Porous block hydroxyapatite in orthognathic surgery

By Harvey M. Rosen, MD, DMD; James L. Ackerman, DDS

As the breadth and scope of orthognathic surgery have expanded, maxillofacial surgeons have surgically treated multidimensional dentofacial deformity. In attempts to correct skeletal hypoplasias in the sagittal, vertical and transverse planes of space, bone defects and osteotomy gaps are created. These skeletal defects frequently require bone grafting to help stabilize repositioned bone segments in an effort to minimize relapse. Autogenous bone continues to be the most widely used material for this purpose since it promotes osseous healing and is rapidly revascularized, thereby resisting infection. The obvious disadvantages of autogenous bone grafts are the related donor site morbidity[1,2] and postoperative bone graft resorption which may lead to osseous instability.[3,4]

This paper reports on the authors' experience with the use of porous block hydroxyapatite as an interpositional bone graft substitute in orthognathic surgery. The excellent stability observed in this patient series in association with minimal morbidity supports the continued use of this implant material as a bone graft substitute. In addition, postoperative histologic and radiographic data generated in a subset of these patients confirm the favorable biologic behavior of hydroxyapatite implanted into the maxillofacial skeleton.

Materials and methods

In 76 nonconsecutive patients undergoing orthognathic surgery, blocks of porous hydroxyapatite (Interpore 200) were implanted into surgically created osteotomy gaps. There were 45 females and 31 males with ages ranging from 14 to 58 years (mean 25 years). Patients under-

Abstract

Seventy-six nonconsecutive patients undergoing orthognathic surgery, in whom blocks of porous hydroxyapatite were implanted into osteotomy gaps in lieu of autogenous bone grafts, are the subjects of this report. Surgical procedures include inferior maxillary repositioning (10 patients), maxillary advancement (24 patients), transverse maxillary expansions (17 patients) and inferior repositioning of the chin (25 patients). A total of 140 anatomic sites were implanted. Eleven patients later consented to open biopsy of the implant material at a mean 10.2 months following implantation.

At the time of follow-up, mean 16.3 months, excellent osseous stability was observed. Three patients developed complications relative to the presence of the implant. Twenty-one of 24 biopsy specimens demonstrated an osseous union of implant to bone with osseous deposition within the implant pores. Radiographic follow-up revealed implant blocks to maintain their volume with no change in density or discreteness.

The biological behavior and biomechanical properties of porous block hydroxyapatite are discussed. These implant characteristics make it a feasible bone graft substitute in orthognathic surgery and justify its continued use in this context.

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Key Words

Hydroxyapatite • Orthognathic surgery • Bone grafts

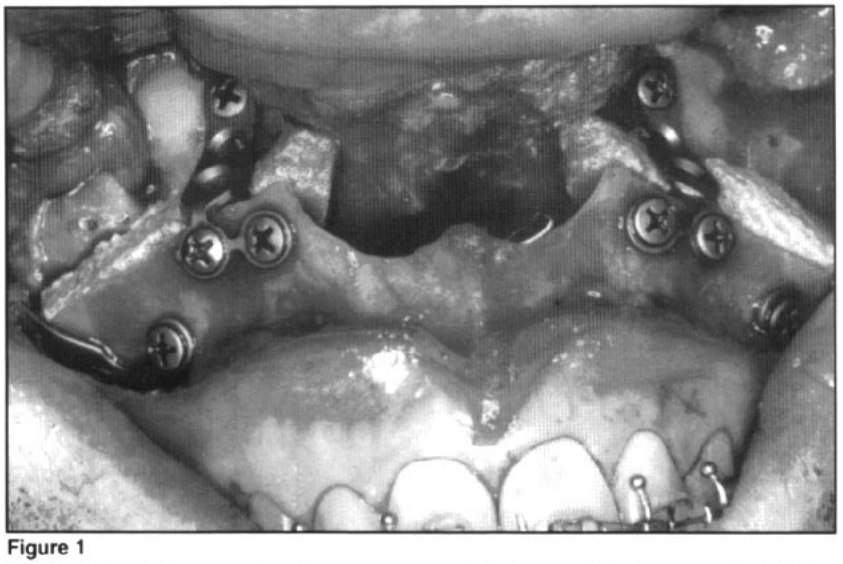

Figure 1

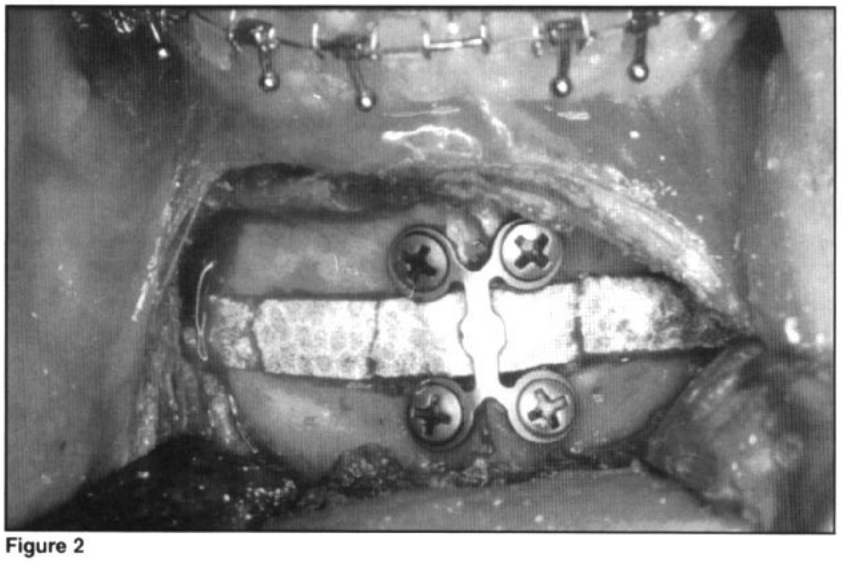

Figure 2

Figure 1
Inferior repositioning of the maxilla of 7 mm with advancement of 3 mm. Blocks of porous hydroxyapatite are placed in osteotomy gaps in the lateral nasal wall and the antero-lateral portion of the maxilla. Bone plates are applied to the piriform and zygomatic buttresses.

Figure 2
The chin is repositioned inferiorly 6 mm with implanted hydroxyapatite blocks in an anterior horizontal osteotomy of the mandible.

going implantation of this material were only those in whom autogenous bone grafts would have been considered for interpositional use if block hydroxyapatite had not been available. Patients undergoing skeletal displacements that would not ordinarily indicate interpositional bone grafting were, therefore, not included in this study. Hence, this patient group was nonconsecutive. Indications for the use of hydroxyapatite implants were as follows:

1. Maxillary inferior repositioning unaccompanied by major sagittal advancement. Ten patients' maxillae were inferiorly repositioned ranging from 4.5 mm to 7.5 mm (mean 6.5 mm). Implants were positioned along the anterolateral maxillary and lateral nasal walls[5] (Figure 1).
2. Inferior repositioning of the chin unaccompanied by posterior repositioning. Twenty-five patients underwent inferior chin repositioning ranging from 4 mm to 7.5 mm (mean 5.6 mm). Implants were placed within the entire osteotomy gap of the anterior mandible[6] (Figure 2).
3. Maxillary advancements of 8 mm or greater. Eighteen patients were included in this group with advancements ranging from 8 mm to 13 mm (mean advancement 9.2 mm). Implants were placed in a vertical step osteotomy site at each zygomatic tuberosity of the maxilla[7] (Figure 3).
4. Maxillary advancement in any cleft lip and palate patient. Six patients were included in this group with advancements ranging from 4 mm to 11 mm (mean advancement 7.6 mm). Blocks were placed in the identical fashion as in non-cleft patients undergoing maxillary advancement.
5. Maxillary transverse expansion of a minimum of 5 mm. Seventeen patients underwent such a procedure with the maxilla sectioned into two or four segments. Transverse expansions ranged from 5 mm to 10 mm (mean transverse expansion of 6.7 mm). All palatal osteotomies in the posterior aspect of the maxilla were made in the para-sagittal position along the nasal floor with blocks of hydroxyapatite placed into the osteotomy gap once the dento-osseous segments were expanded and wired into a prefabricated surgical splint[7] (Figure 4).

In a total of 76 patients, 140 anatomic sites were implanted with porous block hydroxyapatite. All patients received intravenous Ancef at the time of anesthetic induction. This was continued until the fourth postoperative day at which time oral cephalosporins were prescribed for an additional week. All maxillary osteotomies were rigidly fixed with miniplates as previously described.[8] Osteotomies of the anterior mandible were fixed with either 24-gauge interosseous wires or miniplates. Implants were shaped with fissure and contour burs under constant irrigation to clear the pores of the implant of any debris. Because of the extreme brittleness of hydroxyapatite prior to autogenous tissue ingrowth, no attempt was made to pass wires or screws through the implant. Fixation was achieved through the high degree of friction created at the bone-implant interface once fixation devices were applied. Following skeletal fixation, excess hydroxyapatite was removed with a contour bur. All implanted sites were copiously irrigated with diluted betadine solution prior to mucosal closure. All osteotomies to transversely expand the posterior maxilla were placed in the para-sagittal position through either the right or left nasal floor. In this area, the palatal mucosal is thickest, thereby minimizing the chance of mucosal perfora-

tion and subsequent exposure of the implant to the oral cavity.

Follow-up of these patients ranged from 6 to 46 months (mean follow-up of 16.3 months). All patients had P-A and lateral cephalometric radiographs prior to surgery, immediately postoperatively, and at the time of follow-up. Standardized hard tissue cephalometric landmarks were used to determine stability of anteriorly and inferiorly repositioned maxillae and inferiorly repositioned chins. Since no attempt was made to expand the dental arches presurgically with orthodontic appliances, maintenance of normal buccal lingual cuspal relationships following active postoperative orthodontics indicated the stability of maxillary transverse expansion.

Histology data

Eleven patients in whom blocks of porous hydroxyapatite were implanted later consented to open biopsy of the bone-implant interface. A total of 24 biopsies were harvested from the zygomatic buttress of the maxilla (12), piriform buttress of the maxilla (4), the maxillary interdental premolar region (2), and the anterior chin (6). Biopsies were obtained at a mean of 10.2 months following implantation. Six early biopsy specimens were harvested from 3 to 6 months (mean 4.2 months) and 18 late specimens were harvested from 11 to 15 months (mean 13.9 months). Biopsies were retrieved as a composite of implant and host bone to include the bone-implant interface.

The undecalcified specimens were imbedded in methylmethacrylate and cut with a low speed diamond saw into 150 millimicron thick sections. Sections were then stained with a modified Villanueva-Goldner trichrome stain. Histologic parameters recorded were fibro-vascular, osteoid and bone ingrowth into the implant specimens, type of union at the bone-implant interface and evidence of any resorption or remodeling at the bone-implant interface.

Radiographic findings

Eight of 11 patients biopsied were followed radiographically for a minimum of 24 months. Range of follow-up was from 24 to 36 months (mean of 30.2 months). Osteotomy sites implanted in these 8 patients included the chin (5) and the antero-lateral maxillary wall (10).

Results

At the time of follow-up, stability was documented by comparing cephalometric tracings with those obtained in the immediate post-surgical period. Excellent stability was found in those non-cleft patients undergoing maxillary advancement with no patients demonstrating horizontal relapse greater than 1 mm. Of the six cleft patients undergoing maxillary advancement, one patient had a significant relapse of 2.5 mm. All other cleft patients had insignificant degrees of posterior maxillary displacement of less than 1 mm. Surprisingly, of the 10 patients undergoing inferior maxillary repositioning, the greatest superior relapse was .5 mm with three patients actually demonstrating slight inferior movement. This yielded an overall mean extent of vertical relapse of 4.5%. In those patients undergoing inferior repositioning of the chin, no measurable change from the immediate postoperative chin position could be appreciated. Two patients who had undergone transverse maxillary expansions of 8 mm to 9 mm demonstrated a tendency for transverse collapse noted 3 to 5 months following surgery.

Three patients developed complications related to the presence of the implant blocks. One block placed in a nasal floor osteotomy became

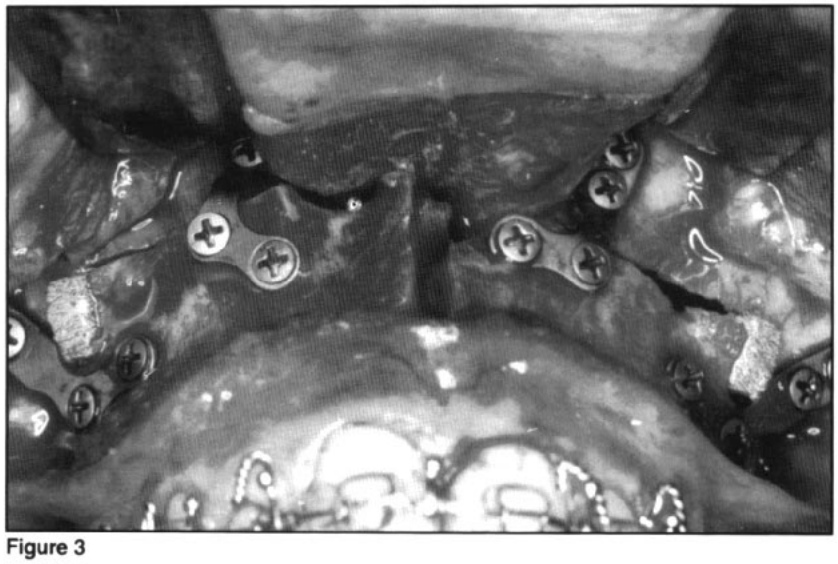

Figure 3

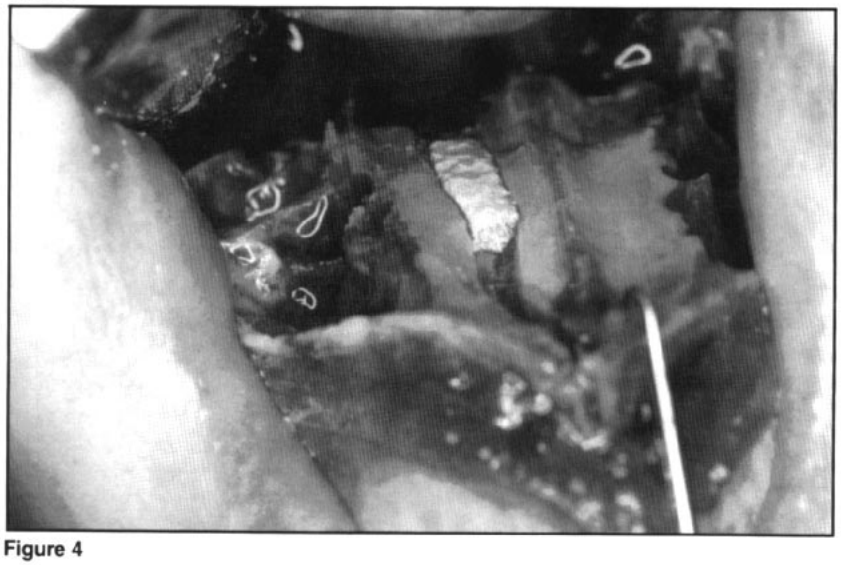

Figure 4

Figure 3
An 8 mm two-piece maxillary advancement is stabilized with implant blocks placed in a vertical step cut at the zygomatic buttress.

Figure 4
Transverse maxillary expansion of 6 mm is stabilized with an implant block placed in the parasagittal osteotomy of the right nasal floor. Maxilla is in a downfractured position.

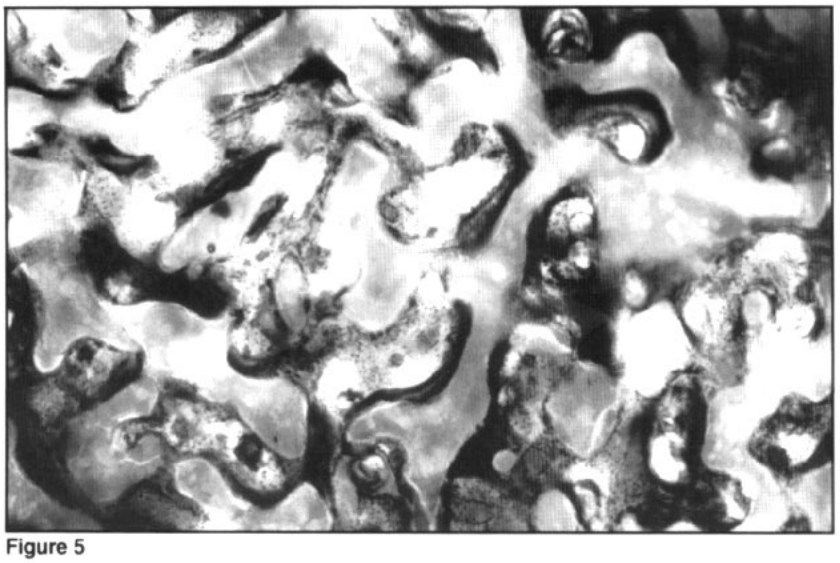

Figure 5

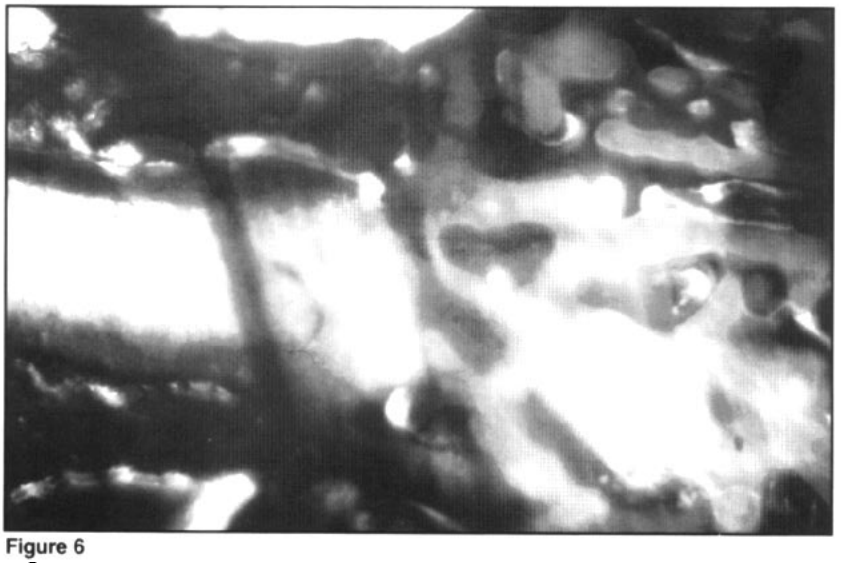

Figure 6

An hydroxyapatite biopsy specimen harvested from the zygomatic buttress 3 months following implantation. The implant matrix does not strain. There is modest bone deposition along the implant walls. Osteoid seams are adjacent to bone. The remainder of the implant pore is filled with fibrovascular tissue. (Villaneuva-Goldner trichrome stain, x10)

Figure 6
Composite implant specimens (bone-left, implant-right) harvested from the zygomatic buttress 13 months following implantation. There is extensive bone deposition within the implant pores. Osteoid seams are present. There is a direct implant-to-bone union with no intervening fibrous tissue or resorption of host bone at the bone/implant interface. (Villanueva-Goldner trichrome stain, x10)

dislodged. Its subsequent removal was required through a transnasal approach. The second patient complained of a palpable implant edge at the inferior border of the mandible following a genioplasty procedure. A revisional procedure was required to re-contour the implant. The third patient developed an infection involving the implant. Ten weeks following inferior repositioning of the chin, the patient developed a S. aureus osteomyelitis in the symphysis. Surgical debridement of a small sequestrum of bone and hydroxyapatite until bleeding was obtained from both the bone and implant resolved this infection. In addition, 6 weeks of intravenous antibiotics was required.

Histologic findings

Twenty-one of 24 biopsied specimens demonstrated fibro-vascular and bone ingrowth into the interstices of the hydroxyapatite implants. Intervening between the calcified bone and fibrous tissue, in a diffuse fashion, were seams of osteoid tissue (Figure 5). Osteoid seams were consistently seen in these 21 specimens regardless of the time interval following implantation (Figure 6). No osteoclastic activity could be demonstrated in any specimen within the implant block.

Comparison of the extent of bone ingrowth among different implant blocks was highly variable. All six early implant specimens demonstrated only modest degrees of bone ingrowth (Figure 5). Six of the 18 late specimens demonstrated extensive degrees of bone ingrowth (Figure 6). No correlation existed between the extent of bone ingrowth and anatomic biopsy site, the type of fixation employed, or the extent of surface area contact between host bone and implant block.

Histologic examination of the bone-implant interface demonstrated no evidence of resorption or remodeling of the bone, i.e., no Howship's lacunae or osteoclasts were observed. Twenty-one of 24 implants healed to adjacent bone with direct osseous continuity (Figure 6). Two implants healed with a fibrous union only. The same two implants harvested at 5 months from the chin and at 11 months from the zygomatic buttress demonstrated only fibrovascular tissue ingrowth. A third specimen harvested from the chin 3 months following implantation and adjacent to infected bone had no histologic evidence of healing, either fibrous or osseous.

Radiographic findings

At the time of radiographic follow-up all implants appeared identical to those in films obtained in the immediate postoperative period. There appeared to be no change in the radiographic density of implant blocks or in the discreteness of their margins (Figure 7A-B).

Discussion

Surgical repositioning of the maxilla and chin frequently creates large osteotomy gaps. As the magnitude of osseous repositioning increases, bone contact decreases and osseous gaps enlarge. Although the increasing use of rigid plate and screw fixation has obviated the need for bone grafting in many surgically created osteotomy

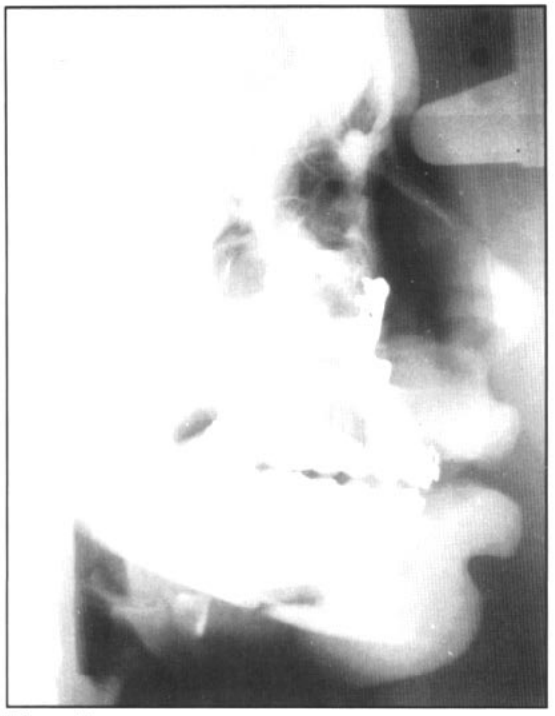

Figure 7A

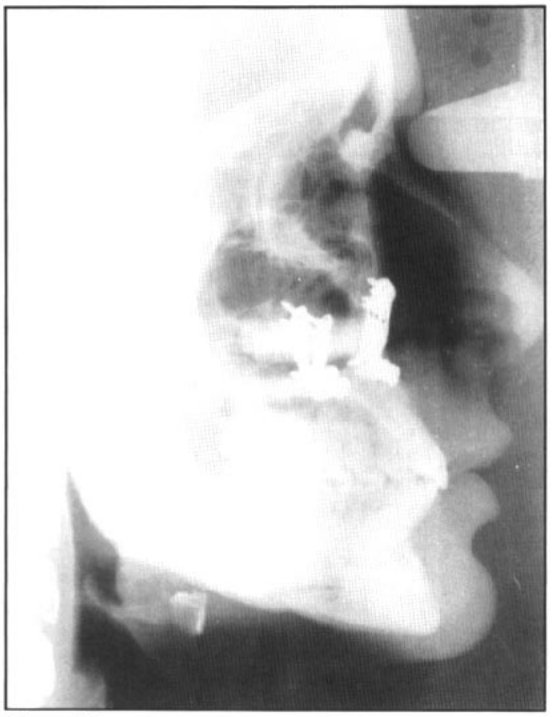

Figure 7B

Figure 7A
Immediate postoperative cephalometric radiograph following inferior maxillary repositioning of 7 mm, mandibular advancement of 6 mm and simultaneous inferior repositioning and advancement of chin of 6 mm and 5 mm, respectively. Implant blocks are well seen in the antero-lateral maxillary walls and the anterior portion of the mandible.

Figure 7B
Thirty-six month postoperative radiograph. There is no measurable loss of volume of the implant blocks. The radiographic density and marginal discreteness of the blocks remain unchanged. Excellent stability is observed in both vertical and sagittal dimensions.

gaps, rigid fixation may not reliably prevent relapse in the presence of minimal bone contact and restrictive soft tissue forces. Such is the environment created following extensive maxillary advancement, transverse expansion and inferior maxillary repositioning procedures. Under such conditions, osseous relapse has been shown to occur in the early postoperative period despite tight screw placement and unchanged plate contour.[8]

In this situation, interpositional bone grafting becomes necessary to promote stability of repositioned dento-osseous segments. Unfortunately, bone grafting in conjunction with rigid fixation has not eliminated this relapse potential because of the tendency of autogenous bone to undergo early postoperative resorption.[3,4] This phenomenon may occur as a result of pressure generated from soft tissue restrictive forces in extensive advancements and from masticatory forces generated both during and after intermaxillary fixation following inferior maxillary repositioning.

Accordingly, the use of nonresorbable bone graft substitutes for interpositional use has much appeal. Such bone graft substitutes would ideally exhibit the following biochemical characteristics: (1) have structural rigidity, (2) promote rapid tissue incorporation and direct osseous healing, (3) promote osteoconduction and/or osteoinduction, (4) undergo minimal volume loss, (5) have a low complication rate associated with use. Porous block hydroxyapatite possesses many of these properties.

The implant blocks are derived from specific marine corals having a completely interconnected porous matrix with a pore size averaging 200 microns. The calcium carbonate skeleton is converted by the manufacturer to hydroxylated calcium phosphate. This mineral matrix is architecturally and chemically similar to the nonvascularized interstitial matrix of human cortical bone. It, therefore, provides a suitable scaffold for the rapid ingrowth of fibrovascular tissue and bone. This healing process has been repeatedly demonstrated in experimental[9-12] and clinical settings.[13-17] The presence of osteoid tissue in addition to calcified bone and fibrovascular tissue within the implant pore unassociated with osteoclasts suggests that ongoing bone production takes place.[17]

This material clearly has no intrinsic osteoinductive properties.[17,18] When placed in soft tissue or when implant blocks heal with a fibrous union (as in two of our specimens) no bone ingrowth occurs. This material must be in direct contact with the bone, i.e. it is osteoconductive only. Dry implant blocks are extremely brittle but gain strength as tissue incorporation proceeds. Compressive strength of the ingrown implant far exceeds masticatory forces.[19] The torsional strength of the ingrown implant has been estimated to be approximately 60% to 70% of human cortical bone.[19]

Loss of volume of the implant has been minimal, estimated at less than 2% within a 2-year period.[19] This would explain the unchanged radiographic appearance of the implant blocks in our patient series.[17]

Stress shielding of adjacent host bone has not been a significant consideration[9,11] since the elastic modulus of ingrown porous hydroxyapatite has been shown to be quite similar to that of human cortical bone.[20] As seen in our histologic studies, there is no evidence of resorption or remodeling of the adjacent host bone.[17] Apparently the intimate bonding of host bone to the implant transfers stress directly to the bone adjacent to the implant.

These biomechanical properties favor the use of porous block hydroxyapatite as an interpositional bone graft substitute in orthognathic surgery. Rigid fixation of maxillary osteotomies should be used in conjunction with this implant material. This fixation method allows tissue ingrowth to occur so that the implant will achieve adequate compressive strength prior to subjecting it to full masticatory loading.[5] These masticatory forces can be generated by chewing or during intermaxillary fixation. Rigid plate and screw fixation obviates intermaxillary fixation and patients can be placed on a soft diet for six weeks postoperatively.

The high compressive strength of the implant achieved with tissue ingrowth coupled with its low rate of resorption and lack of host bone remodeling help explain the tremendous osseous stability seen in this patient series.[5,7]

The low complication rate associated with the implant material is primarily attributed to secure soft tissue coverage over the implant. The extremely low rate of infected implants and sinusitis, when placing hydroxyapatite implants adjacent to an open maxillary sinus, has been a consistent finding. This probably relates to the rapid vascularization of the implant block[9,11] and the prophylactic use of antibiotics.

Conclusion

Coralline derived, porous block hydroxyapatite represents a valuable bone graft replacement for interpositional use in orthognathic surgery. Through its judicious application, the stability of repositioned dento-osseous segments shows potential for improvement and the morbidity associated with bone graft harvesting is eliminated. The low rate of complications associated with its use as well as its rapid healing to bone justify its continued use in elective facial osteotomies.

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Commentary: Porous block hydroxyapatite

By Dale S. Bloomquist, DDS, MS

The use of porous block hydroxyapatite as a substitute for autogenous bone grafting has quickly gained popularity in orthognathic surgery. Rosen and Ackerman present a good review of the reasons for this change, as well as a discussion of their own clinical experience with this implant material. A couple recent articles on this subject were overlooked by the authors and should be included to expand our knowledge.[1,2]

The premise that a nonresorbable block, such as coralline hydroxyapatite, decreases relapse in orthognathic surgery needs to be tested. Many clinicians who have experience with interpositional blocks in osteotomy gaps have seen relapse. The authors did note problems in some patients in whom the hydroxyapatite blocks were placed in palatal osteotomies in an attempt to hold transverse expansions. Their statements about the advantages of these blocks over autogenous bone grafts, especially for holding increases in anterior facial height, have yet to be proven. A difference in relapse may be difficult to prove, because the use of bone plates has minimized the relapse previously seen with this type of facial-skeletal correction.[3] Other research difficulties must be overcome before definitive statements can be made about the full value of porous block hydroxyapatite in orthognathic surgery. As the authors point out, however, this material is well tolerated in facial osteotomies and holds an advantage over autogenous bone grafts simply in its elimination of morbidity at the donor site.

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Author's Response

Although minimized, relapse has certainly not been eliminated with the use of bone plates and autogenous bone grafts when inferiorly repositioning the maxilla. Mean relapse rates of 25% are still reported (Reference #4 in the text). In addition to the elimination of morbidity at any potential donor site, porous block hydroxyapatite continues to have an additional, proven advantage over autogenous bone grafts which are subjected to pressure i.e. it maintains its volume and thus, promotes stability.