Clinical Experience of the Brushite Calcium Phosphate Cement for the Repair and Augmentation of Surgically Induced Cranial Defects Following the Pterional Craniotomy

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Objective: To prevent temporal depression after the pterional craniotomy, this study was designed to examine the safety and aesthetic efficacy of the brushite calcium phosphate cement (CPC) in the repair and augmentation of bone defects following the pterional craniotomy.

Methods: The brushite CPC was used for the repair of surgically induced cranial defects, with or without augmentation, in 17 cases of pterional approach between March, 2005 and December, 2006. The average follow-up month was 20 with range of 12-36 months. In the first 5 cases, bone defects were repaired with only brushite CPC following the contour of the original bone. In the next 12 cases, bone defects were augmented with the brushite CPC rather than original bone contour. For a stability monitoring of the implanted brushite CPC, post-implantation evaluations including serial X-ray, repeated physical examination for aesthetic efficacy, and three-dimensional computed tomography (3D-CT) were taken 1 year after the implantation.

Results: The brushite CPC paste provided precise and easy contouring in restoration of the bony defect site. No adverse effects such as infection or inflammation were noticed during the follow-up periods from all patients. 3D-CT was taken 1 year subsequent to implantation showed good preservation of the brushite CPC restoration material. In the cases of the augmentation group, aesthetic outcomes were superior compared to the simple repair group.

Conclusion: The results of this clinical study indicate that the brushite CPC is a biocompatible alloplastic material, which is useful for prevention of temporal depression after pterional craniotomy. Additional study is required to determine the long-term stability and effectiveness of the brushite calcium phosphate cement for the replacement of bone.

KEY WORDS: Bony defect · Pterional craniotomy · Brushite calcium phosphate cement · Augmentation.

INTRODUCTION

Pterional craniotomy is commonly used for anterior circulating artery aneurysms and anterior cranial base tumors. This approach involves a simple method that allows wide and safe exposure of the anterior and middle cranial fossa. To secure more comfortable exposure and minimize the brain retraction, it becomes necessary to remove the greater wing of the sphenoid bone as well as some parts of the frontal and temporal bone. Postoperative temporal muscle atrophy and bone defects after the pterional craniotomy create a depression of the temporal fossa that sometimes turns to the main postoperative complaint of patients. With the current emphasis on minimally invasive surgery, increasing care is being taken to prevent this complication. In practice, however, we often see patients with temporal fossa depression after surgery.

Since the first discovery of the calcium phosphate cement (CPC) by Brown and Chow in the 1980s, applications of a broad spectrum of calcium phosphate cements (CPCs) have been increased as an alternative to alloplast or even bone.
grafs in craniofacial reconstruction. The CPCs are easily
applied for contouring as a paste and hardens in minutes.
Accompanying a negligible exothermic reaction, the CPCs
provide structure integrity in hours. In addition, the minor
exothermic nature of the CPC setting, together with the
fact that no special fixation elements e.g., screws, miniplates
or suture materials are needed to fix the CPC, makes this
material ideal for craniofacial reconstruction.34,7,11,17–19

In this article, we report our clinical experience in repair
and augmentation of bone defects to prevent postoperative
temporal depression in several perioral craniotomy cases
using a brushite CPC, PolyBone® (Kyungwon Medical Co.
Ltd., Seoul, Korea).

MATERIALS AND METHODS

Seventeen consecutive patients with anterior circulation
aneurysm were included in this retrospective study. The
objective patients were operated by a surgeon at our insti-
tution between March 5, 2005 and June 25, 2006. The series
included 5 men and 12 women, ages ranging from 45 to
73 years, at the time of surgery.

All patients had been followed by postoperative aesthetic
outcomes for 1 year and the cosmesis was graded by the scale
described in Table 118. The minimum follow-up lasted for
12 months. After a year following the completion of recon-
struction, 3-dimensional skull computer tomography was
taken for the documentation of the fate of the brushite CPC.

<table>
<thead>
<tr>
<th>Grade</th>
<th>Components</th>
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<tr>
<td>A</td>
<td>Well preservation of temporal fossa</td>
</tr>
<tr>
<td>B</td>
<td>Slight depression of temporal fossa</td>
</tr>
<tr>
<td>C</td>
<td>Prominent depression of temporal fossa</td>
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Operative technique

After fixing the craniotomy bone flap with minifxation
(Biomet), the powder component of calcium phosphate
was mixed with liquid component, and left for 1–2 minutes,
for dense viscosity of the paste. The paste of brushite CPC
was applied to the surgically induced bone defect area such
as pterion, sphenoid ridge, burr hole sites, or temporal
bone defect area. Then the CPC paste was contoured with
a spatula. Once the desired contour was formed, the cement
was left untouched for 10 minutes.

We divided patients into 2 groups: For group A (first 5
patients, repair group) (Fig. 1A), bony defect areas such as
pterion, sphenoid ridge and temporal bone were only repair-
ted to its original contour without augmentation. For group
B (12 patients, augmentation group) (Fig. 1B), bony defect
areas of pterion, sphenoid ridge and temporal bone were
augmented rather than repairing original contour. The
brushite CPC graft material was allowed for 5–8 minutes to
set in situ until it turned into a harder state. No special fixing
elements such as screws, miniplates, or suture materials
were necessary to fix the brushite CPC graft material.

RESULTS

Patients were followed-up for 12 to 27 months subsequent
to surgery, with a mean period of 20 months. Postoperative
recovery has been excellent thus far in all patients. None of
the patients showed any evidence of foreign body reaction
to the implant material or infection at the implant site.
Depending on methods of cranioplasty, the results of
aesthetic effect were variable. In group A (repair group),
only 1 case was categorized into Grade A (Fig. 2), 3 cases were
considered as Grade B (Fig. 3), and 1 case was classified as
Grade C (Fig. 4). However, in group B (augmentation
group), 7 cases were categorized into Grade A and 5 cases
were considered as Grade B.

Three-dimensional computed tomography scans that
were taken 1 year after reconstruction confirmed the slightly
reduced volume of the CPC implants. However, the sec-
dary temporal depression was not observed during the
follow-up period (Fig. 5).

DISCUSSION

Temporal depression after perioral craniotomy would be
one of the complaints arising from patients. With the current
emphasis on minimally invasive surgery, increasing care is
being taken to prevent this complication.18 In practice, how-
ever, we often see patients with temporal fossa depression
after surgery. Many alloplastic materials such as titanium
mesh, polymethylmethacrylate (PMMA) bone cement, polymers and calcium phosphate cements have been used to repair the bone defects in craniofacial area. To be an ideal cranioplasty material, the material should ideally feature the following characteristics: 1) good tissue compatibility, 2) the ability to be easily contoured, 3) stable through the patient’s lifetime or if desorbed, replaced by structurally stabilizing bone without significant loss of volume or change in shape; 4) radiolucent to allow unimpeded computed tomography scanning of the intracranial contents, and 5) the ability to become ingrown by living tissue.

Until present, one of the most commonly used materials to repair the cranial bone defect is PMMA bone cement. However, on the negative side of PMMA bone cement, PMMA may cause a marked inflammatory response and fibrous encapsulation of the implant, resulting in the possibility of infection and loosening and/or exposure of the implant. In addition, the setting phase of PMMA is highly exothermic with temperatures as high as 140°F which may cause local cellular destruction. In addition, it is hard to shape the contour of implant after polymerization has commenced. Furthermore, fixing the PMMA implant to the surrounding bone may be difficult to use with subtle defects without fixation systems. Titanium mesh and polymer cannot be easily formed or shaped; therefore, it is not easy to make satisfactory contouring in a complicated shape area, especially in the fronto-zygomatic-temporal area without special fixing elements. Calcium phosphate cement is highly biocompatible and is gradually replaced with autologous bone by osteoconduction. Because of these characteristics, calcium phosphate cement has been used for the repair of craniofacial fractures in plastic and reconstructive surgeries. Calcium phosphate cements are composed of an aqueous solution and of one or several calcium phosphates. These two components are mixed together during preparation; the calcium phosphates dissolve and precipitate into a less soluble calcium phosphate. Growth and entanglements of the calcium phosphate crystals provide mechanical rigidity to the cement. Two types of cements are distinguished depending on the end product of the setting reaction: apatite and brushite (DCPD or dicalcium phosphate dihydrate) cements, of which the latter recently
raises great interest\(^{10}\). Brushite cements are resorbed faster than apatite cements\(^{8,13,15,20}\), but concerning the mechanical strength, brushite calcium phosphate cement is slightly weaker than apatite calcium phosphate cement\(^{10}\). However, in the non-weight bearing conditions of the skull, the difference between two cements may be irrelevant\(^{10}\). The high biocompatibility of brushite calcium phosphate cement\(^{10}\) as well as no heat generation during the hardening process allows it to be directly placed onto the dura. In addition, its plasticity enables satisfactory contouring before hardening. After setting, undesirable irregularities could be removed using fine instruments such as a knife, and it achieves sufficient intraoperative strength for scalp closure without any problem. In these respects, calcium phosphate cements proves to be superior to acryl cement (PMMA). However, since the calcium phosphate cements have hydrophilic properties in general, it is recommended to be used as a dense paste and placed into a relatively dry operative field for a successful reconstruction\(^{11}\). The CPC is advised not to be applied at large craniofacial bone defect areas, due to its low compressive and tension strengths.

In this study, repairs of the surgically induced bone defects such as pterion, sphenoid ridge, squamosal temporal bone without (group 1) or with augmentation (group 2) are easily undertaken using the brushite calcium phosphate cement. The bone bonding effect of CPC makes it possible to have a great advantage of mold and adaptation to the individual defect with no need of special fixation elements. One of the first calcium phosphate cements, Bone Source has shown positive results when it is used in craniofacial reconstruction\(^{4,17,18}\). Bone Source shows excellent retention of implant volume, with no interference of craniofacial growth over a 3-year study period for the cases of pediatric patients\(^{6}\).

Nearly half of the reported complications have been related to infection, with an overall complication rate ranging from 0% to 11%\(^{12}\).

In this study, none of our patients showed any evidence of foreign body reaction to the implant material or infection at the implant site during the follow-up period. In the 3-D computed tomography scans which were taken 1 year after reconstruction, showed the slightly reduced volume of the CPC implants. However, the secondary temporal depression was not observed during the follow-up period. In respect of aesthetic efficacy, much better results were seen in the augmentation group. We think this finding was due to the compensation of the delayed temporal muscle atrophy. For better long term cosmetic results, we currently augment both pterion and temporal areas with somewhat larger volume of the CPC than the bone defect cases. Since the brushite calcium phosphate cement remains malleable for only a few minutes, it is prudent to complete all surgical preparation of the graft site before mixing the product. It has been well known that the CPC is gradually replaced with autogenous bone by osteoconduction. Even though the CPC shows almost equivalent CT density to bone, biopsy of the reconstructed site is required to assure bone ingrowth into cement restoration. Although no biopsy study is carried out during our follow-up period, numbers of orthopedic studies on long bones encourage the results with brushite cements\(^{11,12}\). From a practical view point, because the craniofacial skeleton is a non-stress-bearing site, the fact that the CPC does not totally convert to bone is not vital. As long as the cement integrates into the host bone and maintains its volume over the period, it would appear to be satisfactory for craniofacial skeleton augmentation. In this study, we demonstrated an excellent tissue compatibility with anatomic tissue as well as superior aesthetic effects of cranioplasty using calcium phosphate cement during the follow-up period after the perional craniotomy, based on the clinical evaluation and 3-D computed tomography.

CONCLUSION

The results from this clinical study show that brushite CPC is a biocompatible and alloplastic material, which is useful for the prevention of temporal depression after perional craniotomy. In the cases of augmentation group, aesthetic outcome is much better than the cases of simple repair groups. Additional study is required to determine the long-term stability and effectiveness of brushite calcium phosphate cement replacement by bone.

References
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