Customized 3D Cranioplasty in Peru: Cost-Effective Results with Polymethylmethacrylate

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Introduction

Extensive craniectomy often requires biocompatible materials for cranioplasty when autologous bone is not viable. While PEEK mplants are effective, they are costly and delayed by importation. Polymethylmethacrylate (PMMA) offers a low-cost alternative but is less effective for large defects. This report outlines the first use of PMMA with 3D-customized molds in Peru, highlighting its surgical technique, outcomes, and cost-effectiveness compared to CAD implants.

Methods

We present five pediatric cases, all under 18 years, with extensive cranial defects resulting from trauma, treated over an 8month period with a minimum follow-up of 6 months. Defects were caused by initial injuries, decompressive craniectomy, or bone resorption. Thin-slice (0.5mm) CT scans were used to generate 3D digital models of the defects in stereolithography (.stl) format using 3D Slicer software. These models were processed in MeshMixer® to create customized molds, 3D-printed in acrylonitrile butadiene styrene (ABS), and sterilized with ethylene oxide to prevent deformation.

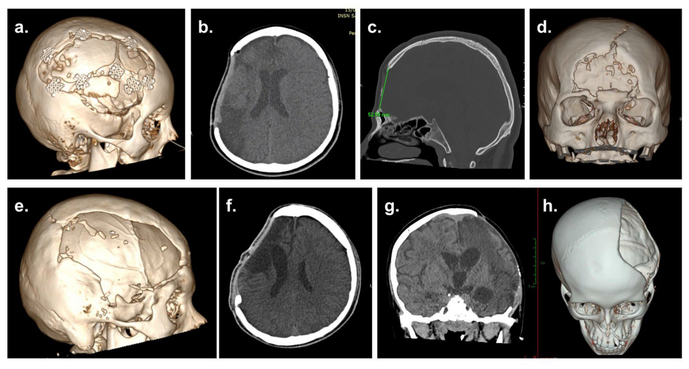


Figure 1. CT images illustrating the cranial defects observed in the case series.

a. Patient 1 3D Reconstruction	e. Patient 4 3D Reconstruction
b. Patient 2 axial view	f. Patient 4 Axial View
c. Patient 3 sagittal view	g. Patient 5 Coronal View
d. Patient 3 3D Reconstruction	h. Patient 5 3D Reconstruction

Surgical Technique

Ssterile molds lined with polyethylene bags were used to shape PMMA (Cemex® RX), which polymerized within 4-7 minutes. Once semi-solid, the molds were removed, and the implants were left to fully polymerize. Before placement, 5-8 perforations were added to prevent fluid Accumulation beneath the implant. The implants were secured using a non-absorbable cranial fixation system (Craneofix) and sutures.

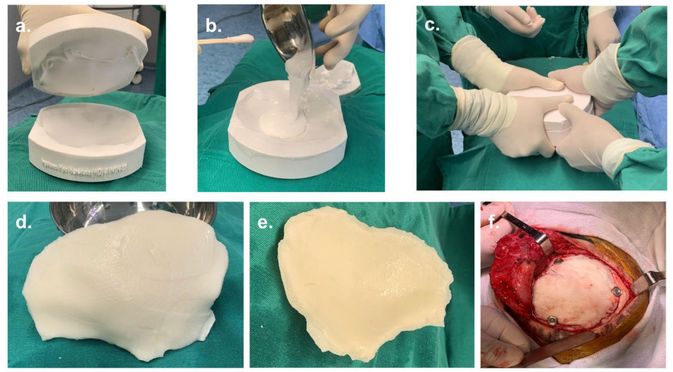


Figure 3.

a. Preparation of 3D Printed Mold: Sterile custom molds were prepared by lining them with layer of polyethylene bags to ensure a clean, non-stick surface.
b. The PMMA mixture was carefully prepared and left to sit for three minutes to achieve optimal consistency before being poured into the custom mold.
c. Once the PMMA was in the mold, it was sealed and kept closed for three to four minutes, allowing the solidification process to begin.
d. After the initial setting, the mold was carefully removed, and the implant was left on the operating table until the exothermic polymerization reaction was fully completed. Pictured is the external surface of the implant.
e. This is the internal surface of the implant.
f. The implant was then secured using a non-absorbable cranial fixation system (Craneofix).

Case 1

Male patient 9 years old. He underwent decompressive craniectomy due to severe TBI and Cranioplasty with autologous bone. Progressive bone resorption was observed. A reconstruction of the right frontotemporal parietal cranial defect of 117.7mm x 85.7mm was performed using CT. The time from the tomography to the fabrication of the personalized mold for cranioplasty was 7 days.

Case 2

9-year-old male patient with severe traumatic brain injury. He underwent right hemispheric decompressive craniectomy 15 months ago in another institution. At the time of evaluation, the [atient had a 15-point GCS with mild left brachial paresis. Cranial Reconstruction was performed by tomography, obtaining a defect of 90.2mm x 84.2mm. The time from the tomography to the fabrication of the personalized mold for cranioplasty was 5 days.

Case 3

16-year-old male patient with severe traumatic brain injury due to a vehicle accident, with bifrontal comminuted fracture of 12 months of evolution. At the time of this hospitalization, the patient had a Glasgow coma scale of 15 points, without motor deficit. The tomographic reconstruction showed an asymmetric defect with major diameters of 74.8mm x 52.6mm. The time from the tomography to the fabrication of the customized mold for cranioplasty was 5 days.

Case 4

17-year-old male patient who underwent right hemispheric decompressive craniectomy due to severe traumatic brain injury secondary to a grenade explosion 13 months ago. The patient had a Glasgow coma scale of 15 points and left hemiparesis. Cranial tomographic reconstruction showed a defect of 116.9mm x 88.3mm. The time from the tomography to the elaboration of the customized mold for cranioplasty was 5 days.

Case 5

12-year-old male patient with severe traumatic brain injury who underwent left hemispheric decompressive craniectomy 12 months ago. The patient had right hemiparesis and mixed aphasia. Cranial tomographic reconstruction showed a defect of 117.5mm x 108.9mm. The time from cranial tomography to the elaboration of the customized mold for cranioplasty was 4 days.

Conclusion

The time from CT acquisition to 3D model assembly was 5–7 days, with surgeries averaging 2.5 hours. No complications were observed after 6–12 months of follow-up. Satisfactory aesthetic and functional outcomes were achieved, with the PMMA implant cost ($350) significantly lower than imported PEEK implants ($10,000-$15,000), which require over 45 days for production and shipping. Decompressive craniectomy often necessitates cranioplasty, but high costs and delays in LMICs limit access to advanced implants. PMMA offers a lightweight, durable, and cost-effective alternative when autologous bone is not viable. Using 3D-printed ABS molds sterilized with ethylene oxide, we safely fabricated custom implants intraoperatively, reducing costs by 97% and waiting times eightfold compared to CAD implants.