Reconstruction of Cranial Defects in Armed Forces Personnel - Our Experience

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Abstract

Background: The aim of this study was to evaluate the efficacy of heat cured 'poly methyl methacrylate resin prosthesis and to assess the acceptability of the indigenously manufactured titanium mini bone plate and screws in patients treated for repair of cranial defects.

Methods: 17 patients with cranial defect were treated for reconstruction of the skull defect with two types of implants i.e. Acrylic resin plate prosthesis and titanium minibone plates, either in combination or singularly. In these cases, the skull defects resulted from trauma (88.23%) or due to ablative tumour surgery (11.96%). Acrylic implant was used in 12 cases (70.85%), titanium plates and screws in 2 cases (11.76%) and a combination of both of the above in 3 cases (17.64%).

Results: The primary reconstruction was carried out in 2 cases (11.96%) and secondary reconstruction was done in 15 cases (88.23%). Majority of the cases underwent secondary reconstruction because of the initial surgical emergency requiring quick debulking and closure. In 2 cases where primary reconstruction was done, the second surgery could be avoided with gratifying results.

Conclusion: 70.85% underwent reconstruction with polymethyl methacrylate resin prosthesis and in the rest either titanium plates were used singly or in combination. Only in one patient, there was rejection of the implant due to infection. In 94% cases the graft was well taken up with excellent results.

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Key Words : Cranial reconstruction; Mini bone plates; Cranial prosthesis

Introduction

Cranial vault deformities as a sequelae to trauma may be as high as 70%[1]. The other etiological factors are congenital i.e. craniosynostosis, congenital, malformations as a result of 1st and 2nd branchial arch defects, meningocele and encephaloceles. The acquired defects are mainly due to ablative tumour resection surgery and infections involving the calvarium necessitating its removal. The successful management of a case of trauma in an emergency situation, requires quick evacuation of the haematoma, repair of the dura and the scalp but not necessarily the integrity of the calvarial segment as an immediate measure. So the reconstruction of the calvarial defect in these cases is mostly carried out as a secondary procedure. With the advent of newer implant material, primary reconstruction of traumatic cranial vault defect is possible provided the general condition of the patient permits the surgeons to do so. This is not possible most of the times, but if done, it would avoid a second anaesthesia and surgery. In cases of osteomyelitis, primary reconstruction is not advisable because of the potential danger of infection and rejection of the graft. In planned cases e.g. management of meningocele or encephalocele, primary

reconstruction should be part of entire surgical procedure.

The utilization of autogenous local bone for reconstruction provides autogenous tissue, obviates second surgical intervention, donor site morbidity and is rarely rejected. In an emergency situation this may be the best option as the bone fragments are easily available and the results can be very gratifying. The titanium mini bone plate or mesh and screw system is a good alternative which provides rigid fixation of calvarial bone fragments with adequate strength alongwith good aesthetic contour and excellent results. This procedure is good for secondary reconstruction as a planned case but is likely to take time and requires preoperative planning. In most cases of secondary reconstruction 'poly methyl acrylic resin' prosthesis is used to restore the defect. These are the most convenient to use because of easy availability, low cost, quick application and excellent results, but is usually done as a secondary reconstruction. Once pre-fabricated plates are made available this would facilitate primary reconstruction thus obviating the need of second surgery. The purpose of this study was to evaluate the efficacy of heat cured 'poly methyl methacrylate resin' prosthesis and to assess

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the acceptability of the indigenously developed titanium mini bone plate and screws in patients treated for repair of cranial defects.

Material and Methods

From Aug 1997 to Jul 2002, 17 patients with various calvarial defects were managed. In 15 cases, the defect resulted from trauma and in 2 cases due to ablative tumour surgery. The reconstruction was carried out with poly methyl methacrylate resin plate in 12 cases, with Ti mini bone plate and screws in 2 cases and combination of both of the above in 3 cases. All the patients were clinically and radiologically evaluated by the neurosurgeon prior to undertaking any reconstructive procedure. The radiological investigations included X-ray skull-AP and lateral view supplemented with CT scan for defining the site and size of the defect. Patch test was carried out in all the patients planned for reconstruction with poly methacrylate resin plate to rule out any hypersensitivity reaction. Prior to the secondary reconstruction, the defect was marked on the scalp (Fig. 1) and impression of the defect was taken. A cast was made with dental stone. In case of fabrication of acrylic cranial plate prosthesis the processing was carried out in a water bath at 168°F for 12 hours and boiled for 30 minutes to ensure a complete cure and maximum reduction of free monomer. Multiple holes of 1.5 mm diameter were made over the entire plate at a distance of 1.5 mm to 2 mm from each other. The edge of the prosthesis was beveled with a flame shaped acrylic burn. The prosthesis was given a final finish and high polish (Fig. 2). The prosthesis is then sterilized by soaking for 48 hours in 2% glutaraldehyde solution. During surgery, prior to the placement of the prosthesis, a step cut of depth 2mm is

made at the periphery of the defect. It facilitates the proper seating of the prosthesis and smooth marginal adaptation. Before fixation of the prosthesis, the dural hitch sutures are placed through any suitable perforation already made in the plate (Fig. 3). It prevents the subsequent formation of the subdural haematoma. The prosthesis is fixed with a synthetic non-absorbable suture material and the knot is kept under the prosthesis. It is important to fabricate the plate slightly larger than the actual defect so that the prosthesis does not dip into the defect and lead to an unacceptable aesthetic contour. In case of any minor discrepancy in the curvature, the prosthesis can be moulded by immersing it in a hot glycerin bath. In case of involvement of the frontal sinus, obliteration of the sinus is done with bone wax and spongioson to prevent any retrograde infection or any other complications like formation of a mucocoele etc.

In two cases, immediate reconstruction was carried out. After ensuring the feasibility of a primary reconstruction, a lint piece was placed over the defect and then it is cut according to the shape of the defect. On this lint piece the bony fragments are arranged and fixed with titanium mini bone plates and screws. The screws used are self threading

Fig. 1 : The cranial defect marked.

Fig. 2 : Prosthesis after finish and polish

Fig. 3 : Acrylic plate in-situ

Fig. 4 : Debulked bone fragments united with titanium plates and screws

type and length varies from 3-4mm. The unified bone fragments are placed over the defect (Figure 4). It is ensured that the newly constructed segment are laid passively over the defect. The extended portion of the mini plate is fixed to sound calvarium using monocortical screws. Screws are fixed at least on three sides of the defect. The bone chips and bone dust which are available while making burr holes are also placed between the bony segments, thereby a unified calvarium is formed. Combination technique was undertaken in cases where impression of the defect site could not be taken on the three dimensional plane. In these cases the major defect site of calvarium was reconstructed with the acrylic resin plate and the defect on another plane was restored with titanium mini bone plate and screws or mesh (Fig. 5).

Results

From August 1997 to July 2002, 17 patients were operated for reconstruction of the calvarial defects. Out of them, 15 (88.23%) were males and 2 (11.96%) females with age ranging from 5 to 58 years (Mean 32.5 years) (Table 1). The defects were due to trauma in 15 (88.23%) cases and ablative surgery in 2 (11.96%) cases. Defects were located in frontal region in 6 cases (35.24%). There were 3 cases each (17.64%) in which the defect was in the parietal and frontoparietal region. In 2 cases (11.76%) the defect involved the fronto parietal region extending upto the supra-orbital rim. There was 1 (5.88%) case each involving the temporo, temporoparietal and parieto-occipital region (Table 2). Acrylic resin prosthesis was used in 12 (70.85%) cases, titanium mini bone plate and screws (11.76%) and a combination of the above was used in 3 (17.64%) cases (Table 3). Primary reconstruction of the cranial defect was carried out in 2 cases (11.76%) and secondary reconstruction in 15 cases (88.24%) (Table 4). Patients were reviewed initially daily for 7 days and subsequent follow up was done at interval of 4, 12, 16, 36 and 52 weeks to assess the progress of healing, stability of the implant, infection, wound dehiscence, discharging sinus, exposure of implant and patients satisfaction with regard to cosmesis and reaction to thermal changes (Table 5). Postoperative infection developed in 1 patient who had undergone primary reconstruction which led to wound dehiscence and exposure of the plate in the region of frontal sinus necessitating removal of the plate. This could probably be attributed to the

Fig. 5 : Three dimensional defects reconstructed with acrylic plate and titanium mini bone plate and screws

Table 1

Age distributions of patients

Table 2

Location of cranial bone defects

Location of cranial bony defect	No of patients	%
Frontal bone	6	35.24
Parietal bone	3	17.64
Combination of frontal and parietal bone	3	17.64
Combination of frontal, parietal and supraorbital rim	2	11.76
Combination of temporo-parietal	1	5.88
Combination of parieto-occipital	1	5.88
Temporal bone	1	5.88

incomplete removal of the mucosa of the frontal sinus and obliteration of frontonasal duct. After removal of the plate the patient had an uneventful recovery. In all other cases after 8 weeks of the surgery, there was decrease in the radiolucency of the fracture lines indicating laying of osteoid matrix. The radiographic evaluation after 24-54 weeks showed no evidence of osteolysis in the bone implant interface with complete integration of screws within the bone which was suggestive of osseointegration.

Discussion

Reconstruction of complex fractures and defects in the craniofacial region calls for a teamwork involving the Oral and Maxillofacial surgeon and the

Table 3**Use of prosthesis**

(a) Titanium mini bone plate & screws- 3 cases

(b) Acrylic resin prosthesis- 12 cases

(c) Combination of Titanium mini bone plate & screws & acrylic resin prosthesis- 2 cases

Neurosurgeon. The basic indications for cranioplasty are improvement of disfigured aesthetics and to provide protection to the intra-cranial contents. The decision regarding cranioplasty must be influenced by the patient's age, prognosis, activity level and the specific condition of the scalp and the calvarium. There are two basic methods for reconstruction viz (a) Osteo-plastic reconstruction [2,3] and (b) restoration with alloplastic implants [4,5].

To achieve a successful result, adequate vascularity of the scalp flap, presence of dura, presence of outer layer of periosteum and absence of infection are important factors. In case of osteoplastic reconstruction, autogenous bone is used, which offers a number of advantages viz (1) its radiodensity allows for normal radiographic diagnostic studies and (ii) it becomes a viable part of the host and hence is not susceptible to infection [6]. A composite autogenous graft composed of the outer table of the calvarium and its pericranium may be used to close small defects. However, according to some

Table 4**Reconstruction of cranial defect**

authors, in patients less than 5 years of age, the dura has osteogenic potential and a bony reconstruction may not be required [7]. In our series there was only one patient of less than 5 years age who had to be treated with acrylic resin plate because he had a wide defect necessitating early reconstruction.

In cases where early surgical intervention is required for life threatening condition like an acute subdural haematoma, the debulked bone fragments are readily available and can be used for primary reconstruction. In our series 2 cases of trauma required immediate decompression and debulking surgical intervention for drainage of subdural haematoma, primary reconstruction was carried out with titanium mini bone plate and screws.

Numerous metals and alloys have been employed historically for the reconstruction of cranial defects. Ideally the metal should be light in weight, strong enough to resist trauma, be significantly malleable to allow alteration at surgery, inert so as not to provoke tissue reaction and hypersensitivity, be non-carcinogenic and sterilizable [8]. Previously, among various metals tantalum was most commonly used but presently titanium has gained wide acceptance owing to its favourable biocompatible property and its MRI compatibility [9]. This material possess higher strength, resistance to corrosion, low molecular weight and is considerably malleable to conform to the anatomic contours and has

Table 5**Clinical evaluation**

Types of Complications	No of patients	Immediate post-op	1st week post-op	4th week post-op	12th week post-op	16th week post-op	36th week post-op	52nd week post-op
Infection	1	-	-	+	-	-	-	-
Wound Dehiscence	1	-	-	-	-	-	-	-
Discharging sinus	1	-	-	+	-	-	-	-
Exposure of implant	1	-	-	-	-	-	-	-
Fracture of prosthesis	-	-	-	-	-	-	-	-

*In 1 patient one five hole titanium mini bone plate and three screws were removed in 4th week post-operative phase

got a low thermal conductivity. It also produces minimal artifact in imaging. The modulus of elasticity of pure titanium is $(15 \text{ psi} \times 10^6)^2$ which is close to bone i.e. $(2.4 \text{ psi} \times 10^6)^2$. This property leads to its even distribution of stress at the bone implant interface [10,11]. However the high cost of titanium is a limiting factor. To overcome this problem, Defence Research and Development Organisation has manufactured indigenous titanium bone plates and screws which is of the specification of American Society of Testing Materials (ASTM) B348 Grade I quality and fulfils the requisite criteria.

Many authors have outlined the merits of acrylic resin for cranioplasty procedures as compared with other materials [12,13]. Extensive cranial defects can be reconstructed with this prosthesis without any donor site morbidity.

'Poly methyl methacrylate' - an acrylic polymer produced from esters of methacrylic acid, was first used for reconstruction of cranial defect by Zendar in 1940. It can be used either as a heat cured preformed implant or cold curing form. A preformed poly methyl methacrylate implant is preferred as there is no heat on polymerization and no excess liquid monomer which might irritate and damage the underlying structures [4]. This implant is radiolucent and non-carcinogenic. It possess low thermal and electrical conductivity. The implant is strong and biocompatible and tissue response is minimal. Moreover, unlike most other implants, it does not interfere with computed tomography or magnetic resonance imaging studies [12,13]. However acrylic implant has a tendency to shatter on impact, particularly in large defects. Some schools suggest incorporation of titanium mini plate [14] or stainless steel wire mesh [15] in the acrylic implant which offer better strength to the implant. To overcome the demerit of being radiolucent some authors recommend impregnation of these plates with small amount of barium, so that it becomes detectable by radiographic means in case of accidental fracture of the plate [14]. The perforation in the plate is a definite advantage since they allow accumulated fluid to seep out into the sub-galeal space, permit adhesions between the prosthesis and the soft tissue which helps to secure the former and allows adequate blood supply to the overlying flap i.e. scalp. The highly polished surface makes it well acceptable and is well tolerated. Its wide availability and low cost makes it the most acceptable implant used today.

With the advent of digitally programmed 3-D models of skull, the exact dimensions of the defect can be generated on which an accurately contoured prosthesis can be designed [16]. Although heat cured methyl-methacrylate implant and titanium mini plate and screws

have been giving gratifying results, the search for better and biodegradable material for reconstruction of cranial defects is under trials. These include biodegradable plates and screws and non-ceramic hydroxyapatite cements which stimulates osteoid tissue formation. In the near future these materials will open a new horizon in cranial reconstruction due to their inherent osseous-conduction, osseous-conversion and osseous-integration properties.

In our study of 17 cases, 70.85% underwent reconstruction with methyl methacrylate and in the rest either titanium plates were used singly or in combination. Only in one patient there was rejection of the implant due to infection. In 94% cases the graft was well taken up with excellent results.

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