MEDICAL SCIENCE

Prosthetic rehabilitation of cranial defect with 3-dimensional printed mold using polymethylmethacrylate implant

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ABSTRACT

Aim and Background: Many patients are requesting cranial prosthetics due to the better treatment options for head injuries. A cranial prosthesis helps the patient's psychological health while relieving pain and discomfort. Repairing the cranial vault serves three purposes: safeguarding the brain tissue beneath, lessening any localized discomfort and patients concerned, and enhancing the skull's appearance. *Case description:* This article reports the case of a 30-year-old female patient who underwent cranioplasty and had a personalized three-dimensional (3D) template mold made for polymethylmethacrylate (PMMA) implant fabrication to cover the defect. Using biomaterials and a 3D printer, the virtual representations were turned into accurate models. The unique 3D-printed mold was used to create the PMMA implant. *Conclusion:* With a simple and cost-effective production procedure, 3D molds for PMMA implants may enable an aesthetic reconstruction with the potential for reduced complication rates.

Keywords: Cranioplasty, Cranial implant, Cranial defects, Polymethylmethacrylate resin, PMMA prosthesis, Cranial vault reconstruction, Low-cost prosthesis 3D printing

1. INTRODUCTION

In medicine, there is a growing recognition that, rather than just extending a patient's survival, the outcome must be assessed in terms of quality of life and cost-effectiveness. Such issues are especially significant in decompressive craniectomy, which relieves excessive brain swelling (ICP) in some cases of ischemic stroke, traumatic brain injury, and subarachnoid hemorrhage. Cerebrovascular compliance, cerebral oxygenation, and cerebral perfusion can all benefit from lowering ICP. Although many studies have proven that decompressive craniectomy has a long-term positive effect, it is still considered to be a salvaging procedure. Long-term, negative neurocognitive and psychosocial impacts that result in low quality of life and financial burden are extensively documented (Lal et al., 2020).

The main objectives of cranial defect repair are to safeguard the underlying brain tissue, ease pain at the defect site, enhance appearance, and lessen patient anxiety. Using prostheses and a multi-disciplinary approach can help rebuild a missing body part even though the human body cannot repair it. Cranioplasty is an ancient neurosurgical treatment been used since 3000 BC (De La Peña et al., 2018). Cranioplasty is done using a variety of procedures. The first is to use an autogenous bone flap that was taken from the patient and either frozen or stored in the subcutaneous abdominal pocket, albeit in these situations, the risks of infection, absorption, and diminished strength should be considered. Allograft and xenograft bone transplants carry a high risk of complications and are no longer recommended.

When autologous bone is unavailable, alloplastic repair using biocompatible materials is a decent option. Infection-resistant, inert, noncarcinogenic, flexible, rigid, easy to handle, and cost-effective, this material should be used. For cranioplasties, many biomaterials are employed, frequently based on the institution's routine or the surgeon's expertise. The most common materials are polymethylmethacrylate (PMMA), hydroxyapatite, titanium, bioactive glass ceramics, and polyetheretherketone, each having its own set of benefits and drawbacks (da Silva Júnior et al., 2021). PMMA often known as acrylic, was initially created following World War II and is a heat-resistant, flexible, and biocompatible material with good strength.

It has been regularly used in cranioplasties for decades. The neurosurgeon performs freehand implant molding if required during surgery, but it takes excellent clinical competence and three-dimensional (3D) orientation to get a satisfactory aesthetic result (Eppley, 2005). Production of customized implants based on three-dimensional Computed Tomography scans and computer-aided design/computer-aided manufacture (CAD/CAM), has been continuously enhanced over the last two decades, to achieve an accurate and beautiful fit over the cranial defect. The perfect biomaterial for an implant is still being explored, and several different choices have been tried with comparable results (Jardini et al., 2014; Pucci et al., 2017).

2. CASE REPORT

A 30-year-old female patient presented with severe head trauma after a Road Traffic Accident (RTA) which required to be treated with an immediate decompressive craniotomy. The Patient remained hospitalized for around ten days, after which she was discharged. Six months later patient again reported to the Department of Neurosurgery for reconstruction of the cranial defect. She was assessed clinically and she was alert and oriented, calm, and cooperative. A Computed Tomography Scan showed a 12*10 cm defect in the left temporal-parietal and frontal bones (Figure 1). A multi-disciplinary approach was planned to reconstruct the defect, which also involved the Department of Maxillofacial Prosthodontics.

Figure 1 Patient with a defect in left temporo-parital and frontal bones

3D printing-assisted cranioplast fabrication was planned for this case. In this case, a fresh CT scan of the patient's skull was collected in Digital Imaging and Communication in Medicine (DICOM) format, generating a 3D image of the patient's skull (Figure 2).

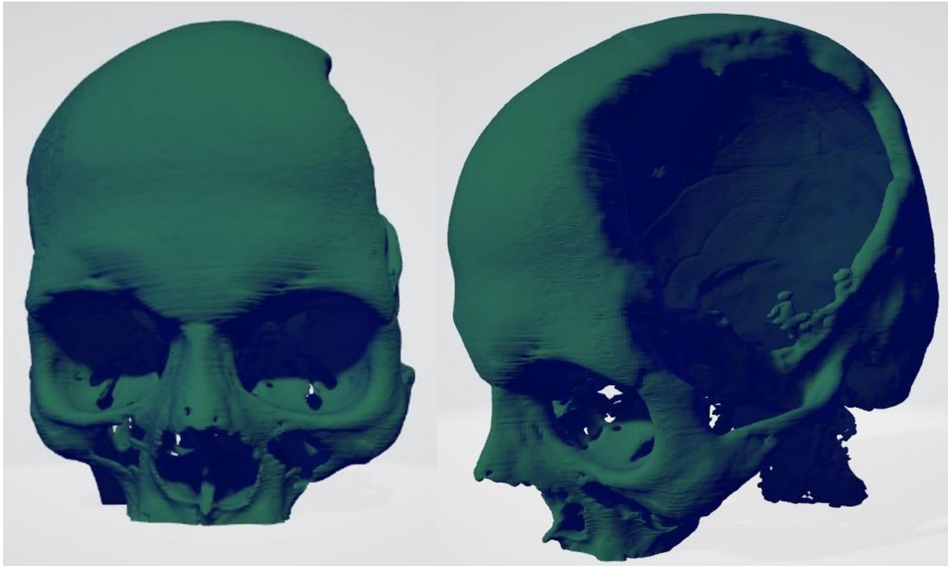

Figure 2 Generation of the 3-D image of the patient's skull using CT-SCAN

The intact contralateral side of the patient's skull was taken as a reference to create a three-dimensional model for fabricating the implant (Figure 3). The 3D model was printed using a Standard Tessellation Language (STL) file (Figure 4).

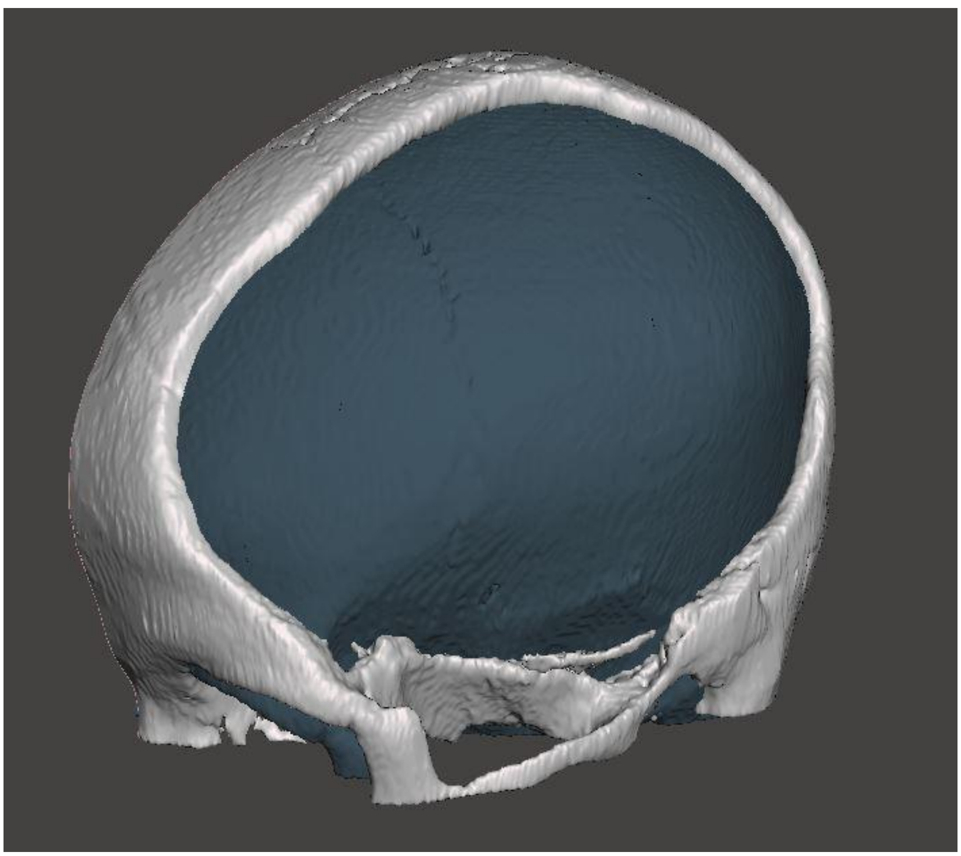

Figure 3 3-D model for fabrication of implant

Figure 4 3-D model printed using STL file for fabrication of implant

Wax was adapted over the replica of the 3D printed model obtained and following the conventional method of dewaxing and compression molding technique heat cure polymethylmethacrylate acrylic implant was obtained (Figure 5).

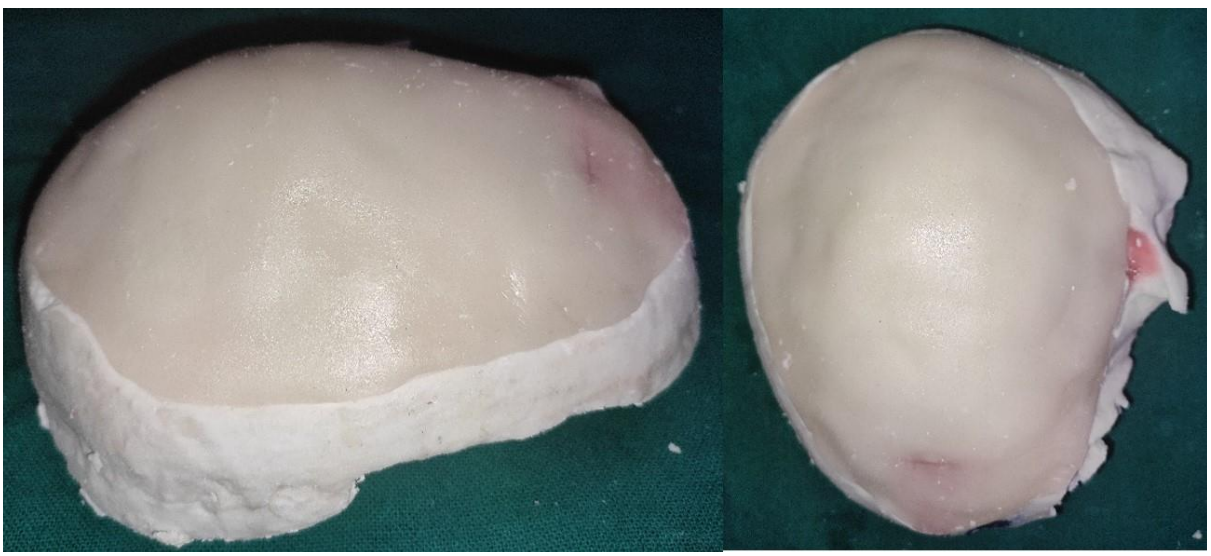

Figure 5 Implant fabricated with PMMA using 3-D model

Random holes were drilled on the surface of the implant to expedite the weeping of fluid in sub-galeal space. The prosthesis was finished and polished and was given to the Central Sterile Supply Department (CSSD) for Ethylene Oxide Sterilization (ETO). Cranioplasty Surgery was planned under general anesthesia in which the flap was raised and the implant was tried. Minimal adjustment of the implant that was needed was made intraoperatively at the time of surgery and was made using acrylic bur and micromotor and the implant was screwed using four titanium mini-plates. The flap was placed back in position and secured with the sutures (Figure 6).

Post-operatively cranial contour was found pleasing and the patient was kept 4 days under observation of the neurosurgery department and discharged thereafter (Figure 7). The patient was kept on regular follow up with the first follow-up visit kept post 7 days of the discharge date.

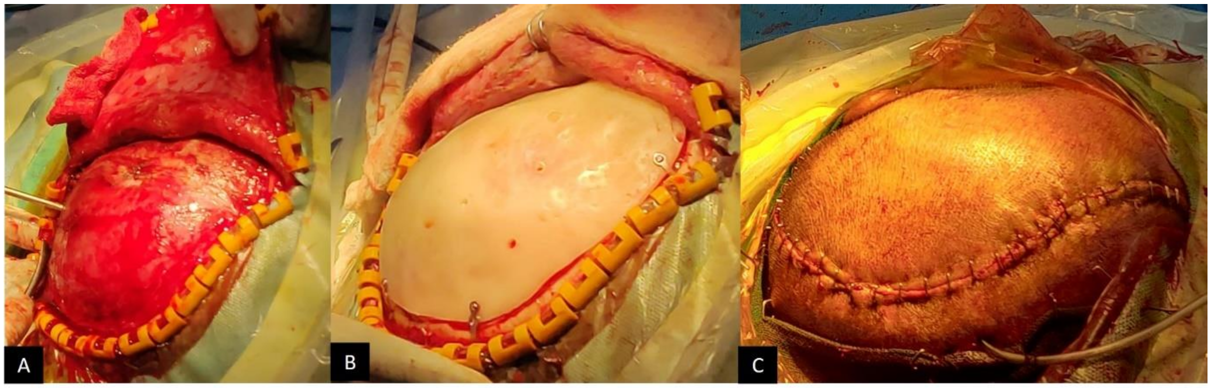

Figure 6 Surgical placement of implant A. Flap reflection B. Placement of the PMMA implant C. Closure of the flap

Figure 7 Post-operative image

3. DISCUSSION

Hydroxyapatite, titanium, and Polyether ether Ketone are commonly used cranioplasty materials because of their biocompatibility, durability, and high adaptability precision. Nevertheless, their use is limited due to the expensive costs and limited availability. A prefabricated, tailored, heat-polymerized Polymethyl methacrylate cranial prosthesis is the greatest option to hydroxyapatite, patient-specific titanium, and Polyether ether Ketone prosthesis. It is widely accessible, inexpensive, dimensionally stable, biocompatible, radiolucent, non-conductive, simple to produce, has a low content of residual monomer, and allows slight intra-operative adjustments if necessary (Abd El-Ghani, 2018).

Since 1970, various processes have been used to make Polymethyl methacrylate prostheses by hand, but these methods have been surpassed by computer-assisted design and manufacturing techniques (CAD/CAM), which involve using images of the cranial defect and fabricating Polymethyl methacrylate prostheses with a three-dimensional printer. However, the main drawback of this technique is cost. Manufacture of Polymethyl methacrylate preoperative implants can also be done manually. Manual manufacturing is less expensive and laborious than using a patient's three-dimensional computed tomography data to create a three-dimensional implant. However, this last procedure has recently acquired favor because it does not need to be attempted on the bone defect to achieve outstanding cosmetic outcomes.

The 3-D model of the patient's entire skull was created for a range of factors. It allowed the operator to compare the carved wax pattern's shape to the intended contralateral contour. The definitive Polymethyl methacrylate prosthesis might also be used to verify symmetry, adaptability, marginal integrity, and any processing errors on the negative cranioplast replica. Furthermore, because it allowed for a better picture and understanding of the planned treatment plan, this model was a highly useful tool for patient explanation (Desai, 2019).

4. CONCLUSION

This procedure is less technique-sensitive, predictable, and reproducible, and it may be used on cranial lesions of various sizes and shapes, regardless of their location. It's a cost-effective and time-saving option that produces outcomes comparable to patient-specific titanium or Polyether ether Ketone prostheses. Furthermore, by generating a good marginal accurate prosthesis, fit, and shape, this unique process for customized mold creation ensures optimum results. PMMA-based implants that are prefabricated have several benefits. In this case, report a simple and cost-effective method of 3D printed positive replicas in the form of PLA molds obtained from the CBCT scan. Because of this, it is suggested to use this special method for making PMMA-based implants to get a better-fitting implant and a highly aesthetic result for cranioplasty at a reasonable price.

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Authors' contribution

Conceptualization, supervision, methodology, resources, data collection, writing, and formal analysis: Smruti Gujjelwar, Ankita Pathak Writing, investigation, resources, analysis, draft preparation, review and editing: Mithilesh Dhamande Writing, investigation, analysis, review, and editing: Seema Sathe. All authors have read and agreed to submit the manuscript.

Informed consent

Written and Oral informed consent was obtained from all individual participants included in the study. Additional informed consent was obtained from all individual participants for whom identifying information is included in this manuscript.

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Conflict of interest

The authors declare that there is no conflict of interest.

Data and materials availability

All data sets collected during this study are available upon reasonable request from the corresponding author.

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