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Cranioplasty: Successful Use of Rib Grafts

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ABSTRACT

Background: Numerous materials are available for use in cranioplasty including bone, ceramics and metals. Rib graft as a construct for cranial reconstruction offers several advantages including autologous bone source, a formable plateform, low infection rate, regeneration at the donor site and high fusion rates.

Aim of the Work: The present series aims to clinical evaluation of the use of rib grafts in cranioplasty.

Patients and Methods: Rib autograft cranioplasty was performed in 15 patients. 12 of them were males and 3 were females. The mean age was 18 years. When single rib needed,it has been harvested from the 5^{th} rib and when two ribs needed, they were harvested from the 4^{th} and 6^{th} ribs. 20 ribs were totally harvested.

Results: The reasons for cranial reconstruction were: Post traumatic calvarial defects (73,6%). Previous craniotomy (13,2%), congenital defect (6.6%) and fibrous dysplasia resection (6.6%). The size of the defects ranged between 15 and $84cm^2$. The mean follow up period was 16 months post-operatively. Normal cranial contour was achieved in all patients. One patient developed CSF leak that resolved spontaneously. No donor site complications were noted (Pneumothorax, haemothorax, post-operative pain), no post-operative infections were encountered and graft resorption was not noticed in all patients.

Conclusion: The use of autologous rib graft for cranioplasty, particularly in young age group, was found to have low cost effectiveness, easily harvested, easily moulded to the skull shape, osteointegrated adequatly with the surrounding bone thus offers good brain protection and is associated with low complication rate.

INTRODUCTION

The primary justification for craniopasty procedures are to re-establish protection for the underlying cerebral and vascular structures and to provide an acceptable cranial contour so that the cosmetic result is aesthetically pleasing. Numerous materials are available including bone, ceramics and metals [1]. In situations in which autogenous bone is lacking or unsuitable, alloplastic compounds may be used. Numerous materials have been used for skull reconstruction. Historically, the inert metals, notably titanium, have been used successfully to reconstruct the cranial vault. Titanium although expensive and difficult to contour in the operating room, is the most biologically inert of the metals [2]. It can be used in a mesh form fixed to the periphery of the defect by screws. Ceramics, notably, polymethylmethaccrylate have been used in cranioplasty because of their strength and biocompatibility, but unlike metals, they are prone to shattering when force is applied [3].

Particularly with the developing skull, use of ceramics and metals are disadventigious as they are biologically inert and fail to keep up with the dynamic contouring of the cranium. Additionally, patients may experience difficulties in the post-operative period as a result of infection, breakage, dislodgement or cephalgia. Further consideration in the pediatric patients include durability of both the graft and the overlying skin which may be thin or atrophic. Autogenous bone is better suited for grafting into the immature skull, as it can produce protection and aesthetic function while also allowing for continued growth [4].

Split calvarial grafts are a good source of autologous bone and have been used successfully for cranioplasty including the pediatric population. A drawback to this method in children less than 4 years of age is difficulty associated with thickness and availability of donor bone [5-7].

The Potential hazards of rib graft cranioplasty that have been mentioned in the literature include persistant pain, scarring at the donor site, bone resorption, prolonged operative time and lack of protective effect during the healing period [8-10]. On the other hand several important clinical and scientific contributions supporting rib graft for cranioplasty [4,11-13]. The present series aimed to clinical evaluation of the use of rib grafts in cranioplasty.

PATIENTS AND METHODS

This series included 15 patients underwent rib graft for cranioplasty. 12 of them were males and 3 were females. Their age ranged between 2 and 45 years. The mean age was 18 years. The mean follow up period was 16 months post-operatively (12-20 months). The medical and radiographic records of patients were reviewed. The review included history taking, physical examination, and neurodiagnostic imaging. Operative records were inspected for intraoperative findings, surgical details and transfusion data. Post-procedural records were reviewed for complications related to the surgery as well as clinical outcome. The outcomes were assessed primarily by physical examination focusing on the contour,stability of the cranioplasty and defect filling.

Rib grafts were harvested as detailed by Sawin et al. [14]. Briefly, the skin and subcutaneous tissues overlying the proposed rib(s) were incised. If multiple ribs were required, non-contiguous ribs (4^{th} & 6^{th} ribs) were selected. Monopolar electrocautry was utilized to traverse the muscular layers and periosteum. The rib was freed from its periosteum and periosteal intercostal muscle attachments, with care taken to preserve the neurovascular bundle and pleura. After ensuring the integrity of the pleura,the rib was resected. Interrupted closure of the periosteum and muscles was secured with absorbable sutures (Vicryl 4/0). The wounds were finally closed subcuticularly by Prolene 3/0 that was removed on the 10^{th} day post-operatively.

At the graft site, the edges of the defect were freshened with a bone rongeur. The rib grafts were splitted, trimmed so as to be adapted to the size of the defect and shaped appropriately to obtain perfect contour of the defect. The ribs were then stabilized with either absorbable sutures (Vicryl 0), stainless steel wire 0.5mm or titanium screws 5mm length. Standard two layer scalp closure was then performed, subcutaneously with Vicryl 4/0 and scalp closure with Silk 3/0 that was removed on the 10^{th} day post-operatively.

RESULTS

The reasons for calvarial reconstruction were: Post-traumatic calvarial defect in 11 patients (They represented 73,6% of cases, 8 of them had open depressed fracture, and three patients had growing skull fracture), previous craniotomy in 2 patients (They represented 13,2% of patients. They had an infiltrating meningioma resected from the fronto-temporo-parietal area one year prior to cranioplasty), congenital defect in one patient (He represented 6.6% of cases and had parieto-occipital defect as a result of parieto-occipital encephalocele repair), and fibrous dysplasia resection in one patient (6.6%) Tables (1-3).

Patients that had compound depressed skull defects were debrided and closed at the time of initial presentation. The patients with growing skull fracture had a history of cranial trauma six months, eight months and one year prior to their rib graft cranioplasty. The dural tear in these patients has been repaired by tensor fascia lata. The size of the defects ranged between 15 and $84cm^2$. The mean size was $40cm^2$. The total number of harvested ribs were 20 (Table 1).

Patient number 10 had a history of craniotomy for resection of basal frontal meningioma one year befor cranioplasty has been done. Part of the calvarial bone over the defect has been utilized for partial closure of the defect. The remaining defect has been closed by rib graft.

Patient number 11 had a history of fronto-parietal open depressed fracture that has been reconstructed by an alloplastic material. Failure occurred because of infection and scalp necrosis at the edges of the defect. The implant has been removed followed three months later by rib graft cranioplasty.

Simple rib cranioplasty was found to have a mean time in the operating room of two hours. No patient required blood transfusion. No donor site complications were noted (haemothorax–pneumothorax-significant post-operative chest pain or post-operative scarring). Patients displayed regeneration of the ribs on follow-up chest radiographs. No post-operative infections were encountered. Patient number 13 developed mild CSF leak that has been resolved completely one week post-operatively. Excellent cranial contour was achieved in each of the 15 patients followed for a minimum of 12 months. The average hospital stay was 5 days. Rib resorption was not recorded in any patient.

DISCUSSION

Within the neurosurgical community as a whole, acrylic resins such as PMMA are the general mainstay for cranioplasty. They are inexpensive, easily molded at the time of operation, associated with short operative time and are associated with low morbidity and mortality. However, in the pediatric population, an alarming rate of complications (23%) was reported in a 15-year retrospective review of 75 patients. The commonest complication was infection (16%) that presented at a mean of 4 years after the cranioplasty. Potential factors increasing the morbidity in children were a thinner scalp or changes associated with continued cranial growth. The authors thus favoured autologous bone for cranioplasty **[15]**.

Guyuron et al. **[18]**, concluded that autogenous skull grafts are the optimal material for cranioplasty in the pediatric population. In addition to morbidity at the donor site, the authors dismissed ribs as stand-alone grafts, as sufficient quantity may not be available, and the shape of the graft may be wrong. Edwards and Qusterhout **[5]** have suggested a shorter operative time when using split calvarial grafts as compared to rib grafts for cranioplasty, however, no data was presented to substantiate this claim. Cranioplasty with subcutaneously preserved autologous bone grafts was studied by Movassaghi et al. **[17]** and by Yano et al. **[18]**. They showed that subcutaneous preservation of craniectomy bone grafts and their later replacement provides a satisfactory cranial vault reconstruction with low infection and revision rates. It has been found to be a promissing strategy for cranioplasty after neurosurgery.

Table (1): Demographic data, reason for cranioplasty, defect characteristics and number of harvested ribs.

Number	Age in years	Sex	Etiology	Site	Size in Cm^2	Number of harvested ribs
1	5	Male	ODF	FTP	72	2
2	40	female	Previous craniotomy	Bilateral F	20	1
3 Fig. (1)	10	Male	ODF	FTP	62	2
4 Fig. (2)	12	Male	ODF	Bilateral F	84	2
5	4	Male	ODF	FT	30	1
6 Fig. (3)	45	Male	ODF	FP	25	1
7	13	Male	GSF	F	30	1
8	23	Female	GSF	F	15	1
9	18	Female	Fibrous dysplasia resection	Fronto-orbital	64	2
10 Fig. (4)	42	Male	Previous craniotomy	FTP	49	1
11 Fig. (5)	4	Male	ODF	FP	42	2
12	4	Male	ODF	TP	16	1
13 Fig. (6)	20	Male	Growing skull fracture	High parietal	39	1
14	2	Male	Congenital defect	Bilateral PO	38	1
15	33	Male	ODF	FTP	22	1

ODF: Open depressed fracture. GSG: Growing skull fracture. F: Frontal. T: Temporal. P: Parietal. O: Occipital.

Table (2): Summary of cranial defect aetiologies and number of patients in each group.

Etiology of cranial defect	Number of patients
Open depressed fracture	8
Growing skull fracture	3
Previous craniotomy	2
Fibrous dysplagia resection	1
Congenital defect	1

Table (3): Location of cranial defects.

Cranial defect location	Number of patients
FTP	4
FP	2
Bilateral frontal	2
F	2
FT	1
Fronto-orbital	1
TP	1
P	1
Bilateral PO	1

Fig. (1-A): Frontal view of patient number 3 with fronto-temporo-parietal defect.

Fig. (1-B): Profile view of patient number 3 with fronto-temporo-parietal defect.

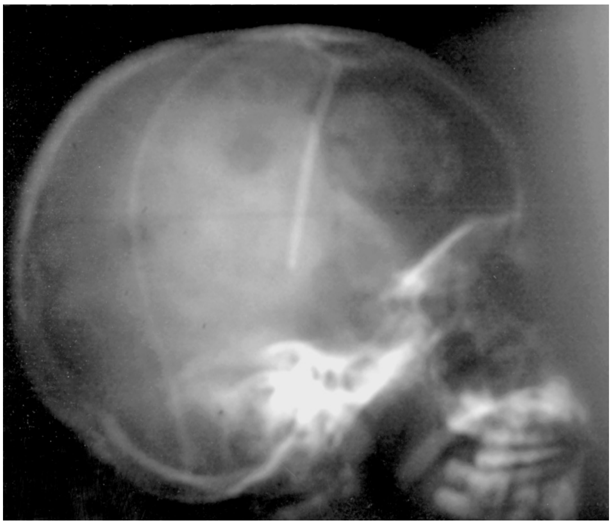


Fig. (1-C): Lateral skull X-ray showing the defect.

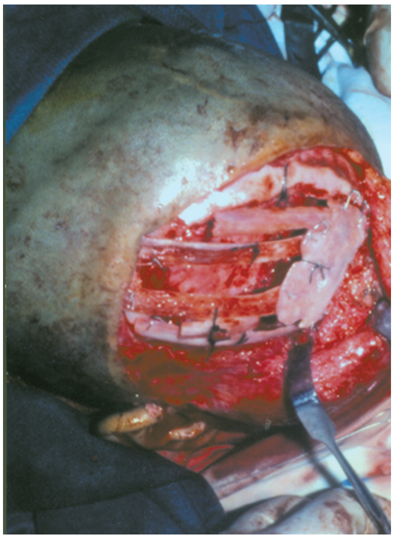


Fig. (1-D): Defect reconstructed with harvested splitted two ribs.

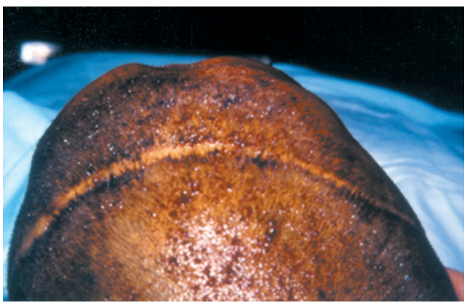


Fig. (2-A): Cephalic view of patient number 4 showing bilateral frontal defect.

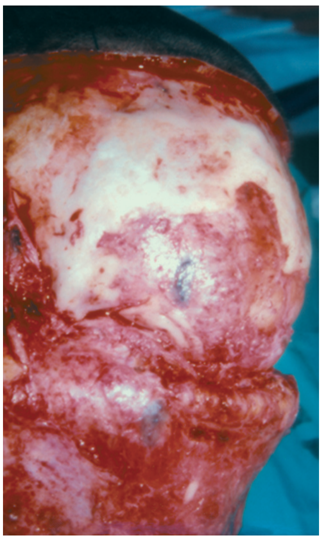


Fig. (2-B): Intra-operative view of patient number 4 showing bilateral frontal defect.

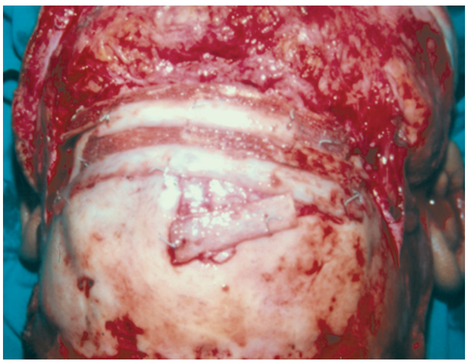
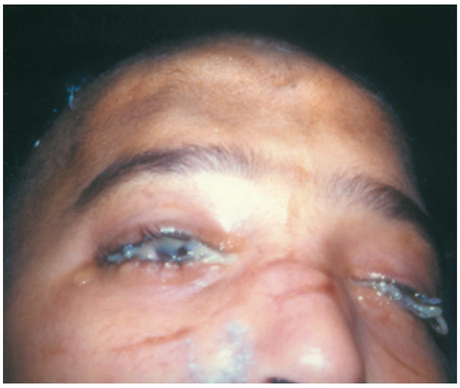


Fig. (2-C): Defect reconstruction with splitted harvested two ribs.



(D)

(E)

Fig. (2-D&E): Immediate post-operative frontal and cephalic view showing excellent contour.

Fig. (2-F): Late post-operative frontal view.

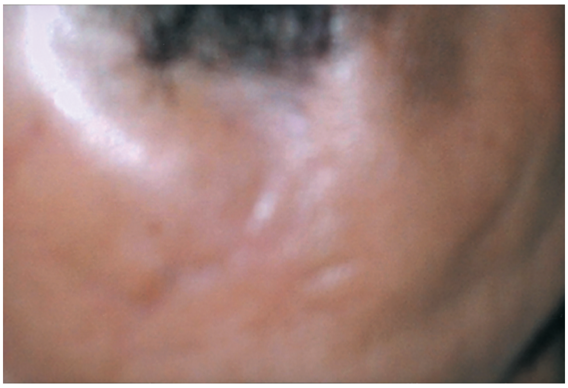


Fig. (3-A): Patient number 6 with frontoparietal defect.

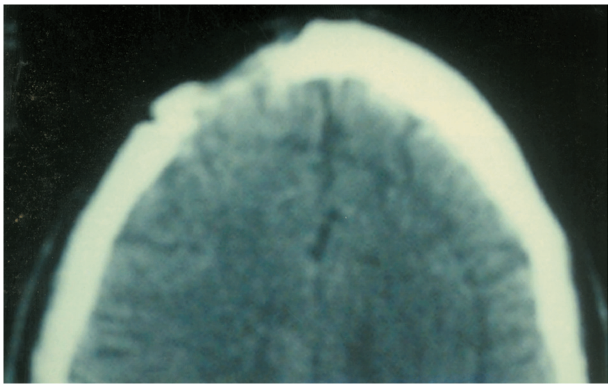


Fig. (3-B): Axial CT scan showing the defect.

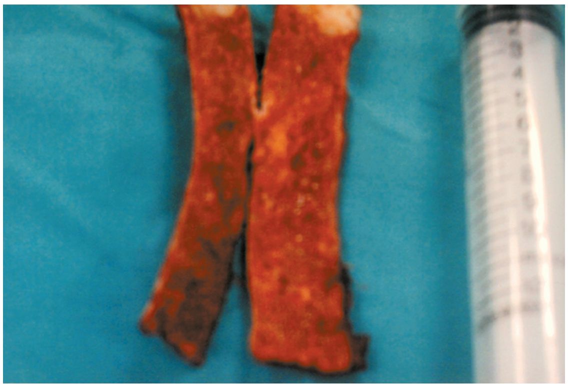
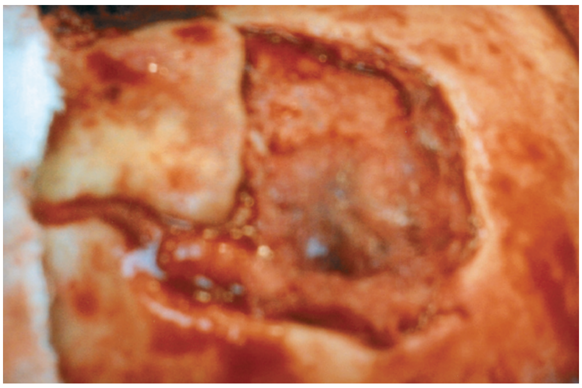


Fig. (3-C): Harvested splitted rib graft.

(D)



(E)

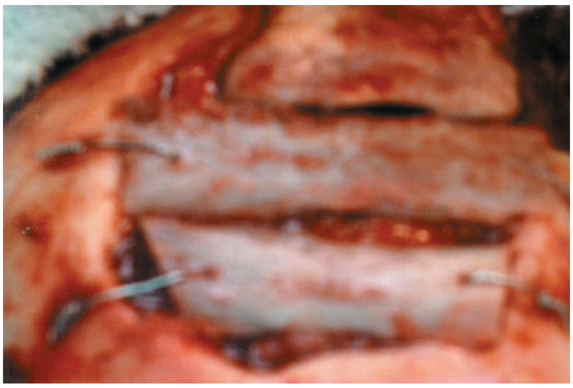


Fig. (3-D&E): Intraoperative view showing the defect and the reconstruction.

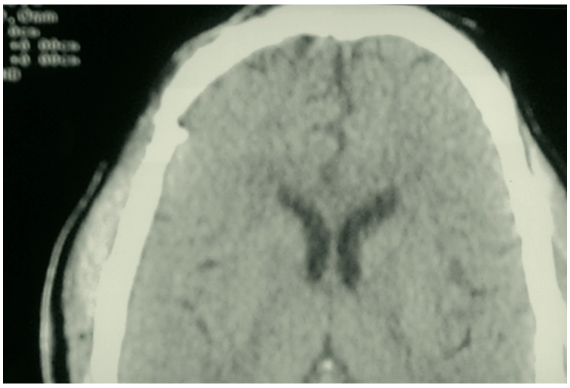


Fig. (3-F): 12 months post-operative axial CT scan showing complete presence of the rib.

Fig. (3-G): Late post-operative view of the reconstructed defect.

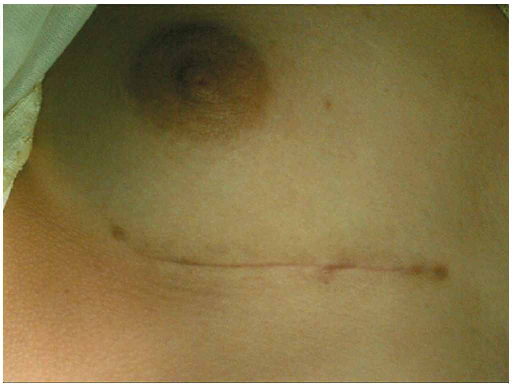


Fig. (3-H): Late post-operative view of the inframamary incision.

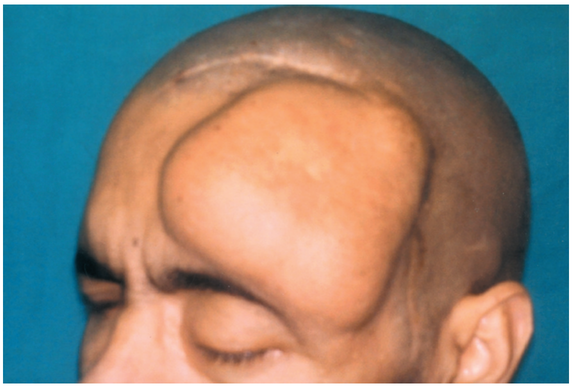


Fig. (4-A): Patient number 10 with FTP defect one year after resection of basal frontal meningioma as shown in the coronal CT scan (B).

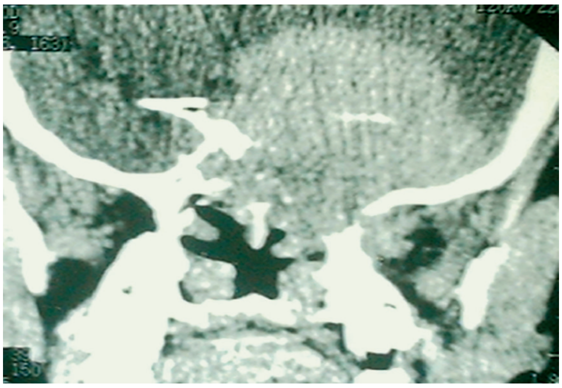


Fig. (4-B): Pre-operative coronal CT scan showing basal frontal meningioma.

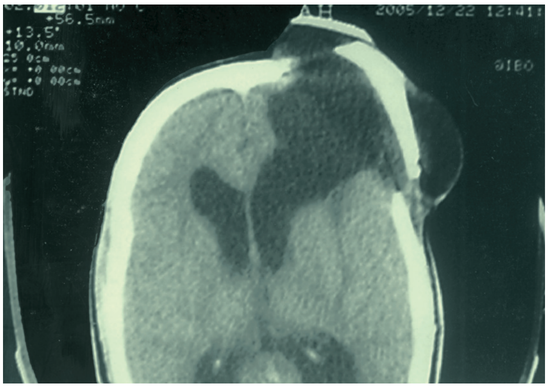


Fig. (4-C): Pre-operative axial CT scan showing post-craniotomy defect with extension of the anterior horn of the lateral ventricle into the scalp.

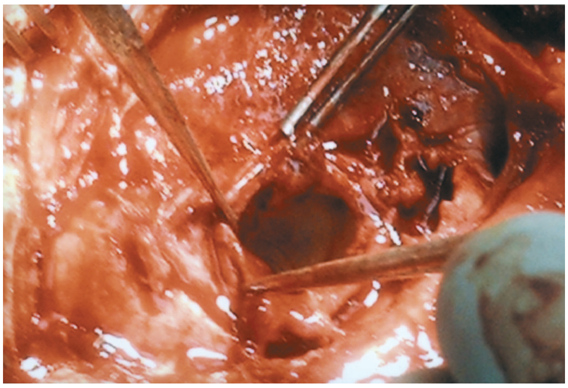


Fig. (4-D): Intra-operative view showing the osseous and dural defect with visible anterior horn of the lateral ventricle from the dural tent.

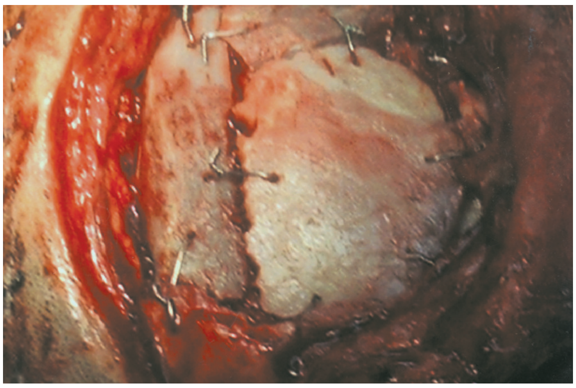


Fig. (4-E): Intra-operative view showing the use of rib graft and calvarial bone for cranioplasty.

Fig. (4-F): Immediate post-operative appearance of the patient with good contour.

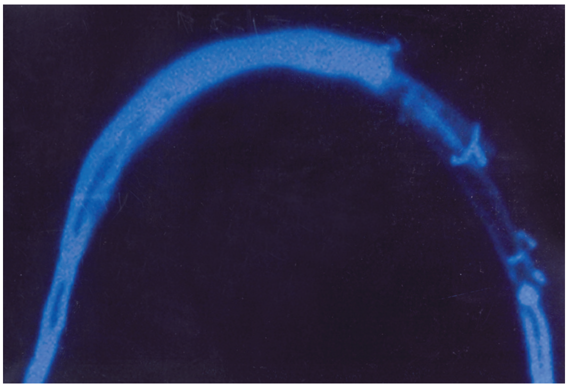


Fig. (4-G): Immediate post-operative CT scan showing excellent contour.

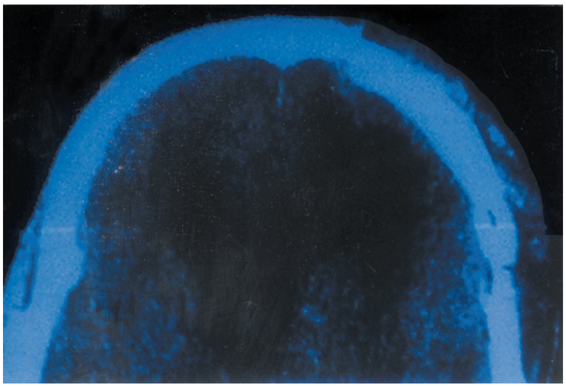
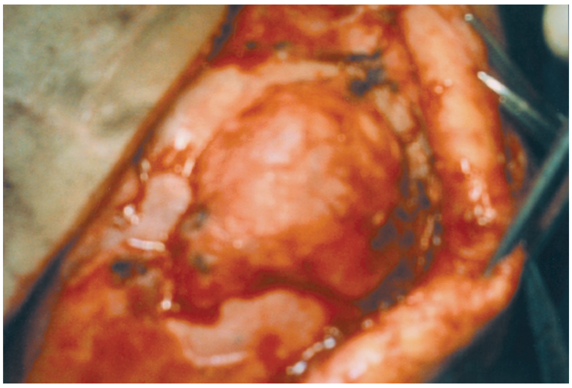
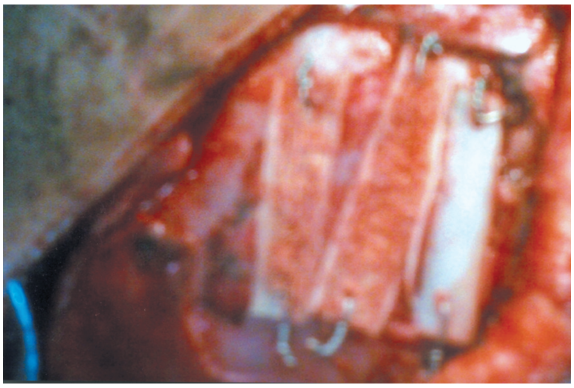


Fig. (4-H): One year post-operative CT scan.

Fig. (5-A): Cephalic view of patient number 11 with fronto-parietal defect.



(B)



(C)

Fig. (5-B&C): Intra-operative view of the defect and the reconstruction.

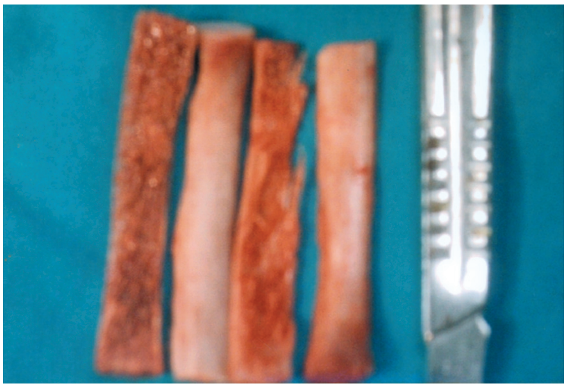


Fig. (5-D): Splitted harvested two ribs.

Fig. (5-E): Immediate post-operative view showing good contour.

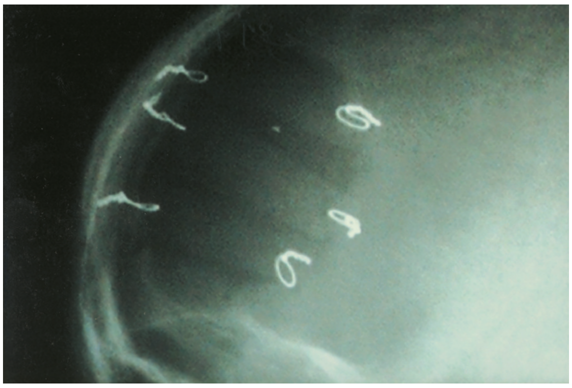


Fig. (5-F): Immediate post-operative lateral X-ray skull showing wire fixation of the rib graftss.

Fig. (6-A): Patient number 13 with growing skull fracture.

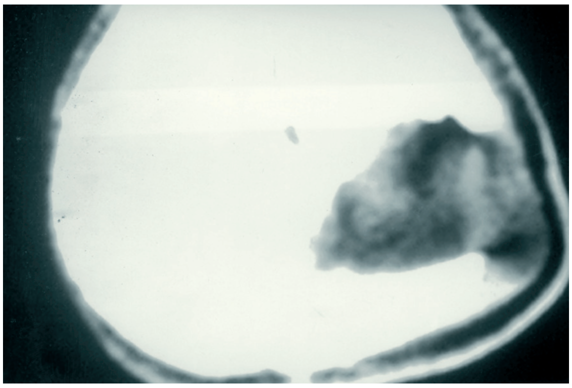


Fig. (6-B): Pre-operative CT scan showing growing skull fracture and gliotic brain.

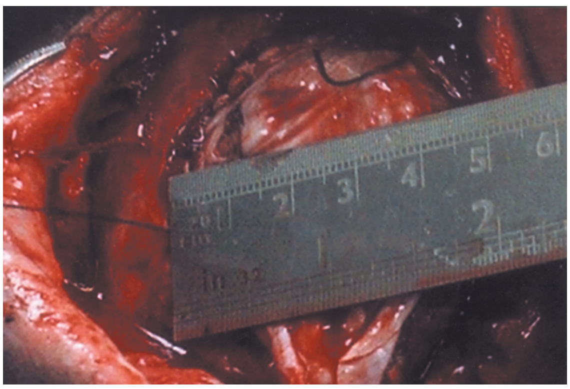


Fig. (6-C): Intra-operative view showing defect size and dural repair by tensor fascia lata.

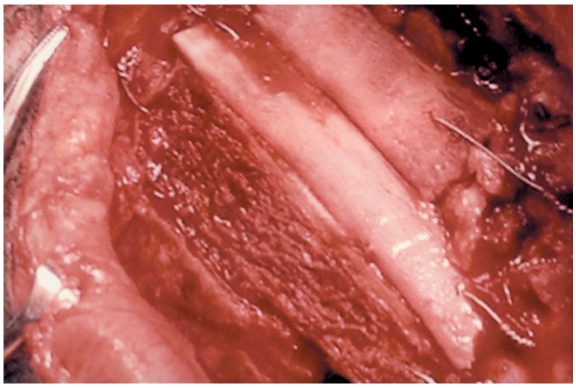


Fig. (6-D): Intra-operative view showing split rib cranioplasty.

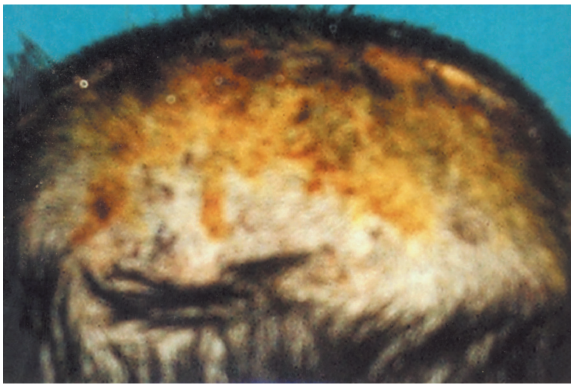


Fig. (6-E): Post-operative view after stitch removal showing normal contour.

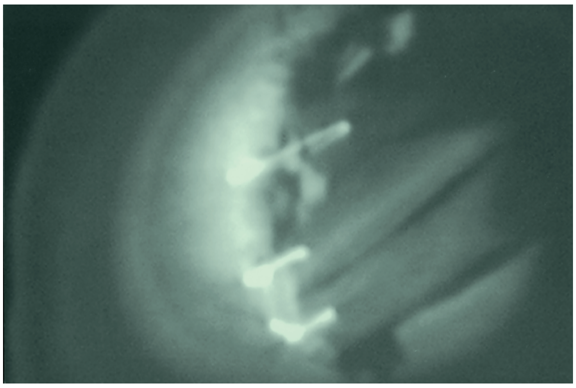


Fig. (6-F): Immediate post-operative CT scan showing defect filling by rib graft fixed by wires.

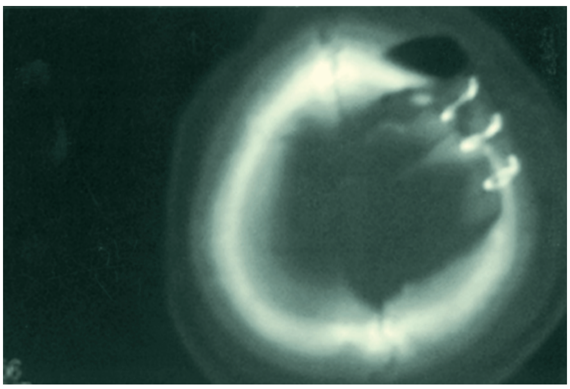


Fig. (6-G): Immediate post-operative CT scan showing defect filling by rib graft fixed by wires.

The present series, that of Derek et al. [4], that of Kawakami et al. [11] and that of Jiwane et al. [12] dispute these arguments. Of the 20 ribs that have been harvested in this series and of the 23 ribs that have been harvested in Derek series, no morbidity existed. No patient suffered haemothorax, pneumothorax, intercostal neuralgia, or chronic chest wall pain. Kawakami et al. [11] reported one patient out of six presented haemothorax after rib harvest. In contrast to criticism regarding the shape of rib grafts, it has been founded that the contour of the ribs can be easily incorporated into the shape of the skull. Moreover, split rib grafts can be easily contoured and molded and are thus easily adapted to regions of high cosmetic importance such as the orbital rim and frontal region.

Calvarial harvest can be difficult and associated with clinically significant blood loss especially in the pediatric age group. In contrast, rib is readily available posteriorly, fully regenerates and contributes little to overall blood loss of the procedure. Moreover, split rib grafts can be easily contoured and moulded and are thus easily adapted to regions of high cosmetic importance such as the orbital rim and frontal region [14]. Several authors have supported the use of rib grafts for large cranial defects [4,6,8,11]. The current series supports this opinion. When the defect is $100Cm^2$ or larger, a staged approach may be necessary when rib is utilized alone. Regenerated sections of ribs may be successfully utilized without threat to the underlying pleura [6].

Either full thickness or split rib grafts may be utilized for grafting. Early recommendations were to split the rib in situ to avoid damaging the pleura and to allow for contiguous rib levels to be harvested. For defects less than $40Cm^2$ full thickness grafts can be used to obtain maximal immediate protection. As defects increase in size, splitting the rib grafts yields better coverage. Ribs may also be split when grafting areas such as the lateral supraorbital rim that require a significant amount of moulding to obtain an acceptable aesthetic result [14]. All the ribs harvested in this study have been splitted so as to minimize the number of ribs harvested, to hasten the revascularization process and to facilitate moulding.

Distraction osteogenesis is a newer reconstructive option that may have a role in cranial vault. The technique involves separating one portion of bone from another and attaching a device across the gap that slowly creates space between the edges. Like a fracture, the space is surrounded by a healing callus that provides a growth factors and cells necessary for healing. As the space between the edges is increased or distracted, the size of the callus stretches and new bone is laid down in the gap [20].

Conclusion:

The use of autologous rib graft for cranioplasty, particularly in young age group, was found to have low cost effectiveness, easily harvested, easily moulded to the skull shape, osteointegrated adequatly with the surrounding bone thus offers good brain protection and is associated with low complication rate.

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