Hydroxylapatite: an adjunct to cranial bone grafting


Departments of Oral and Maxillofacial Surgery and Neurosurgery, University of Alabama at Birmingham, Birmingham, Alabama

Hydroxylapatite is a dense, pure ceramic material which has been used extensively in the reconstruction of atrophic maxillary and mandibular ridges. The authors describe a technique for the use of hydroxylapatite in combination with grafting of bone, either autogenous or from the bone bank, to restore contour to cranial defects. The use of hydroxylapatite in combination with bone grafting for contour restoration is recommended, as attempts to place the material directly on dura were not successful.

Key Words • cranial defect • hydroxylapatite • cranioplasty • bone graft

The purpose of this paper is to describe the use of hydroxylapatite as an adjunct to bone grafting in cranial defects. Hydroxylapatite is a dense, pure ceramic material with the chemical formula Ca_{10} (PO_4(OH)_2). Durapatite (a nonresorbable particulate form of hydroxylapatite) has been extensively evaluated as a tissue implant material in animals. Interpore is a coraline porous form of hydroxylapatite with the same chemical formula as Durapatite. It was found by Drobeck, et al., that hydroxylapatite implanted subcutaneously in animals did not elicit an inflammatory response. In vitro studies by Jarcho, et al., revealed that bone strongly adhered to the hydroxylapatite surface, suggesting direct chemical binding.

Hydroxylapatite has been shown to be osteoconductive rather than osteoinductive when used alone. Its effect on osteogenesis when used with autogenous marrow was studied in mongrel dogs by Boyne, et al., who found no inflammatory or foreign body response; new bone matrix was deposited both on the surface of the implant particles and in the surrounding bone matrix. Chang, et al., established that hydroxylapatite was a stable implant when placed subperiosteally. Hydroxylapatite has been used extensively in oral and maxillofacial surgery to correct atrophic alveolar ridges. Rothstein, et al., found it to be successful in maintaining height, bulk, and contour in atrophic ridges. Hydroxylapatite was also used by Kent, et al., in combination with autogenous cancellous bone to restore atrophic alveolar ridges.

The success of hydroxylapatite in restoring atrophic ridges has led to consideration of its use as an adjunct to bone grafting in cranial defects. It was necessary to find a suitable method to provide cohesiveness for applying hydroxylapatite as an onlay over and around bone grafts. A mixture of microfibrillar collagen (Avitene) and hydroxylapatite was evaluated by Harvey, et al., and proved to be a biocompatible combination. Autogenous blood was used to provide cohesiveness to this mixture.

Clinical Material and Methods

Cranial defects were exposed during elective secondary procedures in 13 patients through standard cranioplasty approaches. Hydroxylapatite was used as an adjunct for cosmesis over either previously placed bone grafts (in two cases) or bone grafts placed at the same operation (in 11 cases). Autogenous (eight cases) or frozen cadaveric rib (five cases) was used as a graft source. In our first case, bone harvested from the iliac crest was used to recontour the supraorbital rims. In two cases, hydroxylapatite was placed directly on the dura without an accompanying bone graft, but stabilization of the material did not occur and the technique was abandoned.

In all cases, a mixture of particulate hydroxylapatite (Interpore or Durapatite), microfibrillar collagen (Avitene), and autogenous blood was used. The ratio of these materials was not constant as the collagen and blood simply serve as a carrier for particulate hydroxylapatite. The particulate hydroxylapatite (10 to 20 gm of Durapatite or 5 to 10 cc of Interpore) was placed in a mixing bowl. To this, approximately 250 mg of Avitene was added, followed by approximately 0.25 to 0.5 cc of autogenous blood to provide cohesiveness.
Hydroxylapatite as an adjunct to cranioplasty
tene and 5 cc of nonheparinized autogenous blood was
added. This combination was mixed into a paste-like
consistency capable of maintaining its shape when
placed over bone grafts.

Although both forms of hydroxylapatite (Durapatite
and Interpore) are chemically identical, Interpore 200
was chosen for use in the last five cases because of its
ease in handling. This relates to its porosity (190 to 230
µ) and irregular particulate form (425 to 1000 µ), and
the fact that it is supplied in bulk form (2- and 5-cc
vials). Durapatite is a dense nonporous material with
18 to 40 mesh size, which is marketed in prefilled
syringes containing 0.75 gm designed for subperiosteal
placement. This latter consideration makes it more
difficult to use in large open defects such as cranioplas-
ties. Some authors have suggested that autogenous mar-
row be added as a potential source of osteogenic cells.12
When used with previously placed bone grafts, the
material was layered on the bone under the periosteum
and the scalp was closed over the area. Scalp incisions
were designed to lie over normal bone. When used with
bone grafts placed at the time of surgery, the bone was
countoured and wired into position and the hydrox-
ylapatite was then applied to the graft to enhance con-
tour and esthetics (Fig. 1).

Soft-tissue flaps were replaced and the final contour
was evaluated. Care was taken not to dislodge the
implant material at this stage. The wounds were then
closed in a routine fashion and normal postoperative
care was given. All patients received antibiotic agents
(usually a cephalosporin) during surgery and for at least
1 week after.

Results
This technique has been used on 13 patients, ranging
in age from 4 to 56 years. There were 11 frontal defects,
one parietal, and one occipital. All patients had an
uneventful postoperative course and the follow-up pe-
riod ranged from 10 to 44 months. There were no
infections or wound dehiscences. Clinical and radi-
ographic examinations have shown the combination of
hydroxylapatite and collagen to be stable and without
resorption. All patients should require no further inter-
vention. For illustrative purposes, our first case with a
44-month follow-up period is presented.

Illustrative Case
This 40-year-old man sustained maxillofacial and
cranial injuries in October, 1980, secondary to being
beaten with a blunt object. He underwent multiple
reconstructive procedures, including onlay autogenous
split-rib grafts in October, 1982, to reconstruct the
cranial defect. The midfacial injuries had been managed
in a satisfactory esthetic and functional manner. The
rib grafts had provided protection for the cranial vault
but had resorbed and produced an undesirable cosmetic
defect (Fig. 2 left).
Cranial reconstruction was performed through a conventional bicoronal frontal flap. For reconstruction of the supraorbital rims, 6.0 × 1.5 × 1.0-segments of bone from the iliac crest were placed. A mixture of 28 gm hydroxyapatite and 1 gm Avitene was then applied to restore evenness of contour to the previously grafted site. The patient was discharged on the 4th postoperative day. Healing progressed well, but 8 weeks after the surgery it became apparent following resolution of the postoperative edema that small but significant irregularities in the forehead still existed. These small residual defects were corrected by placement of hydroxyapatite through two 1-cm incisions.

This patient has been followed for 44 months without complication. There has been no change in the form or shape of the implant during this period (Fig. 2 right).

Discussion

Autogenous bone is the standard cranioplasty material by which other substances must be judged. Grant and Norcross8 gave an excellent review of the early history of bone grafting in cranioplasty. It included the earliest report of an attempt at bone grafting in 1670 in which bone from a dog was used to repair a cranial defect in a man. This graft was later removed because of opposition from the church. Successful bone grafting of cranial defects began in the latter half of the 19th century. Although rib grafts were first used for cranial defects by Kappis11 in 1915, the first split-rib graft was described in 1917 by Brown2 and subsequently by others.15-17 Work by Holmstrand, et al.,3 included experimental models showing that after 1 year the density of rib grafts approaches that of the normal skull. Ilium grafts were first used in cranioplasty by Mauclaire18 and later by others.19,20

Korlof, et al.,14 reported a series of 55 patients treated with bone grafting of skull defects using both split-rib and iliac crest grafts; they recommended the use of autogenous bone for skull defect grafting. The majority of these cases consisted of split-rib grafts, but there were nine iliac crest grafts. It should be noted in their report that in 24% of the repairs there was an unevenness of the grafted region. This emphasizes an important point in restoring contour to cranial defects. Bone from either split rib or iliac crest, when placed in defects, can leave uneven ridges and depressions. It is advantageous to find a material to mold into these areas, thereby providing a smooth transition. Cancellous bone can be used for this purpose but resorption inevitably occurs.

A previous extensive experience with hydroxyapatite as a bone substitute in maxillofacial surgery stimulated interest in the use of this material in other areas. Experience has shown hydroxyapatite to be totally biocompatible, essentially noninflammatory, and nonresorbable.8 These characteristics would seem to make the material ideal as a readily available alloplastic implant which is clinically applicable as an osteoconductive rather than osteoinductive material. This may make placement into a defect surrounded by viable bone and covered by osteogenic periosteum mandatory for success.

While the longest follow-up period in this series of patients with cranioplasty is 44 months, clinical evaluation by Kent, et al.,13 demonstrated stability of this material for 4 years in mandibular and maxillary augmentations. These data and the results of others10 indicate hydroxyapatite to be biocompatible and nonresorbable, with no evidence of inflammatory or foreign-body response. There is no indication that this stability will not occur when hydroxyapatite is used in other areas of the body. The ease of handling of the material should also be noted. No special molds, preoperative preparations, or custom devices are necessary to utilize the material with or without concurrent grafting. It should also be noted that the cranioplasty in the last five cases was performed with cadaveric ribs, obviating the need for preparation and treatment of a donor site.

These cases are being presented in order to reinforce the conceptual transition from traditional maxillofacial uses of hydroxyapatite to its use in other areas of the body. To date, our grafts have been stable with the exception of one case in which the graft was displaced immediately postoperatively. Studies are continuing to investigate the use of this material in other craniocutaneous deformities and in other clinical circumstances, such as spinal intervertebral fusion.

References

Hydroxylapatite as an adjunct to cranioplasty


Manuscript received July 20, 1987.
Accepted in final form April 20, 1988.
Address reprint requests to: Victor J. Matukas, M.D., Department of Oral and Maxillofacial Surgery, University of Alabama, 1919 7th Avenue South, Birmingham, Alabama 35294.