Efficacy of Autogenous Split Thickness Calvarial Graft in the Management of Residual Cranial Defect

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Abstract

Introduction The patients with cranial deformity suffer from headache, dizziness, irritability, loss of concentration, depression, anxiety, intolerance to noise and vibration and neuromotor weakness. It is therefore essential to restore the calvarium.

Material and Method This study was conducted in the Department of Oral and Maxillofacial Surgery, Armed Forces Medical College, Pune between Oct 2010 and Mar 2012. The study population was selected from the outpatient department and from the referred cases. The aim was to study the uptake of split thickness calvarial graft in the management of residual cranial defect. After applying the inclusion and exclusion criterions, ten cases were selected with residual cranial deformity, operated for cranioplasty using split thickness calvarial graft and evaluated.

Conclusion It was concluded that cranioplasty using autogenous split thickness calvarial graft for restoring cranial defects is a useful technique and this procedure

allows the surgeon to reconstruct a moderate-to-large cranial defect, without breaching the inner cortical plate.

Keywords Cranioplasty · Split calvarial graft · Syndrome of the trephined · Residual cranial defect · Autografts · Biomaterials

Introduction

Cranioplasty is an operative procedure designed to improve the symmetry and/or shape of the head. It involves the resection, remoulding and movement of the bones of the head [1], to achieve morphological and functional rehabilitation of the cranial vault affected with a severe bony defect resulting from trauma, infection, tumour, cerebral decompression procedure or congenital deformities [2]. The patients with cranial deformity suffer from headache, dizziness, irritability, loss of concentration, depression, anxiety, intolerance to noise and vibration and neuromotor weakness. This condition is collectively termed as “syndrome of the trephined” [3].

It is therefore essential to restore the calvarial symmetry in order to protect the brain inside a secured case of calvarium. A biologically and physiologically acceptable material for restoration of form and function of the individual is required. The first attempt to use bone for cranial reconstruction was made as far back as 1670 by Van Meekren who repaired cranial bone defect in a Russian soldier using bone from a dog. In 1821 Von Walther performed the first autologous bone graft and in 1867 Ollier emphasised the role of periosteum in bone regeneration [4]. Since then a number of different methods have been introduced for the management of cranial defects.

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In restoring the cranial defects the material used can be broadly classified as autografts and alloplasts. The ideal material should be bio-compatible, non-thermo conductive, radio-transparent, nonmagnetic, lightweight, rigid, simple to prepare, easily applicable and inexpensive [5]. No graft qualifies all the prerequisites in totality. However autogenous split calvarial graft has proved its worth to be used as one of the best choices in the world literature.

However it has its own share of limitations such as: it cannot be used in a very large defect, in patients with extremes of ages, previously failed cranial reconstruction, donor site morbidity, post-operative infection, graft resorption and loss of physical properties [6].

Split thickness calvarial graft was documented ages back, and is the most versatile graft used in reconstruction of residual cranial defect today. This graft, however has few disadvantages like age and anatomic restrictions, cannot be used in larger defects, donor site morbidity and risk of damaging the dura while harvesting. The aim of this study is to evaluate the uptake of autogenous split thickness calvarial graft, donor site status and restoration of form and function, both clinically and radiologically in the management of residual cranial defect, with an objective to enumerate the pros and cons of this novel graft.

Materials and Method

The study was conducted in the Department of Oral and Maxillofacial Surgery, Armed Forces Medical College, Pune between Oct 2010 and Mar 2012. The study population was selected from the outpatient department (OPD), from cases referred by the Neurosurgery Department and from other peripheral hospitals.

The following inclusion and exclusion criterion were applied to select the study sample.

Inclusion Criterion:

1. Cases of residual cranial defect, irrespective of the etiology.
2. Age group between 10 and 65 years of both the sexes.
3. Patients with minimum of 6 months post craniectomy observation period.
4. Patients who agreed for a minimum of 6 months post cranioplasty follow up.
5. Radiologically sufficient calvarium with adequate diploic differentiation.

Exclusion Criterion:

1. Medically compromised cases.
2. Cases with history of graft failure or rejection.
3. Recipient site with residual disease.

4. Patients who have undergone or planned for chemo/radio therapy.

A total of 10 cases of residual cranial defect were selected. All patients were preoperatively evaluated for presenting complaints and signs and symptoms. The defect size and site were clinically studied. Pre-operative, lateral skull and postero-anterior (PA) view skull, computed tomography (CT) scans with three dimensional (3D) reconstructions (Fig. 1) were done to determine the location, shape and size of the defect. CT images were evaluated in axial, coronal and sagittal sections to determine the diploic width (Fig. 2). Cases were discussed with neurosurgical team.

Surgical Procedure

After part preparation and draping, the incision line was marked, either dictated by existing scar mark or as per the requirement to expose the defect. Adrenaline (1:100,000) was injected along the proposed line of incision, cross-hatching and hemostatic suturing were done. Dissection was carried out to expose the defect (Fig. 3). To optimize the fit and contour, a malleable aluminium foil was used to create the template from the defect. The template was cut into multiple strips.

The incision was extended to expose the donor site (Fig. 4). The parietal region was chosen as the donor site for harvesting the outer table because it is thick with necessary diploic differentiation, easily assessable part of skull and the suitable contour. The template strips were

Fig. 1 Three Dimentional reconstructed image of the cranial defect

Fig. 2 Evaluation of CT to determine the diploic width

Fig. 3 Exposure of the defect

transferred to the donor site and the area was marked with No 4 round bur 1.5 cm away from the sutural areas. Multiple strips were harvested by splitting along the diploic interface between the inner and outer tables using reciprocating saw, fine tapering and straight fissure burs with copious saline irrigation and fine osteotomes. The continuity of the inner table was maintained. The harvested graft was transferred to the recipient site and fixed using titanium micro screws (Fig. 5) and micro plate. Hemostasis was achieved, vacuum drain was secured and activated and the surgical wounds were closed in layers.

Patients were reviewed with post op radiograph (postero-anterior (PA) view skull, and lateral view skull) on 10th POD. Subsequently cases were reviewed in the sequence of 1 and 6 month intervals. Cases were evaluated clinico-radiologically and the result was drawn under the following clinical and radiological criteria to evaluate the outcome of the technique in harvesting the autogenous split thick-

Fig. 4 Exposure of the donor site

Fig. 5 Fixation of graft using titanium micro screws

Fig. 6 Pre and post op photographs to compare the clinical outcome

Fig. 7 Pre and post op radiographs to compare the radiological outcome

Table 1 Clinical and radiological criterions

Clinical criterions	Radiological criterions
Post-operative infection both at recipient and donor site	The restoration of the calvarial symmetry
The restoration of the calvarial symmetry	Continuity of the inner cortical table of the donor site
Palpability of the donor site defect	The approximation of the graft with the adjacent bone
Palpability of graft and fixation system at the recipient site	Any signs of graft resorption
Signs of neurological deficit, if any	–
Improvement in neuro-motor function	–

ness calvarial graft and restoring the cranial defect, to study clinical and radiological uptake of the graft and restoration of form and function and to assess the donor site morbidity. Pre and Post-operative results were compared clinically (Fig. 6) and radiologically (Fig. 7).

Ten criterion were formulated that included six clinical and four radiological criterions (Table 1). All patients were evaluated for these criterions at one and 6 month intervals. The statistical analysis for all these criterions was drawn using MINITAB-1513 software. The results were tabulated accordingly.

Result

Ten selected cases with residual cranial deformity, operated for cranioplasty using split thickness calvarial graft were evaluated using mentioned clinical and radiological criterions. The data base of the patients is given in Table 2. The patients were between 09 and 58 years of age with a mean age of 32.5 years and standard deviation of 13.99. The maximum numbers of patients were between 31 and 40 years of age. There were 6 male and 4 female patients. Male to female ratio was 1.5:1.

Table 2 Patient data

Serial no	Age in years/sex	Aetiology	Indications	Defect site	Follow-up period in months
1	09/F	Trauma	Protection	Occipital region	17
2	34/M	Trauma	Cosmesis and protection	Fronto-parietal region	15
3	40/M	Trauma	Cosmesis and protection	Temporo-parietal region	13
4	31/F	Osteoid-osteoma	Protection	Frontal region	10
5	32/M	Trauma	Cosmesis and protection	Frontal region	08
6	32/F	Trauma	Cosmesis and protection	Fronto-parietal region	08
7	40/F	Trauma	Cosmesis and protection	Temporo-parietal region	07
8	12/M	Trauma	Cosmesis and protection	Frontal region	07
9	37/M	Trauma	Cosmesis and protection	Temporo-parietal region	06
10	58/M	Trauma	Cosmesis and protection	Fronto-parietal region	06

The aetiology for cranial defect in nine cases was severe head injury, followed by evacuation of intracranial haemorrhage using emergency craniectomy procedure and in one case it was osteoid osteoma, operated for tumour resection. Out of ten cases, six cases were operated in fronto-parietal region, three cases in temporo-parietal region and the remaining one case in occipital region. The prime indications for surgery in all the cases were to offer a protection for the brain and to restore the aesthetics. The minimum period of case review was six months and maximum was seventeen months (Average: 9.7 months).

All the cases were evaluated clinically and radiologically during the post-operative follow up period and the results were compared with pre-operative data. One case showed wound dehiscence in the immediate post-operative period. Continued parenteral antibiotics and local dressing resolved the wound dehiscence. Two cases showed supra-trochlear and supra orbital nerve paresthesia. Patients showed recovery after 6 months. None of the cases had loss of calvarial symmetry, graft rejection or breach in inner diploe continuity both clinically and radiologically. Out of four patients who had pre-operative neuro-motor weakness, two showed improvements at 6 months review. The margins between the graft and the host bone were palpable in all cases. The class interval and test of significance were evaluated for all ten criteria and overall statistical significance was $Z = 0.63$ and P value = 0.527.

Discussion

The primary indication of cranioplasty is to provide a mechanical protection to the brain. The unsupported dura and the scalp make the underneath brain viable to pressure change in the external environment like blow of heavy breeze or due to contact sports. As a result these patients may suffer from a spectrum of symptoms varying from headaches and motion intolerance to seizures. “Syndrome of the trephined” or

sunken skull syndrome represents cluster of signs and symptoms from headache, dizziness, irritability, loss of concentration, depression, anxiety, intolerance to noise and vibration and neuromotor weakness [3]. The first pathophysiologic explanation for this syndrome was suggested by Gardner et al. [7] in 1945, who claimed that, unlike the brain in the closed calvaria, in a trephined skull the brain pulsates with every alteration of arterial or venous pressure.

Therefore the goal of cranioplasty is to achieve a life-long, stable, structural reconstruction of the cranium covered by a healthy skin and scalp flap. The accepted major clinical findings that can be reliably improved by cranioplasty are protection of the cerebrum and improved cosmetic appearance [8]. The split thickness cranioplasty technique undertaken in this study was successful in achieving these goals.

The broad classification on materials [8, 9, 10] used for reconstruction of cranial defect is:

1. Bone grafts

• Autografts

- Cranial vault: full thickness or split thickness (Preserved graft in patients anterior abdominal wall or cryo-frozen graft)
- Mandible
- Rib
- Ilium
- Tibia.

- Allografts
- Xenografts

2. Biomaterials

- Methyl methacrylate
- Hydroxyapatite

- Calcium phosphate
- Porous polyethylene implants
- Titanium implants
- Combined biomaterials

3. Combination of bone grafts and biomaterials

Autogenous bone graft has always been used as standard material for reconstruction of cranio-maxillofacial defect since ages. Repair of skull defects paralleled the practice of trephination among ancient cultures. Cranioplasty with varied materials was performed by many ancient civilizations; and a number of these procedures date back to 3000 BC, particularly the Inca period in Peru [11]. The main three sources of autogenous bone graft to discuss are iliac crest bone graft, rib graft and split calvarial graft.

Embryologically the calvarial bones are intramembranous in origin. Therefore the calvarial bone grafts are the most embryologically matching material of all. The intramembranous bone is more stable than the endochondral bone. Endochondral bone resorption rates are as high as 60–80 %, whereas membranous bone resorption rates range from 17 to 20 % [12]. No graft/implant is available on date that will suffice all the requirements. Extensive research in the field had given rise to implants that produced promising results. However autogenous grafts are the most successful and the most desired material of all. Amongst autogenous grafts, split thickness calvarial graft will fit into almost all the ideal requirements for cranial reconstruction. In a comparative study conducted by Moss et al. [13], the three main sources of autogenous bone grafts i.e., calvarial graft, iliac crest graft and rib graft were compared with demineralized bone matrix in restoring the cranial defect. They found that amongst the autogenous graft, calvarial graft is the ideal one for restoring the cranial defect in offering good contour and adequate mechanical support.

McCarthy and Zide [14] described three techniques of calvarial bone grafting: full thickness graft, split thickness graft, and calvarial bone flap. Of late calvarial graft saved in anterior abdominal wall or cryo-preserved grafts are also being used. The technique of autogenous split-skull cranioplasty used in our study was first stated by Muller [8].

The choice between the methods is mostly a matter of personal experience and preference. While choosing the operative technique as well as the graft material, the pros and cons must be thoroughly evaluated. The use of autogenous bone grafts is physiologically sound and widely preferred as the standard cranioplasty material since it becomes a living part of the host, being less susceptible to infection and giving no foreign body reaction. The most valuable property of fresh autogenous bone graft material

is its potential to become incorporated as a living matrix with reparative capabilities. This asset cannot be matched by any existing alloplast. The ability to recruit fresh, autogenous bone for the repair of skeletal defects is at the center of Reconstructive, Oral and Maxillofacial and Craniofacial Surgery. Contemporary surgical principles and technical refinements allow for the effective harvesting of bone from a number of different anatomic sites (e.g., cranial vault, mandible, rib, anterior and posterior ilium, and tibia). The proximity of the cranial vault to other surgical sites, availability of relatively large quantities of bone, and favourable consistency make cranial bone harvest an extremely viable reconstructive maneuver.

Some of the notable disadvantages of the autogenous split calvarial graft are: Absorption and loss of contour are possible, it may be difficult to form cosmetic contour in certain areas of the skull, donor site morbidity, increased operative time to obtain and prepare the donor material, this graft may be inadequate to restore a large defect [15] and visible scarring at the donor site [8]. This is not a preferred graft in extremes of ages because at age below 7 years, there might not be adequate diploic width to harvest and the availability will be insufficient. The skull reaches 75 % of its thickness by the age of 5 years and adult thickness by the age of 17 years. The mean thickness of the adult skull ranges from 6.80 to 7.72 mm but varies between 3.0 and 12 mm [16]. In this study the maximum number of patients was between 31 and 40 year group, which is the safest age group. Exploring the calvarium below the age of 7 is at risk of damaging the dura and other complications. This is a disadvantage of the technique. However most allograft materials may not be suitable in pediatric patients owing to skull growth; thus, autologous bone grafts are often preferred in the reconstruction of the pediatric skull because of their capacity to osseointegrate and grow with the pediatric skeleton [17]. At age above 60 years systemic status may not fit the subject into this procedure and the splitting of the two tables due to sclerotic changes in the diploic space in the older patient may be difficult, leading to dural exposure [18].

In recent years the approach to stimulate new bone formation by osteoinduction, using growth factors has gained wide support. Bone morphogenetic proteins (BMPs) have been used in a few human studies with promising results [19]. This is further supported by Arnaud et al., who showed bone formation in experimental studies when using TGF-beta1 and fibrin glue applied on a natural coral skeleton in cranial reconstruction [20]. Although these results are encouraging, further improvements and studies are needed, especially for the reconstruction of large complex defects in the cranio-maxillofacial region.

Conclusion

Cranioplasty using single-table autogenous calvarial bone grafting for restoring cranial defects resulting from trauma or tumour is a useful technique, and this procedure allows the surgeon to reconstruct a moderate-to-large cranial defect, without breaching the inner cortical plate. Using careful surgical technique, the morbidity associated with the harvesting of cranial bone is low and residual harvest site defects are clinically insignificant. This novel technique has opened new vista in the field of oral and maxillofacial surgery, where committed works could unfold many modifications in future dates.

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