 3D printing system that was used to create the 3D osteotomy guide. It should be noted, however, that a complete 3D production of the entire calvaria is not necessary to produce the osteotomy and positioning guides. C: The contoured osteotomy guide based on the 3D model. D: The 3D porous positioning guide to aid in securing the split fragments. All of these 3D tools can be produced within 1–2 weeks of order.](image-url)
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split-thickness graft, multiple smaller pieces and fragments of bone were separated from the outer layer. Using the osteotomy guide as a template, a piece of bioabsorbable plate (Stryker Delta System) was fashioned to fit the shape of the defect and this plate was placed inside the positioning guide. Bone pieces were positioned above and below the bioabsorbable plate, within the positioning guide. Thus, the positioning guide served as a shape-matched receptacle or basket in which the free bone pieces sandwiched the bioabsorbable plate. The bone pieces were affixed to the bioabsorbable plate on both sides using 1.73-mm bioabsorbable screws (Fig. 2B). With this approach, despite being unable to successfully split the original bone flap into two distinct outer and inner grafts, we were able to essentially construct a structurally sound graft from free bone pieces in the exact shape and size of the defect, without any osseous gaps. Both “halves” were then fixed to the surrounding skull with bioabsorbable plates and larger (4-mm) screws (Fig. 2C) to fill the cranial defects. The scalp was closed in the usual fashion. After 6 months of follow-up, the patient’s cosmetic result has been excellent and no further imaging is planned.

Discussion

Autologous split calvaria garners near unanimous support as the preferred option for pediatric cranioplasty.\(^1\)\(^,\)\(^2\)\(^,\)\(^9\)\(^,\)\(^10\) Cautioning against its use in children under the age of 3 years, some authors, especially in older reports, point to the lack of a true diploic space in the parietal bones of children in this age group.\(^4\)\(^,\)\(^8\) As has been described by Steinbok et al., however, by squeezing the craniectomised bone with Tessier bone benders to create a plane of separation, fixing the graft to a vice clamp, and then separating the 2 layers with thin osteotomes and a 3-mm sagittal saw, we are often able to split the graft in two in these younger patients with relative ease.\(^6\) However, there exists marked variability in skull thickness among children.\(^8\)\(^,\)\(^9\) Furthermore, prior infection, trauma, and long-standing hydrocephalus may affect the integrity and quality of the bone available for grafting.\(^9\)\(^,\)\(^10\) Even in the most experienced hands, therefore, splitting the bone into 2 identical pieces in some circumstances may prove impossible.

The advent of 3D printing has enabled surgeons to create perfectly customized alloplastic implants for cranioplasty.\(^7\)^\(^1\)\(^1\) While such materials are certainly acceptable in adults, we disapprove of their use in the skull of a growing child because they may destabilize with growth.\(^2\)\(^,\)\(^4\) Nevertheless, by using 3D printing to develop specific tools to facilitate the creation of a solitary split graft from multiple bone pieces and bioabsorbable plates, the surgeon can circumvent the problems posed by even the thinnest and most brittle of pediatric skulls.

Conclusions

When anticipating difficulty in splitting calvarial bone in a young child, a customized 3D trellis-like basket designed to match the shape of the skull defect can be a helpful adjunct in the construction of a structurally sound and cosmetically appealing graft.

Disclosure

The authors report no conflict of interest concerning the materials or methods used in this study or the findings specified in this paper. The authors harbor no financial interest in any of the products presented in this paper.

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