Management of traumatic skull bone defects

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Abstract: Objective: Review pathophysiology of traumatic skull bone defect, indications and different methods of cranioplasty**. Patient and Methods:** This study was carried out on 30 patients who attended to emergency room (ER) and admitted to the neurosurgery department in Al-Azhardamietta university hospital. Data collection was extracted from hospital records (Admission ICU books, patient admission sheets, operative details and progressive notes). The study included 30 patients diagnosed as severe closed TBI. Preoperatively all the patients were evaluated using a standardized sheet and the findings were tabulated as preoperative clinical (subjective and objective) and radiological data. **Results:** The age range was 4-57 years, mean age was 30.97 years, in our study the cosmetic result were good to excellent in 95 % of the patients (19 cases). Protection of the neural tissue was achieved in 95% of the patients (19 cases). One case (5% of all the patients) suffered complications in the form of infection, this case was 29 years old male with right parietal defect and reconstruction was done after 7 months of the initial injury using titanium mesh. The occurrence of infection in this case could not be controlled except after removal of the titanium mesh. **Conclusion:** Calvarial bone defect are frequently the result of trauma, previous operative procedure, infection, or neoplasm. Making the decision regarding the need for repair is frequently not difficult. Its timing dependent on the patient's neurological conditions, the risk of infection, and the healing potential of the surrounding tissue. The operative procedure for repair of these cranial defects is determined by the size of the defect, its location, and the implant material employed.

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1. Introduction:

Cranioplasty is a widely practiced neurosurgical procedure that not only aims to protect underlying brain tissue from skull defects, but also attempts to restore normal calvarial contour in a cosmetically accepted manner ***(Mohammad S, et al.2013).***

Cranioplasty can improve neurological status in patients with skull bone defects. Mechanism of postoperative improvement in neurological status due to increased cerebral blood flow velocity due to elimination of the effects of atmospheric pressure ***(JinnRung, et al. 2004).***

It is agreed that the autologous bone flap that has been removed at the time of decompressive craniectomy is superior to any other material for use in cranioplasty. Previous reports suggested that cryopreservation of the autologous bone flaps should be a standard technique of preservation for delayed cranioplasty**.** But, the freezing process causes cell damage due to ice crystal formation and recrystallization during warming ***(Chiarini L, et al. 2004).***

2. Patients and Methods

This study was an analytical study conducted on 20 patients with traumatic skull bone defects admitted to the neurosurgery department in Al-Azhardamietta universityhospital undergoing cranioplasty if indicated and clinical & radiological follow up was done after a period of 6 months.

Inclusion criteria

1- Post Traumatic skull bone defects

Exclusion criteria

1- Non traumatic causes of skull bone defects
2- Combined cranioplasty with other operation

All patients involved in this study were subjected to:

1. **Clinical assessment through:**

Complete medical history
Complete general examination
Neurological examination

2. **Radiological studies**:

X-ray skull
CT – brain with bone window and 3D
MRI brain if indicated

3. **Surgery**:

Patients were subjected to surgical reconstruction of skull bone defects through cranioplasty

Intra – operative difficulties and complications were reported

3- Postoperative assessment

All patients were assessed postoperatively

1- Clinically focusing on postoperative occurrence of any complications or neurological deficit

Surgical site infection

CSF leak

2- Radiological:

X-ray skull

CT – brain with bone window and 3D.

❖ These patients were classified into two groups, one group was reconstructed using autogenous bone graft (7 patients = 35 % of all cases) and the other group was reconstructed using synthetic grafts (13 patients = 65 % of all cases).

❖ As regarding the 1st group, 5 patients were reconstructed using iliac graft (71.4% of this group = 25 % of all cases) and 2 patients were reconstructed using rib grafts (28.6 % of this group = 10% of all cases).

❖ As regarding the 2nd group, 9 patients were reconstructed using titanium mesh (69.2 % of this group = 45 % of all cases), and 4 patients were reconstructed using polyethylene blocks "Medpor" (30.8 % of this group = 20 % of all cases).

❖ **Technique of cranioplasty:**

- **Preparation of the patient:**

The scalp is scrubbed with disinfectant soap, the entire head is shaved the morning of surgery.

Preoperative antibiotics active against staphylococcus species are administered (especially in cranioplasty using synthetic materials)

- **Preparation of the wound:**

Scalp incision must be designed to be lie outside of the defect, behind the hairline, never parallel to previous wounds or scars, and with a broad flap base to accommodate the vascular supply to the area of skin within the flap. If an incision is made through the old scar, one must exercise cautiously to avoid penetrating the dura in areas where it is adherent to the scalp.

- **Intra-operative techniques:**

The planned skin incision is made, scalp bleeding is secured with scalp clamps if the incision is made through normal scalp, but if made through a previous incision or scar then clamps should be used only on the galea or galeal scar

If the incision is made through old scar that overlies the skull defect, special attention is needed to avoid incision of the underlying dura.

Careful undermining of the scalp is performed particularly over the defect to avoid penetrating either the dura or the adherent scalp. As much scar tissue as possible should be left attached to the undersurface of the scalp to maintain maximal scalp thickness where this will overlie the prosthesis. Total exposure of the cranial defect must be achieved.

- **Cranioplasty using synthetic materials:**

1- Reconstruction using titanium mesh:

The major disadvantage of titanium was the difficult molding to fit the contour of the skull; the current complex mesh patters available allow it to be shaped without difficulty while maintaining its strength in the final formed position.

After designation of the titanium mesh to fit the defect, it's fixed to the calveria using titanium micro screws.

2- Reconstruction using *Poly-methylmethacrylate (PMMA):*

Following application of this doughy alloplastic material, the acrylic remains workable for approximately 5 minutes. During this time, we filled the deepest recesses of the cranial defect and molded the PMMA into the desired shape. When possible, we tried to avoid applying a second coat of acrylic because it can produce a lamellar plate that lacks the structural integrity of a single coat. Fifteen minutes after the mixing of the PMMA, exothermic polymerization occurs, hardening the material.

- **Cranioplasty using autogenous bone:**

1- Reconstruction using Calvarial bone from previous craniotomy

The best autogenous membranous bone is that removed from the initial trauma or operative site. It can be reinserted with ease into the defect and provides excellent anatomical continuity and preshapedcosmesis. The use of such bone is particularly advantageous in the difficult fronto-orbital cranioplasty.

Fixation of the bone graft was performed with titanium craniofacial plates, suture, or wire. Titanium craniofacial plates offered excellent fixation with minimal skin irritation and did not interfere with magnetic resonance imaging.

2- Reconstruction using rib grafts:

The entire rib can be taken from transverse process to the costochondral junction using a sub periosteal dissection.

Leaving periosteum intact allows the ribs to regenerate over the course of several months.

The graft is cut into segments remolded and fixed to the cranial defect.

- **Post-operative care:**

All patients were dressed daily using povidine iodine for one to two weeks.

All patients received post- operative antibiotics in the form of third generation cephalosporin.

Stiches were removed for all patients one to two weeks following surgery.

- **Follow up:**

Follow up of the patients were done for a period ranging between four to twelve months.

3. Results:

❖ The result were as follows:

- The cosmetic result were good to excellent in 95 % of the patients (19 cases).
- Protection of the neural tissue was achieved in 95% of the patients (19 cases).
- One case (5% of all the patients) suffered complications in the form of infection, this case was 29 years old male with right parietal defect and reconstruction was done after 7 months of the initial injury using titanium mesh.
- The occurrence of infection in this case could not be controlled except after removal of the titanium mesh.
- In the infected case the principal aims of cranioplasty could not be achieved i.e.:
  - ✓ Cosmetic appearance: bad
  - ✓ Protection of the neural tissues: not achieved.
- The patient who was suffering from epilepsy complained one attack of epilepsy 2 weeks after cranioplasty, in spite of being on single treatment of anti-epileptics in the form of phenytoin sodium (epanutin) 100mg cap. t.d.s, EEG was done postoperatively and showed no increase in the initial EEG pattern.
- The fits were controlled by combination of phenytoin sodium (epanutin) 100mg cap. t.d.s and carbamazibin (tegretol) 200mg tab b.d.
- No other complications were encountered during the follow up period e.g. granulomas, pneumatocele, sinus tract between the plate used and skin, dural tear…… etc.

The results will be analyzed and illustrated in the following tables:

Table (1): Age (in years) in patient group

Age (in years)	Number of cases	Minimum age (in years)	Maximum age (in years)	Mean age (in years)	SD
	20	12	55	30.05	11.14

Table (2): Age (in years) regarding the site of the defect

Site of the defect	Number of cases		Minimum age (in years)	Maximum age (in years)	Mean age (in years)	SD
	No.	%				
Parietal	7	35%	20	42	29.29	7.25
Temporal	3	15%	35	43	39.67	4.16
Frontal	6	30%	15	37	24.00	7.72
Occipital	1	5%	44	44	44.00	-
Fronto-temproparietal	2	10%	12	55	33.50	30.41
Fronto-parietal	1	5%	22	22	22.00	-
Total	20	100%	12	55	30.05	11.14

Table (3): Clinical presentations of the patient group

Clinical manifestations	Absent		Present		Total	
	No.	%	No.	%	No.	%
Cosmetic unacceptance	0	0%	20	100%	20	100%
ICP	20	100%	0	0%	20	100%
Motor deficit	20	100%	0	0%	20	100%
Sensory deficit	20	100%	0	0%	20	100%
Epilepsy	19	95%	1	5%	20	100%

Table (4): Relation between type of the material used for reconstruction and protection of the neural tissue

Type of the material	Neural protection				Total		X^2	P. value
	Yes		No		No.	%		
	No.	%	No.	%				
PMMA	4	20%	0	0%	4	20%	0.26	>0.05
Titanium	8	40%	1	5%	9	45%	1.29	>0.05
Rib	2	10%	0	0%	2	10%	0.12	>0.05
Calvarial	5	25%	0	0%	5	25%	0.35	>0.05
Total	19	95%	1	5%	20	100%		

Test is not significant (P – value > 0.05)

Table (5): Relation between sex and cosmetic acceptance

Sex	Cosmetic appearance						Total		X^2	P. value
	Excellent		Good		Bad					
	No.	%	No.	%	No.	%	No.	%		
Male	12	60%	3	15%	1	5%	16	80%	1.25	>0.05
Female	4	20%	0	0%	0	0%	4	20%		
Total	16	80%	3	15%	1	5%	20	100%		

Test is not significant (P – value > 0.05)

Table (6): Relation between site of the defect and cosmetic appearance

Site of the defect	Cosmetic appearance						Total		X^2	P. value
	Excellent		Good		Bad					
	No.	%	No.	%	No.	%	No.	%		
Parietal	5	25%	1	5%	1	5%	7	35%	1.273	>0.05
Temporal	3	15%	0	0%	0	0%	3	15%	0.75	>0.05
Frontal	5	25%	1	5%	0	0%	6	30%	0.319	>0.05
Occipital	1	5%	0	0%	0	0%	1	5%	0.25	>0.05
Fronto-temproparietal	1	5%	1	5%	0	0%	2	10%	1.958	>0.05
Fronto-parietal	1	5%	0	0%	0	0%	1	5%	0.25	>0.05
Total	16	80%	3	15%	1	5%	20	100%	-	-

Test is not significant (P – value > 0.05)

Table (7): Relation between type of the material used in reconstruction and cosmetic appearance of the patient

Type of the material used in reconstruction	Cosmetic appearance						Total		X^2	P. value
	Excellent		Good		Bad					
	No.	%	No.	%	No.	%	No.	%		
PMMA	4	20%	0	0%	0	0%	4	20%	1.25	>0.05
Titanium	8	40%	0	0%	1	5%	9	45%	3.84	>0.05
Rib graft	0	0%	2	10%	0	0%	2	10%	12.59	<0.05
Calvarial graft	4	20%	1	5%	0	0%	5	25%	0.44	>0.05
Total	16	80%	3	15%	1	5%	20	100%	-	-

Test is significant regarding rib graft (P – value < 0.05) and not significant regarding other materials (P – value > 0.05)

Table (8): Relation between type of the material used in reconstruction and complications

Type of the material used in reconstruction	Complications						Total		X^2	P. value
	Absent		Infection		Others					
	No.	%	No.	%	No.	%	No.	%		
PMMA	4	20%	0	0%	0	0%	4	20%	0.26	>0.05
Titanium	8	40%	1	0%	0	0%	9	45%	1.29	>0.05
Rib graft	2	10%	0	0%	0	0%	2	10%	0.12	>0.05
Calvarial graft	5	25%	0	0%	0	0%	5	25%	0.35	>0.05
Total	19	95%	1	5%	0	0%	20	100%	-	-

Test is not significant (P – value > 0.05)

Table (19): Time interval between initial injury and reconstruction in relation to complications

Time interval between initial injury and reconstruction (in months)	Complications						Total		X^2	P. value
	Absent		Infection		Others					
	No.	%	No.	%	No.	%	No.	%		
6	6	30%	0	0%	0	0%	6	30%	0.45	>0.05
7	1	5%	1	5%	0	0%	2	10%	9.47	<0.05
8	3	15%	0	0%	0	0%	3	15%	0.19	>0.05
9	3	15%	0	0%	0	0%	3	15%	0.19	>0.05
10	1	5%	0	0%	0	0%	1	5%	0.06	>0.05
11	3	15%	0	0%	0	0%	3	15%	0.19	>0.05
12	2	10%	0	0%	0	0%	2	10%	0.12	>0.05
Total	19	95%	1	5%	0	0%	20	100%	-	-

Test is significant regarding 7 month interval (P–value <0.05) and not significant regarding other time intervals (P–value>0.05).

Table (10): Time interval between initial injury and reconstruction in relation to follow up period of the patient

Time interval between initial injury and reconstruction (in months)	Complications					Total			X^2	P. value
	Number of cases without complications during follow up		Number of cases with epilepsy		Cases with removed graft					
	No.	%	No.	%	No.	%	No.	%		
6	6	30%	0	0%	0	0%	6	30%	0.95	>0.05
7	1	5%	0	0%	1	5%	2	10%	9.51	<0.05
8	2	15%	1	5%	0	0%	3	15%	6.06	<0.05
9	3	15%	0	0%	0	0%	3	15%	0.39	>0.05
10	1	5%	0	0%	0	0%	1	5%	0.12	>0.05
11	3	15%	0	0%	0	0%	3	15%	0.39	>0.05
12	2	10%	0	0%	0	0%	2	10%	0.25	>0.05
Total	18	90%	1	5%	1	5%	20	100%	-	-

Test is significant regarding 7 and 8 month interval (P – value < 0.05) and not significant regarding other time intervals (P – value > 0.05).

N.B: The case of epilepsy was controlled after cranioplasty by combination treatment of antiepileptic drugs i.e. cranioplasty did not improve epilepsy

Table 12.1: Summary of cranioplasty series since 1995.

Author and year	Material	Cases, *n*	Significant complications
Inoue et al. 1995	Split calvarium	10	No failures
Jho et al. 2007	Ethylene oxide gas sterilized bone flap	103	8 (7.8%) removed (infection/resorptic
Joffe et al. 1999	Titanium	148	1 (<1%) removal (infection)
Josan et al. 2004	Bone flap	16, paediatri	3 (21%) removed (infection)
infections)	Split calvarial graft	8, paediatric	No failures
	PMMA	3, paediatric	No failures
	Titanium	1, paediatric	No failures
Kshettry et al. 2012	Titanium mesh	12	2 (20%) removed (infection)
Lee et al. 1995	Split calvarium	8	1 (12.5%) fixation plates removed (infection)
Lin et al. 2012	Polyethylene (Medpore)	9	No failures
Matsuno et al. 2006[30]	Cryopreserved bone flap	54	14 (25.9%) removed (infection)
	In situ moulded PMMA	55	7 (12.7%) removed (infection)
	Custom-made PMMA	3	1 (33.3%) removed (infection)
	Titanium mesh	77	2 (2.6%) removed (infection)
	Custom-made ceramics	17	1 (5.9%) removed (infection)
Mokal and Desai 2011[55]	High density porous polythene	7	No failures
Morina et al. 2011[56]	Subcutaneously preserved bone flap	75	2 (3%) removed (infection)
Movassaghi et al. 2006[57]	Subcutaneously preserved bone flap	52	2 (4%) removed (infection)
Paşaoğlu et al. 1996[60]	Subcutaneous bone flaps	27	No failures
Rogers et al. 2011[61]	Exchange calvarial graft	20, paediatric	5 (25%) residual bony defects
Sahoo et al. 2010[62]	Split calvarial graft	11	No failures
	Titanium mesh	6	1 (17%) removed (infection)
	PMMA	5	4 (80%) (3 implant exposures/1 infectio
Barone and Jimenez 1997	Split calvarium	16, paediatric	No failures
Durham et al. 2003	HA cement/tantalum mesh	8	2 (25%) removed (infections)
Ducic 2002	HA cement/titanium mesh	20	No failures
Gooch et al. 2009	Preserved autologous bone flap	57	No failures; 16 (26%) required second operation
	Titanium	3	No failures
Gosain et al. 2009	Prefabricated polyethylene (Medpore)	3, paediatric	No failures
Inamasu et al. 2010	Subcutaneous stored bone flap	38	2 (5%) removed (infection)
Taggard and Menezes 2001	Split rib	13	No failures
Vahtsevanos et al. 2007	Titanium	42	2 (5%) removed (infection)
Viterbo et al. 1995	Split calvarial graft	11	2 (19%) required second operation
	Split rib	2	No failures
	Conchal cartilage	1	No failures
Wiltfang et al. 2004	Split calvarium + HA cement	41	No failures
Zins et al. 2007	HA cement + titanium/ resorbable mesh	16	8 (50%) removed (fragmentation)

Discussion:

Our study was an analytical study conducted on 20 patients with traumatic skull bone defects admitted to the neurosurgery department in Al-Azhardamietta university hospital undergone cranioplasty and clinical & radiological follow up was done over a period of 6 months.

Skull restoration remains a challenge for neurosurgeons and plastic surgeons. The number of patients in need of cranioplasty is increasing because of continuous improvements in neurosurgical critical care and a growing number of decompressive craniectomies performed. Common complications in cranial repair surgery include for example infection, wound dehiscence, intracranial hemorrhage, resorption, and/or dislocation of the graft. The reported complication rate of cranioplasties today is 16%–40%, with a general reoperation rate of 25%. Patients' autologous removed and stored bone has been considered as the gold standard in cranial vault reconstruction, but there are studies reporting superior results achieved with synthetic materials such as hydroxyapatite, bioactive fiber-reinforced composite, polymethylmethacrylate, or titanium. **(Thesleff et al., 2016).**

In our study all patients (20 cases = 100%) were suffering from the presence of cranial defects in different sites and of variable sizes, the complaints were; not accepted cosmetic appearance & fear from brain tissue injury.

No manifestations of increased ICP in all cases (20 cases = 100%)

No motor deficit in all cases.

No sensory deficit in all cases.

One case (5% of all cases), was complaining from epilepsy as a result of the initial injury (post traumatic epilepsy).

These patients were classified into two groups, one group was reconstructed using autogenous bone graft (7 patients = 35 % of all cases) and the other group was reconstructed using synthetic grafts (13 patients = 65 % of all cases).

As regarding the 1st group, 5 patients were reconstructed using calvarial graft (71.4% of this group = 25 % of all cases), all were males and 2 patients were reconstructed using rib grafts (28.6 % of this group = 10% of all cases), both were males.

As regarding the 2nd group, 9 patients were reconstructed using titanium mesh (69.2 % of this group = 45 % of all cases), 6 were males and 2 were females and 4 patients were reconstructed using Poly-methylmethacrylate (PMMA) (30.8 % of this group = 20 % of all cases), 3 were males and 1 was female.

Results were as follows:

The cosmetic result were good to excellent in 95 % of the patients (19 cases).

Protection of the neural tissue was achieved in 95% of the patients (19 cases).

One case (5% of all the patients) suffered complications in the form of infection, this case was 29 years old male with right parietal defect and reconstruction was done after 7 months of the initial injury using titanium mesh.

The occurrence of infection in this case could not be controlled except after removal of the titanium mesh.

The choices of cranioplasty material are either an autogenous bone graft or a bio-material. Analysis of the literature since 1995 shows a wide variety of materials in use (Table 12.1). **(Williams et al., 2014)**

The most common bone grafts for cranioplasty are preserved craniectomy bone flaps and split calvarial grafts. Split ribs lacks current case series of significant numbers of patients. A preserved craniectomy bone flap is an intuitive choice for reconstruction, as the bone flap theoretically provides a perfect fit and contour for the defect as well as offering the potential for revascularization, ultimately becoming vital bone that matches normal skull. In reality the use of preserved craniectomy bone flaps is associated with high failure rates, particularly in pediatric cases. **(Cheng YK et al., 2008)**

Analysis of the published case series since 1995 shows several techniques for preserved bone flap cranioplasty including preserving in a subcutaneous pocket. In a series of 57 preserved bone flap cranioplasties. Seven case series reporting split calvarial grafts since 1995 showed very low complication rates, only one series of eight patients reported a 12.5% infection and failure rate**. (Morina A et al., 2011)**

Split calvarial grafts in adults are principally limited by the quantity of bone available and post-operation contour defects at the reconstruction and donor sites. Harvesting large areas of outer or inner table inevitably weakens the donor site and the diploe is poorly developed in young children precluding bone harvest. Intra-cranial penetration and cerebral damage or damage to the venous sinuses are reported risks of harvest but rarely occur. **(Rogers GF et al., 2011)**

Split rib is uncommonly used, with one specific case series and one other paper reporting split ribs in a larger series of other cranioplasties since 1995, although isolated reports of extensive defects being repaired with split rib exist. No failures were reported in the 15 patients comprising the two series. However limitations of split rib include resorption, a washboard effect at the reconstruction site, difficulty in achieving

satisfactory contour, and significant donor site problems including pneumothorax, chest wall deformity, pain, and post-operation atelectasis. **(Takumi I et al., 2008)**

Demineralized bone matrix reconstructions are under-reported for cranioplasty, with recent publications comprising two small specific case series and one other case series reporting use in three paediatric patients since 1995. One failure was reported in a total of 24 patients across the three series. **Chao et al., 2009** reported an average of 98% defect healing in a series of 11 young children using demineralized bone and resorbable mesh, however these results were not seen in a series of 10 adults reported by **Chen and Wang, 2002**using demineralized bone matrix and autogenous bone paste, as complete bony infill was observed in only two patients of the series.

Biomaterials offer several advantages over bone grafts. Custom-made implants can perfectly replicate the normal shape of the skull, shorten the operation time, are available in unlimited quantities, and avoid donor site complications. There are, however, several material-specific disadvantages. Several case series have reported high failure rates with hydroxyapatite ceramics, and the use of this material for reconstruction of all but the smallest full-thickness defects is contraindicated. **(Zins JE et al., 2007)**

Hydroxyapatite cements were greeted with considerable enthusiasm on their introduction, as the material has been shown to have osseoconductive properties and was thought to eventually be replaced by normal bone; however this has not been demonstrated in large defects. Hydroxyapatite cements are prone to fracturing on setting due to pulsations of the underlying dura and on minor impact once set, resulting in ingress of tissue fluid into the material, propagating the fractures and resulting in complete fragmentation of the implant. Material fragmentation and infection are the most common reasons for failure, with reported failure rates of up to 50%. **(Verret DJ et al., 2005)**

Hydroxyapatite ceramics have been associated with a sterile inflammatory tissue reaction leading to thinning of overlying skin and material extrusion. **Wong et al., 2011** reported nine infections and material extrusions in 17 paediatric cases treated using the Norian system for full and partial thickness craniofacial bone repairs.

Hydroxyapatite cement has been combined with resorbable plates or titanium/tantalum mesh for use in large defects and load-bearing areas, although this does not improve results and gives worse failure rates than using a metal implant alone. The addition of titanium mesh or other forms of supporting framework increases the likelihood of material fracture on impact so the logic in using both materials together when metal alone will suffice should be questioned. **(Sahoo N et al., 2010)**

Polymethylmethacrylate (PMMA) is the most widely reported alloplastic material. Thirteen case series of custom-made and in situ moulded PMMA show failure rates of up to 80%. **(Akan M et al., 2011)**

PMMA, particularly when mouldedin situ, has distinct characteristics that may contribute to the high frequency of failure seen with this material. The quality of the soft tissue envelope surrounding a cranioplasty implant is critical to long-term success; studies have demonstrated that poor quality soft tissues are associated with cranioplasty failure. The exothermic polymerization reaction of PMMA generates temperatures of up to 110 8C necessitating constant cooling with cold saline during setting to prevent thermal damage to surrounding tissues, and methylmethacrylate monomer, present in cold cured PMMA, is an irritant. These two characteristics of PMMA may adversely affect the overlying skin over time, contributing to the high failure rates seen with PMMA. **(Akan M et al., 2011)**

The titanium cranioplasty, either custom-made or using a mesh system, is reported widely and supported by the largest case series of all biomaterials. Custom-made implants are associated with excellent fit to the defect, highly satisfactory cosmetic results, and high patient satisfaction. **Joffe et al., 2005** reported one failure in a series of 148 custom-made cranioplasties, and a multicentre retrospective review of 143 CAD/CAM manufactured titanium cranioplasties showed a 9.8% failure rate. The principle disadvantage with custom-made titanium implants is cost and the expertise and equipment required in their manufacture: it is estimated that a large cranioplasty from the hospital laboratory costs approximately £1000 to manufacture. More than any other reconstruction, titanium provides an instantly protective reconstruction. One of the patients in this series who had a titanium plate following decompressive craniectomy was subsequently assaulted with an iron bar which dented the cranioplasty but spared the patient neurological injury. It is unlikely any of the other reported biomaterials, or even a normal skull, would have provided such protection to the patient. **(Eufinger H et al., 2005)**

Favorable results using material such as PEEK, porous polyethylene (Medpore), carbon fiber reinforced epoxy resin, and bioactive glass for cranioplasty are reported, however these materials are un-supported by large case series with long-term follow-up. The optimum method of cranioplasty remains unproven. This case series of 151 titanium cranioplasties with a long-term failure rate of 4%

demonstrates that titanium has clear advantages over other biomaterials and provides further evidence that titanium remains a tried and tested solution for full-thickness calvarial defects. **(Mokal NJ et al., 2011)**.

Conclusion:

Calvarial bone defect are frequently the result of trauma, previous operative procedure, infection, or neoplasm. Making the decision regarding the need for repair is frequently not difficult. Its timing dependent on the patient's neurological conditions, the risk of infection, and the healing potential of the surrounding tissue. The operative procedure for repair of these cranial defects is determined by the size of the defect, its location, and the implant material employed.

It is generally accepted that protection of the brain is one of the most important indications for cranioplasty, although brain injury due to a cranial defect is rare. Cosmetic problems also need cranioplasty. The syndrome of trephined (seizures and cerebral atrophy) are also considered indications for cranioplasty, although the clinical evidence remains controversial. Neurological deficits as hemiparesis, sensory disturbance, and aphasia improved dramatically after cranioplasty.

To be suitable for cranioplasty, the material must meet several criteria. It must be biologically inert, nonresorbable, nonantigenic, relatively inexpensive, readily available, radiolucent, sterilizable, pliable, and light-weight but strong enough to withstand impact. In addition, the material should have low thermal and electrical conductivity and a low propensity for infection. In children, the material should be able to allow the skull to growth. Although no currently available material satisfies all of these requirements.

Fresh and subcutaneously preserved autografts are the best at present. autogeneous endochondral bone and membranous bone are excellent substitute materials. Membranous bone can be harvested from the surrounding calvaria. A graft of such bone can be harvested through the same incision as the one needed for exposure of the cranial defect. Membranous bone also offers the advantage of having a lesser potential for resorption than endochondral bone grafts. Endochondral bone cane be taken from a rib or iliac crest. Rib and iliac crest bone grafts are more difficult to shape into the desired configuration but are an excellent source of bone when large implants are needed.

Alloplastic cranioplasty is frequently employed for the repair of cranial defects. Although popular during World War II, metallic materials have fallen into disfavor because of their inherent properties of poor malleability, excellent thermoconductive capacity, and interference with current radiological techniques. Methylmethacrylate is an alloplastic material that is easy to mold and shape and more amenable to the repair of large defects. Acrylic is similar in strength to bone and does not interfere with computed tomography or magnetic resonance imaging. It is ideal for fronto-orbital cranioplasty because it can be feathered along its edges to make an unobtrusive junction with the surrounding bone that produces an aesthetically pleasing result. However, its use should be avoided when bacterial contamination is likely because of the increased risk of infection.

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