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Split Calvarial Graft Reconstruction for Growing Skull Fracture in Pediatrics

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Abstract

Background: Growing skull fracture is a rare but well-known complication of skull fracture in infancy and early childhood. The definitive treatment is Duro-cranioplasty. The use of alloplastic material in cranial reconstruction has been well described in adult but in children it is hesitation about the safety of nonexpansible alloplastic material.

Aim of Study: This is a retrospective study to evaluate autologous split thickness skull grafts and cranioplasty for treatment of growing skull fractures in pediatrics.

Patients and Methods: This is a retrospective study of complicated calvarial fractures presented at Mansoura University Hospital from 2015 to 2018 and included 10 patients with growing skull fractures. All patients underwent autologous cranioplasty of the skull defect secondary to growing skull fracture after duroplasty.

Results: The age at injury ranged from 5M-6 years. The cause of these fractures included falls and vehicle accident. On average, progressive swelling was diagnosed 7 months after the initial injury. The size of the cranial defects was average 3 X 3cm after restoration of dural contour (duroplasty). Six patients (60%) needed blood transfusion. Follow-up for patients was an average of 6 months. All patients showed post-operative bone fusion without evidence of complications.

Conclusion: The concern for growth restriction or implant instability in a growing pediatric skull also the cost, limit the use of alloplastic materials. Our data show that autologous bone grafting is the standard in pediatric population regarding the safety and cost with limited post-operative complications. Moreover, early recognition is crucial in the management of GSFs to avoid the progression of neurological consequences and skull deformities.

Key Words: *Growing skull fractures – Leptomeningeal cyst-Graft.*

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Introduction

THE term Growing Skull Fracture (GSF) was first used by Pia and Tonnis (Germany, 1953) to describe that unusual complication of head trauma that occurs mainly in the pediatric group under the age of 30 months [1]. Consensus on the pathophysiology involved in the formation of this entity is a fracture of the skull that occurs around infancy with an underlying dural tear or brain injury resulting in an enlarging force under the fracture causing the growth of the fracture of the skull [2]. Other terms used to describe this entity of skull fractures associated with an underlying dural tear and intact arachnoid membrane included leptomeningeal cyst, traumatic leptomeningeal cyst, and cranio-cerebral erosion [3].

Clinical presentation usually entails a swelling or a defect of the scalp [4]. The low incidence of this phenomenon (0.05-1.6%) and the subtlety of its presentation often make diagnosis challenging with consequent delays in management [2]. The resulting delay in treatment can lead to progression of a GSF by facilitating parenchymal herniation, and subsequent gliosis, through the continuously enlarging cranial defect. Sequelae of a GSF include neurological deficits, such as seizures, hemiparesis, mental retardation, and headaches. Prompt recognition and management are key in minimizing these neurological complications [5].

Growing skull fractures are more common in young children, particularly those under 3 years of age due to the thinner calvarium, increased malleability of the skull and rapid cranial growth in this age group. Yet, patients with late onset of a dural defect following an undetected GSF in adults have been described and were found to be related to prior head trauma in childhood. In addition, GSFs can also occur following neurological and craniofacial surgeries, or as a complication of traumatic assisted delivery using obstetrical forceps [5].

Many hypotheses have been described in the literature with regard to the pathogenesis of GSF. Most experts would agree that a GSF requires the following to occur: A skull fracture resulting in rupture of the dura with subgaleal fluid collection under the fracture, immature membranous bone formation, and the presence of an outward driving force (growing brain, hydrocephalus, or edema). However, the pathogenesis of GSFs is interesting and still not completely understood [6].

Although there is old literature suggesting conservative treatment strategy in the management of growing skull fracture, surgical repair is now considered the treatment of choice. That surgical treatment requires repair of the dura in small defects, but larger defects usually require cranioplasty that may not be possible in neglected cases who present with very large defects. Shunt surgery may be needed for some cases of growing skull fractures with porencephaly with or without hydrocephalus [6].

Autologous split calvarial bone is considered the most preferred material for filling these cranial defects and craniofacial reconstruction in both children and adults as well [7,8]. As diploic spaces between the outer and inner calvarial tables are not completely developed under the age of 7 years, it has been suggested that calvarial splitting is not possible for pediatrics below that age [9]. On the other hand, other surgeons have split the two calvarial tables successfully in much younger children via standard techniques, using a high-speed drill or oscillating saw and osteotomes [10]. Barone and Jimenez reported that the minimum thickness for splitting calvaria using a fine high-speed drill and ultra-thin osteotomes was 0.7mm, and that procedure was performed for a 13-month-old child [11].

Patients and Methods

Study design:

This a retrospective study including pediatric patients who presented with complicated calvarial fractures at Mansoura University Hospital from 2015 to 2018. Ten patients with growing skull fractures were diagnosed.

Patient sample:

Ten pediatric patients with growing skull fractures were diagnosed and included in the study.

Patient consent:

A written formal consent was obtained from the children parents after the explanation of the details, advantages and drawbacks of the surgical procedure.

Patient preparation:

All study cases were evaluated clinically as well as radiologically by Computed Tomography (CT) scan of the brain in addition to the routine pre-operative laboratory investigations.

Operative procedure:

First of all, operative exposure is essential for optimum closure of these unhealed fractures. As the dural margin may extend well beyond the penumbra, the whole length and breadth of the fracture in addition to a 2-cm penumbra were exposed. Whereas brain surface was covered by pseudodura at the site of the fracture, the true dura was retracted beneath the defect margins. The most physiologic material for dural grafting was usually provided from the pericranium. However, vascularized pedicle is more likely to have more osteoblastic potential when compared to the free pericranial grafts.

After separation of dura and pseudodura from the fracture bony margins, it was noticed that the fracture edges were often thicker than the subjacent skull and that was suitable for splitting. Thin, straight, and curved osteotomes were preferred more than an oscillating saw as the saw is known to waste too much bone in sawdust and burn the osteoblastic cells.

After completion of the planned craniotomies, the free bone pieces were split. Tessier bone bender was used to initialize the shearing of the inner and outer skull tables, even when there was no visible diploic space. This was done gradually to prevent fracture.

In children younger than 2 years, a freshly sharpened osteotome that was handled much like a knife was used and allowed us to slice the bone apart. On the other hand, the thick bone was split with thin high-speed drill in older children.

The defects in the skull were filled using these bone grafts. Small grafts were left loosely over the exposed dura whereas larger grafts were secured in its position using vicryl 2/0 sutures. No rigid fixation with plates was used. Figs. (3-4) illustrate the surgical technique.

Outcome measures:

The study evaluated the following parameters as regard that surgical procedure; operative complications, post-operative complications, cosmetic appearance, bone fusion, and need for another operation.

Statistical analysis:

The collected data were coded, processed and analyzed using the SPSS (Statistical Package for Social Sciences) Version 22 for Windows® (SPSS Inc, Chicago, IL, USA). Qualitative data was presented as number (frequency) and Percent. Quantitative data was tested for normality by Kolmogorov-Smirnov test and was expressed as median (range).

Results

We included 10 cases in this study (5 males and 5 females) with median age of 2 years (range 5 months-6 years). Six cases (60%) had a history of fall from height, while the remaining 4 cases (40%) reported previous road traffic accidents (RTA). The mean time between injury and presentation was 7 months (range 2 months-1 year) as shown in (Table 1).

All cases (100%) presented with head swelling, but seizures were reported in two cases (20%). Moreover, bilateral 6th cranial nerve palsy was diagnosed in one case (10%).

When it comes to radiological diagnosis, five cases (50%) had a fracture in the right parietal bone, while 3 cases (30%) had it at the same bone in the left side. Right tempropar ietal and left subccipital fractures were diagnosed in one case (10%) for each. Regarding the swelling content, 4 cases (40%) were having porencephalic cyst whereas other four (40%) had leptomeningeal cyst. Gliotic cerebellum and brain were diagnosed in only one case for each (10%).

The average size of cranial defect measured intraoperatively was 3*3cm. Intraoperative bleeding was encountered in two cases (20%), one from transverse sinus, and the other from sagittal sinus. Intraoperative blood transfusion was commenced for 6 cases (6%). No complications were detected at the early post-operative period.

The mean follow-up period for the study cases was 6 months. All cases experienced excellent bone fusion on follow-up CT scans. Slight irregularities of the calvarian contour were detected in 2 patients (20%), but the overall cosmetic outcome was good. No cases required further surgical procedures at the follow-up period.

Table (1): Data of the study cases.

Variable	Number (%)-Median (range)
Age (months)	24 (5-72)
Sex:	
Male	5 (50%)
Female	5 (50%)
Previous trauma:	
Falling from height	6 (60%)
Road traffic accident	4 (40%)
• Time between trauma and presentation (months)	7 (2-12)
Presentation:	
Swelling	10 (100%)
Seizures	2 (20%)
6th nerve palsy	1 (10%)
Location:	
Right parietal	5 (50%)
Left parietal	3 (30%)
Left suboccipital	1 (10%)
Right tempropar ietal	1 (10%)
Content:	
Proencephalic cyst	4 (40%)
Leptomeningeal cyst	4 (40%)
Gliotic cerebellum	1 (10%)
Gliotic brain	1 (10%)
Operative bleeding	2 (20%)
Blood transfusion	6 (60%)
Early post-operative complications	0 (0%)
Follow-up (months)	6 (5-11)
Bone fusion	10 (100%)

Fig. (1): Female child, 3 years old, progressive sub occipital swelling after falling from height diagnosed as growing skull fracture (intra operative positioning).

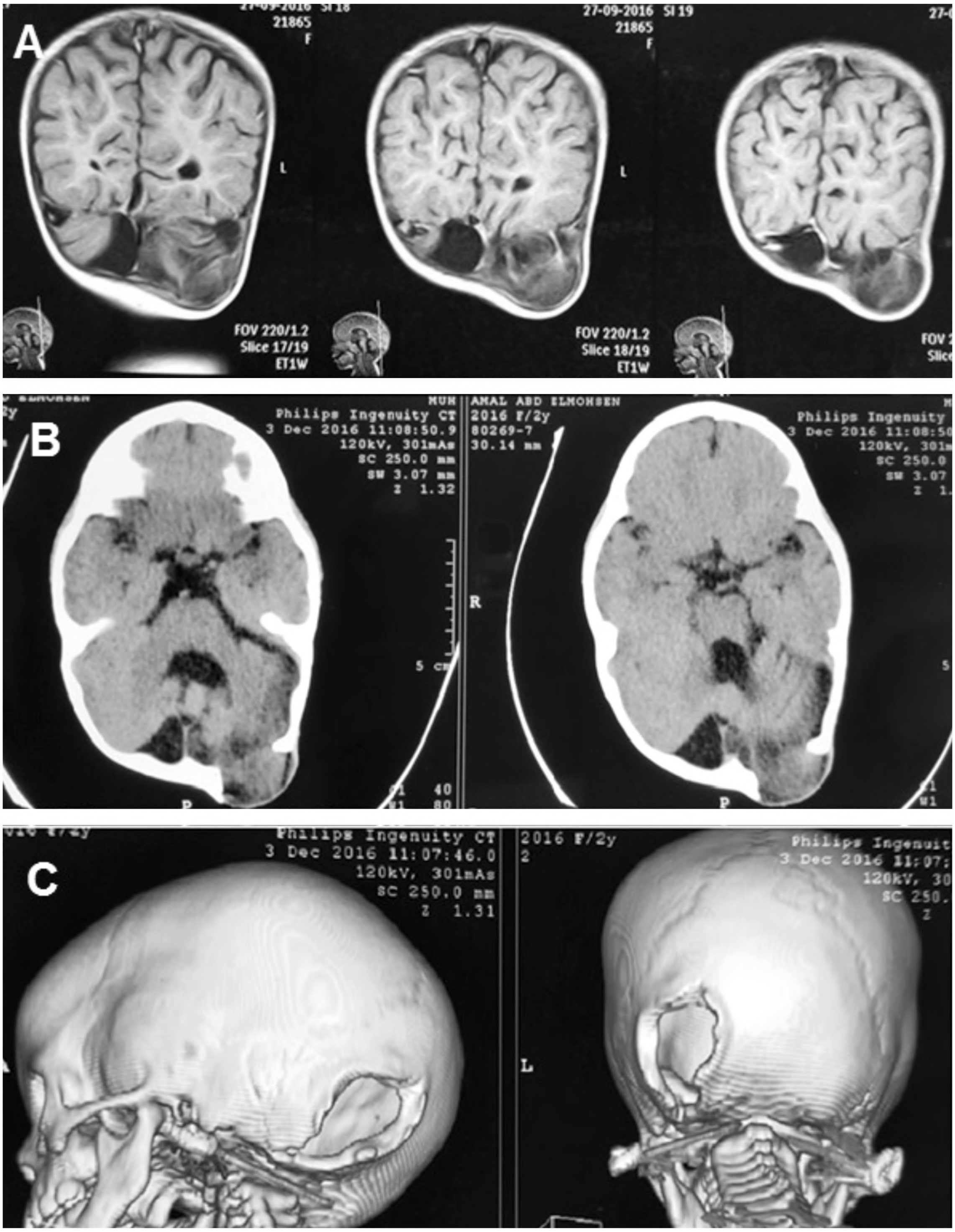

Fig. (2): Pre-operative radiology of the previous case. (A) T1-weighted image MRI (coronal section) showing left cerebellar growing skull fracture. (B) Brain CT scans (axial section) showing left cerebellar growing skull fracture. (C) Pre-operative 3D CT-scan demonstrating left sub occipital defect.

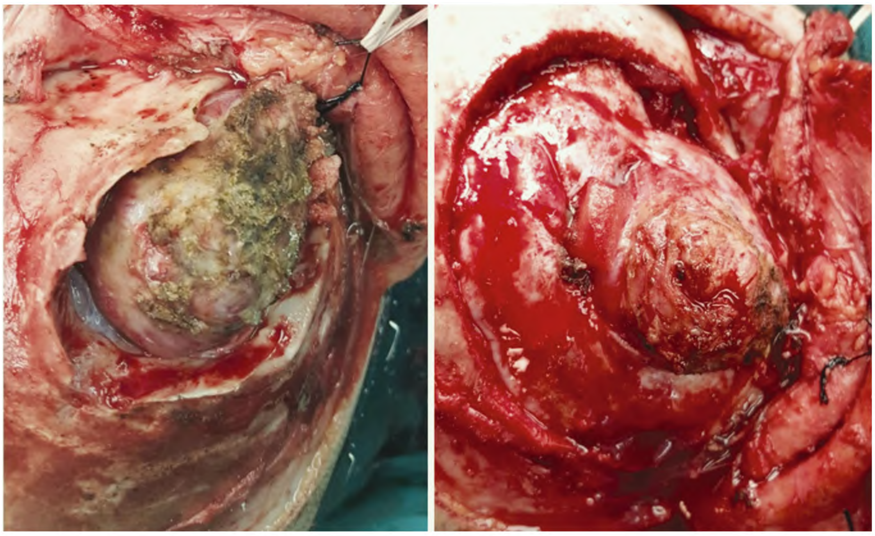

Fig. (3): Operative photo showing that content was gliotic cerebellum.

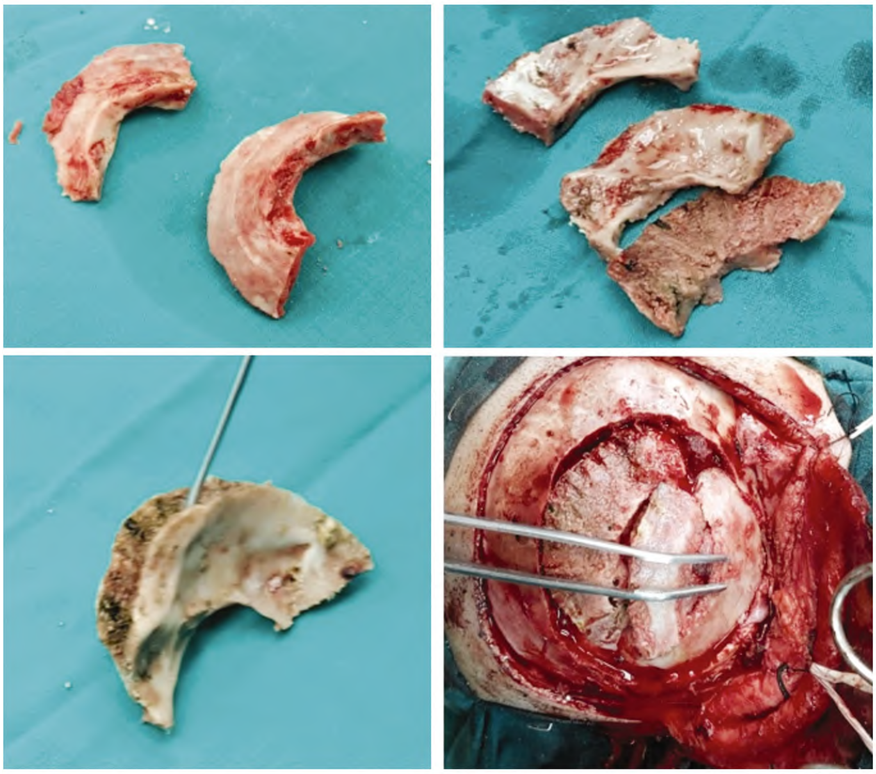

Fig. (4): Intraoperative bone splitting and repositioning.

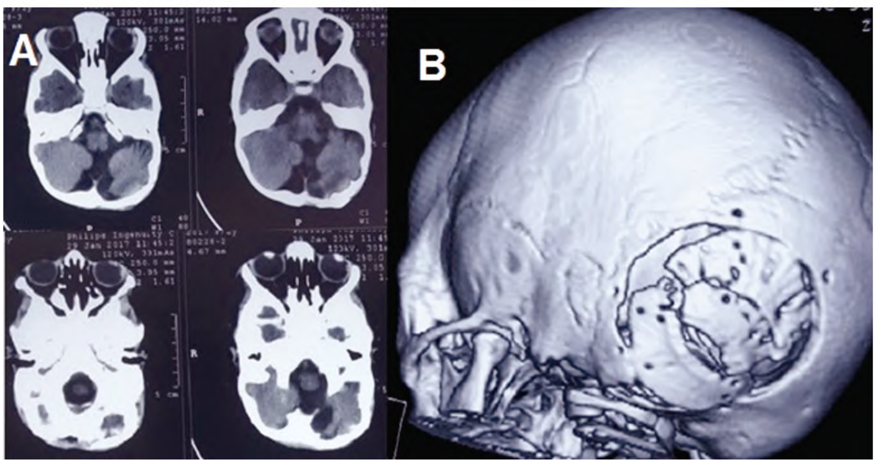

Fig. (5): Post-operative CT. (A) Brain CT scan showing bone reconstruction (B) Postoperative 3D CT-scan demonstrating the defect reconstructed.

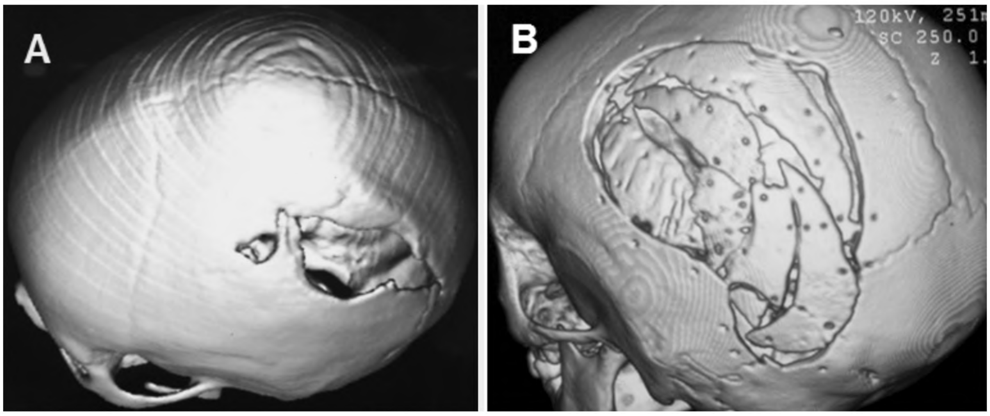

Fig. (6): Male child, 2 years, with history of head trauma 5 months ago. (A) Pre-operative 3D CT-scan demonstrating left parietal defect. (B) Post-operative 3D CT-scan demonstrating the defect reconstructed.

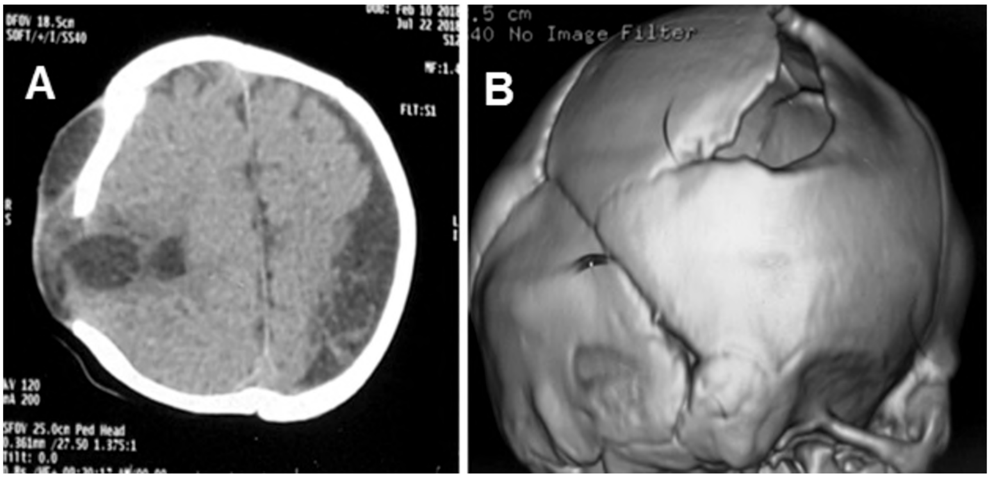

Fig. (7): 7-month old child with right parietal growing skull fracture. (A) Pre-operative CT-scan (axial section). (B) 3D CT-scan demonstrating right parietal defect.

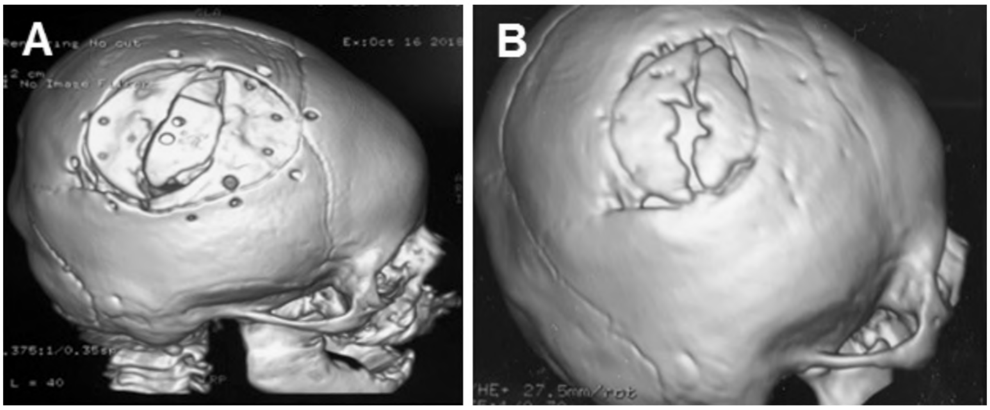

Fig. (8): 7 post-operative follow-up CT of the previous case. (A) Immediate post-operative 3D CT-scan. (B) 5-month post-operative 3D CT-scan demonstrating fused bone graft.

Discussion

Under the age of 6 months, the endosteal layer of the dura has osteogenic properties that allows calvarial defects in areas with normal dura to heal in a reliable way and thus, leaving such defects in that age to heal on its own without cranioplasty is accepted **[12]**.

It was reported that is autologous cranial bone is the optimal tissue for filling these calvarial defects, and these grafts could be harvested by splitting the bone between the inner and outer tables **[12]**.

We conducted this study at the Neurosurgical Department of Mansoura University Hospitals aiming to evaluated the role of split calvarial graft reconstruction in the management of pediatric growing skull fractures.

Barone and Jimenez recommended that the minimal bone thickness had to be 0.7mm as they were able to successfully split of the calvarial bone in a 13-month-old child with the aid of a fine high-speed drill bit and thin osteotomes **[11]**.

Using the previously described technique, we had the ability of splitting the infantile calvarial bone in cases as young as 5 months.

We included 10 cases in this study with median age of 2 years (5 months-6 years). Males and females had equal distribution (50% for each). Six cases had a history of falling from height, while the remaining reported a history of RTA (4 cases-40%). Our patients often presented after 7 months from the date of trauma (2 months-1 year).

A recent study handling the same perspective included 20 patients (11 males and 9 females) with a mean age of 22 months (range 6 months to 5 years). Falling from height was reported in 11 cases (55%) **[6]**.

Authors of previous studies have reported that more than half of GSFs occur in persons under the age of 12 months and 90% in persons under the age of 3 years **[13-15]**. Two theories can explain the high incidence of GSF in pediatric population when compared to adults. One theory is that during the first 2 years of life, there is rapid growth of both brain and skull making dura more adherent to the overlying bone and thus, easily torn if bone fracture occurs **[16,17]**. The other hypothesis proposes that the skull is thinner, less stiff, and more deformable, and in deforming can more readily tear the dura **[16]**.

An Egyptian study was conducted to evaluate the role of early diagnosis and surgical repair using autologous split thickness skull grafts for cranioplasty, in theprevention of complications and improving the outcome of growing skull fractures. The study was conducted at Cairo University Hospitals and included 10 patients (60% females and 40% males). The mean age of the included cases was 11 months. Falling from height was reported in 80% of cases while the remaining 20% experienced previous RTA **[18]**.

The previously mentioned Egyptian study reported that scalp swelling was present in all cases, while seizures were reported by the patient mother in 20% of cases. Moreover, contralateral weakness was present in 20% of cases whereas right sixth nerve palsy was detected in only one case (10%). The time ranging between trauma and diagnosis ranged between 2 weeks and 1 year in that study **[18]**.

In our study, head swelling was also the predominant complaint (10 cases-100%) while seizures were reported by parents of two children (20%). Only one patient was diagnosed to have 6 th cranial nerve palsy at the time of presentation (10%).

Patients who have been diagnosed with a skull fracture in the prophase, regardless of brain herniation, should be closely followed clinically for 3 months to confirm fracture healing as recommended by multiple studies **[19-21]**. Imaging studies have been reported to be used as an adjunct to follow-up in patients harder to assess clinically or when clinical suspicion is high. With respect to the imaging modalities used in the diagnosis of GSF, radiographs, and Computed Tomography (CT) scans are the most commonly used. Magnetic Resonance Imaging (MRI) has the additional property of identifying an advanced dural tear and underlying parenchymal damage (eg, leptomeningeal cyst, gliotic brain, porencephalic cyst, brain herniation, or ventricular dilatation) **[5]**.

In another study that included 20 GSF cases, 7 cases had focal neurological deficit and another 5 experienced seizures immediate to the injury. The fracture was located in the parietal region in 8 (40%) patients, parieto-temporal (4 cases), frontal (3 cases), fronto-parietal (3 cases), fronto-orbital (1 case) and occipital (1 case) **[6]**.

Our study revealed that right parietal bone fractures were the most common (5 cases-50%), followed by the same bone on left side (3 cases-30%). The remaining two cases experienced fractures that were located at the left suboccipital and right temproparietal regions (10% for each).

In another study, the fissure fracture involved the parietal bone alone in 6 cases (60%), the frontal bone alone in 1 case (10%), the fronto-parietal bones in 2 cases (20%), and the temporo-parietal bone in 1 case (10%). The dural defects seen intra-operatively ranged from 4-9cm and in all cases the dural defect extended some distance beyond the bony defect **[18]**.

CT images provided us with the detailed content of each fracture. Porencephalic cyst was present in 4 cases (40%) as well as leptomeningeal cysts, that was diagnosed in another 4 cases (40%). Gliotic cerebellum and brain had a lower incidence by being diagnosed in only one case for each (10%).

Usually, CT is not as sensitive enough to detect the dural tear following head injury, and that dural tear is the primary pathology that will lead to a growing fracture later on. However, early diagnosis and proper management is of crucial importance to prevent brain damage and other complications related to delayed surgery [22].

Magnetic Resonance Imaging (MRI) is known to have a higher predictive value for growing skull fractures when compared to CT scan, as it picks up early dural tears and brain herniation when such changes are not evident on other imaging modalities [4,20].

The defects measured intraoperatively in our study had an average dimension of 3*3cm. Moreover, operative sinus bleeding was encountered in two of our study cases (20%) and 6 cases (60%) required intraoperative blood transfusion.

In all cases, we performed cranioplasty using autologous bone from the surgical site, in the form of a split calvarial bone graft. It is recommended not to use autologous bone from other sites, such as rib or iliac crest graft, as more incisions will be created without having more advantages over the calvarial graft [23].

There is a general consensus in the literature that a watertight closure of the dura is the cornerstone of management to decrease morbidity following GSFs. Watertight dural closure can be achieved either primarily, or using autologous tissue or allografts [24]. In certain patients, adequate bony coverage of the dural reconstruction site is crucial for successful defect closure regardless of the material used [25].

The craniotomy should be always wider that the bony defect as the dura usually retracts behind the fracture edges. That dural tear often stops when it reaches the wall of adjacent venous sinus like sagittal or transverse sinuses and thus, one should be more careful to avoid sinus injury as bleeding and blood loss would be more dangerous in such age group. Moreover, early surgical intervention is associated with more blood oozing in the operative filed (from brain, scalp, and bone) due to the underlying acute inflammation. Ten cases required blood transfusion (62.55%) in the study conducted by singh et al. They used a patch of pericranium to close the dural defect because it is biocompatible, economical, easy to harvest, and has a negligible risk of infection [6].

Post-operatively, no early complications were detected in our study. With average follow-up of 6 months, all our cases showed bone fusion on CT scans. Calvarian contour irregularities were detected in 2 cases but they were just slight (20%). No cases required additional surgical procedures during their follow-up.

In another study, 10 patients with growing skull fractures were also included. These cases included 5 males (50%) and 5 females (50%) with mean age of 10.9 months (range 8.5-18.2 months). After their management with cranial bone splitting, no patients had fusion problems at follow-up visits. Good cosmesis was achieved in five cases (50%). Slight calvarial contour irregularities were noted in four cases (40%), and one case had mild forehead asymmetry (10%). No patients required further surgical interventions in the follow-up period [12].

Regarding complication reports in the literature, one case was complicated by post-operative hydrocephalus (10%) 4 days following surgery and was managed by a surgery for CSF diversion using a ventriculo-peritoneal shunt. One case had superficial wound infection (10%) which was managed by frequent dressings, intravenous and local antibiotics. No neurological deterioration or recurrence of cyst occurred in any in the patients of the previously mentioned Egyptian study [18].

In our study no case experienced post-operative surgical site infection. Split-thickness skull cranioplasty are biocompatible, which are easy harvested and with less infection and reaction risks. For this reason, it is considered a good option for cases with high risk of infection [26]. In pediatric patients whom skull growth is continuing, split-thickness skull grafts showed integration and cooperated with the remolding skull, in contrast to fixed nonbiologic materials which resulted in restricted growth of the skull and deformities in adult ages [3].

No fracture recurrence was reported during the follow-up period of our study. Recurrence of GSFs was found to occur at a rate of 2%, and thus prevention is important in such patients. To that end, elevated ICP has to be taken into account in the management of GSF as failure to do so often leads to recurrence. In some patients, removal of the porencephaly or leptomeningeal cyst along with dural and cranial repair was not enough to control the raised ICP. In such patients, some form of permanent CSF diversion, such as ventriculo-peritoneal shunt, can be used to treat hydrocephalus [5].

Conclusion:

The concern for growth restriction or implant instability in a growing pediatric skull also the cost, limit the use of alloplastic materials. Our data show that autologous bone grafting is the standard in pediatric population regarding the safety and cost with limited post-operative complications. Moreover, early recognition is crucial in the management of GSFs to avoid the progression of neurological consequences and skull deformities.

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إعادة ترقيع كسر الجمجمة المتزايد بعظم الجمجمة المنقسم فى الأطفال

تزاير كسر الجمجمة هو أحد المضاعفات النادرة لكن المعروفة لكسر الجمجمة فى الطفولة. العلاج النهائى هو التدخل الجراحى لترقيع الأم الجافية وعظام الجمجمة. لقد تم وصف إستخدام مادة من خارج جسم المريض فى إعادة بناء الجمجمة بشكل جيد لدى البالغين، لكن عند الأطفال، لم يتم التأكد من سلامة هذه المواد غير القابلة للتوسع. هذه الدراسة بأثر رجعى لكسور الجمجمة المعقدة فى الأطفال المقدمة فى مستشفى جامعة المنصورة فى الفترة من ٢٠١٥ إلى ٢٠١٨ وتضمنت ١٠ مرضى يعانون من كسور متزايدة فى الجمجمة. خضع جميع المرضى لعمل أشعات مقطعية على المخ وثلاثية الأبعاد على عظام الجمجمة تمهداً لإجراء جراحات ترقيع الأم الجافية وعظام الجمجمة بإستخدام عظم الجمجمة المنقسم من نفس المريض. كانت متابعة المرضى فى المترسط ٦ أشهر. قيمت الدراسة المعايير التالية فيما يتعلق بهذا الإجراء الجراحى المضاعفات الجراحية والمضاعفات اللاحقة للعمليات الجراحية والمظهر التجميلى والألتحام العظمى والحاجة لعملية أخرى. أظهرت جميع المرضى إندماج العظام بعد العملية الجراحية دون دليل على حدوث مضاعفات. أظهرت بياناتنا أن ترقيع العظام الذاتى هو المعيار فى الأطفال فيما يتعلق بالسلامة والتكلفة مع تجنب مضاعفات ما بعد الجراحة. علاوة على ذلك، يعد التشخيص المبكر لكسر عظام الجمجمة المتزايد للأطفال أمراً بالغ الأهمية لتجنب تطور المضاعفات العصبية وتشوهات الجمجمة.