

The Use of Porous Granular Hydroxyapatite in Secondary Orbitocranial Reconstruction

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The search for the ideal bone-graft substitute has been the focus of many research and clinical studies. Hydroxyapatite is one such material that combines osseointegration with maintenance of implant volume and excellent durability. We present our experience in 29 patients ranging in age from 3 to 22 years (mean age 10.5 years) who underwent secondary orbitocranial reconstruction of large contour defects utilizing porous granular hydroxyapatite. Follow-up ranges from 6 to 72 months (mean 30 months). Indications for secondary surgery included residual bony contour defects of the frontal bone, temporal areas, and superior orbital rims that were present 12 months or more after initial surgery. There was one infection secondary to a chronic seroma necessitating removal of the porous hydroxyapatite, and one patient required revision for underfilling and another for overfilling. Excellent permanent contour improvement was obtained with a smooth skin surface in the remainder of our patients. The contour corrections have been long lasting, without evidence of porous hydroxyapatite resorption or migration. (*Plast. Reconstr. Surg.* 100: 869, 1997.)

There has been interest in biomaterials that can be used as bone substitutes in craniofacial and maxillofacial surgical applications.^{1,2} Certain mechanical and biologic properties are desirable but difficult to obtain; these include biointegratability, mechanical strength, torque resistance, ease of application, and stability over time.¹⁻³ Hydroxyapatite is a synthetic bone-graft substitute made by conversion of the calcium carbonate exoskeleton of sea coral that is available in block and granular forms. Its porous structure behaves as a scaffold and allows ingrowth of native surrounding osseous tissues, with bony union seen as early as 90 days after implantation.^{3,4} The use of block hydroxyapatite to span osteotomy gaps in maxillofacial surgery has been successful despite its fragility

when submitted to rotatory stresses.⁵⁻⁷ Block hydroxyapatite is difficult to shape and fix because of its inherent fragility, particularly after it absorbs moisture, making it less than ideal for filling of contour defects.⁶⁻⁹ The edges of the blocks often show below relatively thin soft-tissue covering such as the forehead and peri-orbital regions. Porous granular hydroxyapatite, although lacking in compressive strength, is ideal for filling contour defects in the upper facial skeleton. Porous granular hydroxyapatite is well tolerated by both soft and osseous tissues, can be mixed into an easily applicable paste, and does not show under relatively thin soft-tissue cover. Marchac¹⁰ in 1991 and Byrd et al.¹¹ in 1993 reported their experience utilizing hydroxyapatite granules for a variety of small craniofacial skeletal defects in various anatomic locations. Although the use of block hydroxyapatite in maxillofacial applications and of porous hydroxyapatite in limited orbitocranial defects has been largely successful, little is known regarding the use of porous hydroxyapatite for large contour defects of the orbitocranial region.^{5,7-11} Furthermore, the use of porous hydroxyapatite in growing children and adolescents has not been specifically addressed. We report on our use of porous hydroxyapatite for reconstruction of clinically significant orbitocranial contour defects in infants, adolescents, and young adults.

PATIENTS AND METHODS

Twenty-nine patients ranging in age from 3 to 22 years (mean, 10.5 years; 16 males and 13 females) underwent porous hydroxyapatite re-

construction of a variety of frontal bone, temporal, and upper orbital bony contour defects. These included 9 patients with frontal-basilar trauma and 17 patients who had surgery for craniosynostosis (Table I). All patients were at least 1 year after initial reconstruction at the time of their secondary surgery. Follow-up was from 6 to 72 months (mean 30 months). Porous hydroxyapatite (granule size 425 to 1000 μm) was mixed in a ratio of 1 cc porous hydroxyapatite to $\frac{1}{2}$ cc of the patient's blood and $\frac{1}{2}$ cc of microfibrillar collagen to form a dense paste of adherent porous hydroxyapatite. The bony defects were all approached through a coronal incision, taking great care to stay in a supraperiosteal plane. The periosteum was raised as an anteriorly based vascularized flap (Figs. 1 and 2). In patients in whom the temporal areas needed to be addressed, the temporalis muscle was raised in the deep subperiosteal plane. Protuberant hardware was removed, and all bony peaks were burred down before filling the defects with the porous hydroxyapatite paste. The periosteal flaps were

TABLE I
Patient Summary

Age (years), Sex	Diagnosis	Complications
11, M	Left coronal synostosis	None
22, M	Fibrosis dysplasia	Excess porous hydroxyapatite
2, F	Metopic synostosis	None
5, M	Sagittal synostosis	None
18, M	Trauma	None
13, M	Crouzons disease	None
23, F	Trauma	None
13, F	Right coronal synostosis	None
11, F	Trauma	None
18, M	Left coronal synostosis	Deficient porous hydroxyapatite
10, M	Sagittal synostosis	None
14, M	Trauma	None
13, F	Facial clefting	None
4, F	Metopic synostosis	None
22, F	Trauma	None
15, M	Trauma	None
4, F	Bicoronal synostosis	None
18, F	Trauma	None
4, M	Metopic synostosis	None
18, M	Trauma	None
8, M	Trauma	None
5, F	Metopic synostosis	None
5, F	Facial clefting	Infection of porous hydroxyapatite
3, M	Metopic synostosis	None
7, M	Aperts	None
5, F	Metopic synostosis	None
3, M	Metopic synostosis	None
2, M	Sagittal synostosis	None
10, F	Bicoronal synostosis	None

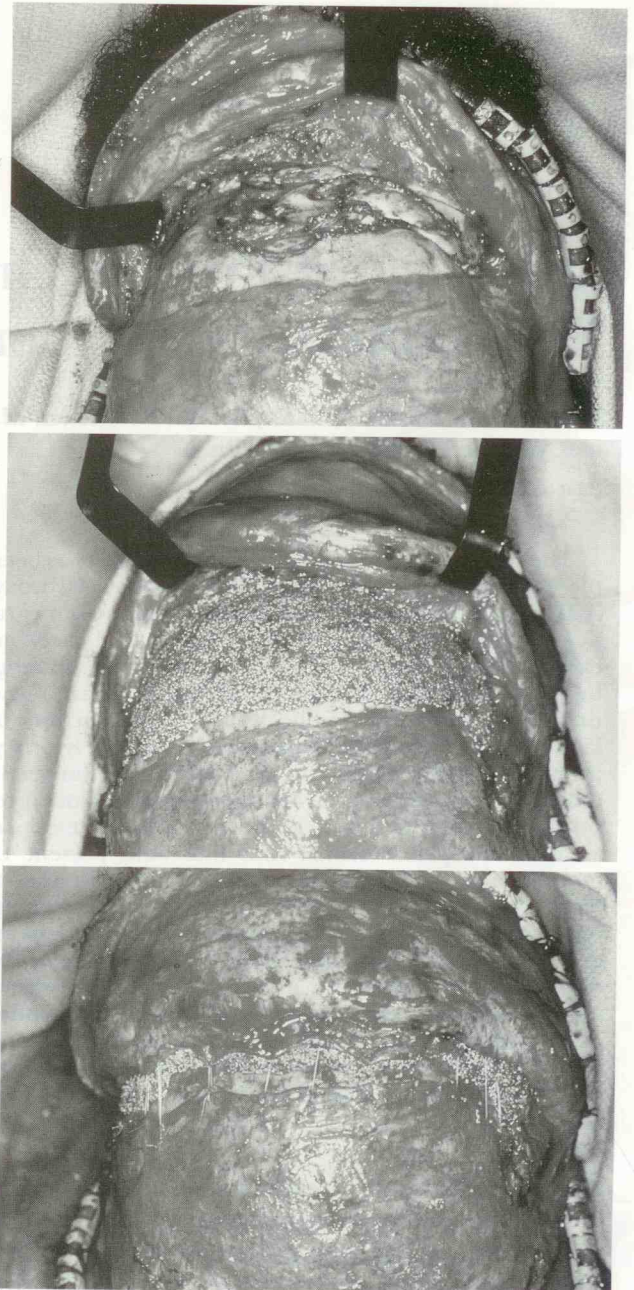


FIG. 1. (Above) Intraoperative photograph of patient 1 year after open reduction and internal fixation for fronto-basilar trauma. Bicoronal scalp flap is at top of photograph. Note irregular bone resorption along fronto-orbital complex. Periosteal flap is under black retractors. (Center) Intraoperative photograph. After burring down high points, all contour defects are filled with porous hydroxyapatite paste. Note feathering of porous hydroxyapatite thickness at edges. (Below) Periosteal flap has been sutured to the intact posterior periosteal edge, covering and retaining the porous hydroxyapatite construct. Bicoronal flap is at top of photograph.

then sutured at the borders of the bony defects in order to create a sealed pocket for the porous hydroxyapatite paste. A neurosurgical type head dressing was kept on for 5 days post-

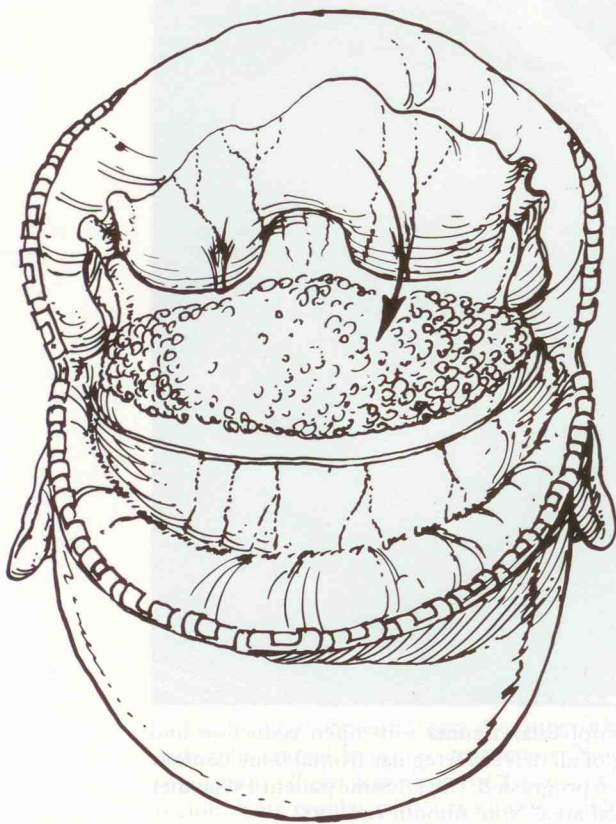


FIG. 2. Artist's depiction of the procedure. Separate bicoronal scalp flaps and vascularized periosteal flaps are demonstrated. The porous hydroxyapatite has been sculpted over the fronto-orbital region to give a uniform contour (arrow).

operatively, followed by a soft headband for an additional 2 weeks (Figs. 3 through 5). All patients received one intravenous dose of cephalosporin, followed by 5 days of oral cephalosporin.

RESULTS

There were no major surgical complications. One patient had a persistent temporal fossa infection after placement of porous hydroxyapatite, with granule extrusion through the coronal wound, necessitating debridement of all porous hydroxyapatite. One patient had underfilling of a temporal fossa defect, whereas another had overfilling of a temporal fossa defect; both required surgical correction and achieved satisfactory results. The remaining 26 patients had no postoperative problems, with good contour correction of the porous hydroxyapatite-filled defects, maintenance of implant volume, and nonvisible interfaces between the porous hydroxyapatite-grafted areas and the native bone (see Fig. 3). We were able to examine the porous hydroxyapatite-grafted

areas in 4 patients who underwent other procedures 9 to 36 months after porous hydroxyapatite placement. In all 4 patients there was visible bony ingrowth into the consolidated porous hydroxyapatite and bleeding from the porous hydroxyapatite surface. There was no visible shifting of the porous hydroxyapatite granules. The granules did not appear to migrate into either the overlying soft tissues or the underlying bone. Four patients had computed tomographic (CT) scans at least 9 months after the original placement of the porous hydroxyapatite that demonstrated no implant migration (Fig. 6).

DISCUSSION

Contour defects in the orbitocranial region after surgery for trauma, tumor, or synostosis are relatively common, even in experienced hands, due to bone resorption and temporalis muscle atrophy.¹⁰⁻¹⁶ Posttraumatic problems include superior orbital bony retrusion and frontal bone defects, particularly in high-impact trauma with bony comminution. Temporal hollowing after fronto-orbital advancement may be due to temporalis muscle atrophy or failure to bone graft temporal fossa defects at the time of advancement.¹²⁻¹⁴ We have found that even when the temporal fossa is overgrafted at the time of fronto-orbital advancement, bone resorption and remodeling and deficient transverse cranial growth can result in visible temporal hollowing years after the initial surgery. In the past we attempted to bone graft these contour defects but were disappointed by minor irregularities that became visible over time. Next, we attempted to use block hydroxyapatite but experienced problems with fixation, palpation, and visible edges and with intraoperative shattering of the blocks. Porous hydroxyapatite overcomes many of these problems and offers an alternative to conventional autografts or demineralized allografts, maintaining its volume and becoming at least partially osseointegrated.^{7,13,14} Osterhout¹⁴ in 1985 attempted to fill craniofacial contour defects with demineralized bone matrix but reported significant resorption, which has not been reported with porous hydroxyapatite. Byrd et al.¹¹ point out, and our experience confirms, that careful surgical technique is essential for clinical success. Previous reports utilizing porous hydroxyapatite have used subperiosteal injections of porous hydroxyapatite in contrast to our open periosteal flap tech-

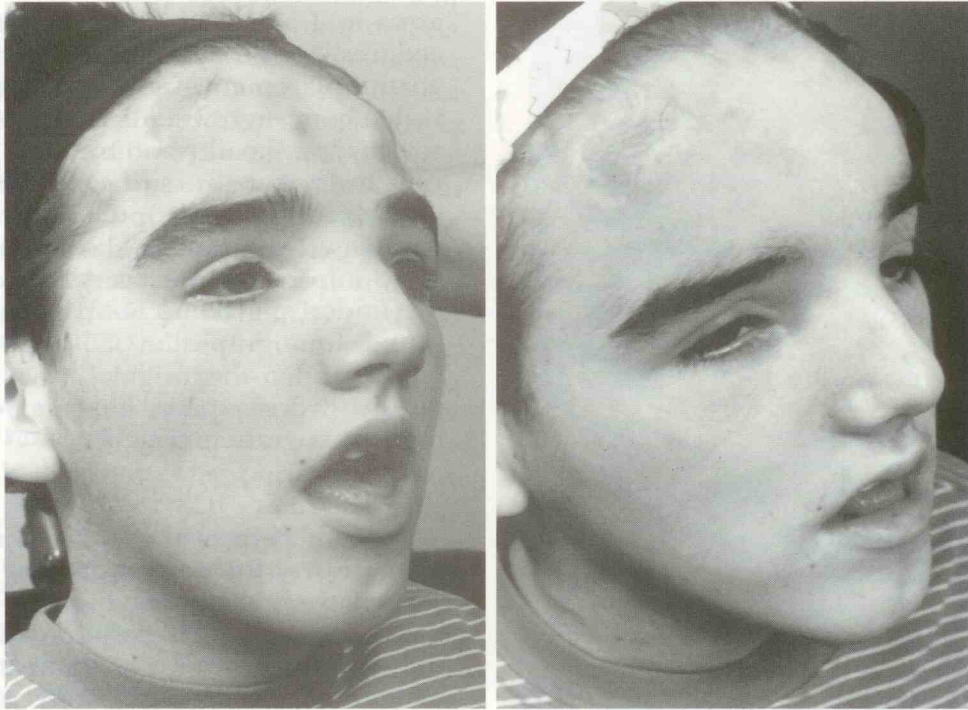


FIG. 3. (Left) Patient 3 years after severe frontobasilar trauma with open reduction and microplate fixation with immediate bone grafting of all defects. Irregular frontal bone contour became more apparent with time, as bony resorption progressed. (Right) Same patient 1 year after porous hydroxyapatite application to fronto-orbital area. Note smooth contour.



FIG. 4. (Left) Patient 3 years after fronto-orbital advancement with temporal bone grafting for metopic synostosis. Note temporal hollowing giving pinched appearance and slight irregularities of frontal bone. (Right) Same patient 1 year after temporal fossa contour augmentation with porous hydroxyapatite placed under the temporalis muscle. Note natural temporal contour without pinching.

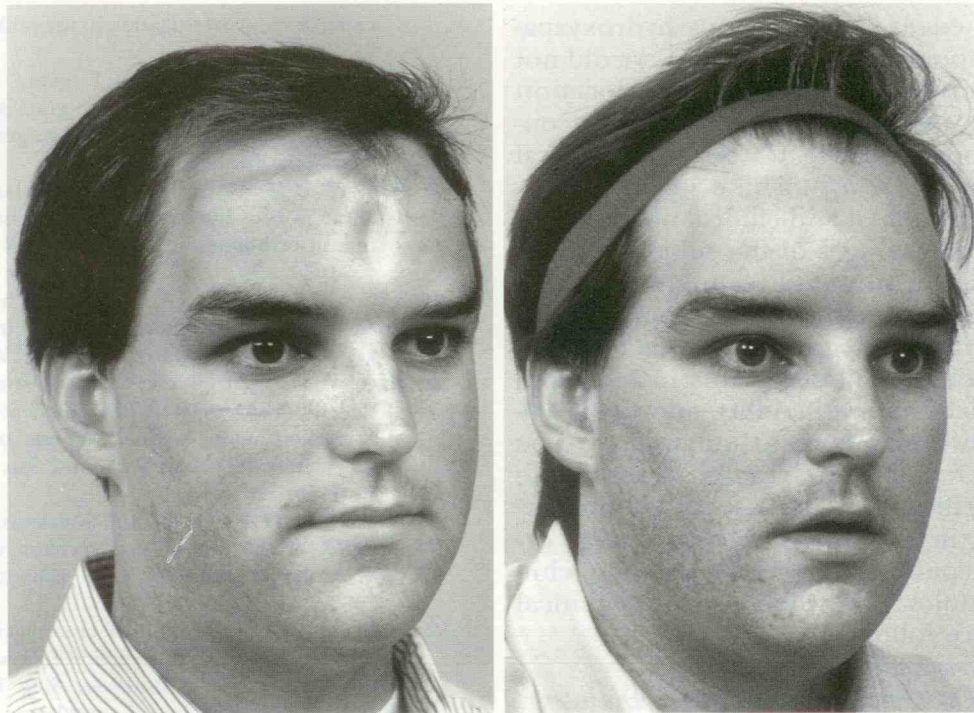


FIG. 5. (Left) Patient 2 years after superorbital and frontal bone resection for fibrous dysplasia with split cranial bone reconstruction. Note irregular contours secondary to variable bone resorption. (Right) Same patient 2 years after application of porous hydroxyapatite to frontal region. Note regular contours without visible edges.



FIG. 6. Axial CT scan of patient with craniofacial clefting and severe plagiocephaly 2 years after augmentation of right temporal fossa with porous hydroxyapatite. Note bone density of porous hydroxyapatite in distinct pocket. No evidence of migration through cranial bone.

nique.^{10,11,17} Although the pocket with injection of porous hydroxyapatite is sealed, we feel that this advantage is outweighed by the difficulty of precise porous hydroxyapatite placement in contact with viable bone. In addition, the injection technique could result in potentially dangerous complications if applied to large

contour defects. These include difficulties ensuring subperiosteal placement of the porous hydroxyapatite, avoiding injections through small areas of exposed dura, and volume control. The maintenance of viable periosteum is very important, since it provides a source of osteogenic cells to populate the porous hydroxyapatite surface.¹⁷⁻²⁰ Similarly, the porous hydroxyapatite needs to be in contact with viable bone for adherence and vascularization to take place.^{3,4,8,9} Careful closure of the periosteal pocket is important to prevent surface extrusion and possible bacterial contamination of the porous hydroxyapatite, as occurred in one of our patients. Furthermore, a compressive dressing is necessary during the first 5 days, as the granules consolidate, to retain the intraoperative contour.

The long-term fate of porous hydroxyapatite remains controversial. Experimental studies indicate that extensive, though not complete, bony ingrowth takes place over time.¹⁻⁴ Clinical reports vary from those reporting only fibrous ingrowth to those reporting partial osseointegration.^{5,7-9} Marchac¹⁷ has demonstrated the deposition of new bone on top of the porous hydroxyapatite radiographically. Our clinical observations confirm partial bony ingrowth

