

## Cranioplasty in Neurosurgical Procedures: Experience At A Tertiary Care Centre

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### ABSTRACT

**Background:** The primary aim of this trial was to study the efficacy of various cranioplasty materials available at our tertiary center and its related complications; thereby Standardising future protocols. **Material and Methods:** A total of 100 patients were selected as per specified criteria and two groups of Cranioplasty material types were created (Autologous and Artificial). Cranioplasty was done and results were compared for types of material of cranioplasty, early and late cranioplasty, complications associated with each type and overall cosmetic yield. **Results:** Patient undergoing Artificial cranioplasty within 6 weeks of primary surgery yielded superior results than Autologous cranioplasty and also had overall lesser complications. **Conclusion:** Cranioplasty with artificial material is better than those with autologous variety and patient specific engineered 3D Mesh are the future as they have lesser complications but better cosmetic yield.

**Key words:** cranioplasty, autologous, artificial

### Introduction

Cranioplasty (CPL) is a secondary surgical procedure performed to restore a defect on the cranial vault after a previous operation made with the removal of skull bone flap. This commonly happens when a decompressive craniectomy is needed for brain edema due to traumatic injury, ischemic or hemorrhagic stroke, after the removal of cranio-dural tumors, or even after the correction of skull malformations. Cranial reconstruction is important for several motives: it can provide protection to the underlying brain, may improve neurological function by recovering cerebro-spinal fluid (CSF) dynamics and cerebral blood flow, and it can restore cosmetically the cranial contour, hence brain protection & cosmetic aspects are the major indications of cranioplasty<sup>[1]</sup>. Moreover, the incidence of epilepsy is shown to be decreased after cranioplasty.<sup>[2]</sup> The repair of cranial defects gives relief to

psychological drawbacks and increases social performance. It is important not only for cosmetics and protection of underlying brain but also for restoring the dynamics of a closed cavity, which are disturbed when in the absence of overlying bone the atmospheric pressure is allowed to exert an influence. On the other hand, contraindications for cranioplasty are the presence of infection, and brain swelling. Presence of hydrocephalus is a relative contra indication. Timing of cranioplasty is important to prevent the development of devitalized autograft or allograft infections. It is generally accepted to wait 2 to 6 months before reconstructive surgery. If there is an infected area, this waiting period can be as long as one year.

Many different types of materials were used throughout the history of cranioplasty. Cranial reconstruction may be performed with autogenous and natural material, like the skull bone of the patient, or with alloplastic materials, like ceramics, acrylic resin, titanium, and others. With the evolving biomedical technology, new materials are available to be used by the surgeons. Several factors may influence the appearing of complications: time lapse between bone decompression and cranial reconstruction, materials used for CPL, age and conditions of patients, the experience of the surgeon on cranial reconstruction<sup>[3,4]</sup>.

### Material and method

A total of 100 patients all above the age of 6 years without any active infection with hemicraniectomy or bilateral craniectomy due to stroke, space occupying lesions and trauma excluding bone defect due to depressed fracture studied for the role of cranioplasty, its indications in various age group, materials used and post operative results including complications.

Patients were admitted under Neurosurgery Department at Civil Hospital Ahmedabad between January 2021 to May 2023 & retrospectively from January 2019 to December 2020 for primary surgery (bone flap removal) & subsequent cranioplasty. Also outside done bone flap removal were admitted for cranioplasty.

Patients were operated for cranioplasty by Autologous bone graft with preserved, plasma sterilized and apparently viable bone and those without Autologous bone graft or apparently doubtful preserved bone were given option of Artificial cranioplasty with standard titanium mesh or 3D titanium mesh. Abstracted data included age at the time of cranioplasty (years), sex (male or female), medical comorbidities (hypertension, diabetes), indications for craniectomy [road traffic accidents (RTA), fall from height (FFH), physical assault, stroke, and intraoperative swelling in tumours & aneurysm], laterality of cranioplasty (bilateral, unilateral, or bifrontal), time between craniectomy and cranioplasty (months), type of graft (autologous or artificial), type of prosthesis if used (standard titanium, 3D Titanium), storage of bone flap if used (subcutaneous /deep freezer/ plasma), operative time (minutes), and complications following cranioplasty. We included all infections, wound breakdowns, cases of significant bone resorption, and symptomatic hematoma, CSF leak/ Pseudo meningocele, implant displacement requiring reoperation. The indications for reoperations were recorded separately. Patient data collected from medical records retrospectively and were prospectively followed up through outpatient department (OPD) and by phone till May 2023. A proforma for the symptoms, signs, procedure, and outcome for each patient was used to record the data.

**Data analysis:** Continuous variables were expressed as Mean +SD, while categorical variables were expressed in numbers and percentages

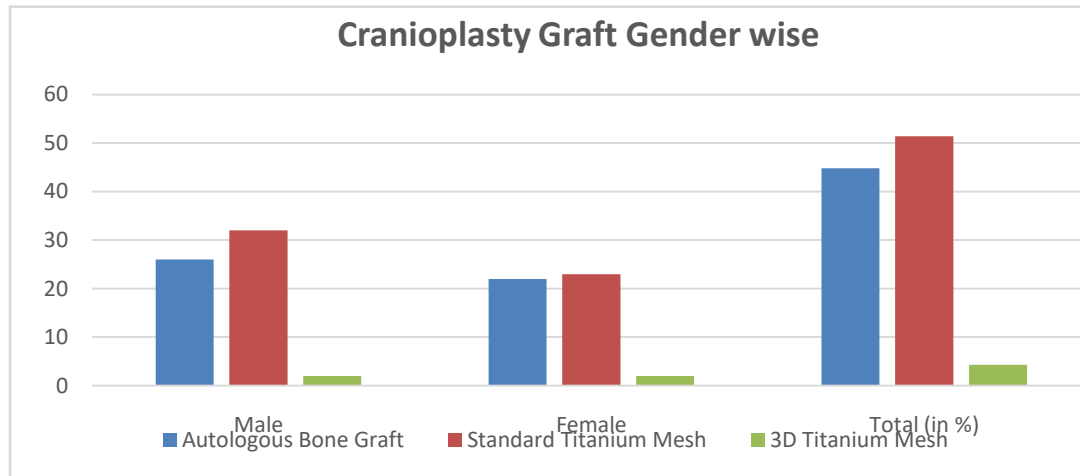
### Results

#### Demographic data

Of the 100 patients included in the study, maximum were in the age group of 21–30 years, i.e., 32% (n = 32). Mean age of the patients was 33.47 years. Among all the patients, 59.0% (n = 59) were

males and 41.0% (n = 41) were females. Mean age of males was 33.47 years and of females was 33.70 years.

**Table 1 Types of Cranioplasty materials used as per gender**



**Type of the preservation method**

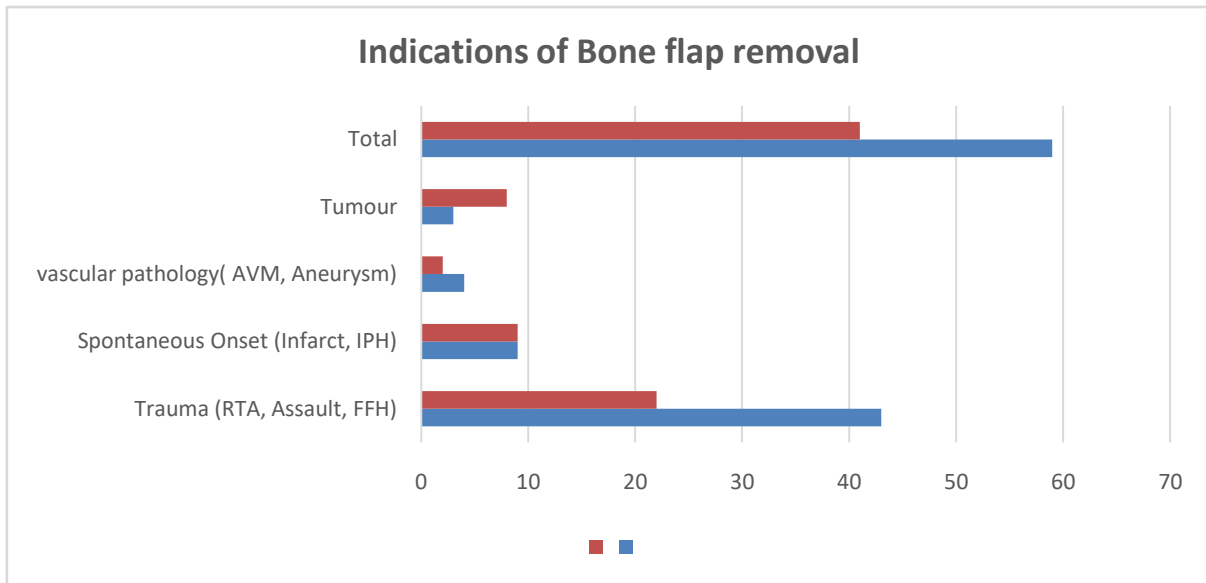
Bone was preserved in subcutaneous tissue in abdominal wall in 1% (n = 1) done outside, preserved in deep freezer in 10% (n=10) outside the institute and bone plasma sterilisation was done in 89% (n = 89) of the patients in our institute. However, bone flap that were stored in deep freezer were inspected cautiously and used for cranioplasty when bone looked apparently viable to be used and in rest instead titanium mesh was used as reliability of the deep freezer preservation was uncertain.

**Reason for removal of bone flaps**

The initial diagnosis of the patients included Trauma (RTA, FFH, assault), vascular pathology and tumours with associated pre operative or intraoperative swelling. The most common cause of the bone flap removal was RTA (65%, n = 65) followed by stroke (18%, n = 18), followed by tumours and vascular pathology (11% & 6%) respectively, as depicted in **Table 2**.

**Table 2**  
**Indications for removal of bone flaps**

Primary pathology	Male	Female	Total
Trauma (RTA, Assault, FFH)	43	22	65
Spontaneous Onset (Infarct, IPH)	9	9	18
vascular pathology (AVM, Aneurysm)	4	2	6
Tumour	3	8	11
<b>Total</b>	<b>59</b>	<b>41</b>	<b>100</b>



**Laterality of cranioplasty**

Regarding laterality of the defect, the most common cranial defect was unilateral 97% (n = 97) followed by bilateral (2%, n = 2), and bifrontal (1%, n = 1).

**Time of the surgical procedure**

With respect to the time of surgical procedure, most patients were operated between 121–180 minutes, 60.75% (n = 65), with a mean operative time of 134.06 minutes followed by between 61–120 minutes (36.44%, n = 39) followed by >180 minutes 2.8% (n=3). The mean operative time of autologous and artificial cranioplasty was 118.55 ± 14.58 minutes and 133.03 ± 12.07 minutes, respectively.

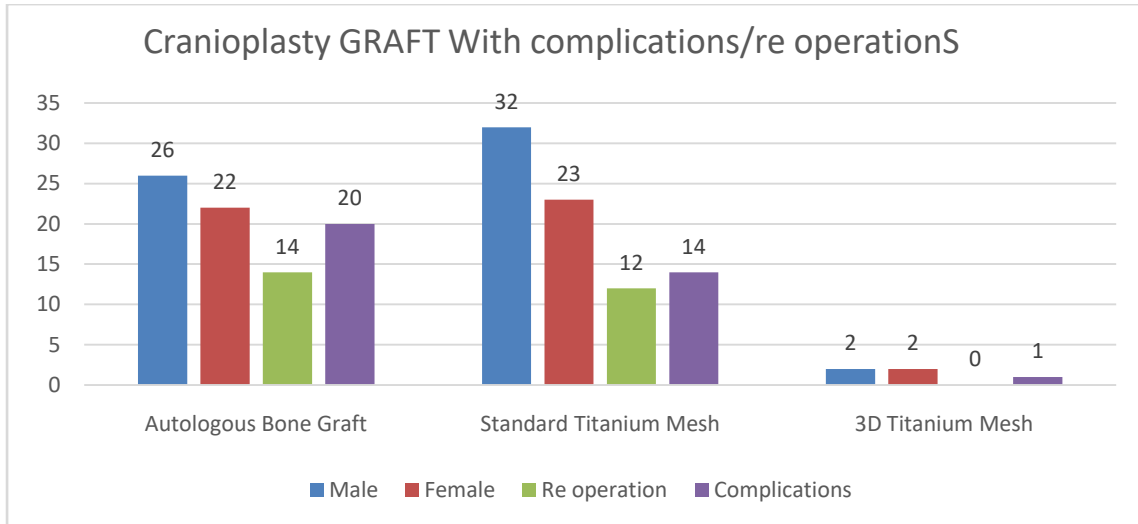
**Complication following cranioplasty**

Complications were noted in 32.7% (n = 35) of the surgeries; bone flap infection/skin infection/dehiscence 16.8% (n = 18) was the most common complication encountered. Postoperative hematoma was also seen in 1.8% (n=2) following cranioplasty. Other complications included seizures 2.8% (n = 3), bone resorption 2.8% (n = 3), mesh/bone displacement in 1.8% (n=2), CSF leak/pseudo meningocele seen in 2.8% (n=3) and sunken bone plate 1.8% (n = 2). 26 out of the 35 patients having complications had to undergo reoperation. Complications were more common in females 29.26% (12 out of 41 females) than males 15.25% (9 out of 59 males).

**Table 3**

**Types of the graft used and ensuing complications**

Cranioplasty Graft	Male	Female	Re operations	Complications
Autologous Bone Graft	26	22	14 (29.16%)	20
Standard Titanium Mesh	32	23	12 (21.81%)	14
3D Titanium Mesh	2	2	0	1



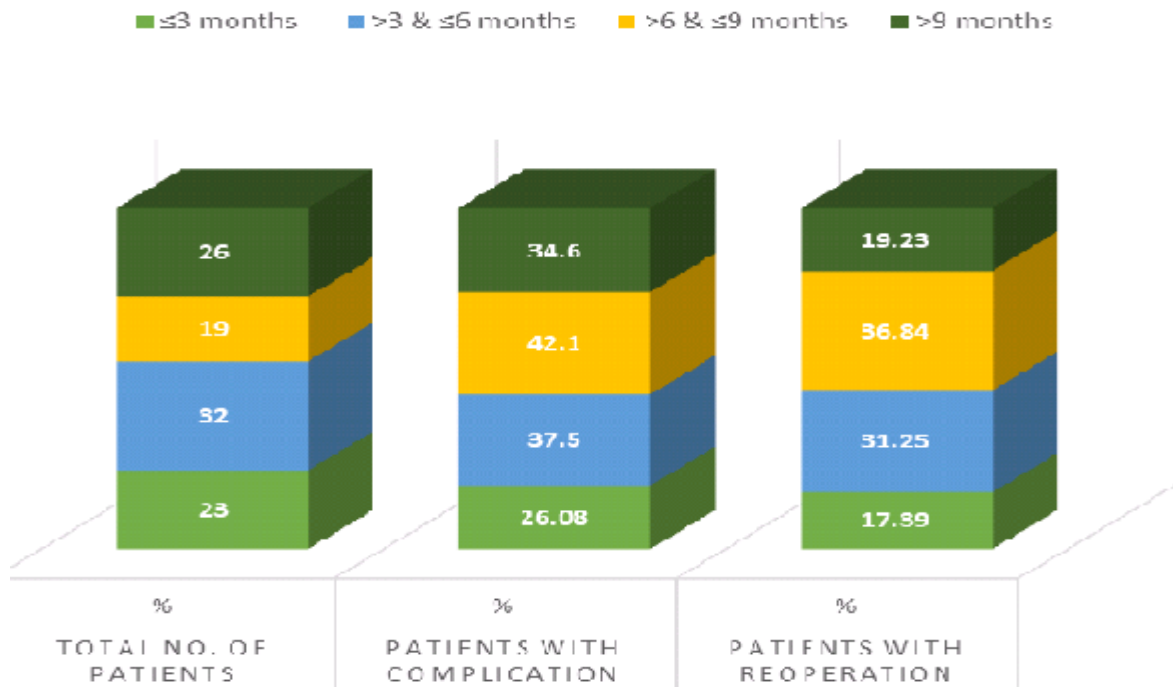
**Time between craniectomy and cranioplasty and ensuing complications:**

Most of the patients 32 % (n = 32) were operated between 13 and 24 weeks after the primary procedure. Complications were most commonly seen in patients 42.1% (n = 8) who had undergone cranioplasty after 6 months of the initial primary procedure. Re operation rate of 36.84% was seen in patients undergoing cranioplasty greater than 24 weeks from the primary procedure as depicted in **Table 4**

**Time between craniectomy and cranioplasty, complications & re operations**

Interval (months)	Total no. of patients		Patients with complication		Patients with reoperation	
	n	%	n	%	n	%
≤3 months	23	23	6	26.08	4	17.39
>3 & ≤6 months	32	32	12	37.5	10	31.25
>6 & ≤9 months	19	19	8	42.1	7	36.84
>9 months	26	26	9	34.6	5	19.23

**CRANIOPLASTY INTERVAL WITH COMPLICATIONS & REOPERATION**

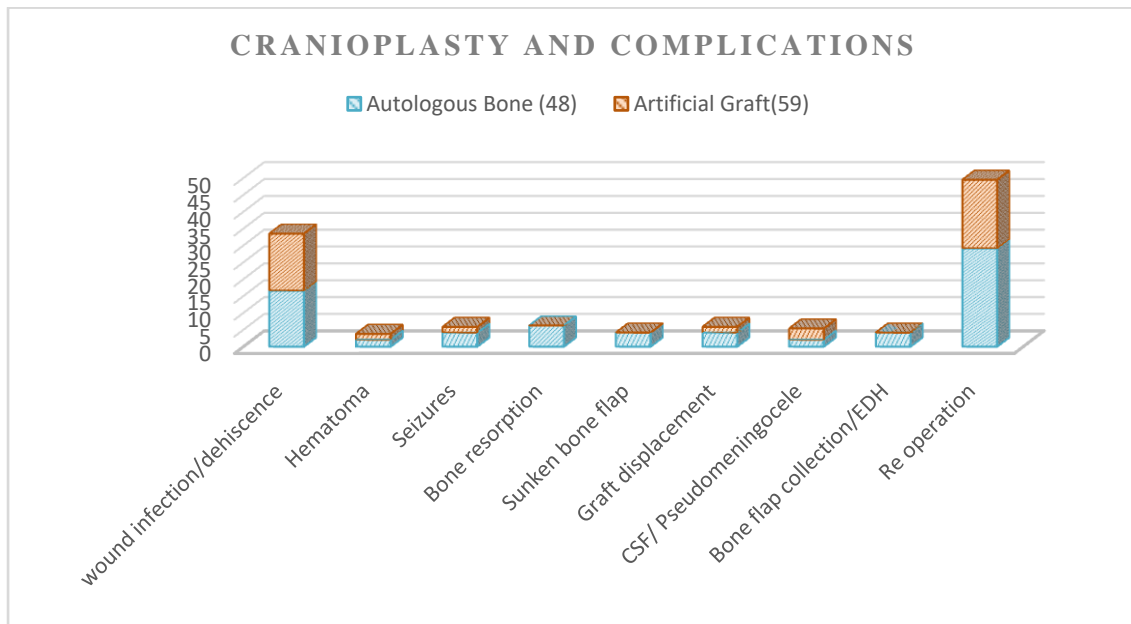


**Type of graft used (Artificial or Autologous) and associated complications**

Wound infection was seen in 16.94% (n = 10) of the patients who had undergone artificial cranioplasty compared to 16.66% (n = 8) of the patients who had undergone autologous cranioplasty. Net complication rate of 41.66% was seen in autologous group compared to 25.42% in the artificial group. (Table 5 )

**Table 5**  
**Cranioplasty graft vs complications**

Complications	Autologous Bone (48)		Artificial Graft (59)	
	n	%	n	%
Wound infection/dehiscence	8	16.6	10	16.94
Hematoma	1	2.08	1	1.69
Seizures	2	4.16	1	1.69
Bone resorption	3	6.25	0	0
Sunken bone flap	2	4.16	0	0
Graft displacement	1	2.08	1	1.69
CSF/ Pseudo meningocele	1	2.08	2	3.3
Bone flap collection/EDH	2	4.16	0	0
<b>Total</b>	<b>20</b>	<b>41.66</b>	<b>15</b>	<b>25.42</b>
<b>Re operation</b>	<b>14</b>	<b>29.16</b>	<b>12</b>	<b>20.33</b>



#### Complication requiring reoperation

Reoperation rate was exclusively seen in patients who had undergone unilateral cranioplasty compared to patients who had undergone bilateral/bifrontal cranioplasty, however complications were seen with one bifrontal cranioplasty. Reoperation rate was slightly higher in patients who had undergone autologous cranioplasty than artificial cranioplasty.

#### Discussion

Of the 100 patients included in the study, maximum were in the age group of 21–30 years, i.e., 32% (n = 32). Mean age of the patients was 33.47 years. Among all the patients, 59.0% (n = 59) were males and 41.0% (n = 41) were females. Mean age of males was 33.47 years and of females was 33.70 years. Hamandi et al. reported in their study that 85.7% (n = 12) were males and 14.3% were females, and maximum were in the age group of 21–30 years, which is somewhat in accordance to our study.<sup>[5]</sup> Lal et al. reported in their study that 77.3% (n = 68) were males and 22.77% (n = 20) were females and the mean age of patients was  $33 \pm 14.8$  years, which is somewhat in accordance to our study.<sup>[6]</sup>

Bone was preserved in subcutaneous tissue in abdominal wall in 1% (n = 1) done outside, preserved in deep freezer in 10% (n=10) outside the institute and bone plasma sterilisation was done in 89% (n = 89) of the patients. In our institute plasma sterilization is most preferred method of bone preservation as it is more advanced and avoids complexities like bone resorption, osteomyelitis.

The initial diagnosis of the patients included Trauma (RTA, Fall From Height, hit by stone, intraoperative swelling in tumour/aneurysm, stroke, physical assault. The most common cause of the bone flap removal was Trauma (65%, n = 65) followed by stroke (18 %, n = 18), and vascular pathology/tumours (17%, n = 17). Lal et al. in their study reported that the leading primary pathology was traumatic brain injuries including both blunt as well as penetrating injuries, which is somewhat in accordance to our study.<sup>[6]</sup>

Regarding laterality of the defect, the most common cranial defect was unilateral (97%, n = 97) followed by bilateral (2%, n = 2), and bifrontal (1, n = 1). Various studies on cranioplasty have shown

that unilateral defect is the most common cranial defect. Basheer et al. in their study of 114 patients reported that 90.35% (n = 103) were unilateral, 5.26% (n = 6) were bilateral, and 4.39% (n = 5) were bifrontal, which is somewhat in accordance to our study.<sup>[8]</sup> Walcott et al. in their study of 239 patients reported that 90.63 (n = 219) were unilateral, 2.92% (n = 70) were bilateral, and 5.44% (n = 13) were bifrontal, which is somewhat in accordance to our study.<sup>[7]</sup>

With respect to time of surgical procedure most of the patients were operated within 121–180 minutes 65% (n = 65), with a mean operative time of 134.06 minutes followed by 61–120 minutes (32%, n = 32). The mean operative time of autologous and artificial cranioplasty was  $118.34 \pm 14.58$  minutes and  $133.03 \pm 12.07$  minutes, respectively. Al-Shalchy conducted a study in which 90% (n = 18) of the patients were operated within 1–3 hours, which is somewhat in accordance to our study.<sup>[9]</sup> Basheer et al. in their study reported that the mean operative time was  $143 \pm 28$  minutes, which is as per as our study.<sup>[8]</sup>

Complications were noted in 32.7% (n=35) of the surgeries; bone flap infection/skin infection/dehiscence 16.8% (n=18) was the most common complication encountered. Postoperative hematoma was also seen in 1.8% (n=2) following cranioplasty. Other complications included seizures 2.8% (n = 3), bone resorption 2.8% (n = 3), mesh/bone displacement in 1.8% (n=2), CSF leak/pseudo meningocele seen in 2.8% (n=3) and sunken bone plate 1.8% (n = 2). Net complication rate was 32.7% (n=35). 26 out of the 35 patients having complications had to undergo reoperation. Complications were more common in females 29.26% (12 out of 41 females) than males 15.25% (9 out of 59 males). Walcott et al. in their study reported that wound infection 12.13% (n = 29) was the most common complication following cranioplasty. They had a net complication rate of 23.85% (n = 57), which is somewhat in accordance to our study.<sup>[7]</sup>

Most of the patients 47.46% (n = 11) were operated within 13–24 weeks after the primary procedure. Complications were most commonly seen in patients (18.29%, n = 15) who had undergone cranioplasty after 6 months of the initial primary procedure. The reasons for delayed cranioplasty include patients deemed medically or neurologically unstable until the point of intervention or nonresolution of cerebral edema or centralized nature of neurosurgical care at our place where there are logistic difficulties in operating patients early. Reoperation rate of 10.98% was seen in patients undergoing cranioplasty greater than 24 weeks from the primary procedure.

The optimal timing of cranioplasty following craniectomy is intensely debated. Studies have been performed that either support or refute its influence on post cranioplasty infection.<sup>[10,11,13,14,15]</sup> Commonly, performing cranioplasty 3 months after craniectomy is recommended; if the patient has a history of intracranial infection or open craniocerebral injury, the procedure can be delayed for at least 6 months after the first surgery. However, some authors have advanced the idea of early cranioplasty after decompressive craniectomy to alleviate complications from craniectomy.<sup>[11,12,16]</sup> Early cranioplasty performed before massive scar formation reduces operative time by facilitating soft tissue dissection. Liang et al. reported that early cranioplasty was safe and assisted in improving patient's neurological function and prognosis. In addition, early cranioplasty has an advantage in dissection for cranioplasty.<sup>[44]</sup> Joon et al. in their study concluded that early cranioplasty provides satisfactory securing of dissection plane during operative procedures compared with later cranioplasty, without causing additional complications, including infection, subdural hygroma, and brain parenchymal damage in selected cases.<sup>[12]</sup>

Complication was seen in 41.6% (n = 20) of the patients who had undergone autologous cranioplasty compared to 25.42% (n = 15) of the patients who had undergone artificial cranioplasty, however re



operation rate in both the groups was significantly lower. Net complication rate of 47.91% was seen in the autologous group compared to 38.98% in the artificial group. However, considering only infection/wound dehiscence, artificial group had less no. of patients (n=8, 13.4%) than autologous group (n=10, 20.83%). Basheer et al. in their study reported that the complication rate was slightly higher in the artificial group.<sup>[8]</sup>

Reoperation rate was higher in patients who had undergone autologous cranioplasty (29.16%, n=14) compared to artificial group (20.33%, n=12). Basheer et al reported Reoperation rate of 13.3% (n = 14) was seen in the autologous group compared to 16.7% noted in the artificial group.<sup>[8]</sup> & reported reoperation rate of 13.5% (n = 14) seen in patients who had undergone unilateral cranioplasty compared to 16.7% (n = 1) in patients who had undergone bilateral cranioplasty.

## Conclusion

Cranioplasty (CPL) is too often considered an easy and routine surgical procedure, occasionally performed by surgeons not very skilled with cranial reconstruction, and without the supervision of an experienced surgeon. This may cause a suboptimal surgical management, increasing the risk for complications and possibly conditioning the cosmetic result, especially with materials such as acrylic resin or autologous bone. Indeed, cranial reconstruction is a delicate type of operation that should be carried out with meticulous surgical technique, not underestimating in patients their general health state, neurological conditions, and head skin integrity around the cranial defect. Only with the careful evaluation of risk factors for failure, and substantial surgical experience in cranial reconstruction, CPL morbidity and complications may be reduced.

Complications from Cranioplasty were believed to be more frequent with alloplastic materials, while indeed a high rate of complications is also possible with autologous bone and the recent trends show cranioplasty with newer alloplastic materials with patient specific engineered mesh are the future as they have less complications rate and yield better cosmetic results.

Storage of bone flap also plays a vital role in ultimate outcome of the surgery as subcutaneous storage of bone has high bone resorption rate along with patient related morbidities. Deep freezer storage is also less preferred nowadays as there is more advanced Plasma sterilization technique is on the rise which is also practiced in our Institute. This has by far best results among all the sterilization technique.

Timing of cranioplasty, which has long been a debatable affair can be stated that; it results in better outcome if done within 6 months and best if done within 3 months of primary surgery if no other indications of delaying present.

Last but not the least of all, cranioplasty material to be used has seen the paradigm shifting from Autologous bone flap to finally Standard Titanium Mesh to more optimized patient specific engineered 3D Titanium Mesh which has no inherent infection rate & best cosmetic results possible.

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