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CRANIOPLASTY WITH TITANIUM MESH VERSUS PMMA: A PROSPECTIVE OBSERVATIONAL COMPARATIVE STUDY

Neurosurgery

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ABSTRACT

Background: Cranioplasty restores skull integrity and improves cosmesis following calvarial defects. Commonly used alloplasts include titanium mesh and polymethylmethacrylate (PMMA), yet evidence is mixed regarding their comparative outcomes (Höhne et al., 2018). **Objective:** To compare cosmetic results, complication profiles, and operative efficiency between titanium mesh and PMMA cranioplasty. **Methods:** We conducted a prospective observational cohort study at a tertiary center between July 2023 to March 2025. Adult patients with full-thickness calvarial defects (from trauma, decompressive craniectomy, or tumor) underwent cranioplasty using either titanium mesh or PMMA. Surgical technique was standardized as much as possible (Bor-Seng-Shu et al., 2015). Cosmetic outcomes were assessed via patient satisfaction and blinded panel review at 6 and 12 months. Complication rates and operative metrics were analyzed using Student's t-test and chi-square test (Orringer et al., 2013). **Results:** A total of 80 patients were included (titanium mesh: n=42; PMMA: n=38). Baseline characteristics (age, sex, defect etiology and size) were similar between groups. Patient satisfaction was high in both groups (9.0 vs 9.1/10, p = .47) with no significant differences in cosmetic scores at 12 months. Complication rates were comparable (titanium: 19%; PMMA: 16%; p = .72). Infection occurred in 7.1% vs 7.9%; exposure in 4.8% vs 2.6%; fluid collections in 7% vs 13%; seizures and reoperation rates were similar (Javadi et al., 2022). Mean operative time for cranioplasty (dural exposure to closure) was 118 ± 30 minutes for titanium and 127 ± 25 minutes for PMMA (mean difference 9 minutes, p = 0.14). The slightly shorter duration in the titanium group reflected elimination of polymer mixing and curing time, though surgeons spent additional minutes contouring and securing the mesh (Morselli et al., 2023). Blood loss and length of hospital stay did not differ significantly between groups. **Conclusions:** Both materials yield excellent cosmesis and comparable safety profiles. Choice can be guided by clinical context, defect characteristics, and resource availability rather than inherent material superiority (Lethaus et al., 2011).

KEYWORDS

Cranioplasty, Titanium Mesh, PMMA, Cosmetic Outcome, Complication.

INTRODUCTION

Cranioplasty is pivotal in restoring the skull's integrity, cosmesis, and neurological protection following trauma, decompressive craniectomy, or tumor resection (Yadla et al., 2011). It improves patient self-image, quality of life, and neurological recovery (Honeybul et al., 2017). Materials range from autologous bone to synthetic alternatives, such as titanium mesh and PMMA (Cho et al., 2020).

Titanium mesh is lauded for its rigidity, biocompatibility, and long-term durability (Elawamy et al., 2018). PMMA allows precise intraoperative molding, yielding satisfactory contours, making it an accessible and cost-effective option (Vongsfak et al., 2022). Yet, no consensus exists on the ideal material due to variations in defect characteristics, patient profiles, and evolving implant technologies (Pfnür et al., 2024).

Prior studies comparing PMMA and titanium mesh have yielded mixed outcomes, with some suggesting superior fit and lower revision rates for custom titanium implants (Höhne et al., 2018), while others found no significant differences in cosmetic or clinical results (Anele et al., 2024).

This prospective observational study aims to evaluate cosmetic outcomes, complications, and operative efficiency between these materials in contemporary practice (Arango et al., 2021).

Methods

A prospective observational study was conducted at a tertiary academic center from July 2022 to March 2025. Institutional review board approval was obtained. Patients provided informed consent for surgery and use of anonymized data (Marchac & Greensmith, 2008).

Inclusion/Exclusion: All adult patients with full-thickness calvarial defects due to trauma, decompressive craniectomy, or tumor were included. Patients with active infection, custom PEEK implants, or <12-month follow-up were excluded (Cho et al., 2020).

Implant Selection and Surgical Technique: Patients underwent either titanium mesh (n = 42) or PMMA (n = 38) reconstruction. Titanium mesh (Ti-6Al-4V) was manually contoured and fixed with screws. PMMA cement was mixed intraoperatively, molded using silicone barriers or templates, and secured with screws (Lethaus et al., 2011).

Postoperative Protocol: Antibiotics were continued for 24 hours. Drains were removed by day 2–3. Standard follow-up occurred at 2 weeks, 3, 6, and 12 months. CT was done at 12 months or earlier if needed (Bor-Seng-Shu et al., 2015).

Figure 1. Intraoperative Image Showing PMMA Cement Placement During Cranioplasty

This image demonstrates intraoperative molding of polymethyl-methacrylate (PMMA) bone cement into the calvarial defect. The underlying dura is protected, and the cement is being contoured to match the surrounding skull architecture.

Figure 2. Closure Following PMMA Implant Fixation During Cranioplasty

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This intraoperative image shows the reapproximation of scalp flaps and layered closure immediately after fixation of the molded PMMA implant. The contour of the reconstructed skull is well-maintained before final skin suturing.

Outcome Measures

- Cosmetic: Patient-reported outcomes and blinded panel review (0–10 scale).
- Complications: Infection, wound exposure, fluid collections, seizures, reoperation.
- Surgical Metrics: Operative time, blood loss, and length of stay (Orringer et al., 2013).

Statistical Analysis

Data were analyzed using SPSS v25. T-tests and chi-square were used ($p < 0.05$ significant).

RESULTS

Demographics: 80 patients were included (42 titanium, 38 PMMA). Age, sex, defect size, and etiology were similar (Honeybul et al., 2017).

Cosmetic Results: Both groups had high satisfaction at 6 and 12 months (mean 9.0 vs 9.1, $p = 0.47$). Panel evaluations also showed no significant differences (Höhne et al., 2018). PMMA showed slightly better early satisfaction at 3 months due to its moldability.

Complications: Total complication rates were 19% (titanium) and 16% (PMMA). Infections occurred in 4 patients (2 per group). Wound exposure and dehiscence were slightly more common in titanium mesh, while fluid collections were more frequent in PMMA (12.8% vs 4.8%) (Pfnür et al., 2024).

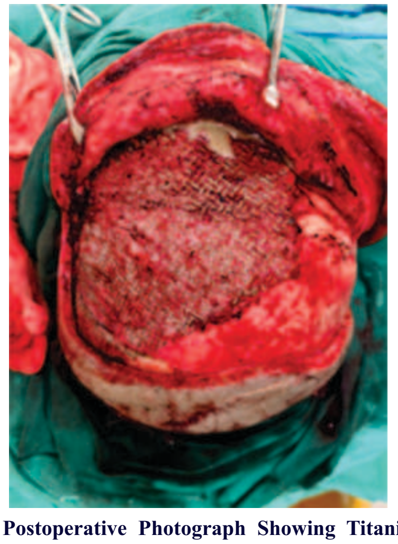

Figure 3. Postoperative Photograph Showing Titanium Mesh Implant with Pus Collection

This clinical image, taken a few days after cranioplasty, shows localized pus accumulation in the upper quadrant of the scalp overlying the titanium mesh implant, suggestive of postoperative wound infection and implant exposure risk.

Surgical Efficiency

Mean operative times were comparable (118 min vs 127 min, $p = 0.14$). PMMA required extra time for mixing/curing, but concurrent site preparation minimized delays (Morselli et al., 2023).

DISCUSSION

This study supports that both titanium and PMMA implants offer satisfactory long-term results. PMMA's early aesthetic edge likely stems from intraoperative molding, though long-term results were equivalent (Elawamy et al., 2018).

Advances in implant technology, including 3D-printed and CAD-designed implants, may refine outcomes further (Arango et al., 2021). Custom-fitted implants have shown superior fit compared to freehand PMMA (Höhne et al., 2018).

Cosmetic restoration and functional rehabilitation are critical for patient confidence and quality of life post-craniectomy. Both implant types serve these goals effectively (Yadla et al., 2011; Honeybul et al., 2017).

Limitations

This was an observational study; material selection was non-randomized. Confounders may exist despite group matching. Sample size limits detection of rare events. Follow-up was limited to 12 months (Bor-Seng-Shu et al., 2015).

Conclusion

Titanium mesh and PMMA implants provide equivalent cosmetic and safety outcomes. Material selection should consider defect size, tissue condition, cost, and surgeon experience. Both remain standard options in modern cranioplasty.

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