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CALVARIAL BONE GRAFT FOR CRANIAL BONE DEFECTS

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SUMMARY: Cranial defects are commonly a result of high velocity trauma. Bone loss may also occur as a consequence of infection or following surgical excision for tumour. Reconstruction of these defects has been attempted with both alloplastic and autogenic materials. This paper outlines the use of the calvarium, as a source of autogenic graft, for such defects in 12 patients. Two techniques for safely harvesting calvarial bone grafts, selection of appropriate procedure, fixation and results are discussed along with relevant literature.

INTRODUCTION

Cranial defects are commonly an outcome of trauma. Occasionally it may be due to loss of bone secondary to infection or tumour excision. The need for corrective surgery is mostly cosmetic. However apprehension about possible trauma to the unprotected brain, directs the patient to seek treatment.

A variety of alloplastic materials (viz. methyl methacrylate, stainless steel, titanium) and autogenic material have been used for reconstruction of calvarial defects[1,2]. The use of membranous bone as a reconstructive material, for craniofacial defect, has become increasingly popular in the last decade, because of significant advantages over other autogenous material. Calvarial bone graft with its advantage of less resorption, good cortico-cancellous volume and accessibility from the same operative site has made it the material of choice over other available sources[2,3,4].

PATIENTS AND METHODS

From June '94 to March '96 twelve patients underwent reconstruction of their calvarial defects using calvarial bone. All were adult males, with defects ranging from 24 to 144 sq.cms. Of these patients, 8 were the result of trauma, 2 were secondary to bone loss, following infection of osteoplastic flaps and two were following excision for advanced orbital tumours infiltrating the anterior cranial fossa. (Table 1).

The main complaints of the patients while presenting for reconstruction were headache and heaviness; but the commonest reason was their apprehension of possible injury to the unprotected brain. All defects were confined to an area bounded by a line 3 cm. behind the coronal suture to the supra orbital rim anteriorly (Fig. 1).

OPERATIVE TECHNIQUE

All patients underwent a thorough head scrub, a day prior to surgery. Shaving of the scalp was avoided and only trimming of the hair was done along the course of the incision. The approach was through the bicoronal incision, reflecting the scalp both anteriorly and posteriorly, exposing a large area of calvarium. The defects were defined, sclerosed margins were nibbled and the tethered dura freed. Where feasible, the donor site was the parietooccipital area overlying the non-dominant hemisphere, 2 cm. lateral to the midline. A flap of pericranium was elevated from the donor area prior to harvesting of the bone graft.

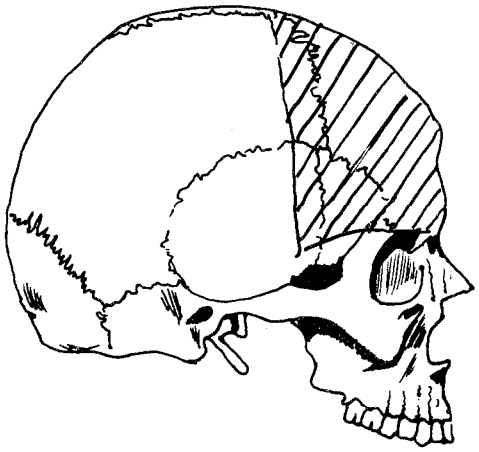
Harvesting of graft was done by two techniques:

In the "EX VIVO" procedure, the neurosurgical trephine was used to remove a disc of full thickness of calvarium (Fig 2A & B). This was then split on the side table into two tables along the diploic space from the centre to the periphery using a powered sagittal saw and an osteotome. One fragment was returned to the donor site and the other shaped to the size of the defect and fixed.

In the second procedure, harvesting was done "IN VIVO". A pattern of the defect was marked on the selected donor site. Along this marking a groove, 2 mm wide, beveled inwards extending up to the diploe was made. Using a curved osteotome the outer table was then split along the diploic space from centre to periphery. Small osteotomes wedged between the graft and bed helped to guide the osteotome along the right plane. The chance of accidental penetration of the full thickness of the skull is reduced (Fig. 3A & B). The grafts were rigidly

TABLE 1. - Results

Age	Etiology	Site of Defect	Size (Cms)	Donor area	Technique	Method of Fixation	Complication
40	Trauma	Centre-fronto-parietal	6 x 8	Left & Right Parietal	In vivo	Plate & Screws	Seroma or inner table penetration
18	Trauma	Left Frontal	8 x 10	Right Parieto Occipital	Ex vivo	Interosseous wiring	Palpable wires
21	Trauma	Right Frontopartietal	6 x 4	Left Parietal	Ex vivo	Plates & Screws	----------
16	Trauma	Centre Frontopartiatal	10 x 6	Right Parietal	Ex vivo	Interosseous	----------
28	Trauma	Left Frontoparietal	4 x 6	Right Parietal	In vivo	Plate & Screws	----------
44	Post Infective	Left Temporal	10 x 8	Right Parietal	In vivo	Plate & Screw	Seroma, inner table penetration
52	Tumour excision	Right Frontal orbital rim	16 x 9	Right Parietal	Ex-vivo (Two grafts)	Interosseous wiring	----------
24	Trauma	Left Parietal	6 x 4	Right Parietal	Ex-vivo	Interosseous wiring	Palpable wires
30	Trauma	Right Frontal	8 x 6	Right Parietal	Ex-vivo	Plate & Screws	----------
46	Tumour excision	Left Frontoorbital	12 x 1	From harvested Frontal bone flap	Ex-vivo In-vivo	Interosseous wiring	----------
28	Post infective	Left Temporal	7 x 6	Right Parietal	In-vivo	Plate & Screws	Seroma
26	Trauma	Frontoparietal	7 x 7	Right Parietal	Ex-vivo	Plate & Screws	----------



(Fig-1) Site of post traumatic calvarial defects

fixed using either interosseous wires or miniplates and screws. The pericranial flaps were draped over the donor site, and the wound closed over a closed suction drain.

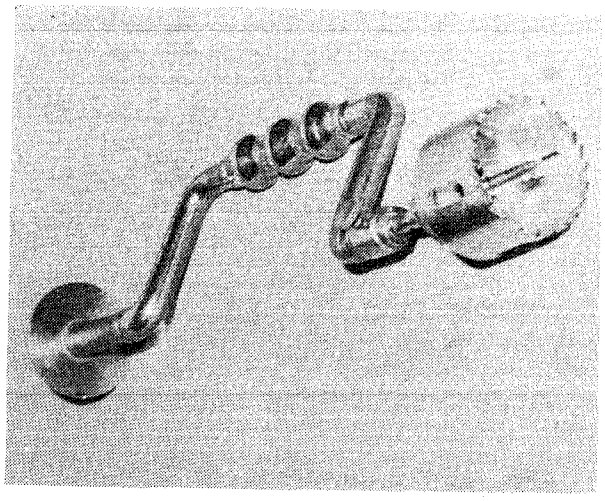
RESULTS

The follow up ranged from six months to two years. Three (25%) patients developed a seroma in the immediate postoperative period, which subsided on aspiration and pressure dressing. Complaints of palpable irregularity and pain at the donor site were noted in all the patients in whom the bone graft was harvested by the "in situ" method. Even two years following their reconstruction the irregularities continued to be palpable. In two (17%) patients, interosseous wires used for graft fixation were palpable externally, necessitating their removal. Though volumetric analysis was not performed, no contour changes were observed on follow up.

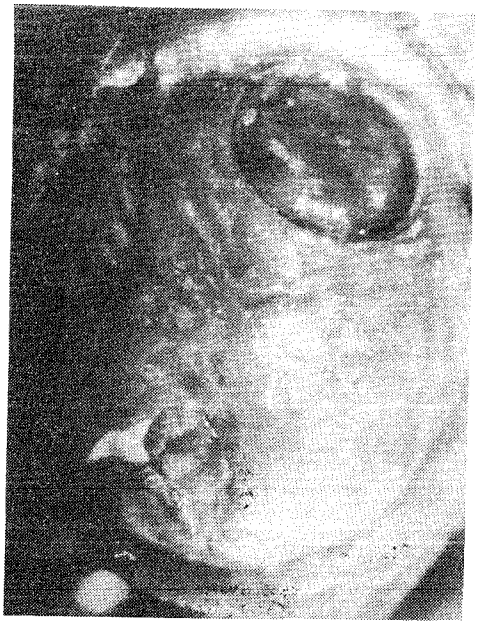
DISCUSSION

Most patients in our study had cranial defects secondary to trauma. In the series by Posnics et al, of the 27 children with calvarial defects, more than 50% resulted from trauma and tumour excision[2]. Primary reconstruction of compound depressed skull fractures is a possibility but the overlying soft tissue injury may complicate such reconstruction.

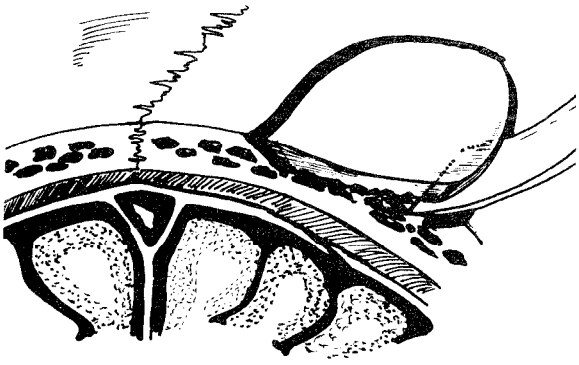
The usual indications for cranioplasty are for providing protection and cosmesis[1,2]. In our study all the patients fell into this group. They were all apprehensive regarding any possible injury to their unprotected brain. Speech dysfunction and hemiparesis have



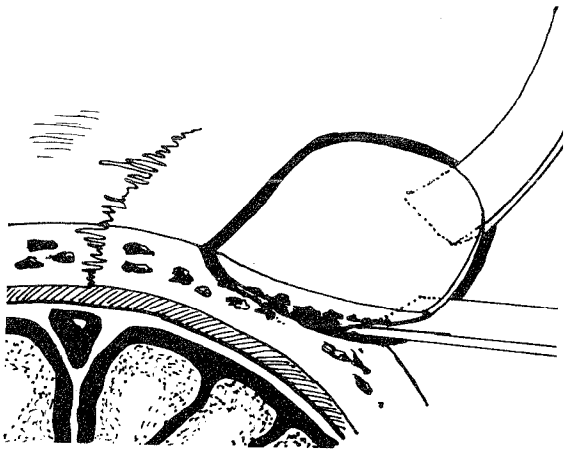
(Fig-2a) Neurosurgical trephine used for harvesting bone graft



(Fig-2b) Calvarial bone graft harvested using a neuro surgical trephine



(Fig-3a) Harvesting a calvarial bone graft by the "in vivo" technique



(Fig-3b) Calvarial bone graft-"in vivo" technique: wedging of small osteotome to guide the curved osteotome

occasionally improved following cranioplasty and vague symptoms like headache, dizziness, apprehension, insecurity have also variably and unreliably improved[1]. This is probably because of the release of the tethered dura from the scar.

Frontal impact, in most high velocity trauma, results in most of the defects being confined to the anterior cranial vault. It was observed that all traumatic defects were confined to an area bordered posteriorly by a line 3 cm behind the coronal suture, and anteriorly by the supra orbital ridges.

The choice of autogenic material over alloplastic material is guided by the fact that autogenic tissue is a biological tissue, which gets incorporated into the body. Methylmethaycrylate, the common alloplastic material in use, has proven to be an accepted space filler that has no resorption. This material is however not resistant to infection or trauma and may get exposed as a later complication [1,6]. Foreign body reaction, resorption of surrounding bones and lack of incorporation with chances of migration are some of the drawbacks of methylmethycrylate[2,7].

Analytical studies in the last decade have shown the superiority of membranous bone graft, in comparison to endochondral grafts (rib, ilium)[4]. Membranous grafts are now a common procedure in craniofacial surgery [8,9,10]. Their exceptionally low degree of resorption[3], easy accessibility (as it can be obtained through the same operative incision), the large volume of available bone of similar nature and shape and a

donor site that is well concealed, along with its low morbidity, all add up to make this presently the ideal choice for calvarial defects,[1,2,8]. This is reflected in the increased use of this graft in recent times.

Knowledge of the thickness of bone and its diploic space is necessary for safe harvesting of calvarial bone grafts. Various studies have documented the thickness of the calvarium at various sites[11,12]. A study of fixed points in the fresh cadaver skull documented a mean thickness of 6.8 to 7.72 mm increasing from anterior to posterior, there being no significant difference between left and right half[4]. A recent study by Koenig et al shows a predictable increase in parietal bone thickness with age; ranging from 4.25 mm to 11.25mm, average being 7.45mm[13]. In 20% of children there was no diploic space demonstrable on CT. This is clinically significant, and most authors agree that in vivo bone splitting should not be done before the age of 9 years or below a thickness of 6mm.[8,10,12]. In those below 9 years of age, a full thickness of bone graft should be harvested and split on the side table (ex-vivo). Absence of diploic space in children below two years makes splitting of graft difficult. Temporary reconstruction using methylmethacrylate, till the skull is thick enough to be split, has been suggested[13].

Techniques of harvesting of calvarial bone graft have been well described[10, 14,15]. Harvesting of bone grafts were done both by the technique of splitting a full thickness graft removed by a neurosurgical trephine (diameter 5 cm) on the side table ("ex vivo"), or by harvesting the outer table in situ ("in vivo"). The maximum dimension of the defect decided the choice of procedure. For defects less than the maximum diameter of the neurosurgical trephine (5 cm), the "ex vivo" technique was followed. This provides a disc of bone, from the selected donor site, easily and rapidly. It is a common technique of neurosurgical access, familiar to most neurosurgeons. Splitting of this bone was done using a sagittal saw, and a curved osteotome. This is time consuming and difficult. While splitting it is difficult to do so evenly due to its curvature. The graft may fracture in the process. This occurred in two out of seven "ex-vivo" grafts. Splitting has to be done gradually from periphery converging uniformly towards the centre. Of the two split tables, the outer smooth table was used for defects below the hairline, the inner table being returned to the donor site. For defects above the hairline, the opposite was practiced. Posnic et al used the full thickness of calvarium to replace defects of the supraorbital, and lateral orbital region, replacing the donor defect partially with split thickness grafts from a different site [2].

The "in vivo" technique was selected in patients with calvarial defects whose maximum dimension exceeded the size of the trephine (5 patients). The limitation in earlier described techniques, are the small width of graft that can be harvested in one piece[8] and the risk of penetration of the inner table. Beveling inwards, careful elevation from periphery concentrically towards the center, with wedging of small osteotomes, help in elevating relatively large pieces of graft (maximum dimension 8 x 10 cm) in one piece. Inner table penetration occurred in two patients. However the dura was not injured. Kellman[14] described the use of a malleable blade reciprocating saw, to lift the outer table. Positioning of the blade is highly critical, and must be checked repeatedly, as there is a high risk of fracture or deeper penetration. Grafts of a maximum size of 7x10cm were harvested by this technique.

Rigid fixation of bone is now an accepted procedure in craniofacial techniques[2,16]. Graft harvesting using the trephine, results in circumferential bone loss as bone dust of around 1-2mm. The bone when returned to its bed fits loosely requiring ancillary support, using either interosseous wires or mini plates and screws. The use of plates and screws may be preferable when grafts suffer partial fracture during elevation which can be retained with plate and screws and because bone graft resorption is less with rigid fixation[18]. The hardware rarely requires removal. Jackson et al[16] reported no plate removal six years following use. Visible projections may necessitate removal of hardware. With the availability of low profile screws and plate this may not be required.

The purpose of elevating a pericranial flap, before harvesting of the graft, serves in providing a vascularised tissue[17], to drape over the site. It also helps in retaining the bone dust packed in the space between the graft and calvarium, after fixation.

Various complications of harvesting of calvarial bone graft have been reported [9]. In 62 "in situ" bone grafts 3 donor site seromas were reported by Parsa et al.[19]. Jackson et al reported 5.6% incidence of complications following 265 cranial bone grafts[20]. In a multicentre study of 12,673 grafts only 3 temporary neurological complications resulted. Intracranial hematoma, hemiparesis which fully recovered and epidural hematoma occurred [19]. In the present study, 3 patients developed donor site seroma, which settled with aspiration and compression dressings. Donor site pain (n=3), contour changes (n=4) and palpable hardware requiring removal (n=2) were the other late complications. Dural exposure during "in vivo" harvesting of graft (n=3) cannot be considered a complication as it does not add to the morbidity[13]. Donor site should be placed away from the saggital sinus. No

incidence of dural tear or intracranial injury occurred.

CONCLUSION

Calvarial bone grafting is presently the procedure of choice for cranial defects. Careful selection of patient site and technique makes this a safe and reliable procedure.

References

1. **Posnic JC, Goldstein JA, Armstrong D, Rutka JT.** Reconstruction of skull defects in children and adolescents by the use of fixed cranial bone grafts: Long term results. Neurosurgery 1993; 32:2785-2791.
2. **Zins JE, Whitaker LA.** Membranous versus endochondral bone. Implications for craniofacial reconstruction. Plast Recon Surg 1983; 72: 778-784.
3. **Adeloye A, Shokumbi MT.** Immediate bone replacement in compound depressed skull fractures. Central African Jour of Med 1993; 39: 70-73.
4. **SalyerKE, Taylor DP.** Bone grafts in craniofacial surgery. Cl. in Plast Surg 1987; 14: 27-35.
5. **Lesavoy M.** Partial skull loss-reconstruction with bone grafts. In Stark RB ed. Plastic surgery of the head and neck Vol. 1. New York: Churchill Livingstone, 1987: 49-51.
6. **Pensler J, McCarthy JG.** The calvarial donor site. An anatomic study in cadavers. Plast Recon Surg 1985; 75: 648-651.
7. **Craft PD, Sargent LA.** Membranous Bone Healing and Techniques in Calvarial Bone Grafting. Cl. in Plast Surg 1989; 16: 11-19.
8. **Kline RM, Wolfe SA.** Complications associated with harvesting of cranial bone grafts. Plast Recon Surg 1995; 95: 5-13.
9. **Tessier P** - Complications associated with the harvesting of cranial bone grafts. Plast Recon Surg 1995; 95: 14-20.
10. **McCarthy JG, Zide BM.** The spectrum of calvarial bone grafting. Introduction of the vascularised calvarial bone flap. Plast Recon Surg 1984; 74:10-18.
11. **Koenig WJ, Donovan JM, Pensler JM.** Cranial bone grafting in children. Plast Recon Surg 1995; 95: 1-4.
12. **Persing JA. Discussion in Posnic JC, Goldstein JA, Armstrong D, Rutka JT.** Reconstruction of skull defects in children and adolescents by the use of fixed cranial bone grafts: long term results. Neurosurgery 1993; 32: 791.
13. **Hendel PM.** The harvesting of Cranial bone grafts. A guided osteotome. Plast Recon Surg 1985; 76: 642-644.
14. **Kellman RM.** Safe harvesting of large outer table Calvarial bone grafts. Arch Otolaryngo, Head & Neck Surg. 1994; 120:856-860.
15. **Jackson IT, Ross JH, Fukuta K and Audet BU.** "Side table assembly" - An adjuvant to craniofacial reconstruction. Brit J Plast Surg 1991; 44:348-350.
16. **Fukuta K, Potparic Z, Sugihara T, Rachmiel A.** A Cadaver investigation of the Blood supply of the Galea Frontalis Flap. Plast Recon Surg 1994; 94:794-800.
17. **Philips JH, Rahan BA.** Fixation effects on membranous and endochondral onlay bone grafts resorption. Plast Recon Surg 1988; 82:872-877.
18. **Parsa FD.** Nasal augmentation with split calvarial grafts in Orientals. Plast Recon Surg 1991;. 87:245.
19. **Jackson IT, Pellett C, Smith JM.** The skull as a bone graft donor site. Ann Plast Surg 1983; 11:527.

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