

# Diversifying the rehabilitation of calvarial defects: Rejuvenating precision: A case series

### ABSTRACT

Cranial vault defects are either congenital or acquired in origin. Cranioplasty is most commonly done in patients after trauma, decompressive craniectomies, tumor resections, infections or because of congenital malformations. The purpose of a Cranioplast is to protect the underlying brain tissues, reduce pain, and to improve the calvarial contour, symmetry, and esthetics. Rehabilitation of these defects possesses a challenge to the surgical team and prosthodontist. With advancement in three-dimensional (3D) engineering technology, the use of rapid prototyping technology (RPT) can be used in the fabrication of 3D skull eliminating conventional impression for recording defect region. Custom-made cranial prosthesis now can be fabricated using the conventional method of wax-up and lost-wax method. Case 1 had a history of road traffic accident followed by decompressive craniectomy, which led to frontoparietotemporal defect of the right side. The 3D model was fabricated using RPT technology. The wax pattern fabricated on 3D prototyped skull was contoured using digital photographic superimposition method. Case 2 had a history of trauma on the head causing intracerebral hemorrhage followed by decompressive craniectomy which led to frontoparietotemporal defect of the right side. The 3D model was fabricated using RPT. The wax pattern fabricated on 3D prototyped skull was contoured using the compass method. The use of these methods with the added advantage of RPT resulted in prosthesis with good esthetics and better fit. The contour of the prosthesis was replicated in the same manner as compared to the contralateral side. These techniques are easy to use and are less time consuming and had few chances of errors.

**Keywords:** Cranial implant, cranioplast, maxillofacial prosthesis, polymethylmethacrylate cranioplast

### INTRODUCTION

Decompressive craniectomies result in cranial defects in patients with trauma, infections, intracerebral, and subarachnoid hemorrhage.<sup>[1]</sup> Cranioplasty is surgical repair of acquired or congenital cranial defects. The cranioplasty includes protection of brain tissues and provides esthetics and reconstruction of the deficit anatomical cranium. Rehabilitation in these patients requires a multidisciplinary approach embodying neurosurgeons, plastic surgeons, and prosthodontists. Cranioplast can be either autograft or allograft. Several allografts such as polymethylmethacrylate (PMMA), titanium, silicone, polyethylene, polytetrafluoroethylene (PTFE), and polyetheretherketone (PEEK) have been used for the same.<sup>[2]</sup> PMMA is one of the most commonly used alloplastic graft materials worldwide.<sup>[3]</sup> The use of rapid prototyping technology (RPT) has been an advancement in

three-dimensional (3D) reconstruction of those cranial defects which have larger surface area and had complex curvature of defects.<sup>[4]</sup>

To simulate the final contour and esthetics, the symmetry of wax pattern on the defect side should replicate the

**ABHISHEK KUMAR GUPTA, MAMTA KUMARI, REKHA GUPTA, SHUBHRA GILL**

Department of Prosthodontics, Crown and Bridge, Maulana Azad Institute of Dental Sciences, New Delhi, India


**Address for correspondence:** Dr. Abhishek Kumar Gupta, Department of Prosthodontics, Crown and Bridge, Maulana Azad Institute of Dental Sciences, Bahadur Shah Zafar Marg, New Delhi - 110 002, India.  
E-mail: drabhishek.gupta1994@gmail.com

**Received:** 28 December 2020, **Revised:** 22 March 2021, **Accepted:** 13 July 2021, **Published:** 13 December 2021

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**How to cite this article:** Gupta AK, Kumari M, Gupta R, Gill S. Diversifying the rehabilitation of calvarial defects: Rejuvenating precision: A case series. *Natl J Maxillofac Surg* 2021;12:426-30.

Access this article online	
<b>Website:</b> www.njms.in	<b>Quick Response Code</b> 
<b>DOI:</b> 10.4103/njms.NJMS_288_20	

contralateral side. This case series reveals two methods to assess symmetry and contour. In Case 1, the digital photographic superimposition had been used, whereas in Case 2, a simple and innovative compass method had been used to assess the symmetry.

The use of RPT with symmetry and contour evaluation had resulted in a prosthesis that is better in terms of both precision and esthetics.

## CASE REPORTS

### Case 1

A 50-year-old male reported to the department of prosthodontics for rehabilitation of right cranial defect. A detailed history revealed that the patient had road traffic accident 1 year back. The patient underwent cranioplasty 6 months back using autogenous bone flap which was preserved in the abdominal cavity, back then, but there was subsequent postoperative infection and bone resorption. Therefore, the bone flap was removed and the patient was again planned for revision surgery. Cranial decompression was again planned which led to frontotemporoparietal defect of 15 cm × 15 cm in dimension. Gradually, cerebrospinal fluid (CSF) was accumulated in the defect leading to a diffuse swelling over the margins. This diffuse accumulation of CSF made delineation of underlying bony margins difficult and led to inaccurate impression of the defected area. As the defect size was large, computed tomography (CT) scan gives accurate position and margins of the bony defect, which would be difficult to obtain in conventional impression technique. Hence, rapid prototyping was planned to fabricate 3D skull.

### *Fabrication of three-dimensional prototyped skull along with wax pattern*

A CT scan (slice thickness 0.75 mm) of the patient was planned to get digital imaging and communications in medicine (DICOM) images of the defect area [Figure 1a]. The DICOM images were converted into standard tessellation language (STL) format [Figure 1b] which were converted from CT scan images with the help of software (In Vesalius 3.0). The STL images were transferred to computer-aided design (CAD) Software to generate a virtual model [Figure 2a] of the complete skull using CAD software (Autodesk Meshmixer). This software enabled 3D visualization of the defect. The contralateral contour of the patient's skull was mirrored to design the deficit area [Figure 2b]. A uniform depth deficit of around 5 mm was allocated in the defect area [Figure 2c] to ensure enough thickness of the cranioplast and to provide a base for the waxing. Then, these STL format images were transferred to the 3D printer. Fused deposition modeling

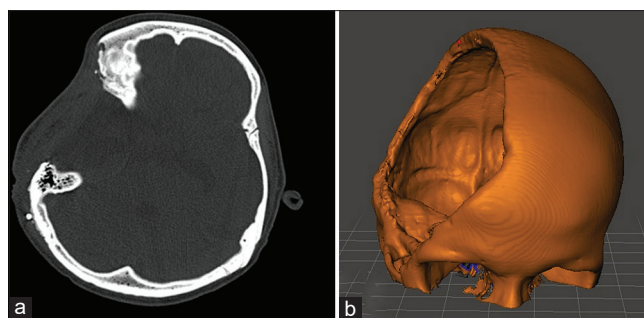


Figure 1: (a) Computed tomography scan (b) standard tessellation language image of computed tomography scan

method of RPT was used in both the cases. In this technique, resin material of polylactic acid (PLA) was used in 3D printer.

The prototyped skull was obtained after 3D printing. A thin sheet of aluminum foil was adapted closely to the defect area to prevent the wax from becoming interlocked in the grooves caused by the layered addition of PLA during fused deposition modeling. Two layers of modeling wax had adapted over this defect area to get the contour of the final prosthesis [Figure 3a]. Wax was carved and contoured to replicate the final contralateral side. The wax pattern was extended 5 mm beyond the bony edge in anticipation of changes caused by polymerization shrinkage to ensure good marginal integrity.

### *Assessing symmetry using digital photographic superimposition method*

A customized digital grid was fabricated to assess symmetry and contour. This grid was fabricated using scale of 30 cm × 30 cm on both the sides of grid with a uniform cross-section of 1 cm × 1 cm.

The grid was fabricated using software Adobe Photoshop version 7.1 (Tokyo, Japan). Photographs of the wax pattern along with skull were taken in both anteroposterior [Figure 3b] view and superoinferior [Figure 3c] view using DSLR macro lens of 1:1 ratio to avoid any magnification or distortion in image dimensions.

To assess symmetry, these images were superimposed over the digital grid. The wax was carved and added accordingly to get the final contour of the prosthesis. It also enabled a 3D assessment of the symmetry of the wax pattern.

### *Fabrication of polymethylmethacrylate cranioplast*

Due to large wax pattern, it was difficult for us to use conventional flask. A custom clamp and flask of dimensions 10 × 10 × 5 inches with interlocking spurs and having an overall assembly height of 20 inches was fabricated using stainless steel [Figure 4]. The wax pattern was invested in

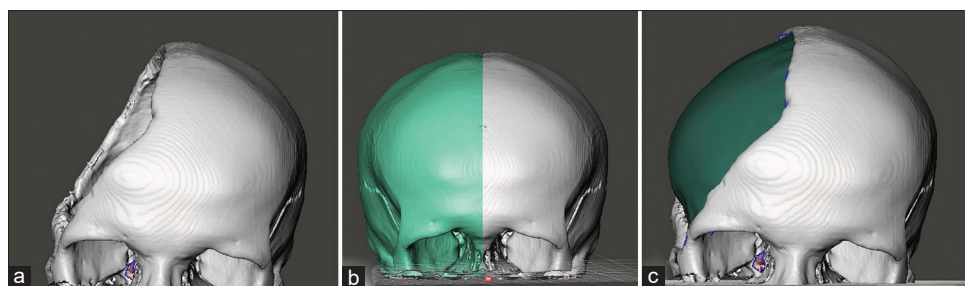


Figure 2: (a) Three-dimensional skull in computer-aided design/computer-aided manufacturing (b) mirroring of contralateral side on defect side (c) base added on defect side with depth of 5 mm using computer-aided design/computer-aided manufacturing

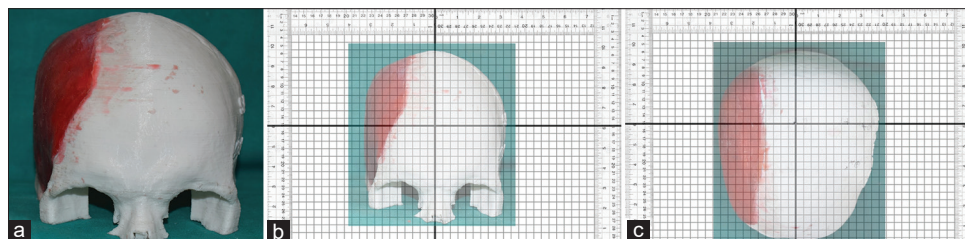


Figure 3: (a) Three-dimensional printed skull with wax pattern (b) digital photographic superimposition of anteroposterior view (c) digital photographic superimposition in superoinferior view

Type II gypsum product followed by dewaxing and packing with clear, heat polymerizing PMMA (Trevion; Dentsply Sirona). A long polymerization cycle was followed. The polymerized cranioplast was retrieved, finished, and polished. The marginal integrity was examined on the 3D skull and the excess acrylic resin was trimmed to achieve a butt joint at the defect margin. Symmetry was re-evaluated using the grid software. Multiple 2-mm holes were made 1 cm apart in the cranioplast to prevent the development of an epidural hematoma, permit escape of underlying fluid, and its absorption by the lymphatics, and allow for in growth of fibrous connective tissue and neoangiogenesis. The holes also provide a mean for securing prosthesis to the underlying bone. Then, prosthesis was immersed in distilled water at 37°C for 24 h to leach out any residual monomer followed by immersion in 2% glutaraldehyde for 48 h for sterilization.

#### Surgical placement of cranioplast

All the surgical procedures were carried out under general anesthesia. The hemicoronal incision was made over the healthy tissues away from the defect. The entire dissection was performed to delineate margins of entire defect. The fit of the margins of the cranioplast was checked and found to be accurate. Then, the prosthesis was fixed firmly to the desired area by titanium miniplate fixation [Figure 5]. Closure was then performed in layers using Vicryl suture to close the underlying tissues, and finally, the skin was sutured. A drain was placed to reduce postoperative hematoma and removed after 4 days. Postoperative care of surgical site was given to the patient and follow-up appointments were scheduled weekly for 4 weeks to check for postoperative

complications. The patient was advised to avoid pressure on the site of cranioplasty and to maintain the hygiene around the surgical site. In comparison with preoperative view, the patient showed excellent esthetics at the end of 2 weeks postoperatively.

#### Case 2

A 19-year-old boy reported to the outpatient department for rehabilitation of the right-side cranial defect, referred from the Department of Neurosurgery. On examination, the defect was large and pulsating. For proper recording of the extent of the defect, the patient's CT scan was utilized to fabricate 3D model of his skull showing the exact extent of the defect in all directions.

#### Wax pattern fabrication of cranioplast

Once 3D model of the skull is fabricated using rapid prototyping technique, the conventional method of wax pattern fabrication started. Thin aluminum foil was adapted over the defective area. Red modeling wax was adapted over the defect portion to build up the cranial contour.

#### Compass method for symmetrical wax pattern

Posterior reference line was marked horizontally passing through the apex of the skull [Figure 6a]. To make the wax pattern of future cranioplast symmetrical to contralateral nondefected side, we used compass. One arm of the compass was fixed at the center of the top of the skull using acrylic [Figure 6b]. The other arm with a pencil was kept free to be rotated which will evaluate the symmetry.

After adding wax to get the desired contour of the cranium, the compass was rotated from nondefected side to defected side, the dimensions should be measured and kept the same all over the contralateral areas for symmetry. The wax was added or removed to make equal dimensions measured by rotating compass all over the skull in both horizontal and vertical extent.

### Acrylization of cranioplast

The wax pattern was invested, dewaxed, and cured using clear PMMA in customized flask similar to previous case report. It was finished and polished. Cranioplast was surgically placed by neurosurgeons. The result obtained was esthetically pleasing restoring the cranial defect [Figure 7].

### DISCUSSION

Cranioplasty refers to the surgical repair of the cranial defects whether congenital or acquired. The main aim of cranioplasty is to protect intracranial components and improve esthetics.<sup>[5]</sup>

Many materials are used for the fabrication of cranioplast. They may be classified as autograft, allograft, xenograft, and alloplast. Alloplasts are further divided into metallic and nonmetallic materials. Various metallic alloplasts are gold, titanium, and tantalum.<sup>[6]</sup>

Nonmetallic alloplasts include PMMA, PTFE, carbon reinforced polymer, and recently introduced PEEK.<sup>[6]</sup> During the early 1900s, cranioplast was fabricated using conventional impression technique which was cumbersome, extensive, and includes extraclinical and laboratory steps. In case of extensive defects and where bony margins are delineated, conventional impression does not give promising results.

Recently, 3D printing and rapid prototyping provides more promising results when compared to recording with conventional impression method and can be used in case of larger defects. Still, there is ongoing research on printable medical-grade acrylics. The only materials which can be 3D printed are titanium and PEEK, which are expensive. Hence, heat polymerized PMMA was used in both the cases as an alloplastic cranioplast. PMMA is biocompatible, inert,

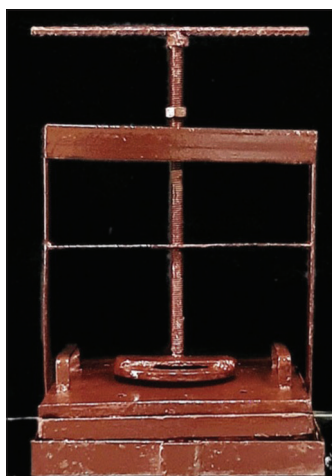


Figure 4: Custom fabricated flask

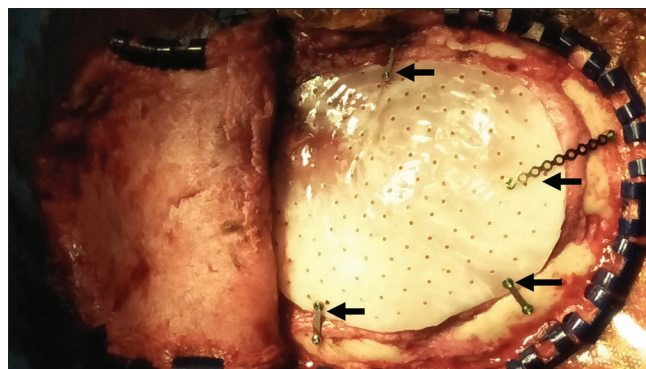


Figure 5: Cranioplast *in situ* at the defect site. Arrows indicate titanium miniplates for fixation

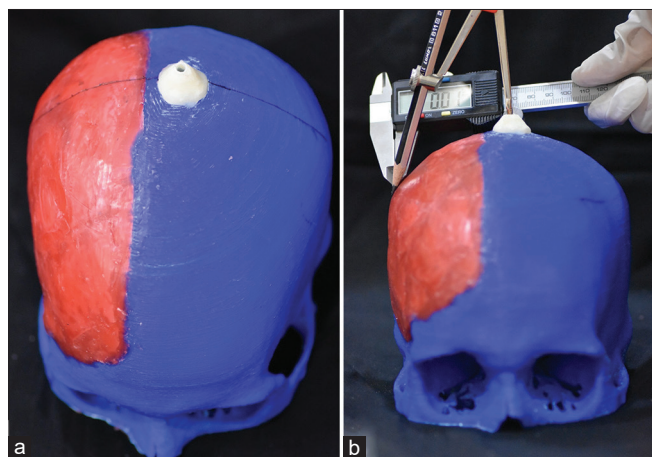


Figure 6: (a) Wax pattern with marked posterior lines (b) compass with Vernier caliper attached at the apex of the skull



Figure 7: Rehabilitation view (a) pretreatment view (b) posttreatment view

deformation resistant, has good compressive strength, and is easily available. It is radio-opaque, nonferro-magnetic, and is highly economical than other alloplasts.<sup>[7]</sup> The only disadvantage of PMMA is its residual monomer content which may hamper the healing process at the deficit area and may cause postoperative hematoma.<sup>[8]</sup>

To assess the symmetry of the wax patterns, two simple methods have been explained in this case series out of which digital photographic superimposition method provided optimum results in terms of contour and esthetics. Macro lens (1:1) was used to take images of the wax pattern along with the prototyped skull. This method circumvents the chances of image distortion and magnification. This method also permitted a detailed sectional analysis and comparison of wax pattern from the contralateral contours. The corrections can be made at desired location and can be checked again.

The compass method yielded optimum results, but the stability of compass over the skull was an issue. The compass method can be used only in those cases where the defect has limited vertical dimension. In extensive vertical cranium defects, the compass method is indecisive.

The custom flask fabricated for these cases helped to accommodate the entire wax pattern. It allowed a uniform gypsum product around the wax pattern thus avoiding distortion of the wax pattern. It also ensures the proper polymerization of heat cure PMMA without any water seepage, thus reducing porosities in the final prosthesis.

## CONCLUSION

Rapid prototyping along with reverse engineering is an advanced and predictive method used for the fabrication of cranioplast. Different tools used to assess symmetry and contour provide a greater esthetic result. RPT along with symmetry analysis had provided better patient satisfaction. These techniques had provided more accurate and precise prosthesis with enhance esthetics and contour.

## Declaration of patient consent

The authors certify that they have obtained all appropriate patient consent forms. In the form, the patient has given his consent for his images and other clinical information to be reported in the journal. The patient understands that his name and initials will not be published and due efforts will be made to conceal identity, but anonymity cannot be guaranteed.

## Acknowledgment

I would like to thank my senior guides Dr. Rekha Gupta and Dr. Shubhra Gill constantly guiding me in completing this challenging clinical case. I would like to thank my colleague Dr. Mamta for helping in each step of clinical and laboratory procedure till completion of the case. We would like to thank my parent and friends for constant support.

## Financial support and sponsorship

Nil.

## Conflicts of interest

There are no conflicts of interest.

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