

Outcomes and Complications in Cranioplasty: A Retrospective Analysis of Surgical Techniques and Materials

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ABSTRACT

Background: Cranioplasty is performed to restore cranial integrity, improve neurological function, and provide cosmetic benefits following decompressive craniectomy or cranial defect. Despite advancements in implant materials and surgical techniques, complication rates remain significant, and functional outcomes are influenced by multiple factors. **Methods & Materials:** This retrospective study included 115 patients who underwent cranioplasty at Dhaka Medical College and Green Life Hospital, Bangladesh, between June 2023 and May 2024. Data on demographics, comorbidities, indications, implant materials, surgical techniques, complications, and functional outcomes (Glasgow Outcome Scale, GOS) at 6 months were analyzed. **Results:** The mean age was 38.6 years, with a male predominance (64.3%). Post-traumatic cranial defect was the leading indication (56.5%). Autologous bone was most frequently used (56.5%), followed by PMMA (24.3%), titanium mesh (13.0%), and PEEK (6.1%). Overall, 29 patients (25.2%) developed complications, most commonly surgical site infection (10.4%). Complication rates were highest with autologous bone (27.7%) and lowest with PEEK (14.3%). Modified/staged reconstruction showed a slightly higher complication rate (29.0%) compared with standard onlay fixation (23.8%). At 6 months, 72.2% achieved favorable outcomes (GOS 4–5). Early cranioplasty (<3 months) tended to yield better outcomes (78.9%) compared with delayed procedures (68.8%). Functional outcomes were similar across surgical techniques. **Conclusion:** Cranioplasty provides significant functional and reconstructive benefits, though complications remain common, particularly with autologous grafts. Synthetic implants demonstrated

lower complication rates, while earlier surgical intervention was associated with improved recovery. Patient factors and surgical timing appear to influence outcomes more strongly than material type or fixation method.

Keywords: Cranioplasty, Surgical technique, Materials, Postoperative complications, Functional outcomes, Surgical timing.

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INTRODUCTION

Cranioplasty is a crucial neurosurgical procedure performed to reconstruct cranial defects resulting from trauma, tumors, congenital anomalies, or decompressive craniectomy^[1]. Initially aimed at cosmetic restoration, it also provides functional benefits, including protection of the brain and improvement of neurological symptoms associated with the “syndrome of the trephined”^[1,2]. The choice of implant material significantly influences outcomes; autologous bone remains popular for its biocompatibility, but synthetic materials such as polymethyl methacrylate, titanium, and hydroxyapatite are increasingly used due to reduced infection risk and improved structural stability^[2–4]. Recent advances have introduced innovative materials and composites designed to enhance osteointegration, mechanical strength, and patient-specific customization, further expanding the options available for cranioplasty^[4]. Historically, cranioplasty materials have evolved from simple metals and bone grafts to advanced polymers and composites, reflecting improvements in durability, osteointegration, and customization^[5,6]. In addition, modern fixation techniques, including plates, screws, and resorbable systems, have enhanced implant stability

and reduced complications^[6]. Despite these advances, cranioplasty is associated with complications such as infection, bone flap resorption, hematoma, and implant failure, which are influenced by factors like patient age, comorbidities, defect size, and material choice^[7–9]. Systematic reviews and meta-analyses have highlighted differences in complication rates among various materials, emphasizing the need for careful material selection tailored to individual patients^[8]. Understanding these risks and outcomes is essential for optimizing surgical planning and improving both functional and aesthetic results^[7–9].

Given the variability in outcomes and complication rates associated with different materials and surgical techniques, there remains a need for comprehensive analyses to guide clinical decision-making. This study aims to retrospectively evaluate the outcomes and complications of cranioplasty, with a focus on how surgical approaches and choice of implant materials influence patient results. The findings are expected to provide evidence-based insights to optimize surgical strategies, minimize complications, and improve functional outcomes in cranioplasty procedures.

METHODS & MATERIALS

This retrospective observational study was conducted at Dhaka Medical College (DMC) and Green Life Hospital, Dhaka, Bangladesh, from June 2023 to May 2024. The study aimed to evaluate postoperative complications and functional outcomes associated with different cranioplasty materials and surgical techniques. Medical records of 115 patients who underwent cranioplasty during the study period were reviewed. All age groups and both genders were included. Patients with incomplete records or lost to follow-up were excluded. Data were extracted on patient demographics, comorbidities, indications for cranioplasty, materials used (autologous bone, PMMA, titanium mesh, PEEK), surgical techniques (standard onlay fixation or modified/staged reconstruction), timing of surgery (early <3 months vs. delayed >3 months), postoperative complications, and functional outcomes assessed at 6 months using the Glasgow Outcome Scale (GOS). The primary outcome was the incidence and type of postoperative complications, including surgical site infection, wound dehiscence, bone resorption, hematoma, seizures, and implant exposure, while the secondary outcome was functional recovery at 6 months, analyzed according to timing of cranioplasty and surgical technique. Data

were analyzed using SPSS version 26.0. The study was approved by the Institutional Review Boards of DMC and Green Life Hospital. Patient confidentiality was maintained by anonymizing records, and the study adhered to the Declaration of Helsinki principles.

RESULTS

Patient Characteristics

Table 1 shows a total of 115 patients were included, with a mean age of 38.6 years (range: 7–72). There was a male predominance, with 74 males (64.3%) and 41 females (35.7%). The most frequent

comorbidities were hypertension in 29 patients (25.2%) and diabetes mellitus in 22 patients (19.1%). The mean follow-up period was 6 months.

Table I
Demographic and Clinical Characteristics of Patients (n = 115).

Variable	Value
Mean age (years)	38.6 (range: 7–72)
Gender	Male: 74 (64.3%) Female: 41 (35.7%)
Comorbidities	Hypertension: 29 (25.2%) Diabetes mellitus: 22 (19.1%)
Mean follow-up	6 months

Indications for Cranioplasty

Table II presents the leading indication was post-traumatic cranial defect (56.5%),

followed by malignant cerebral edema/stroke (21.7%), infection-related

bone flap removal (10.4%), tumor resection (7.0%), and other causes (4.4%).

Table II
Indications for Cranioplasty.

Indication	Number of patients (%)
Post-traumatic cranial defect	65 (56.5)
Malignant cerebral edema / stroke	25 (21.7)
Infection-related bone flap removal	12 (10.4)
Tumor resection	8 (7.0)
Other causes	5 (4.4)

Materials and Surgical Techniques

Table III shows autologous bone flap was the most frequently used material (56.5%), followed by PMMA (24.3%), titanium mesh

(13.0%), and PEEK (6.1%). In terms of surgical technique, standard onlay fixation was performed in 84 patients (73.0%), whereas 31 patients (27.0%) required

modified or staged reconstruction due to large or complex cranial defects.

Table III
Materials and Surgical Techniques Used for Cranioplasty.

Material	Number of patients (%)
Autologous bone flap	65 (56.5)
Polymethylmethacrylate (PMMA)	28 (24.3)
Titanium mesh	15 (13.0)
PEEK	7 (6.1)
Techniques	
Standard Onlay Fixation	84 (73.0)
Modified / Staged Reconstruction	31 (27.0)

Postoperative Complications

Table IV and Figure I presents, 29 patients (25.2%) experienced postoperative complications. The most frequent was surgical site infection (10.4%), followed by wound dehiscence (6.1%), bone resorption

(4.3%), hematoma (2.6%), seizures (1.7%), and implant exposure (2.6%). When analyzed by material, complication rates were highest in autologous bone flaps (27.7%), compared with PMMA (21.4%), titanium mesh (20.0%), and PEEK (14.3%).

Regarding surgical techniques, patients undergoing modified/staged reconstruction had a slightly higher complication rate (29.0%) compared with standard onlay fixation (23.8%), though the difference was not statistically significant.

Table IV
Postoperative Complications by type, material, and surgical technique (n=115).

Complications	n (%)
Overall complications	29 (25.2)
– Surgical site infection	12 (10.4)
– Wound dehiscence	7 (6.1)
– Bone resorption	5 (4.3)
– Hematoma	3 (2.6)

– Seizures	2 (1.7)
– Implant exposure	3 (2.6)
By material	
– Autologous bone flap (n=47)	13 (27.7)
– PMMA (n=28)	6 (21.4)
– Titanium mesh (n=20)	4 (20.0)
– PEEK (n=20)	3 (14.3)
By surgical technique	
– Standard onlay fixation (n=84)	20 (23.8)
– Modified/staged reconstruction (n=31)	9 (29.0)

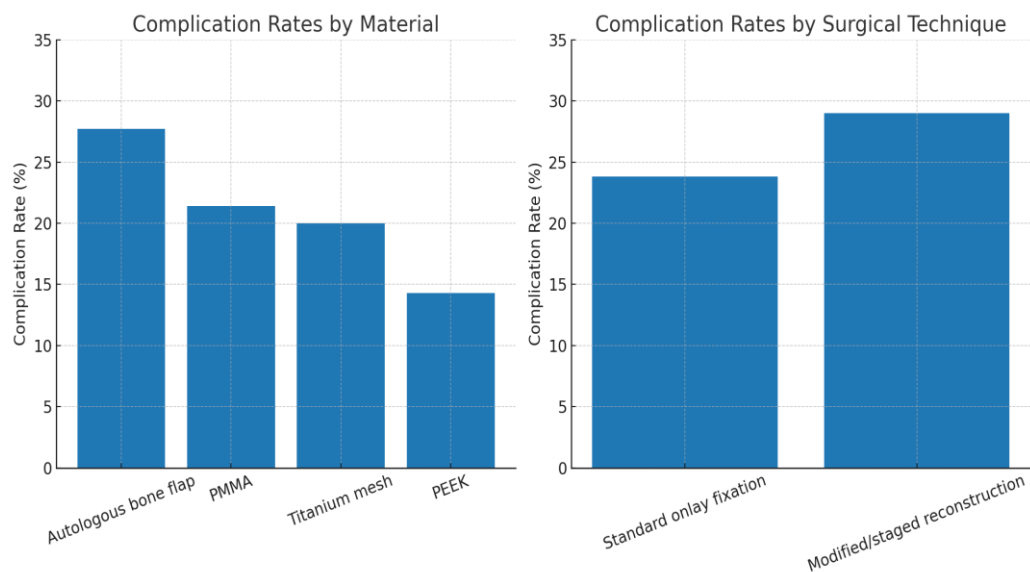


Figure 1 Postoperative Complications by material, and surgical technique (n=115).

Figure 1 shows the postoperative complications by material, and surgical technique. On the left, complication rates are shown by material (highest in autologous bone flap, lowest in PEEK). On the right, complication rates are shown by surgical technique (slightly higher in modified/staged reconstruction).

Functional Outcomes
Table V shows at 6 months, 83 patients (72.2%) achieved favorable outcomes (GOS 4–5), while 32 patients (27.8%) had unfavorable outcomes (GOS 1–3). Early cranioplasty (<3 months) was associated with a greater proportion of favorable outcomes (78.9%) compared with delayed

procedures (68.8%). Outcomes were also comparable between surgical techniques: 74.0% favorable outcomes in standard fixation versus 67.7% in modified/staged reconstruction.

Table V
Functional Outcomes at 6 Months (Glasgow Outcome Scale).

Parameter	Favorable Outcome (GOS 4–5), n (%)	Unfavorable Outcome (GOS 1–3), n (%)	Total (n)
Timing of Cranioplasty			
Early (<3 months)	30 (78.9)	8 (21.1)	38
Delayed (>3 months)	53 (68.8)	24 (31.2)	77
Surgical Technique			
Standard onlay fixation	62 (74.0)	22 (26.0)	84
Modified/staged reconstruction	21 (67.7)	10 (32.3)	31
Total	83 (72.2)	32 (27.8)	115

DISCUSSION

In this study of 115 patients undergoing cranioplasty, the mean age was 38.6 years, with a male predominance (64.3%), consistent with previous reports [10,11]. Hypertension (25.2%) and diabetes mellitus (19.1%) were the most frequent comorbidities, both of which are recognized as potential risk factors for postoperative

complications due to their effects on wound healing and infection susceptibility [10]. Post-traumatic cranial defects were the most common indication for cranioplasty (56.5%), followed by malignant cerebral edema/stroke (21.7%), infection-related bone flap removal (10.4%), and tumor resection (7.0%). These findings mirror earlier studies that identify trauma as the

leading indication, while also emphasizing additional benefits of cranioplasty in neurological recovery, cranial protection, and cosmesis [1,12,13]. Standard onlay fixation was used in most cases (73%), whereas 27% required modified or staged reconstruction for large or complex defects, consistent with literature noting that defect

size and complexity guide the choice of surgical technique^[12,13].

Overall, 25.2% of patients developed complications, most commonly surgical site infection (10.4%). Complication rates were highest with autologous bone flaps (27.7%) compared with synthetic options such as PMMA (21.4%), titanium (20.0%), and PEEK (14.3%). Patients who underwent modified or staged reconstructions had a slightly higher complication rate than those treated with standard onlay fixation (29.0% vs. 23.8%). These findings support prior reports that autologous bone is more prone to resorption and infection, while synthetic materials generally provide greater stability and durability, though infection risk remains a concern^[5]. Reviews have also highlighted that complex or staged reconstructions may carry greater risk due to longer operative times and increased tissue handling^[3,6].

At 6 months, favorable outcomes (GOS 4–5) were observed in 72.2% of patients, aligning with previous studies demonstrating that cranioplasty contributes to neurological and functional recovery^[14]. Early cranioplasty (<3 months) was associated with a greater proportion of favorable outcomes (78.9%) than delayed procedures (68.8%), consistent with evidence that earlier intervention enhances neurological and cognitive recovery without increasing complication rates^[15]. Delayed procedures, on the other hand, have been linked to higher risks of infection and suboptimal recovery^[16]. In our series, functional outcomes appeared similar between surgical techniques (74.0% favorable in standard fixation vs. 67.7% in modified/staged reconstruction), suggesting that recovery is influenced more by timing and patient-related factors than by fixation method^[10]. Taken together, our findings align with the existing literature in showing

that patient comorbidities, material selection, surgical approach, and timing of cranioplasty are important determinants of postoperative complications and functional recovery.

CONCLUSION

Cranioplasty remains a critical neurosurgical procedure with both reconstructive and functional implications. In this study, post-traumatic cranial defects represented the most common indication, with autologous bone being the primary reconstructive material. The overall complication rate was substantial, particularly with autologous grafts, while synthetic substitutes appeared to have comparatively lower risk. Functional outcomes were generally favorable across surgical techniques, and earlier intervention (<3 months) tended to be associated with better recovery. These findings suggest that surgical timing and patient-related factors may play a more important role in outcomes than the choice of material or fixation method. Future prospective studies with standardized outcome measures are warranted to optimize clinical decision-making in cranioplasty.

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