Surgical Neurology International

OPEN ACCESS

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Technical Note

Shape modifications of porous hydroxyapatite prostheses to improve rigid implant fixation: Experience in 12 cases

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Received: 28 August 12 Accepted: 28 October 2012 Published: 26 December 12

This article may be cited as:
Rienzo AD, Iacoangeli M, di Somma LG, Alvaro L, Nocchi N, Scerrati M. Shape modifications of porous hydroxyapatite prostheses to improve rigid implant fixation: Experience in 12 cases. Surg Neurol Int 2012;3:161.

Available FREE in open access from: http://www.surgicalneurologyint.com/text.asp?2012/3/1/161/105100

Abstract

Background: Various methods of fixation have been described for custom made hydroxyapatite cranial implants. Their poor malleability limits most of the common used fixation techniques because of the high risk of cranioplasty's fracturing or higher exposure to infections. We present our experience with a new fixation technique, based on an appositely premodified hydroxyapatite implants.

Methods: In a 2-year time period, 12 patients underwent cranioplasty by a modified custom made porous hydroxyapatite implant. Once the three-dimensional computer model of the prostheses was performed, three semicircular extensions placed at strategic positions were drawn and the final prosthesis was realized. At surgery, holes fitting the extensions were drilled into the skull borders and the implant was easily embedded inside the defect. Small titanium meshes overlying the extensions were fixed by screws to the surrounding bone.

Results: A minimal increase of operative times was recorded, with drilling and fixation requiring additional 30 and 15 minutes, respectively. Optimal contact between cranioplasty and skull borders was always observed at control computed tomography (CT) scans. Permanent rigid fixation was obtained in all cases, with good functional and aesthetic results at follow-up.

Conclusions: Modifications of hydroxyapatite implants are obtained without additional costs. The minimal increase of operative times is largely counterbalanced by optimal fixation results. Finally, the bone drilling and the immediate proximity of bone to prosthesis might enhance the potential for osteogenesis and osteointegration.

Key Words: Bone fixation, decompressive craniectomy, hydroxyapatite cranioplasty, osteointegration, prostheses

Access this article online

Website: www.surgicalneurologyint.com

DOI: 10.4103/2152-7806.105100

Quick Response Code:

INTRODUCTION

In recent years, the increased number of decompressive craniectomies performed all over the world has led to a proportional increase of reconstructive surgeries for cranioplasty.[1,2,4,6] Well-known complications of autologous bone repositioning include bone resorption and infection, which create the need for further operations.[4,6] The extraordinary technological advancement we are witnessing has made available a variety of different materials for cranioplasty, including preformed polymethyl methacrylate (PMMA), titanium and porous hydroxyapatite implants fashioned over the cranial defect.[3,7-9,12] Unfortunately, the ideal prosthesis is far from being realized. Every type of implant has its own advantages and limitations, so it is mandatory to tailor the choice over the patient.

Most of the available materials may be fixed to the skull defect by the use of titanium miniplates and screws. This is not possible when using porous hydroxyapatite, whose poor malleability implies a high risk of implant's fracturing during fixation with self-drilling screws.[10,11]

We present our experience with the use of an appositely premodified hydroxyapatite prosthesis that allows an optimal rigid implant fixation, a good aesthetic results, and no significant increase in the complexity and duration of the cranioplasty procedure.

MATERIALS AND METHODS

In a 4-year time period, from July 2007 to July 2011, 22 cranioplasty procedures were performed at our Institution by the use of custom made porous hydroxyapatite implants. The use of these prostheses was needed because of autologous bone resorption in 17 cases and bone infection in 5. During the first year of this series, five prostheses were implanted and fixed to the skull defect using doubled nylon or silk sutures [Figure 1a]. During the following year, five more patients were operated on. In four cases, appropriately cut titanium meshes were laid over the implant and fixed to the bone by titanium screws. Because of cranioplasty dimensions, at least two large meshes (8 × 8 to 10 × 10 cm) were needed, usually extending from the frontal supraorbital to the temporo-sphenoidal region and from the parietal to the temporal bone [Figure 1b]. In the remaining patients, titanium miniplates were disposed circumferentially over the implant and fixed to the bone borders [Figure 1c]. In the past 2 years, 12 more patients underwent surgery by a completely new technique. After the three-dimensional computer model of the prostheses was performed, three semicircular extensions were added like bridges to the mold image, respectively in the frontal, temporal, and parietal areas. Positions of these extensions were strategically planned according to patients' anatomy and to the characteristics of bone defect. Air cavities of the skull (frontal sinus, mastoid cells) were accurately avoided and care was taken not to cross the midline and the superior sagittal sinus. The width of these extensions was 1.5-2 cm and height was 1-1.5 cm. At surgery, after bone flap reflection and temporal muscle isolation, the dural layer was fully exposed. In all cases the skull borders were first cleaned from the scarring tissue and then lightly drilled in order to refresh the bone and promote osteoblast's activity. The implant was then positioned over the defect. After drying the skull by sterile gauzes, the areas where extensions overlapped the bone were evidenced by a sterile marker. At this point, the implant was immersed in a physiological solution at room temperature and a drilling by a 6-8 mm nondiamond burr took place on the delimited areas, until the underlying dura was exposed [Figure 2a]. Eventual additional irregularities of the skull contour were smoothed. The cranioplasty was finally embedded within the defect and further drilling was sometimes performed, to improve the contact between the implant and the skull. Granular hydroxyapatite was occasionally added to fill residual void space. Three small titanium meshes (3 × 3 cm) were laid down to cover the cranioplasty' s bridges and fix it to the bone by screws [Figure 2a and b]. All the patients were regularly evaluated every 6 months after surgery by clinical and neuroradiological examinations.

RESULTS

The drilling of the skull borders needful to create the niches where to allocate the implant's extensions required from 20 to 30 minutes of additional operative time and it was always safely performed, with no injury to the dural layer and underlying brain. Mesh shaping and fixation required further 15 minutes. Perfect implant fitting was obtained in all cases. No postoperative complications were recorded. Satisfying functional and aesthetic results were always reported at follow up evaluations (follow up range: 12-36 months).

DISCUSSION

The number of surgical procedures aimed at repairing the skull defects has increased proportionally to the diffusion of decompressive craniectomy. Cranioplasty is mandatory to re-create a physiological intracranial compartment, to protect the brain from external insults, and cerebrospinal fluid (CSF) disturbances, and to restore a cranio-facial symmetry. Even though repositioning of the autologous bone is considered the best treatment for such defects, long-term complications, such as bone resorption or infection, may determine the need for further reconstructive surgeries.[4,6] Different materials have been used for these second step procedures, including PMMA, titanium and, more recently, porous hydroxyapatite.

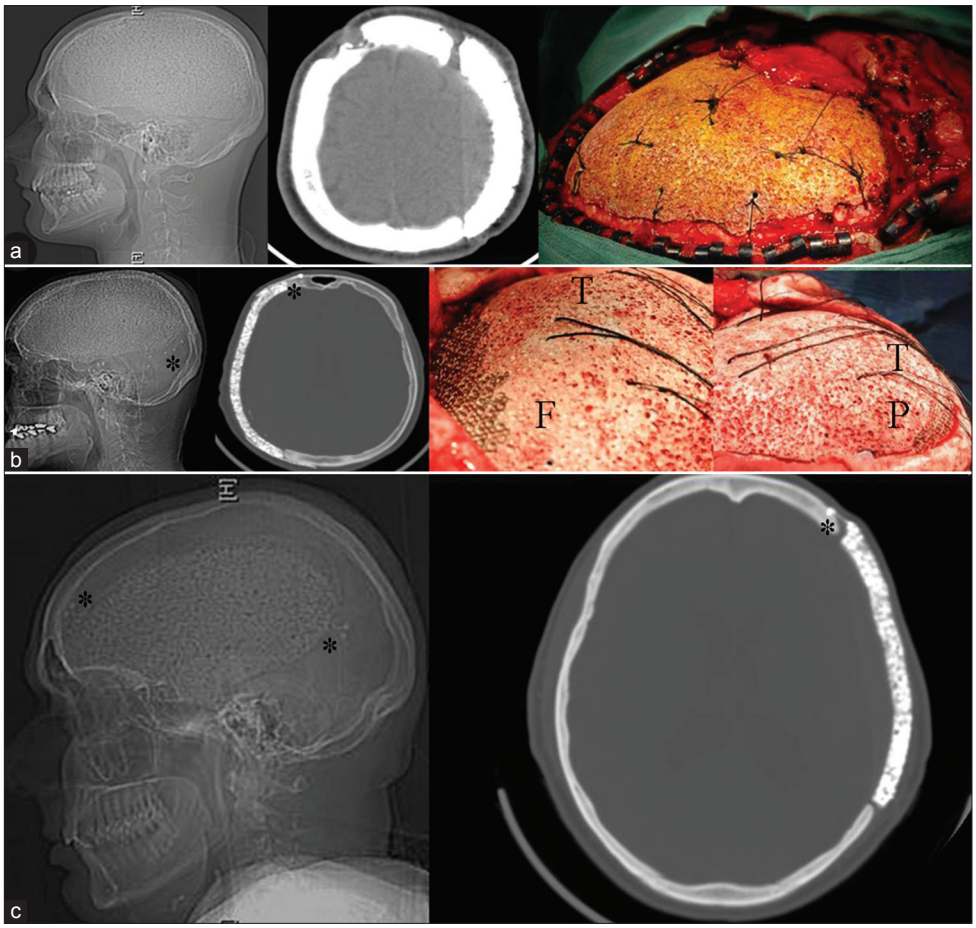

Figure 1: Custom bone hydroxyapatite implants fixed by silk sutures (a), large titanium meshes (b), and titanium miniplates (c) positioned in the frontal (F) and temporo-parietal (T, P) region

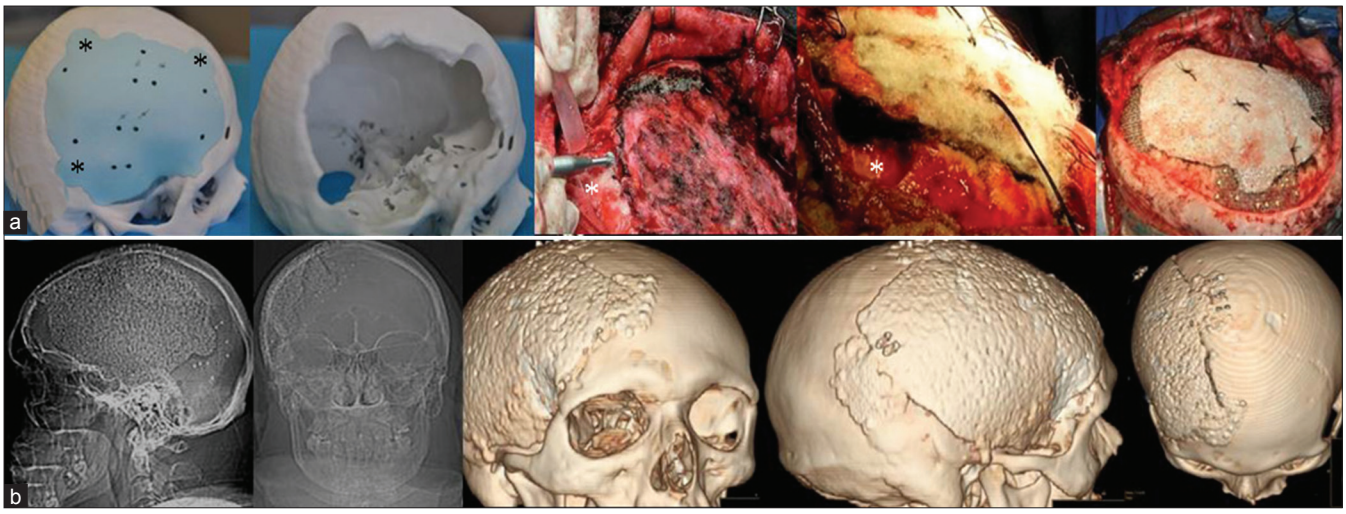

Figure 2: 3D implant model showing the extensions (black asterisks) and intraoperative images demonstrating the areas of drilling (white asterisks) and the final implant position (a), CT scan with 3D reconstruction showing the filling of the cranial defect (b)

[3,7,9,12] Both PMMA and titanium cranioplasty have been widely used in the past. They are easily moldable and may be rigidly fixed to the cranial bone. However, PMMA produces an exothermic reaction during intraoperative modeling that may produce a thermal damage to the underlying dura and brain. This reaction as well as a relatively high rate of infection and unsatisfying cosmetic results in case of large defects, which are the main constrains of these prostheses. These problems have been partially solved since the introduction of preformed,

3D modeled, titanium implants that are associated to a lower rate of infection and to a better cosmetic results.[9] However, the artificial nature of both kinds of implants is a major disadvantage, making osteointegration impossible. Porous hydroxyapatite is a relatively new material in cranial reconstruction and the experience with its use is slowly growing.[3] It is biomimetic and biocompatible, it has a high porosity and presents the same chemical composition of the bone mineral phase. Pore dimensions as well as their shape and spatial distribution, allow for osteoblast migration from the surrounding living bone into the implant, providing prosthesis colonization and, with time, osteointegration. These characteristics lead to a high biocompatibility.[8,11] Despite these properties, major concerns with porous hydroxyapatite are represented by the high costs, the absence of large prospective series and the difficulties in maintaining a rigid fixation, helpful to increase the potential for osteointegration.[5,10,11] The more frequently used and reported method is the fixation by silk or nylon sutures, but, because of the sharpness of the outer aspect of hydroxyapatite implants, sutures may be easily loosened or cut when tightened. In the first patients of our series, where this kind of fixation was used, we observed one implant dislocation and re-surgery was needed. In this phase of our experience, a feeling of discomfort with fixation was always reported by the surgeons. In the following cases, at first we used two-holes miniplates circumferentially laid down over the implant and fixed only to the surrounding bone, then we decided to adopt large titanium meshes extending beyond the borders of cranioplasty. The latest technique was safe and effective in eliminating implant movements but, because of the need of laying down meshes over a large surface, it required an appropriate modeling of the meshes' curvature to fit it to the shape of cranioplasty. This increased the overall length, complexity, and costs of surgery. Furthermore, the excessive use of artificial materials also raised the risks of infection reducing, at the same time, the advantage of biocompatibility and osteointegration. These reasons led us to try an alternative, easily reproducible, and fast method of fixation. The introduction of peculiar semicircular extensions to the originally designed implant was inexpensive and it has allowed the surgeon to use small rather than large meshes to secure the prostheses, so reducing the costs and the duration of the surgical procedure. The creation of a cavity within the bone, fitting the areas protruding from the cranioplasty, made possible to have bone on both sides for mesh fixation. The entrapment of the extensions by the bone, which surround them on a 270° angle, forbids lateral movements of the implant. Furthermore, the use of meshes to cover the extensions limits the potential for outer mobilization of the prosthesis. Finally, the cavities needed to host the extensions are created within a fully vital, previously untouched bone surrounding the extensions themselves. This provide an optimal implant's adaptation to the cranial defect, getting the best contact with the skull borders and a presumably increased potential for re-ossification. However, these modifications required attention to the specific anatomy of the patients, in order to avoid accidental penetration in the air cavities of the head or injury to the strategic vascular structures (like the superior sagittal sinus) while creating the spaces for allocating the adjuncts. This goal was easily obtained by accurately analyzing the high resolution computed tomography (CT) scan images in the axial, coronal and sagittal planes at the moment of planning extensions. There was no increase in surgical complexity, infectious risks, and costs. Long-term functional and aesthetic results were always good and a strong feeling of satisfaction was referred by the operating surgeons. In conclusion, we believe that the gold standard for fixation of porous hydroxyapatite implants is still far from being reached. Nonetheless, considering the advantages of employing such biological materials, the technique here proposed seem to be relatively easy and affordable, representing a valid alternative until a more adequate and definitive solution that may be found.

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