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Comparative Analysis of Using Bone Graft, Hydroxyapatite Coralline and Titanium Mesh for Calvarial Bone Defects

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Abstract

Background: For individuals who have had decompressive craniectomy, it is seen as essential since it improves neurological function, normalizes cerebrospinal fluid and cerebral blood flow, and has a esthetic advantages.

Aim: The goal of this work had been to compare the esthetic and functional results of using autologous bone graft; hydroxyapatite coralline and titanium mesh for reconstruction of calvarial bone defects.

Patients and methods: This had been a comparative study comprising thirty prospective studied cases admitted to the Plastic Surgery and Burn Departments and neurosurgery department, Al-Azhar University Hospitals (Alhussin and Said Galal Hospitals) scheduled for operative intervention from February 1, 2022 to February 1, 2023.

Results: There had been statistical variation among studied groups as regards early complications. There had been no statistical variation among studied groups as regards cosmetic outcomes.

Conclusion: Most frequent postoperative problems following cranioplasty have been infection and bone resorption. This comparison of the utility of different implant materials for cranioplasty using bone graft, hydroxyapatite coralline, and titanium mesh for calvarium bone Defects showed similar cosmetic and function outcomes and late complication while early complication was higher in hydroxyapatite coralline.

Keywords: Bone defects, Bone graft, Calvarial, Hydroxyapatite coralline, Titanium mesh

1. Introduction

Cranioplasty is the surgical correction of skull defects.¹ Medical professional has tried to restore calvarial deformities since the beginning of recorded history. There are numerous methods created to locate the best substance or strategy to protect the brain in a secure and long-lasting way. Although the frequency of occurrence of skull defects is highest during times of war, the civilian surgeon often is asked to correct calvarial deformities that are the result of trauma, infection, neoplasm, and congenital malformation.²

For individuals who have had decompressive craniectomy, it is seen as essential since it improves

neurological function, normalizes cerebrospinal fluid and cerebral blood flow, and has esthetic advantages.¹

Sternum and rib were recommended as materials for cranioplasty by Westermann in 1916 and by Brown in 1917, respectively. In 1917, Babcock successfully repaired a skull defect with a soup bone, and from 1917 to 1919 Sic card, Dambrin, and Rogers reported satisfactory cranial defect repair with cadaver skull grafts. The use of scapular bone material was suggested by MacLennan in 1920, and split-thickness rib grafts were advocated by Fagarasanu (1937).³

Alloplastic materials began to be employed as the art of cranioplasty continued to develop. Celluloid

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plates were used by von Hinterstoisser, von Frey, and Fraenkel in the 1890s with variable results. The use of aluminum to repair a cranial vault defect was first reported in the medical literature by Booth and Curtis in 1893. Unfortunately, their patient died 10 days following the operative procedure. Cornioley described the use of a platinum plate for cranioplasty in 1925, and Liuesma-Uranga experimented with silver wire mesh for the repair of cranial defects in 1936. However, the use of alloplastic materials for cranioplasty did not become widespread until the beginning of World War II with the introduction of tantalum and methyl methacrylate.³

Autologous bone grafts are regarded as the present gold standard for bone regeneration due to their osteogenic potential, osteoinductivity, osteoconductivity, and affordability. But in addition to restrictions and morbidity associated with donor sites, key disadvantages of autogenous bone grafts also include their propensity for resorption and danger of infection.⁴

The goal of this work had been to compare the esthetic and function results of using autologous bone graft; hydroxyapatite coralline and titanium mesh for the reconstruction of calvarial bone defects.

2. Patients and methods

After approval of the local ethical committee, this comparative study included thirty prospective patients admitted to the Plastic Surgery and Burn Departments and neurosurgery department, Al-Azhar University Hospitals (Alhussin and Said Galal Hospitals) scheduled for operative intervention from February 1, 2022 to May 1, 2023.

They were categorized into three groups: group A: 10 studied cases with calvarial bone defects reconstructed with autologous bone grafts. Group B: 10 studied cases with calvarial bone defects reconstructed with hydroxyapatite coralline. Group C: 10 studied cases with calvarial bone defects reconstructed with titanium mesh.

2.1. Inclusion criteria

The defects of different sizes and sites, both sexes (male and female), and all age groups (except Children younger than 3 years).

Inclusion criteria for each group were detected by surgeon experience and patient counseling.

After counseling and explanation of all aspects of the procedure to the patients and or their relatives (parent or guardian of a minor), written consent will be taken before the procedure (consent for the

operation, being involved in this study, and also consent for photography).

2.2. Exclusion criteria

Children younger than three years, cases with active skull or scalp infection, and those with active osteolytic lesions or tumors violating the skull bone will be excluded if the wound was infected, cranioplasty is postponed for at least 6 months, bleeding disorders, and uncooperative patients.

2.3. Methods

2.3.1. Patient evaluation

All studied cases had been subjected to the following: full history taking History will be taken from the patients in the form of personal history, complaints, present history, family history, history, and history of the skull bone loss.

2.3.2. Physical examination

Complete general examination. For determination and documentation of any medical comorbidities pertinent to the procedure. Consultation of neurosurgeon, anesthesiologist, cardiologist, and internal medicine specialist. A complete neurological examination. A full examination of mental status, cranial nerves, coordination, reflexes, gait, motor, and sensory examination. Local examination of the defect. To define the exact location of the defect, size and shape of the defect, condition of the defect whether clean, inflamed, or infected, and simple or compound, and the condition of the surrounding scalp.

2.3.3. Laboratory investigations

Complete blood count, coagulation profile tests, liver function tests, kidney function tests, and viral marker tests.

2.3.4. Radiological examination

Preoperative computed tomography (CT) skull (axial, coronal, and sagittal with three dimensional and 2 ml cuts), is used to detect the location, shape, and size of the cranial defect, condition of surrounding skull bone whether it is osteomyelitis or eroded and to assess the condition of the dura and brain and the presence of a space-occupying lesions.

2.4. Surgical procedure

2.4.1. Intraoperative techniques

Clamps must only be used to galea or galeae scar if planned skin incision will be performed via

existing incision or scar to reduce scalp hemorrhage. Scalp clamps are used to stop bleeding if the incision is made through healthy scalp tissue. To prevent damaging the dura or adherent scalp, the scalp is removed carefully, paying special attention to the area around the defect. To retain the thickest possible scalp where it will cover the prosthesis, as much scar tissue as feasible must be left attached to the underside of the scalp. The cranial defect should be completely exposed.

Exposure of the bone defect all through, refreshment of the bone edges, and removal of any foreign bodies, hair, bone wax etc.

The materials were being used:

Autogenous bone graft: ten patients: The calvarial bone graft considers the best choice for small-sized calvarial bone defects.

2.4.2. Method of calvarial bone graft harvesting

In ten patients, the skull was reconstructed by using outer table calvarial bone grafts. A template of the defect was transferred to an appropriate donor part of the skull. In the most of cases in this study we use a sharp osteotome and hammer after scoring the outlines of the graft with a side-cutting burr or (in small grafts) we use reciprocating or oscillating saw and harvesting partial thickness calvarial bone graft, in some cases (large grafts) we use ultrasonic piezotome which has many advantages but it expensive for the patients, The bone graft is then transferred and fixed to the defect site using titanium mini plate 2 mm thickness of different shapes: L-shape. X-shape Y-shape. Curved and straight shape and screws of 2 mm thickness and 5, 7, and 9 mm length and by using screwdriver handle with dental shaft end and closure of the wound in two layers with suction drain (Fig. 1).

Hydroxyapatite coralline: ten patients: It is considered a good choice for medium-sized calvarial bone defects.

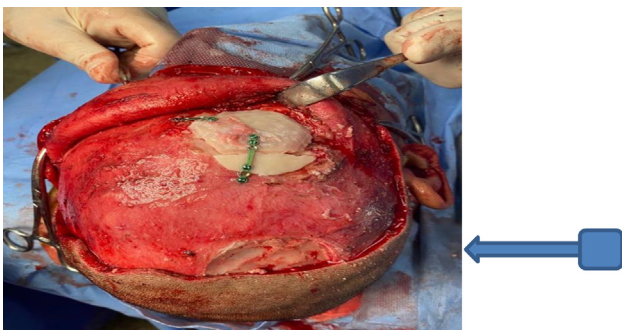


Fig. 1. (A) calvarial bone graft fixed by plate and screws at the defect, (B) the donor site.

The head is positioned with the plane of the defect parallel with the horizontal plane as Hydroxyapatite coralline will be poured into the defect as it hardens. Preparation of Hydroxyapatite coralline is carried out. The appropriate volume of liquid monomer and powder polymer has been mixed in a 1 : 1 ratio, when doughy consistency is attained, material may be poured into the defect as it hardens. Any areas of unwanted overlap, ridges, or rough edges may be easily trimmed and fitted to the desired smooth contour (Fig. 2).

Titanium mesh: 10 patients: it considers a good choice for large-size calvarial bone defects, major disadvantage of titanium is difficult molding to fit the contour of the skull, After the designation of titanium mesh by trimming the overlapping edges to fit the defect, it is fixed to the calvaria using straight shape titanium mini-screws of 2 mm thickness and 5, 7, and 9 mm length and by using screw driver handle with dental shaft end and closure of the wound in two layers in with suction drain.

2.5. Postoperative evaluation

CT skull postoperative, after 3 months and after 6 months, follow-up of the following after 3 and 6 months: patient satisfaction as regard cosmetic result, the fitness of the implant as regard the defect size, postoperative complications, and protection of intracranial structures.

2.5.1. Comparing points

Efficacy had been measured in terms of implant stability, volumetric changes, and radiological results.



Fig. 2. A case in this study with a depressed frontal bone fracture reconstructed with titanium mesh.

Table 1. Comparing cases according to personal data.

	Group A (n = ten)	Group B (n = ten)	Group C (n = ten)	Test of Significance	P
Age (y)					
Range	18–55	18–55	18–54	F = 0.134	0.875
Mean ± SD	30.8 ± 12.59	29.8 ± 11.62	32.4 ± 9.59		
Sex	No. (Percent)	No. (Percent)	No. (Percent)	$\chi^2 = 0.341$	0.843
Female	3 (30.0)	2 (20.0)	3 (30.0)		
Male	7 (70.0)	8 (80.0)	7 (70.0)		

χ^2 , Chi-square test; F, One way ANOVA test; SD, Standard deviation.

p: P-value to compare among studied groups.

*Statistically significant at P less than or equal to 0.05.

Table 2. Comparison between patients according to cosmetic outcome.

Doctor's assessment	Group A (n = ten)	Group B (n = ten)	Group C (n = ten)	Test of Significance	P
	No. (%)	No. (%)	No. (%)		
Complete success	9 (90.0)	8 (80.0)	9 (90.0)	$\chi^2 = 0.577$	0.749
Partial success	1 (10.0)	2 (20.0)	1 (10.0)		
Satisfactory	0	0	0		
Patient's assessment				$\chi^2 = 1.750$	0.782
complete success	8 (80.0)	7 (70.0)	9 (90.0)		
partial success	1 (10.0)	2 (20.0)	1 (10.0)		
Satisfactory	1 (10.0)	1 (10.0)	0		

χ^2 , Chi-square test; F, One way ANOVA test; SD, Standard deviation.

p: P-value to compare among studied groups.

*Statistically significant at P less than or equal to 0.05.

2.6. Statistical analysis

With the use of IBM SPSS software package version 20.0, data had been input into the computer and analyzed. IBM Corp., Armonk, New York Number and percentage had been used to express qualitative data. Normality of distribution had been examined using the Kolmogorov-Smirnov test. Quantitative data had been defined using range (minimum and maximum), mean, standard deviation, median and interquartile range. At the 5 % level, the significance of outcomes had been determined.

They used tests were χ^2 test: for categorical variables, to compare different groups. One way ANOVA test: for normally distributed quantitative variables, for comparing among more than 2 studied groups.

3. Results

This research was a comparative study that was conducted in Al-Azhar University Hospitals (Al-Hussien and Sayed Galal) over thirty patients classified into three groups: group A: 10 patients using autologous bone graft for calvarial bone defects.

Table 3. Comparing cases according to functional result.

Doctor's assessment	Group A (n = ten)	Group B (n = ten)	Group C (n = ten)	Test of Significance	P
	No. (%)	No. (%)	No. (%)		
Complete success	8 (80.0)	7 (70.0)	8 (80.0)	$\chi^2 = 4.487$	0.344
Partial success	2 (20.0)	1 (10.0)	2 (20.0)		
Satisfactory	0	2 (20.0)	0		
Patient's assessment				$\chi^2 = 0.587$	0.956
Complete success	8 (80.0)	7 (70.0)	8 (80.0)		
Partial success	1 (10.0)	1 (10.0)	1 (10.0)		
Satisfactory	1 (10.0)	2 (20.0)	1 (10.0)		

χ^2 , Chi-square test; F, One way ANOVA test; SD, Standard deviation.

p: P-value to compare among studied groups.

*Statistically significant at P less than or equal to 0.05.

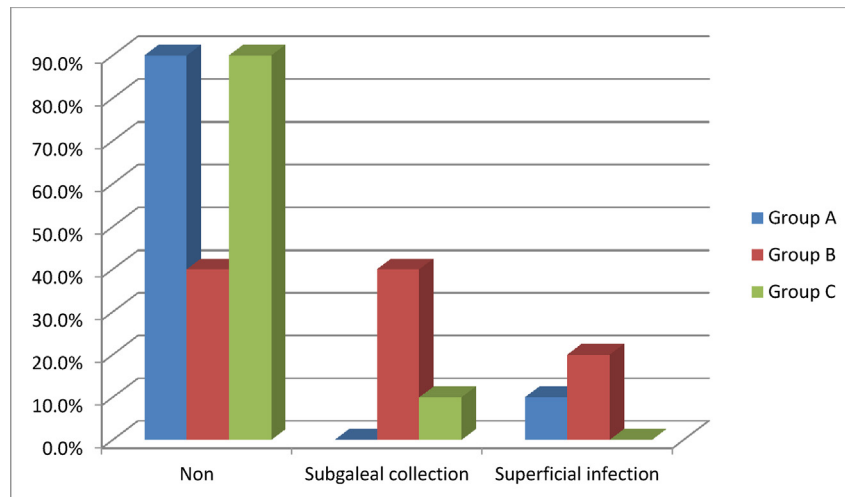


Fig. 3. Comparison between studied cases according to early complications.

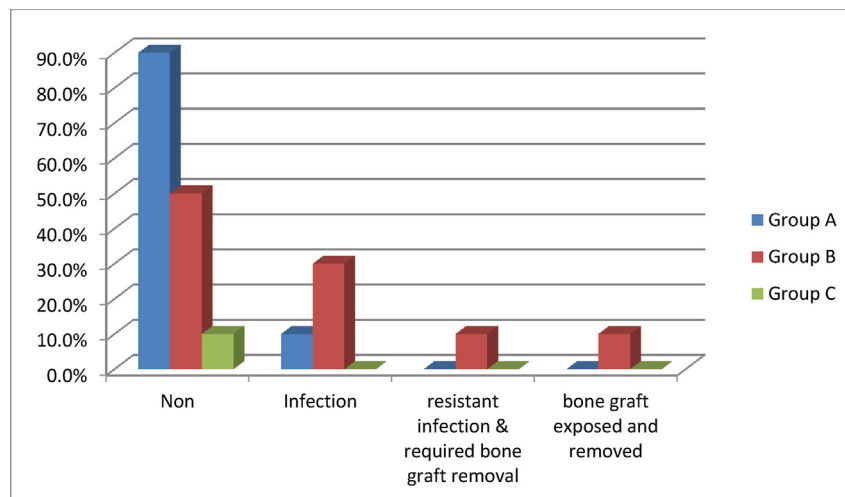


Fig. 4. Comparison between studied cases according to early complications.

Group B: 10 patients using hydroxyapatite coralline for calverial bone defects. Group C: 10 patients using titanium mesh for calverial bone defects, (Table 1).

This table shows that there had been no statistically significant difference among studied groups as regards personal data (Table 2).

This table shows that there had been no statistically significant difference among studied groups as regards cosmetic outcome (Table 3).

This table shows that there had been no statistically significant difference among studied groups as regard functional outcome (Fig. 3).

This table shows that there had been statistically significant difference among studied groups as regard early complications (Fig. 4).

This table shows that there had been no statistically significant difference among studied groups as regard late complications.

3.1. Cases presentation

A male patient 29 years old presented to the outpatient clinic at Said Galal Hospital with post-traumatic depressed frontal bone fracture for three months. The patient is an ex-smoker, with no history of chronic disease, and no history of neurological manifestation. By general examination, no pallor, no cyanosis, no jaundice no, dilated veins and the patient is fully conscious and oriented to place, person, and time. The patient has a left amputated auricle, he has had chronic headaches

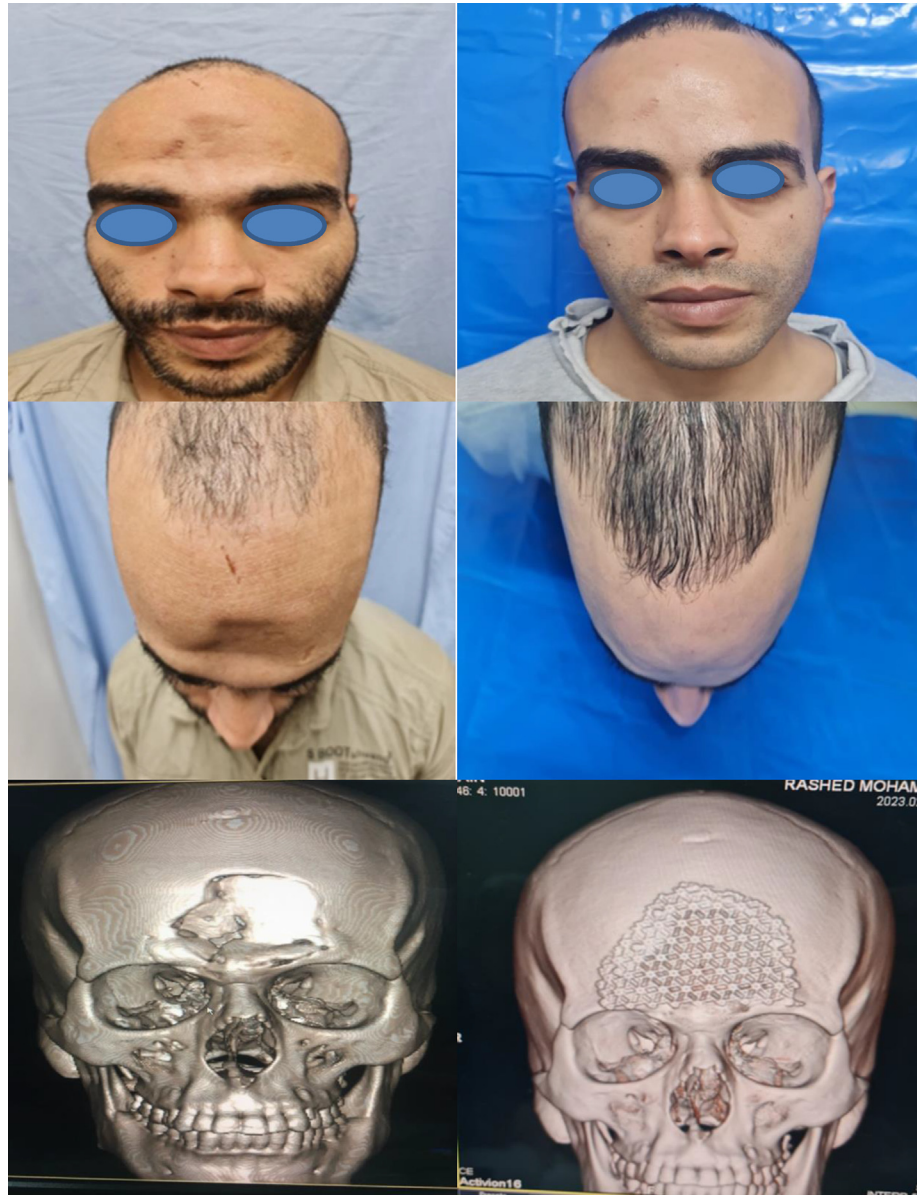


Fig. 5. Right: preoperative photos of the patient and computerized tomography CT of the skull. Left: postoperative photos and computed tomography skull.

since the time of the trauma. By local examination, the defect is about (9 cm × 7 cm) over the forehead (fontal bone and fronal sinus), with no dilated veins (Figs. 5 and 6).

4. Discussion

Surgical replacement of cranial deficiency with objects (bone or nonbiological materials like metal or plastic plates) has been known as cranialoplasty.⁵

The hydroxyapatite bone cement known as coralline hydroxyapatite (Biocoral) has a chemical makeup that is comparable to that of natural bone. It has been a composite scaffold made of coralline core

and synthetic porous biomaterial with an outside layer of hydroxyapatite. It is demonstrated that it promotes the creation of new bone and has been both highly resorbable and osteoconductive.⁶

To the best of our knowledge, there is a lack of studies that compared autologous bone graft; hydroxyapatite coralline, and titanium mesh for the reconstruction of calvarium bone defects.

Therefore, we established this study to compare the esthetic and function outcomes of using autologous bone graft; hydroxyapatite coralline, and titanium mesh for the reconstruction of calvarium bone defects.

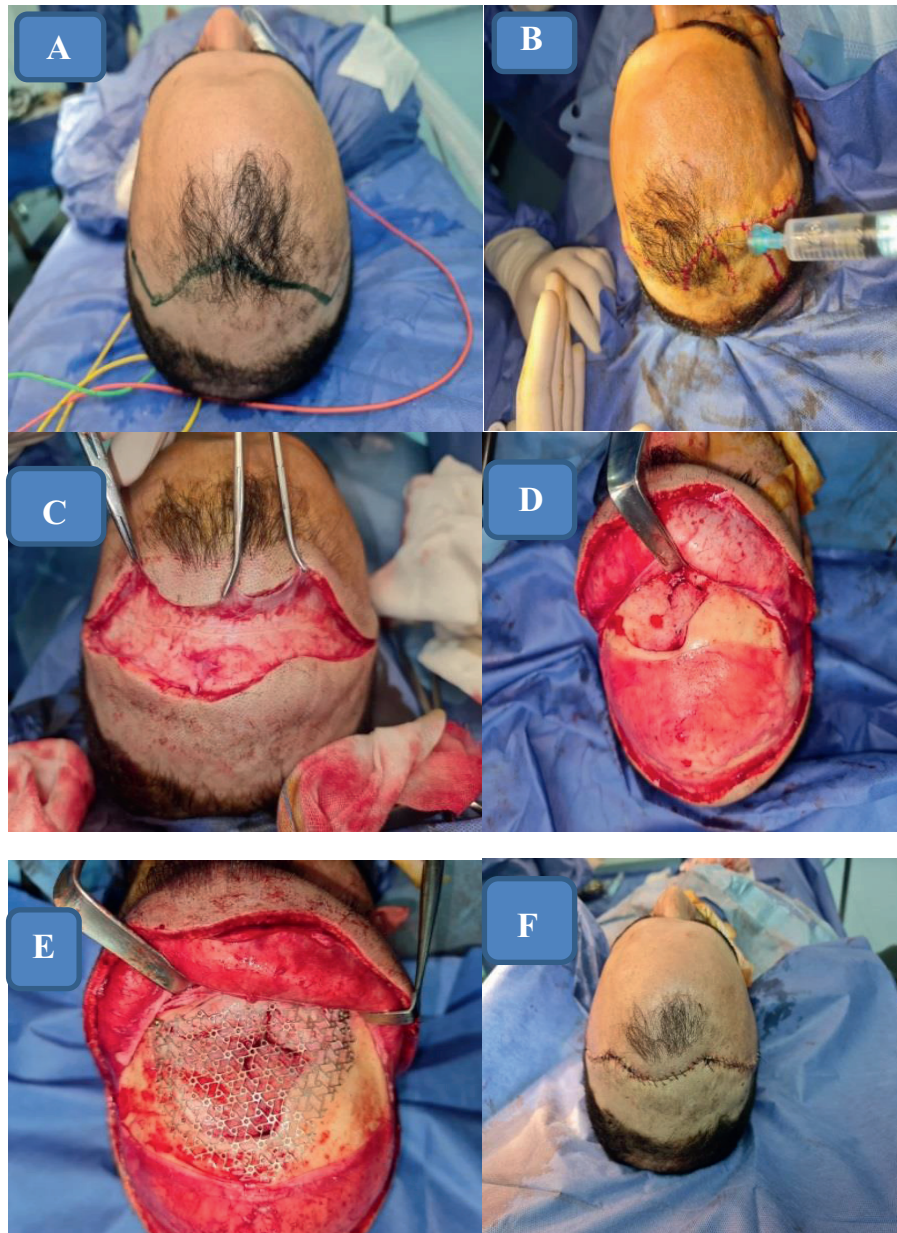


Fig. 6. Intraoperative photos of the patient in different steps, A-marking, B-injection of slain adrenalin for hemostasis and facilitate of dissection, C-bicorporal scalp incision, D-exposure of the defect, E-fixation of titanium mesh by screws, F-closure of the incision.

We enrolled 30 patients who will be categorized into three groups: group A: involved 10 studied cases using autologous bone grafts for calvarial bone defects. Group B: involved 10 studied cases using hydroxyapatite coralline for calvarial bone defects. Group C: included 10 patients using titanium mesh for calvarial bone defects.

All involved studied cases were subjected to full history taking, examination general and local, laboratory investigation, and CT evaluation.

Our finding observed that there had been no variation among three groups as regard age, sex and etiology of cranial defects, and size of defects.

Our findings revealed that, regarding cosmetic outcomes, there was 9 (90 %) patients in group A and C while 8 (80.0 %) patients in group B with complete success. 1(10 %) patient in both groups A and C and 2 (20 %) in group B with parietal success as regards doctor assessment. While as regards patients there were 8 (80 %) patients in group A, 7 (70 %) patients in group B and 9 (90.0 %) studied cases in group C with complete success. 1 (10 %) in both group A and C and 2 (20 %) in group B with parietal success and 1 (10 %) in group A and C with satisfactory. There had been no variation among studied groups as regards cosmetic outcome.

In the same context, Darwish and Zidan,⁷ established a randomized prospective study on 40 adult cases with calvarial skull defects of different etiologies, and divided them into two groups, group 1: 20 studied cases were operated upon using titanium mesh and group 2: 20 studied cases had been operated upon using polymethyl methacrylate (PMMA) acrylic bone cement implants. They found that according to the doctor's assessment, the titanium mesh group has 18 studied cases with complete success and two studied cases with partial success while PMMA has 17 studied cases with complete success and 3 studied cases with partial success.

In our present study, regarding function outcomes, there was eight (80 %) patients in group A and C while seven (70.0 %) patients in group B with complete success. Two (20 %) patient in both group A and C and one (10 %) with parietal and two (20 %) in group B success as regards doctor assessment. While as regard patient there was eight (80 %) patients in group A, seven (70 %) studied cases in group B and eight (80.0 %) studied cases in group C with complete success. One (10 %) in both group A and B and C with parietal success and one (10 %) in group A and C with satisfactory. There had been no variation among studied groups as regards cosmetic outcome.

Also, Darwish and Zidan,⁷ found that according to a doctor's assessment, titanium mesh has 17 studied cases with complete success and 3 studied cases with partial success. 16 PMMA studied cases have experienced total success, two have experienced partial success, and two have experienced satisfactory results. 16 studied cases have reported full success using titanium mesh, while four studied cases have reported partial success, according to studied case evaluations. 15 PMMA studied cases have seen total success, two have experienced partial success, and three have experienced satisfactory results. In terms of doctor and studied case functional assessments, there is no statistically significant difference (P -value 0.05) among the 2 groups, showing that both operations had the same functional outcome.⁷

In our present study, regarding early complications, subgaleal collection occurred in four (40 %) studied cases in group B and one (10 %) studied the case in the group C. Superficial infection occurred in 1 (10.0 %) in group A and 2 (20 %) in the group B and no studied case in the group C. there had been statically significant variation among the three groups as regards early complications.

In agreement with our findings, Darwish and Zidan,⁷ observed that there has been a statistically

significant difference (P -value = 0.017) among both groups regarding early complications.

Klinger *et al.*⁸ reported similar results regarding issues with autologous versus artificial cranioplasty, while Reddy *et al.*⁹ found that studied cases who underwent alloplastic repair had a higher infection rate.

Concerning late complications after 3 months in our study, patients in group C did not have any late complications while infection occurred in 1 (10 %) in group A and 3 (30 %) in group B, resistant infection and required bone graft removal occurred in 1 (10 %) patient and bone graft exposed and removed occurred in 1 (10 %) patient in group B. In Darwish and Zidan none of the studied cases treated with titanium mesh experienced late problems (>3 weeks), but 3 out of 6 studied cases in the bone cement group needed to have their grafts removed.

Wong *et al.*¹⁰ 17 pediatric cases treated with the Norian technique for full and partial thickness craniofacial bone restorations were found to have 9 infections and material extrusions. For usage in big defects and load-bearing areas, hydroxyapatite cement is mixed with resorbable plates or titanium/tantalum mesh, although this does not improve outcomes and produces worse failure rates than using metal implants alone.

In line with our findings, Williams *et al.*¹¹ performed 151 titanium cranioplasties in case of series, with a four percent long-term failure rate reveals that titanium has distinct advantages over alternative biomaterials and gives further proof that titanium remains tried and tested option for full-thickness calvarial deformities.

Supporting our results, Okumus *et al.*¹² establish a comparative study to compare Bone Graft, Hydroxyapatite Coralline (Biocoral) and Porous Polyethylene (Medpor) Implants for Cranioplasty in Rat Model of Cranial Bone Defect and they found that similar implant stability scores for the three implant materials investigated; though, there had been better bone formation and healing of defects with bone grafts, lower risk of complications both Medpor and Biocoral.

However, Hassan et al. 32 studied cases with cranial abnormalities of various aetiologies, locations, and sizes participated in prospective, randomized clinical research. Studied cases were randomly divided into two groups: the autologous group and artificial group. There is a statistically significant difference between autologous and artificial groups in terms of the incidence of overall complications. Each group has 16 studied cases, and overall complication rate had been discovered to be

(25 %) (4 cases out of 16) in the autologous group and (37.5 %) (6 cases out of 16) in the artificial group (P value < 0.025).¹³

Titanium mesh had been used in a total of 8 cases; none of the cases had been infected, but there had been 3 cases where cosmetic outcomes had been subpar (37.5 %), and 1 case where the wound decreased (12.5 %). Overall complication rate for titanium mesh is 50 %, and there is no statistically significant difference between it and methyl methacrylate (bone cement), which also has a 50 % overall complication rate.

Finally, they concluded that once a cranial defect is disclosed, titanium mesh is readily moldable and ready to be applied over it. It is simple to handle and can be shaped and contoured intraoperatively to the required shape. Titanium mesh provides adequate protection for cranial contents, although not as rigid as the bone itself.¹⁴

4.1. Conclusion

Cranioplasty carries a high risk of postoperative complications; Infection and bone resorption have been the most common. This comparison of the utility of different implant materials for cranioplasty using bone graft, hydroxyapatite coralline, and titanium mesh for calvarium bone defects showed similar cosmetic and function outcomes and late complication while early complication was higher in hydroxyapatite coralline.

Conflicts of interest

No conflict of interest disclosure.

References

1. Uno T, Sakamoto Y, Miwa T, Toda M, Kishi K. Effectiveness of custom-made brim-type polyethylene implant for cranioplasty. *J Plast, Reconstr Aesthet Surg.* 2022;75:2387–2440.
2. Lane JC, Black JS. Pediatric cranial defects: what size warrants repair? *J Craniofac Surg.* 2022;33:517–520.
3. Moncayo-Matute FP, Peña-Tapia PG, Vázquez-Silva E, et al. Surgical planning and finite element analysis for the neurocranial protection in cranioplasty with PMMA: a case study. *Heliyon.* 2022;8:e10706.
4. Cannella LA, McGary H, Ramirez SH. Brain interrupted: early life traumatic brain injury and addiction vulnerability. *Experimental neurology.* 2019;317:191–201.
5. Andrabi SM, Sarmast AH, Kirmani AR. Cranioplasty: indications, procedures, and outcome - an institutional experience. *Surg Neurol Int.* 2017;8:91–95.
6. Dewi AH, Ana ID. The use of hydroxyapatite bone substitute grafting for alveolar ridge preservation, sinus augmentation, and periodontal bone defect: a systematic review. *Heliyon.* 2018;4.
7. Darwish M, Zidan Nanous W. Cranioplasty using titanium mesh versus acrylic bone cement: short-term outcomes and complications. *Benha Med J.* 2021;38:146–154.
8. Klinger DR, Madden C, Beshay J. Autologous and acrylic cranioplasty: a review of 10 years and 258 cases. *World Neurosurg.* 2014;82:525–530.
9. Reddy S, Khalifian S, Flores JM. Clinical outcomes in cranioplasty: risk factors and choice of reconstructive material. *Plast Reconstr Surg.* 2014;133:864–873.
10. Wong RK, Gandolfi BM, St-Hilaire H. Complications of hydroxyapatite bone cement in secondary pediatric craniofacial reconstruction. *J Craniofac Surg.* 2011;22:247–251.
11. Williams L, Fan K, Bentley R. Custom-made titanium cranioplasty: early and late complications of 151 cranioplasties and review of the literature. *Int J Oral Maxillofac Surg.* 2015;44:599–608.
12. Okumus A, Guven E, Ermis I. Comparative analysis of using bone graft, hydroxyapatite coralline (BiocoralA®) and porous polyethylene (MedporA®) implants for cranioplasty in a Rat Model of cranial bone defect. *Turk Neurosurg.* 2020;30:263–270.
13. Hassan H, Ali A, Abdalla A. Autogenous bone graft versus artificial substitutes in cranioplasty. *Open J Mod Neurosurg.* 2019;9:338–355.
14. Wallace RD, Salt C, Konofaos P. Comparison of autogenous and alloplastic cranioplasty materials following impact testing. *J Craniofac Surg.* 2015;26:1551–1557.