

Original Article

Cranioplasty: Indications, procedures, and outcome – An institutional experience

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Abstract

Background: Cranioplasty, the repair of a skull vault defect by insertion of an object (bone or nonbiological materials such as metal or plastic plates), is a well-known procedure in modern neurosurgery. Brain protection and cosmetic aspects are the major indications of cranioplasty. A retrospective study was conducted for evaluating the indications, materials used, complications, and outcome of cranioplasty.

Methods: This study was prospective from August 2013 to September 2015 and retrospective from August 2010 to July 2013. In the retrospective study, patients files were retrieved from the mentioned date (August 2010 to July 2013) from the medical records and the findings were recorded. Abstracted data included age at the time of cranioplasty (years), sex (male or female), medical comorbidities (hypertension, diabetes), indications for craniectomy [Road traffic accident (RTA), fall from height (FFH), hit by stone or cricket ball, physical assault, stroke, infection, shell injury, bullet injury, and intraoperative swelling], laterality of cranioplasty (bilateral, unilateral, or bifrontal), time between craniectomy and cranioplasty (weeks), type of graft (autologous or artificial), type of prosthesis if used (methylmethacrylate, titanium), storage of bone flap if used (subcutaneous or deep freezer), operative time (minutes), and complications following cranioplasty.

Results: Of the 236 patients included in the study, maximum were in the age group of 21–30 years i.e., 30.93% ($n = 73$). Mean age of the patients was 33.44 years. A total of 196 (83.05%) were autologous and 40 (16.95%) were artificial. Out of the 40 patients who underwent artificial cranioplasty, 36 (15.25%) had methylmethacrylate graft and 4 (1.7%) had titanium mesh implant. Bone was not preserved in 16.95% ($n = 40$), preserved in subcutaneous tissue in abdominal wall in 2.54% ($n = 6$), and preserved in deep freezer in 80.51% ($n = 190$) of the patients.

Conclusion: Cranioplasty as a procedure is not without complications; however, if performed properly and at proper time with an aseptic technique, good results are achieved

Key Words: Artificial, autologous, cranioplasty, titanium mesh

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INTRODUCTION

Cranioplasty, the repair of a skull vault defect by insertion of an object (bone or nonbiological materials such as metal or plastic plates), is a well-known procedure in modern neurosurgery. Brain protection and cosmetic aspects are the major indications of cranioplasty.^[18] Moreover, the incidence of epilepsy is shown to be decreased after cranioplasty.^[20] The repair of cranial defects gives relief to psychological drawbacks and increases social performance. It is important not only for cosmesis 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. The sinking brain and scalp syndrome associated with neurological deterioration after decompressive craniotomy in traumatic brain edema is an uncommon condition. The recovery of neurological and imaging deficits following cranioplasty is well known.^[5]

Cranioplasty can avoid the recurrence of brain damage, can achieve the plastic effect, can protect the patient from cerebral seizures, can relieve the syndrome of trephine (i.e., headaches, dizziness, intolerance of vibration and noise, irritability, fatigability, loss of motivation and concentration, depression, and anxiety),^[9] increase the brain blood flow, improve the brain energy metabolism and promote the resumption of brain tissue, and treat the encephalocele skull defects with neurological cognition and mental syndrome.

MATERIALS AND METHODS

The Department of Neurosurgery, Sher-i-Kashmir Institute of Medical Sciences (SKIMS), Kashmir has been performing the procedure of cranioplasty since 1982. This study was prospective from August 2013 to September 2015 and retrospective from August 2010 to July 2013. In the prospective study, patients who presented to the Department of Neurosurgery SKIMS with a craniotomy defect and underwent cranioplasty from August 2013 to September 2015 were included in the study. In retrospective study, the files of the patients were retrieved from the mentioned date (August 2010 to July 2013) from the medical records and the findings were recorded. 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), hit by stone or cricket ball, physical assault, stroke, infection, shell injury, bullet injury, and intraoperative swelling], laterality of cranioplasty (bilateral, unilateral, or bifrontal), time between craniectomy and cranioplasty (weeks), type of graft (autologous or artificial), type of prosthesis if used (methylmethacrylate, titanium), storage of bone

flap if used (subcutaneous or deep freezer), operative time (minutes), and complications following cranioplasty. We included all infections, wound breakdowns, cases of significant bone resorption, and symptomatic hematoma requiring reoperation. The indications for reoperations were recorded separately. Patients were prospectively followed up through outpatient department (OPD) and by phone till March 2016. A proforma for the symptoms, signs, procedure, and outcome for each patient was used to record the data. The data was compiled and computed for various results. A total of 236 patients were included in the study.

Statistical analysis

Data was described as mean \pm SD (Standard deviation) and percentages. Chi-square test, Fisher's exact test, and independent t-test were used for data analysis.

RESULTS

A total of 236 patients were included in the study.

Age and gender distribution of the studied patients

Age and gender distribution of the studied patients is shown in Table 1. Of the 236 patients included in the study, maximum were in the age group of 21–30 years, i.e., 30.93% ($n = 73$). Mean age of the patients was 33.44 years. Among all the patients, 81.78% ($n = 193$) were males and 18.22% ($n = 43$) were females. Mean age of males was 33.4 years and of females was 33.58 years.

Type of the graft used

Of the 236 procedures, 196 (83.05%) were autologous and 40 (16.95%) were artificial. Out of the 40 patients who underwent artificial cranioplasty, 36 (15.25%) had methylmethacrylate graft and 4 (1.7%) had titanium mesh implant.

Type of the preservation method

Bone was not preserved in 16.95% ($n = 40$), preserved in subcutaneous tissue in abdominal wall in 2.54% ($n = 6$),

Table 1: Age and gender distribution of the studied participants

Age (Years)	Male		Female		Total no. of patients	
	<i>n</i>	%	<i>n</i>	%	<i>n</i>	%
01-10	8	3.39	2	0.85	10	4.24
11-20	22	9.32	4	1.69	26	11.02
21-30	58	24.57	15	6.35	73	30.93
31-40	49	20.76	12	5.08	61	25.85
41-50	39	16.53	4	1.69	43	18.22
50-60	14	5.93	4	1.69	18	7.63
61-70	3	1.27	2	0.85	5	2.12
Total	193	81.78	43	18.22	236	

and preserved in deep freezer in 80.51% ($n = 190$) of the patients.

Reason for removal of bone flaps

The initial diagnosis of the patients included RTA, FFH, hit by stone, hit by cricket ball, intraoperative swelling, stroke, physical assault, shell injury, and bullet injury. The most common cause of the bone flap removal was RTA (49.15%, $n = 116$) followed by FFH (27.12%, $n = 64$), and stroke (7.63%, $n = 18$), respectively, as depicted in Table 2.

Laterality of cranioplasty

Regarding laterality of the defect, the most common cranial defect was unilateral (94.92%, $n = 224$) followed by bilateral (4.24%, $n = 10$), and bifrontal (0.84%, $n = 2$).

Time of the surgical procedure

With respect to the time of surgical procedure, most patients were operated between 61–120 minutes (69.49%, $n = 164$) followed by between 121–180 minutes 23.73% ($n = 56$), with a mean operative time of 119.51 minutes. The mean operative time of autologous and artificial cranioplasty was 118.34 ± 34.58 minutes and 125.25 ± 27.07 minutes, respectively ($P = 0.235$), as depicted in Table 3.

Complication following cranioplasty

Complications were noted in 15.25% ($n = 36$) of the patients; wound infection/dehiscence 6.78% ($n = 16$) was the most common complication encountered. Postoperative hematoma was also a significant complication following cranioplasty. Other complications included seizures 2.54% ($n = 6$), bone resorption 1.69% ($n = 4$), and sunken bone plate 0.85% ($n = 2$). Nineteen out of the 36 patients having complications had to undergo reoperation. Complications were more common in males 16.06% (31 out of 193 males) than females 11.63% (2 out of 43 females).

Time between craniectomy and cranioplasty and ensuing complications

Most of the patients 47.46% ($n = 11$) were operated between 13 and 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 ($P = 0.520$). Reoperation rate of 10.98% was seen in patients undergoing cranioplasty greater than 24 weeks from the primary procedure ($P = 0.316$), as depicted in Table 4.

Type of the graft used and ensuing complications

Wound infection was seen in 10% ($n = 4$) of the patients who had undergone artificial cranioplasty compared to 6.12% ($n = 12$) of the patients who had undergone autologous cranioplasty. Net complication rate of 14.79% was seen in autologous group compared to 17.5% in the artificial group ($P = 0.665$) [Table 5].

Table 2: Indications for removal of bone flaps

Type of insult	No. of patients		Autologous		Artificial	
	<i>n</i>	%	<i>n</i>	%	<i>n</i>	%
RTA*	116	49.15	97	83.62	19	16.38
FFH+	64	27.12	54	84.38	10	15.62
Hit by stone	8	3.39	6	75	2	25
Hit by cricket ball	4	1.69	4	100	0	0
Intraoperative Swelling	12	5.08	12	100	0	0
Stroke	18	7.63	18	100	0	0
Physical assault	4	1.69	3	75	1	25
Shell injury	8	3.39	2	25	6	75
Bullet injury	2	0.85	0	0	2	100
Total	236		196		40	

*RTA: Road traffic accident, +FFH: Fall from height

Table 3: Time of surgical procedure

	Number of patients					
	Autologous		Artificial		Total	
	<i>n</i>	%	<i>n</i>	%	<i>n</i>	%
≤60 min	12	6.12	0	0	12	5.08
61-120 min	136	69.38	28	70	164	69.49
121-180 min	44	22.44	12	30	56	23.73
≥181 min	4	2.04	0	0	4	1.69

Table 4: Time between craniectomy and cranioplasty and ensuing complications

No. of weeks between craniectomy and cranioplasty	Total no. of patients		Patients with complication		Patients with reoperation	
	<i>n</i>	%	<i>n</i>	%	<i>n</i>	%
≤12 weeks	42	17.79	7	16.66	4	9.52
13-24 weeks	112	47.46	14	12.50	6	5.36
>24 weeks	82	34.75	15	18.29	9	10.98

Type of the autologous bone storage and ensuing complications

The most common method of bone storage was deep freezer 80.51% ($n = 190$). Complications as well as reoperation rate was most commonly seen in subcutaneous bone storage [Table 5].

Complications recurring reoperation

Reoperation rate was most commonly seen in patients who had undergone bilateral cranioplasty 20% ($n = 2$) compared to patients who had undergone unilateral cranioplasty 7.59% ($n = 17$). Reoperation rate was slightly higher in patients who had undergone autologous cranioplasty.

Complications with respect to type of injury

Complications were noted in 15.25% ($n = 36$) of the patients. Out of the 36 patients, 63.89% ($n = 23$) were having open type of injury whereas 36.11% ($n = 13$) were having closed type of injury.

Table 5: Type of graft used (Artificial or Autologous), method of storage, and ensuing complications

Complications	Number of patients			
	Autologous (196)		Artificial (40)	
	n	%	n	%
Wound Infection/Dehiscence	12	6.12	4	10
Hematoma	7	3.57	1	2.5
Seizure	4	2.04	2	5
Bone resorption	4	2.04	0	0
Sunken bone plate	2	1.02	0	0
Reoperation	16	8.16	3	7.5

Complications	Number of patients			
	Subcutaneous (6)		Deep Freezer (190)	
	n	%	n	%
Wound Infection/Dehiscence	12	6.12	4	10
Hematoma	7	3.57	1	2.5
Seizure	4	2.04	2	5
Bone resorption	4	2.04	0	0
Sunken bone plate	2	1.02	0	0
Reoperation	16	8.16	3	7.5

DISCUSSION

It has been documented that cranioplasties were performed by the Incas many centuries ago.^[19,21] Thus, cranioplasty may well be considered to be one of the earliest neurosurgical procedures along with cranial trephinations. However, it was several centuries later, when the first report of cranioplasty by Job Janszoon van Meekeren in 1668, appeared.^[21] It is well known that decompressive craniotomy (DC) has been associated with disturbances of cerebrospinal fluid (CSF) circulation.^[24,26] Furthermore, DC causes significant changes in the dynamics of local cerebral blood flow, as well as cerebral metabolic rate of oxygen and glucose changes, which affect normal brain function and metabolism.^[11,22,24] Thus, the performance of cranioplasty may theoretically restore all the altered conditions and improve the patient's overall neurological condition.^[6,12,13] It has also been demonstrated that cranioplasty can increase the cerebral blood flow by increasing blood flow velocities of the ipsilateral middle cerebral and internal carotid arteries, as well as improve the cardiovascular functions.^[11,24,25] Moreover, there is a syndrome characterized by headaches, dizziness, irritability, epilepsy, discomfort, and psychiatric symptoms observed in patients with cranial defects known as the "syndrome of the trephine."^[10] There is an increasing body of evidence in the literature showing that cranioplasty helps in the prevention or recovery of the trephine syndrome.^[1,10,13]

A total of 236 patients who were admitted in the Department of Neurosurgery of SKIMS, Soura, Srinagar

and had undergone cranioplasty from August 2010 to September 2015 were included in the study.

Of the 236 patients included in the study maximum were in the age group of 21–30 years, i.e., 30.93% ($n = 73$). Mean age of the patients was 33.44 years. Among all the patients, 81.78% ($n = 193$) were males and 18.22% ($n = 43$) were females. Mean age of males was 33.4 years and of females were 33.58. 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.^[15] Lal *et al.* reported in their study that 77.3% ($n = 68$) were males and 22.7% ($n = 20$) were females and the mean age of patients was 33 ± 14.8 years, which is somewhat in accordance to our study.^[16]

Regarding preservation method, bone was not preserved in 16.95% ($n = 40$), preserved in subcutaneous tissue in abdominal wall in 2.54% ($n = 6$), and preserved in deep freezer in 80.51% ($n = 190$) of the patients. Most surgeons prefer subcutaneous pocket because majority are of the opinion that keeping bone in the subcutaneous pocket will ensure viability of bone, resulting in better fusion and less infection rate. However, this adds to the morbidity of the procedure by prolonging the operation time and blood loss, which is very important factor in prognosis especially during decompressive craniectomy. Moreover, patient discomfort and wound complications including infection, hematoma, and seroma are important factors discouraging keeping bone in subcutaneous pocket. Lal *et al.* in their study concluded that the current literature suggests that the storage of bone flaps in freezers is the most common method, which is somewhat in accordance to our study.^[16]

The initial diagnosis of the patients included RTA, FFH, hit by stone, hit by cricket ball, intraoperative swelling, stroke, physical assault, shell injury, and bullet injury. The most common cause of the bone flap removal was RTA (49.15%, $n = 116$) followed by FFH (27.12%, $n = 64$), and stroke (7.63%, $n = 18$). 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.^[16] Hamandi *et al.* in their study reported the cause of bone flap removal at 57.15% ($n = 8$) due to bullet and shell injuries (penetrating injuries), 35.70% ($n = 5$) due to depressed # following fall from height and road traffic accidents, 7.15% ($n = 1$), and skull defect due to congenital encephalocele, which is somewhat in accordance to our study.^[15]

Regarding laterality of the defect, the most common cranial defect was unilateral (94.92%, $n = 224$) followed by bilateral (4.24%, $n = 10$), and bifrontal (0.84%, $n = 2$). 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.^[3] 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.^[23]

With respect to time of surgical procedure most of the patients were operated within 61–120 minutes (69.49%, $n = 164$) followed by within 121–180 minutes 23.73% ($n = 56$), with a mean operative time of 119.51 minutes. The mean operative time of autologous and artificial cranioplasty was 118.34 ± 34.58 minutes and 125.25 ± 27.07 minutes, respectively, with P value of 0.235, which is considered not significant. 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.^[2] Basheer *et al.* in their study reported that the mean operative time was 143 ± 28 minutes, which is slightly higher as compared to our study.^[3]

Complications were noted in 15.25% ($n = 36$) of the patients and wound infection/dehiscence 6.78% ($n = 16$) was the most common complication encountered. Postoperative hematoma was also a significant complication following cranioplasty. The other complications included seizures 2.54% ($n = 6$), bone resorption 1.69% ($n = 4$), and sunken bone plate 0.85% ($n = 2$). Nineteen out of the 36 patients having complications had to undergo reoperation. Complications were more common in males 16.06% (31 out of 193 males) than females 11.63% (2 out of 43 females). 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.^[23]

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. The P value with respect to time between craniotomy and cranioplasty and the ensuing complications was 0.520, which is not significant. Reoperation rate of 10.98% was seen in patients undergoing cranioplasty greater than 24 weeks from the primary procedure with a P value of 0.316, which is considered not significant. The optimal timing of

cranioplasty following craniectomy is intensely debated. Studies have been performed that either support or refute its influence on postcranioplasty infection.^[4,7,9,14,17] 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.^[7,8,27] 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.^[17] 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.^[8]

Complication was seen in 14.79% ($n = 29$) of the patients who had undergone autologous cranioplasty compared to 17.5% ($n = 7$) of the patients who had undergone artificial cranioplasty. Net complication rate of 14.79% was seen in the autologous group compared to 17.5% in the artificial group, with a P value of 0.665, which is considered not significant. Basheer *et al.* in their study reported that the complication rate was slightly higher in the artificial group.^[3]

The most common method of bone storage was deep freezer 80.51% ($n = 190$). Complications as well as reoperation rate was most commonly seen in subcutaneous bone storage. Basheer *et al.* reported complication rate of 21.4% ($n = 8$), with a reoperation rate of 14.3% ($n = 12$) seen in subcutaneous bone storage and complication rate of 22.22% ($n = 4$) with a reoperation rate of 11.1% ($n = 2$) seen in patients whose bone was stored in deep freezer.^[3]

Reoperation rate was most commonly seen in patients who had undergone bilateral cranioplasty 20% ($n = 2$) compared to patients who had undergone unilateral cranioplasty 7.59% ($n = 17$). Reoperation rate was also higher in patients who had undergone autologous cranioplasty. Basheer *et al.* 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. Reoperation rate of 13.3% ($n = 14$) was seen in the autologous group compared to 16.7% noted in the artificial group.^[3]

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Conflicts of interest

There are no conflicts of interest.

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