ORIGINAL ARTICLE

AESTHETIC AND PSYCHOLOGICAL OUTCOMES OF CRANIOPLASTY, POLYMETHYL METHACRYLATE VERSUS TITANIUM MESH

Resultados estéticos y psicológicos de la craneoplastía; Polimetil metacrilato versus malla de titanio

ESSAM M. YOUSSEF, MD [1a*], DINA A. SELEEM, MD [2b], MOHAMED A. YAHIA, MD [3c]

[1]Neurosurgery Department, Faculty of Medicine, Zagazig University, Egypt. [2]Psychiatry Department, Faculty of Medicine, Zagazig University, Egypt. [3]Alahrar Teaching Hospital, Zagazig, Egypt.
*[a] Neurosurgeon, [b] Psychiatrist, [c] Academic fellow of Neurosurgery, *Corresponding author*

ABSTRACT

Introduction: Problems with appearance may negatively affect the mental health of individuals with disfigurement so, cranioplasty has an important role in improving the physical appearance of patients as well as their psychological symptoms.
Objective: This study aims to highlight the aesthetic as well as the psychological outcomes of cranioplasty using the two most widely used synthetic graft materials; polymethyl methacrylate (PMMA) and titanium mesh.
Methods: This is a prospective study conducted on patients with apparent skull deformity who underwent cranioplasty using PMMA or titanium mesh from April 2016 to April 2017 and were followed up for one year. Patients were assessed preoperatively, at three months, and one year postoperatively using the Derriford Appearance Scale 24 (DAS 24) and the Hospital Anxiety and Depression scale (HADS).
Results: 42 patients; 25 males and 17 females were recruited. PMMA was used in 23 patients while titanium mesh was used in 19 patients. There were no significant differences regarding early and late complications between both groups. Revision surgery was necessary in only four cases having equal rates between both groups. There was a marked reduction in DAS 24 and HADS scores postoperatively with better scores in the PMMA group especially at three months after cranioplasty.
Conclusion: Cranioplasty had positive effects on patients' distress regarding their appearance and their psychological symptoms. PMMA had better parameters than titanium mesh. Both PMMA and titanium mesh had comparable aesthetic outcomes with no statistically significant difference regarding the complication rates.

Keywords: *Cranioplasty, Polymethyl methacrylate, Titanium, Physical Appearance, Body, Depression (source: MeSH NLM)*

RESUMEN

Introducción: Los problemas de apariencia pueden afectar negativamente la salud mental de las personas con desfiguración, por lo que la craneoplastía tiene un papel importante en la mejora de la apariencia física de los pacientes, así como de sus síntomas psicológicos.
Objetivo: El objetivo de este estudio es resaltar los resultados estéticos y psicológicos de la craneoplastía utilizando los dos materiales de injerto sintético más utilizados; polimetilmetacrilato (PMMA) y malla de titanio.
Métodos: Este es un estudio prospectivo realizado en pacientes con aparente deformidad de cráneo que se sometieron a craneoplastía con PMMA o malla de titanio entre abril de 2016 y abril de 2017 y fueron seguidos durante 1 año. Los pacientes fueron evaluados antes de la operación, a los tres meses y al año después de la operación utilizando la Escala de Apariencia de Derriford 24 (DAS 24) y la Escala de Ansiedad y Depresión Hospitalaria (HADS).
Resultados: Se reclutaron 42 pacientes: 25 hombres y 17 mujeres. Se usó PMMA en 23 pacientes mientras que se usó malla de titanio en 19 pacientes. No hubo diferencias significativas en cuanto a complicaciones tempranas y tardías entre ambos grupos. La cirugía de revisión fue necesaria sólo en 4 casos con tasas iguales entre ambos grupos. Hubo una marcada reducción en las puntuaciones DAS 24 y HADS después de la operación con mejores puntuaciones en el grupo de PMMA, especialmente a los tres meses después de la craneoplastía.
Conclusión: La craneoplastía tuvo efectos positivos en la angustia de los pacientes con respecto a su apariencia y en sus síntomas psicológicos. PMMA tenía mejores parámetros que la malla de titanio. Tanto la malla de PMMA como la de titanio tuvieron resultados estéticos comparables sin diferencias estadísticamente significativas con respecto a las tasas de complicaciones.

Palabras Clave: *Craneoplastía, Polimetil Metacrilato, Titanio, Apariencia Física, Depresión. (fuente: DeCS Bireme)*

https://doi.org/10.53668/2019.PJNS11153 Peru J Neurosurgery 2019;1 (1): 9-20

Submitted *: September 25, 2018*
Accepted *: December 12, 2018*
HOW TO CITE THIS ARTICLE: Youssef E, Seleem D, Yahia M. Aesthetic, and psychological outcomes of cranioplasty, polymethyl methacrylate versus titanium mesh. *Peru J Neurosurg 2019;* 1(1): 9-20. doi:10.53668/2019.PJNS11153

Cranioplasty is a commonly performed neurosurgical procedure used to reconstruct cranial bone defects. Besides its cosmetic benefits, cranioplasty protects the intracranial structures and plays a role in controlling the alterations in the intracranial pressure (ICP), cerebral blood flow and metabolism. [1-4]

The first historical description of cranioplasty was by *Fallopius* (1523-1562) who described the use of a gold plate to replace a cranial bone defect. [5]

Cranioplasty materials include biological and synthetic materials. Biological materials are further subdivided into autologous grafts, allografts, and xenografts. Allografts (i.e., bone from cadavers) and xenografts (i.e., bone from animals) are out of use nowadays because of their high rates of rejection, osteonecrosis, and infective complications. [6,7]

Autologous cranioplasty utilizes either bony material from the cranium itself or bones from other parts of the body of the patient. Risks of resorption and reoperation with replacement by other materials exist. [8-10]

Synthetic graft materials are in common use nowadays because of avoiding the complications of autografts, better cosmetic and operative results. They include polymethyl methacrylate (PMMA), Titanium mesh, Hydroxyapatite and Polyetheretherketones (PEEK). [11-13]

The choice of the graft material is multifactorial. It takes into consideration the age of the patient, size, etiology and location of the defect and the surgeon's preference. [9,14,15-19] Physical appearance has a pivotal importance in the social life of individuals and interpersonal relationships as even small changes in appearance can affect people's perception of others. [20]

This can affect a patient's mental health negatively, resulting in poor self-esteem, symptoms of anxiety and depression, eventually leading to social avoidance necessitating aesthetic surgery especially on visible parts of the body like the face and head. Thus, successful aesthetic surgery generally improves the overall quality of life in people resulting in good mental health. [21]

Many studies had addressed the psychological outcome of different aesthetic surgical procedures [22-25] but, to our knowledge; no study had addressed such outcome among Egyptian patients undergoing cranioplasty.

The aim of this study is to highlight the aesthetic as well as the psychological outcomes of cranioplasty using the two most widely used synthetic graft materials; the Acrylic (in the form of PMMA) and Titanium mesh.

METHODS

Patients

This is a randomized prospective study carried out in the Neurosurgery department, Zagazig University, Egypt. Cases were recruited from April 2016 to April 2017 and were followed up for one year. The study included all patients with disfigurement at presentation, ≥ 18 years, from both genders, generally fit for surgery, with apparent skull defects (regardless of the etiology whether post traumatic or post injury) planned to undergo cranioplasty by PMMA or titanium mesh. We excluded patients undergoing cranioplasty using materials other than PMMA, titanium mesh or a hybrid of both materials, patients with active infection and patients with marked craniofacial deformity other than pure skull defects especially those requiring major plastic repair. Patients with history of psychiatric disorders including personality disorders and patients unable to understand and complete the scales due to disorders affecting cognition were also excluded.

Methods

Preoperatively
The basic characteristics of the patients including age, sex, etiology, site, and size of the defect were determined.

Operative technique
After induction of general anesthesia, prophylactic antibiotic administration, scrub and preparation, an appropriate skin incision was designed to include the defect with respect to the regional blood supply. Sometimes, a bicoronal scalp incision was utilized in case of frontal defects.

After preparation of the defect, gentamycin impregnated acrylic (in the form of PMMA) was prepared, contoured, and reshaped to cover the defect with the thin edges of the graft overlying the bony edges. No mini plates or wires were used. Sometimes silk sutures were utilized for fixation. In cases where titanium mesh was used, an appropriate sized mesh was fashioned to cover the defect and was fixed in place by screws. Closure in layers was done after proper hemostasis, sometimes with a drain when needed.

Postoperatively
After 48 hours, the drain (if present) was removed, and a computerized tomography (CT) scan was done with bone windows and 3D reconstruction. Stitches or staples were removed after 15 days.

Follow up
At one year postoperatively, a CT scan was done.

Psychometric assessment

Measurement of distress of appearance:
Patients were assessed preoperatively and postoperatively (at three months and one year) for their distress regarding their appearance using an Arabic translation of the Derriford Appearance Scale 24 (DAS 24) [26]. The DAS 24 includes 24 items that measure the distress in relation to self-consciousness of appearance. Participants rate their answers in relation to appearance using a four-point scale. Scores range between a minimum (best) score of 10 and a maximum (worst) of 96. Higher scores represent higher appearance-related distress. DAS 24 is widely used in literature and determines the presence of appearance concerns.

Measurement of anxiety and depression:
Patients were assessed preoperatively and postoperatively (at three months and one year) for anxiety and depressive symptoms using an Arabic version [27] of the Hospital Anxiety and Depression scale (HADS). [28]

The HADS was originally developed to screen for depression (HADS-D) and anxiety (HADS-A) in a hospital setting and in general population. [29] It includes 14 items: seven items assessing anxiety and seven items assessing depression. Responses are rated on a 4-point Likert-type (0-3). Each subscale has a maximum score of 21. Scores 0–7 (normal), 8–10 (borderline case), and 11–21 (positive case of anxiety or depression). [28]

Statistical analysis

All data were collected, tabulated, and statistically analyzed using SPSS 22 for windows (IBM Corp., Armonk, NY, USA) and Microsoft Office Excel 2010 for windows (Microsoft Cor., Redmond, WA, USA). Continuous Quantitative variables were expressed as the mean ± SD & median (range), and categorical qualitative variables were expressed as absolute frequencies (number) & relative frequencies (percentage). Continuous data were checked for normality using Shapiro Walk test. Independent samples Student's t-test was used to compare two groups of normally distributed data while Mann-Whitney U test was used for non-normally distributed data. Friedman test was used for more than two dependent groups of non-normally distributed data. Categorical data were compared using Chi-square test or Fisher's exact test when appropriate. All tests were two sided. p-value < 0.05 was considered statistically significant.

RESULTS

Basic Characteristics of the study sample:

The current study included 42 patients: 25 males and 17 females. PMMA was used in 23 patients while titanium mesh was used in 19 patients. 21 patients were post traumatic (including old, depressed fractures and decompressive craniectomy) and 21 patients were post lesional o postinjury (including skull and meningeal tumors and inflammatory conditions with at least six months after control of infection). There was insignificant difference between both groups regarding the basic characteristics. (Table 1).

Complications:

The overall rate of early complications (up to three months postoperatively) was 16.6% with two cases of superficial infection in each group that responded well to antibiotic

Table 1. Basic Characteristics of the study participants (N=42).

Basic Characteristics	All patients (N=42)		Material used for repair				Test	p-value
			PMMA (N=23)		Titanium mesh (N=19)			
	No.	%	No.	%	No.	%		
Sex								
Male	25	59.5%	15	65.2%	10	52.6%	0.684[a]	**0.408**
Female	17	40.5%	8	34.8%	9	47.4%		
Age (years)								
Mean ± SD	36.85±12.57		36.82±11.57		36.89±14.02		-0.017[b]	**0.986**
Median (Range)	36.50 (18 – 60)		35 (18 – 57)		38 (18 – 60)			
Etiology of defect								
Post-traumatic	21	50%	11	47.8%	10	52.6%	0.096[a]	**0.757**
Post-lesional	21	50%	12	52.2%	9	47.4%		
Site of defect								
Frontal	13	31%	8	34.8%	5	26.3%	5.764[a]	**0.568**
Parietal	10	23.8%	4	17.4%	6	31.6%		
Temporal	4	9.5%	1	4.3%	3	15.8%		
Occipital	3	7.1%	2	8.7%	1	5.3%		
Temporoparietal	3	7.1%	2	8.7%	1	5.3%		
Frontotemporal	4	9.5%	3	13%	1	5.3%		
Parietooccipital	3	7.1%	1	4.3%	2	10.5%		
Frontotemporoparietal	2	4.8%	2	8.7%	0	0%		
Largest diameter (cm)								
Mean ± SD	6.38±1.97		6.65±1.87		6.05±2.09		-1.404[c]	**0.160**
Median (Range)	6 (4 – 11)		6 (4 – 11)		5 (4 – 10)			
Area of defect (cm^2)								
Mean ± SD	32.47±19.46		32.95±18.32		31.89±21.26		-0.915[c]	**0.360**
Median (Range)	27.50 (8 – 88)		30 (8 – 88)		20 (12 – 80)			

Categorical variables were expressed as number (percentage); Continuous variables were expressed as mean ± SD & median (range); a: Chi-square test; b: Independent samples Student's t-test; c: Mann Whitney U test; p-value<0.05 is significant.

Table 2. Complications of cranioplasty in the study participants (N=42).

Complications	All patients (N=42)		Material used for repair				Test[a]	p-value
			PMMA (N=23)		Titanium mesh (N=19)			
	No.	%	No.	%	No.	%		
Early complications								
Absent	35	83.3%	19	82.6%	16	84.2%	0.211	0.900
Subgaleal hematoma	3	7.1%	2	8.7%	1	5.3%		
Superficial infection	4	9.5%	2	8.7%	2	10.5%		
Late complications								
Absent	33	78.6%	19	82.6%	14	73.7%	7.444	0.190
Sunken graft	3	7.1%	3	13%	0	0%		
Screw loosening	2	4.8%	0	0%	2	10.5%		
Material break	1	2.4%	0	0%	1	5.3%		
Skin breakdown	1	2.4%	0	0%	1	5.3%		
Sinus discharging pus	2	4.8%	1	4.3%	1	5.3%		

Categorical variables were expressed as number (percentage); a: Chi-square test; p-value<0.05 is significant.

treatment and repeated dressing. A Subgaleal hematoma occurred in two patients of the MMA group versus one patient among the titanium mesh group. The overall rate of late complications (from three months up to one year postoperatively) among the studied patients was 21.4%. Sunken graft complicated three patients of the PMMA group that did not necessitate revision surgery at the last follow up. Two patients of the titanium mesh group developed screw loosening that did not necessitate revision surgery at the last follow up. Material breaks complicated one case of the titanium mesh group and required revision. Skin breakdown complicated one case of the titanium mesh group and required mesh removal. Sinus discharging pus complicated one case in each group that necessitated graft removal. There was an insignificant difference between both groups regarding early and late complications. (Table 2)

Derriford Appearance Scale 24 (DAS 24):

There was a significant reduction in DAS 24 scores in all studied patients and among patients in each group (p-value<0.001). There was a significant difference in the three months' scores between both groups where patients in the PMMA group had lower distress than patients in titanium mesh group (p-value<0.05). There was a trend towards significance after one year in favor of PMMA (p-value =0.052). (Table 3 and Figure 1)

Hospital Anxiety and Depression Scale (HADS)

A total of 16 cases (38%) had HADS-A scores ≥11 (positive case of anxiety). There was a significant reduction in HADS-A scores among all studied patients (one case at three months (2.4%) and two cases (4.8%) at one year with scores

Table 3. DAS 24 scores among the study participants.

DAS 24	All patients (N=42)	Material used for repair		Test[c]	p-value
		PMMA (N=23)	Titanium mesh (N=19)		
Preoperatively					
Mean ± SD	49.45±13.39	47.43±12.85	51.89±13.97	-1.302	0.193
Median (Range)	49 (23 – 77)	46 (24 – 77)	54 (23 – 77)		
3 months postop					
Mean ± SD	22.64±8.72	18.78±5.56	27.31±9.65	-2.949	0.003
Median (Range)	21 (11 – 44)	19 (11 – 29)	26 (11 – 44)		
One year postop					
Mean ± SD	15.78±7.41	14.43±6.56	17.42±8.20	-1.943	0.052
Median (Range)	13 (11 – 42)	12 (11 – 40)	15 (11 – 42)		
Test [d]	77.024	41.416	35.707		
p-value	<0.001	<0.001	<0.001		

Continuous variables were expressed as mean ± SD & median (range); c: Mann Whitney U test; d: Friedman's test; p-value<0.05 is significant.

≥11) and among patients in each group. There was a significant difference in scores between both groups at three months and at one year postoperatively as patients in the PMMA group had lower anxiety than patients in titanium mesh group (p-value<0.05). (Table 4 and Figure 2)

Nine cases (21.4%) had HADS-D scores ≥11 (positive case of depression). There was a significant change in HADS-D scores among all studied patients (one case at three months (2.4%) and three cases (7.1%) at one year with scores ≥11) and among patients in each group. Mean scores of HADS-D among PMMA group were lower than the titanium mesh group although the difference was not statistically significant. (Table 4 and Figure 3)

Regarding the HADS total scores, there was a significant change in all studied patients and among patients in each group. Scores were significantly different between both groups at three months as patients in PMMA group had more favorable scores than patients in titanium mesh group. (Table 4 and Figure 4)

DISCUSSION

Cranioplasty has an important aesthetic role to restore the normal skull appearance as well as a protective role for intracranial structures. It has long been studied those problems with appearance can cause distress and induce some psychological symptoms like anxiety, depression, low self-esteem, and poor health-related quality of life. [22,30,31]

Table 4. HADS scores among the study participants (N=42).

HADS	All patients (N=42)	Material used for repair		Test[c]	p-value
		PMMA (N=23)	Titanium mesh (N=19)		
HADS-A					
Preoperatively					
Mean ± SD	9.80±3.90	8.91±3.16	10.89±4.50	-1.420	0.156
Median (Range)	9.50 (4 – 18)	8 (4 – 16)	11 (4 – 18)		
3 months postop					
Mean ± SD	3.95±3.23	2.86±2.81	5.26±3.29	-2.482	0.013
Median (Range)	3 (0 – 11)	2 (0 – 10)	5 (0 – 11)		
One year postop					
Mean ± SD	2.64±3.16	1.86±2.45	3.57±3.71	-2.078	0.038
Median (Range)	2 (0 – 14)	1 (0 – 9)	2 (0 – 14)		
Test [d]	64.882	40.651	24.849		
p-value	<0.001	<0.001	<0.001		
HADS-D					
Preoperatively					
Mean ± SD	8.07±3.87	7.39±2.65	8.89±4.93	-0.739	0.460
Median (Range)	8 (3 – 20)	7 (3 – 12)	9 (3 – 20)		
3 months postop					
Mean ± SD	3.26±2.82	2.62±2.28	4±3.26	-1.332	0.183
Median (Range)	3 (0 – 13)	3 (0 – 8)	3 (0 – 13)		
One year postop					
Mean ± SD	2.50±3.90	1.69±2.34	3.47±4.93	-1.280	0.200
Median (Range)	1 (0 – 18)	1 (0 – 8)	2 (0 – 18)		
Test [d]	64.750	40.683	24.543		
p-value	<0.001	<0.001	<0.001		
HADS-Total					
Preoperatively					
Mean ± SD	17.88±7.24	16.30±5.08	19.78±8.99	-1.203	0.229
Median (Range)	18 (7 – 38)	16 (8 – 25)	19 (7 – 38)		
3 months postop					
Mean ± SD	7.21±5.37	5.52±4.41	9.26±5.81	-2.066	0.039
Median (Range)	7 (0 – 19)	6 (0 – 18)	10 (0 – 19)		
One year postop					
Mean ± SD	5.14±6.64	3.56±4.33	7.05±8.39	-1.707	0.088
Median (Range)	3 (0 – 29)	2 (0 – 17)	4 (0 – 29)		
Test [d]	66.199	40.989	25.622		
p-value	<0.001	<0.001	<0.001		

Continuous variables were expressed as mean ± SD & median (range); c: Mann Whitney U test; d: Friedman's test; p-value<0.05 is significant.

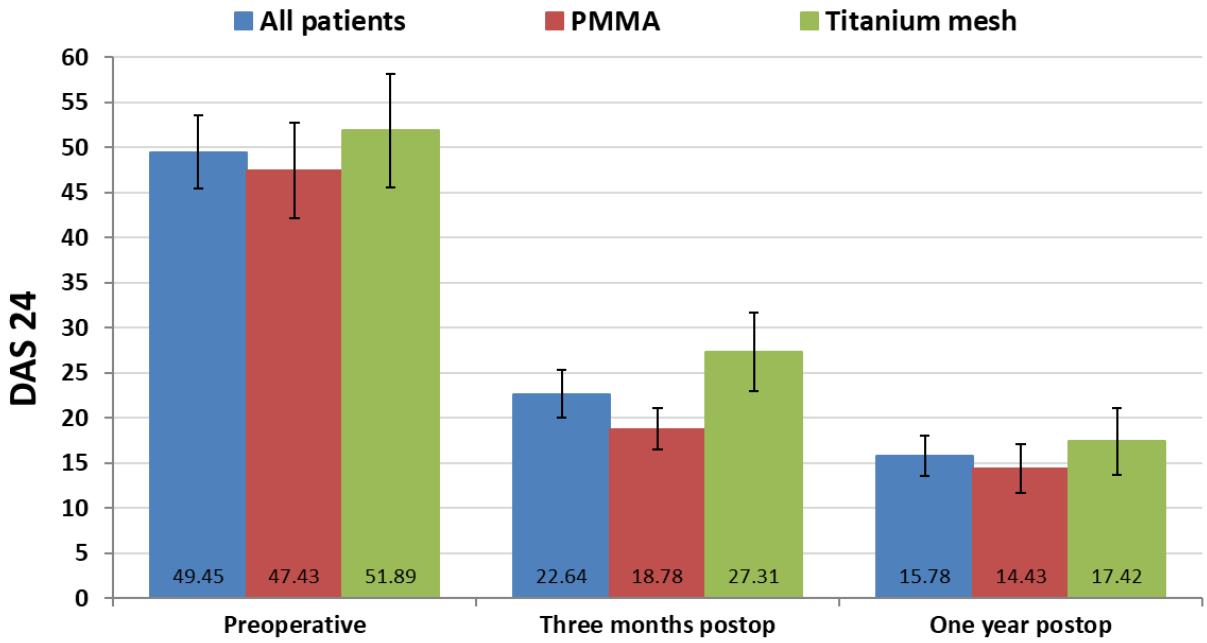


Fig 1. Error Bar chart shows DAS 24 scores among study participants (N=42); bars represent mean scores, and Y-error bars represent 95% CI (Confidence interval).

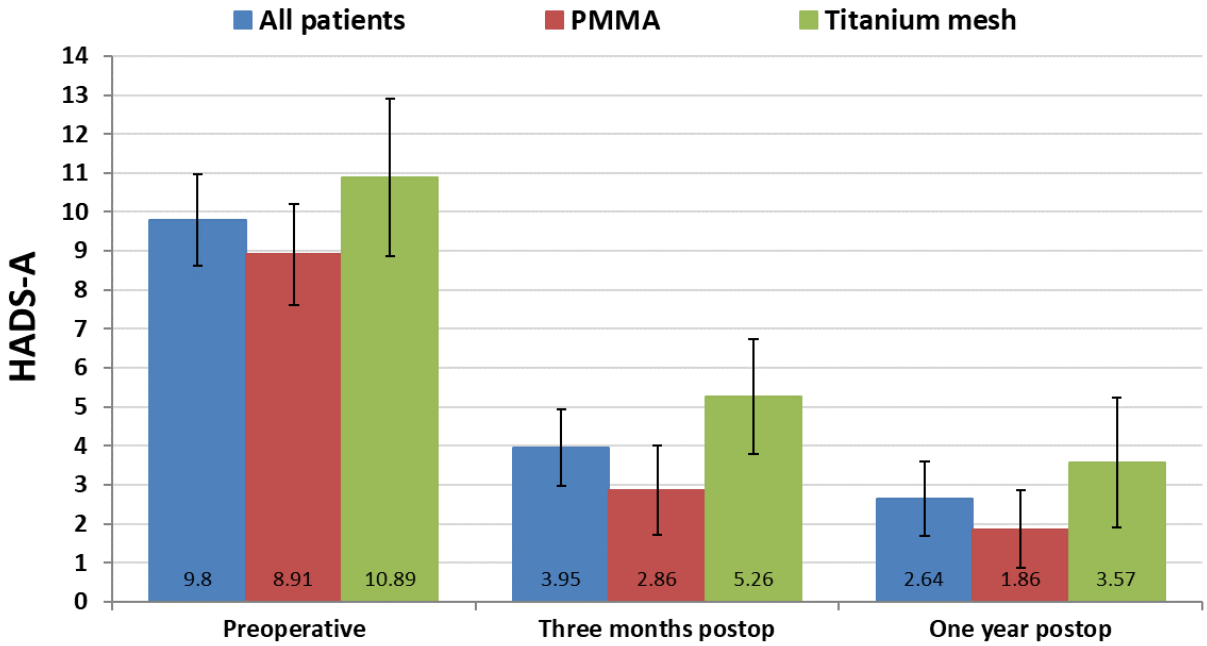


Fig 2. Error Bar chart shows HADS-A scores among study participants (N=42); bars represent mean scores, and Y-error bars represent 95% CI (Confidence interval).

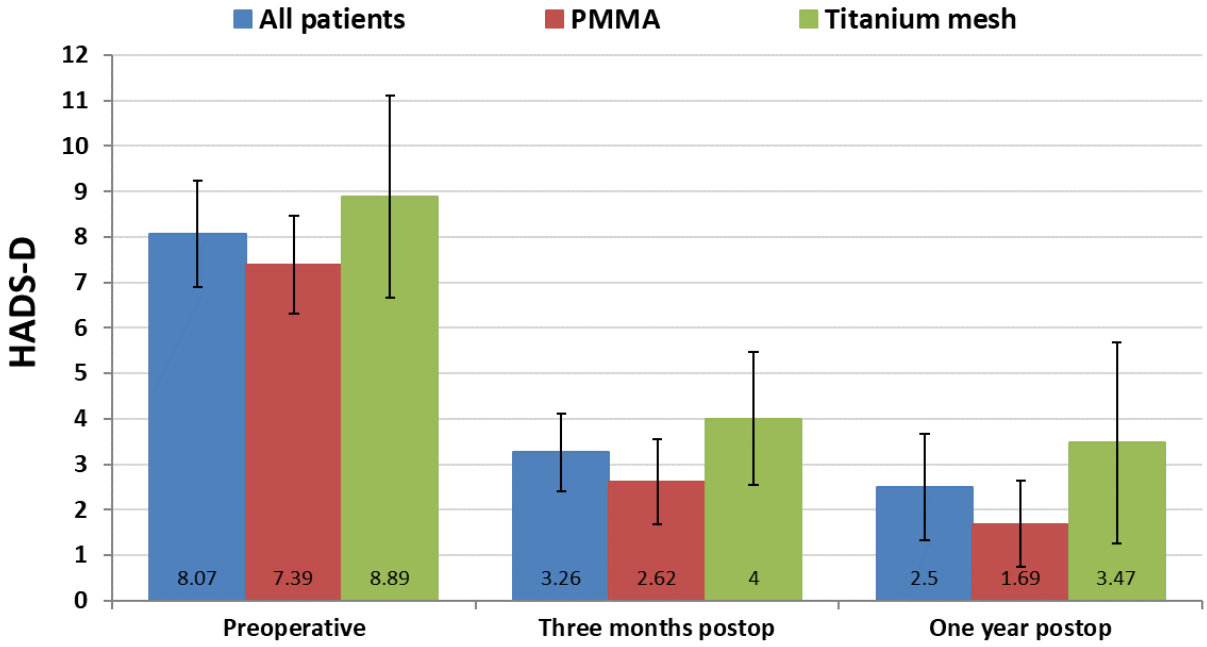


Fig 3. Error Bar chart shows HADS-D scores among study participants (N=42); bars represent mean scores, and Y-error bars represent 95% CI (Confidence interval).

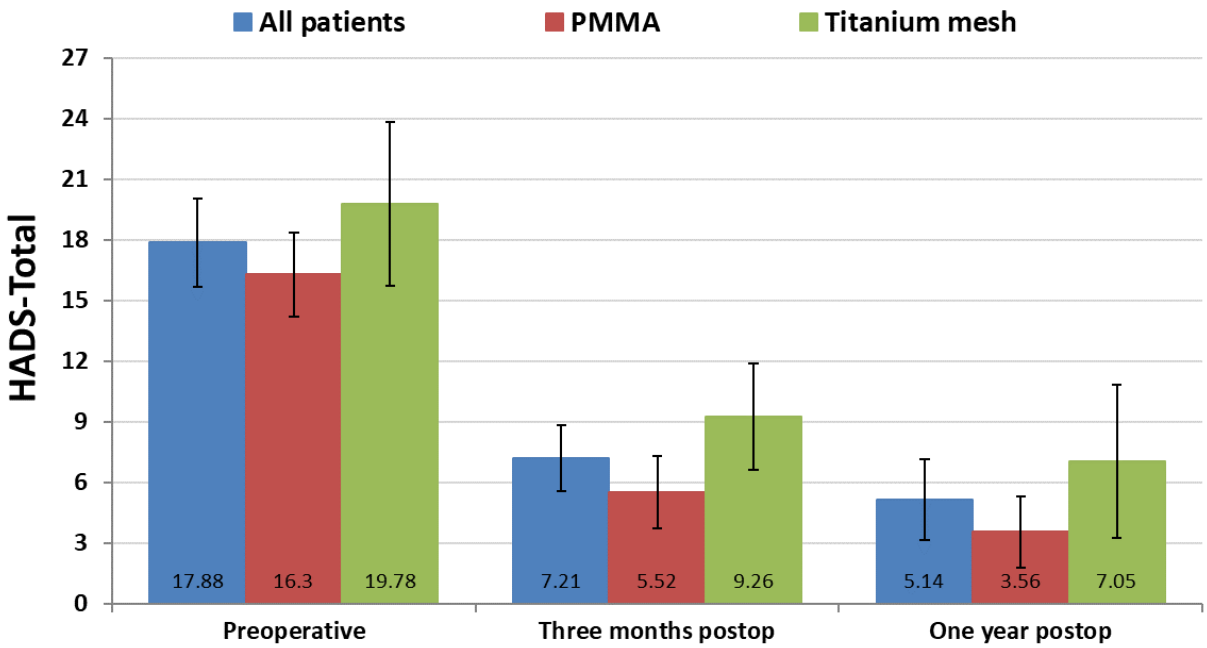
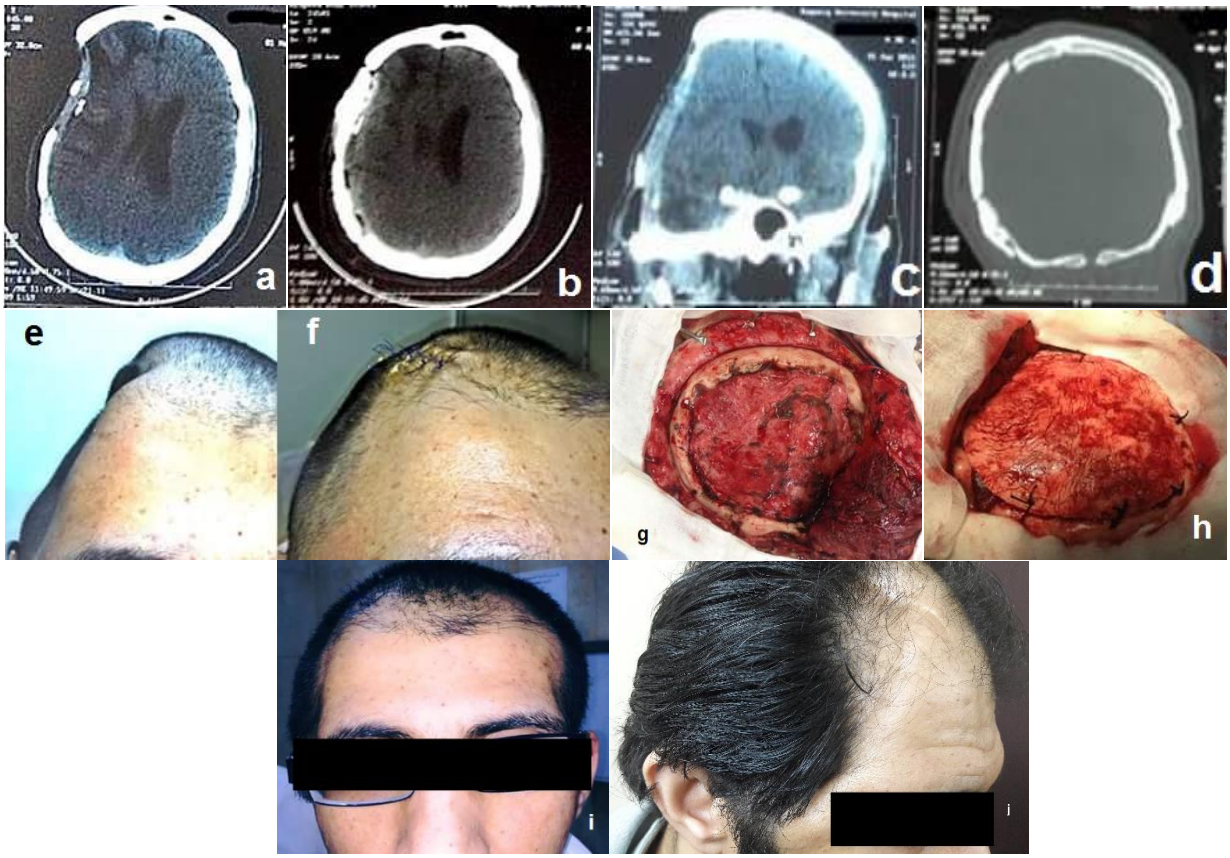


Fig 4. Error Bar chart shows HADS-Total scores among study participants (N=42); bars represent mean scores, and Y-error bars represent 95% CI (Confidence interval).



Case 1: 29 years old male patient with craniectomy after head injury underwent right frontotemporoparietal PMMA cranioplasty. **(a)** Preoperative axial CT, **(b)** Postoperative axial CT, **(c)** Preoperative coronal CT, **(d)** Postoperative coronal CT, **(e)** Preoperative photo of the patient, **(f)** Early postoperative photo of the patient, **(g, h)** Intraoperative images, **(i)** Three months postoperative photo of the patient, **(j)** One-year postoperative photo of the patient with sunken graft.

In this study, the authors aimed at assessing the aesthetic and psychological outcomes of cranioplasty using PMMA and titanium mesh being the most widely used materials for repair.

Forty-two patients presenting with skull disfigurement were recruited according to inclusion and exclusion criteria, underwent cranioplasty and were followed up for one year postoperatively. They were assessed using DAS 24 and HADS scales preoperatively, at three months and at one year postoperatively.

Polymethyl methacrylate (PMMA) is a strong, nonirritant, and radiolucent material that has limited expansion properties. Previously, it resulted in high rates of infection, degradation, and fragmentation. It does not accommodate skull growth; hence it is not used in pediatrics. [9,12,32,33]
Titanium mesh can be used alone or combined with other synthetic materials in cranioplasty. In addition to its satisfying cosmetic results compared with those of other materials, it has the lowest infection rate. However, it was found to be expensive, heat conductive and produces artifacts on imaging. [9,12,18,34-38]

The results of our study showed that both PMMA and titanium mesh groups had comparable early (16.6%) and late (21.4%) complications rates. Regarding the infective complications, previously encountered with acrylic [9], the gentamycin impregnated PMMA has caused marked reduction in infection rates recently. This may explain the similar early and late infection rates between both groups.

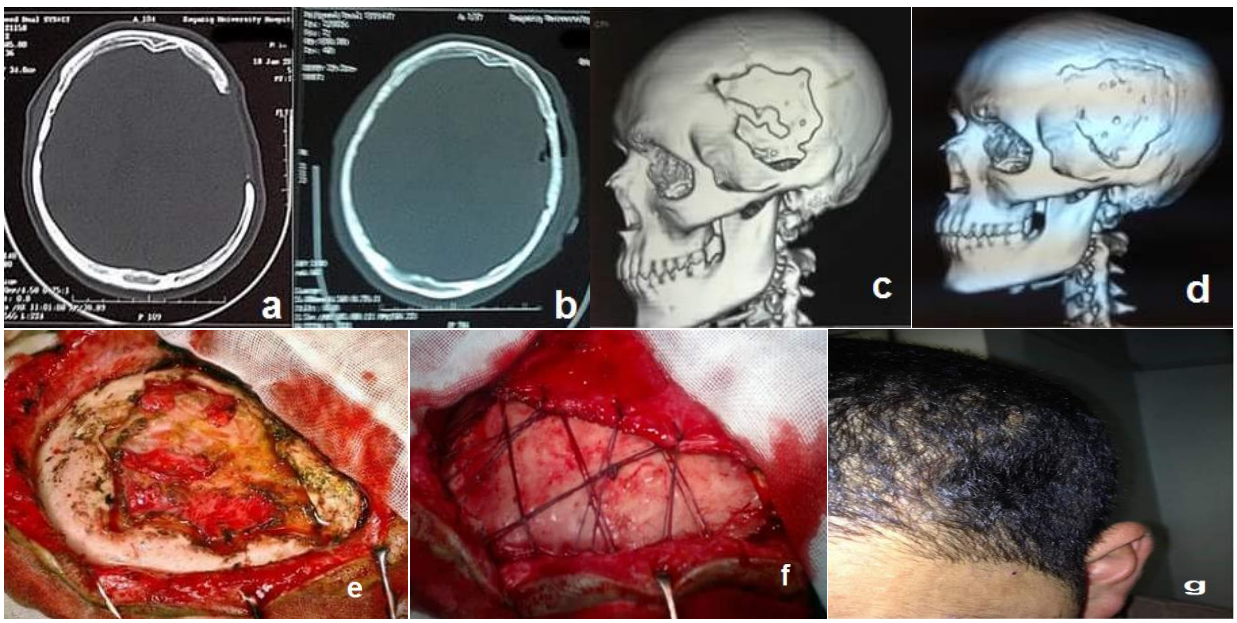
Sunken graft has emerged as a late complication in three cases of PMMA that caused late disfigurement due to bone remodeling and resorption at the edge of the graft raising the need for using alternative surgical techniques of application. Revision surgery was necessary in only four cases in our study having equal rates between both study groups.

A large meta-analysis conducted by *Leao et al. (2018)* [39] had found no difference regarding the complication rates between PMMA and titanium mesh (p = 0.38; RR, 1.59; 95%CI, 0.57–4.48).

Al- Tamimi et al. (2012) [40] conducted a prospective study on 126 patients; PMMA was used in 61 patients (48.4%) with a complication rate of 8.2% (5 patients) and titanium mesh was used in 65 (51.6%) with a complication rate of 12.3% (8 patients).

Sahoo et al. 2010 [19] conducted a retrospective study on 22 patients, PMMA was used in 5 patients, four (80%) of them had complications, while titanium mesh was used in 6 patients; three (50%) of them had complications. Similarly, a retrospective study was conducted by *Matsuno et al. 2006* [12] on 206 patients and found that 13.8% of the PMMA group had complications, versus 2.6% in the titanium mesh group.

Disfigurement is highly distressing for patients and is considered a primary treatment concern for many of them, therefore, regaining self-confidence, self-esteem, and social

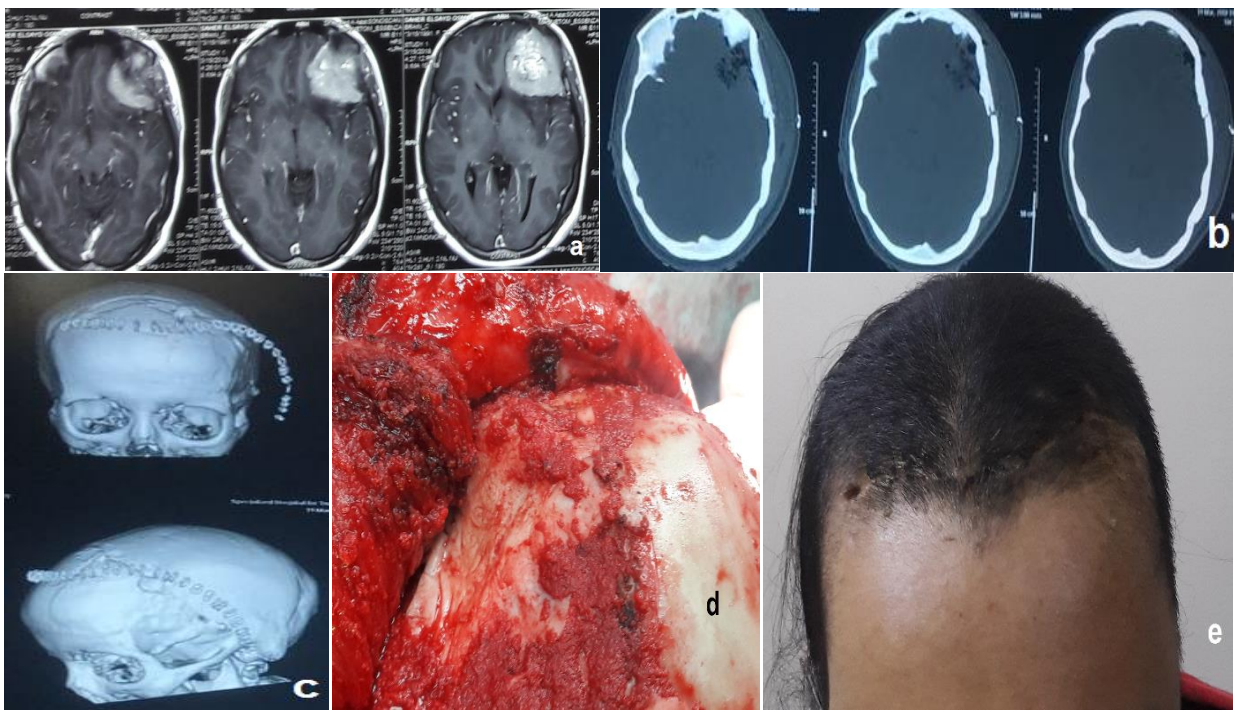


Case 2: 21 years old male patient with craniectomy after head injury underwent left temporoparietal PMMA cranioplasty. **(a)** Preoperative axial CT, **(b)** Postoperative axial CT, **(c)** Preoperative 3D CT reconstruction, **(d)** Postoperative 3D CT reconstruction, **(e, f)** Intraoperative images, **(g)** One-year postoperative photo of the patient with sunken graft.

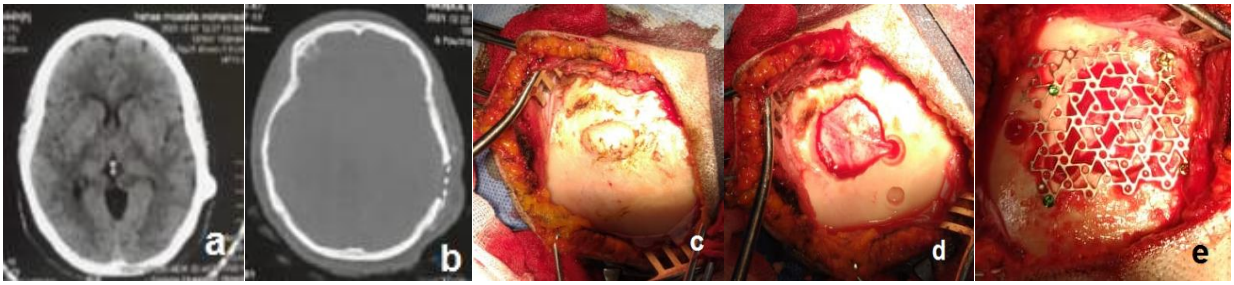
interactions are the most common motivations to pursue aesthetic surgery to improve appearance. [41,42] Research shows that most patients with a clinically satisfactory outcome are satisfied following aesthetic surgery and report improvements in self-esteem, quality of life and relationships. [22,43,44]

However, a small subgroup of patients turns out unsatisfied. Preexisting psychiatric condition can cause poor satisfaction despite a clinically satisfactory outcome. [45] This is the reason why history of psychiatric disorders (before to the disfigurement) or personality disorders were excluded in this study as they may affect the results of the psychological assessment with factors other than the surgical procedure, the main aim of the study. [46]

This is consistent with our study that found that both study groups showed distress regarding their appearance that has lowered markedly after three months of cranioplasty especially with PMMA that is known to be better at reshaping the skull defect. This advantage of PMMA was not very apparent after one year surgery, maybe due to the late



Case 3: 27 years old female patient with left sphenoid wing meningioma underwent left frontotemporal PMMA cranioplasty. **(a)** Preoperative axial T1W MRI with contrast, **(b)** Postoperative axial CT, **(c)** Postoperative 3D CT reconstruction, **(d)** Intraoperative image, **(e)** Postoperative photo of the patient.



Case 4: 42 years old female patient with a posterior temporal (supra-mastoid) osteoma of the skull underwent titanium mesh cranioplasty. **(a)** Preoperative axial CT, **(b)** Postoperative axial CT, **(c, d, e)** Intraoperative images.

complication of sunken graft. Research has shown that all patients with altered appearance seek cosmetic surgery due to psychological factors, like poor appearance-related adjustment, rather than due to clinical factors. [47]

Psychological disorders, especially body dysmorphic disorder have been the focus of much prior research [48,49], however, there are insufficient reports about preoperative evaluation of anxiety and depression in patients seeking aesthetic surgeries. Anxiety and depression disorders are the most prevalent and disabling psychological health conditions. [50,51] Studies has shown that cosmetic surgery has enhanced self-esteem. [52,53] With regards to repairing cranial defects, clear benefits were observed to the patients clinically and psychologically probably due to postoperative satisfaction with the aesthetic results and restoring the protective integrity of the skull after defect reconstruction. [36,54,55]

Research had detected significant differences in psychological symptoms, including depression and anxiety and overall quality of life after skull reconstructive surgery.[56]

This comes in harmony with the results of our study that showed that the prevalence of anxiety and depression were both high and the rates were markedly reduced postoperatively in all patients. The PMMA group had significantly lower rates of anxiety after three months and one year postoperatively and lower HADS total scores at three months postoperatively.

CONCLUSIONS

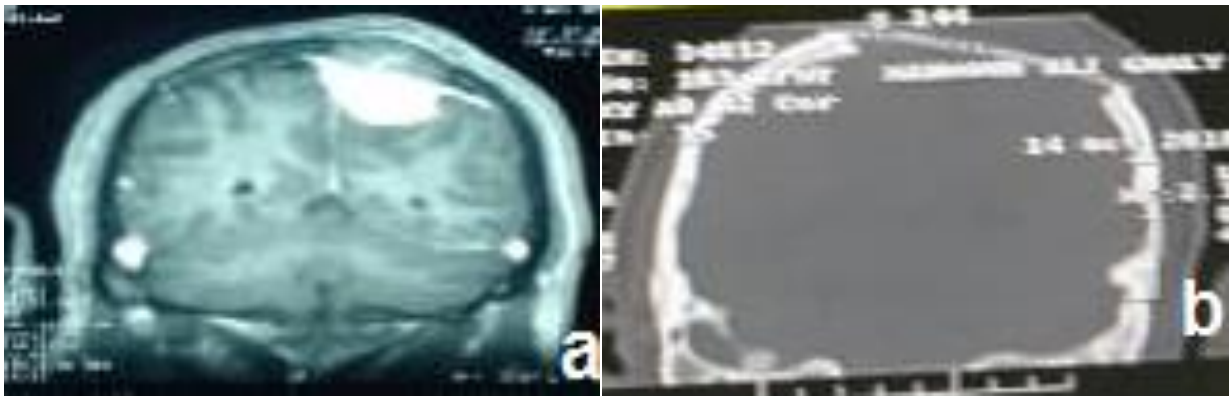
Cranioplasty had positive effects on patients' distress regarding their appearance and on their psychological symptoms in terms of anxiety and depression. PMMA had better parameters than titanium mesh. Both PMMA and titanium mesh had comparable aesthetic outcome with no statistically significant difference regarding the complication rates.

Limitations and recommendations:

This study has some limitations due to the small sample size and the short follow up duration and despite that, this study has highlighted some important outcomes that can be a focus in future studies. So, we recommend larger long-term studies on more homogenous groups of patients to allow for multivariate analysis. Preoperative psychiatric assessment of aesthetic surgery patients is a fundamental step in management.

REFERENCES

1. Jeyaraj, P. (2015). Importance of early cranioplasty in reversing the "syndrome of the trephine/motor trephine syndrome/sinking skin flap syndrome". *Journal of maxillofacial and oral surgery*, *14*(3), 666-673.
2. Carvi y Nievas, M. N., & Höllerhage, H. G. (2006). Early combined cranioplasty and programmable shunt in patients with skull bone defects and CSF-circulation



Case 5: 60 years old male patient with parasagittal meningioma underwent titanium mesh cranioplasty. **(a)** Preoperative coronal T1W MRI with contrast, **(b)** Postoperative coronal CT.

disorders. *Neurological Research*, *28*(2), 139-144.
3. Winkler, P. A., Stummer, W., Linke, R., Krishnan, K. G., & Tatsch, K. (2000). The influence of cranioplasty on postural blood flow regulation, cerebrovascular reserve capacity, and cerebral glucose metabolism. *Neurosurgical focus*, *8*(1), 1-9.
4. Erdogan, E., Düz, B., Kocaoglu, M., Izci, Y., Sirin, S., & Timurkaynak, E. (2003). The effect of cranioplasty on cerebral hemodynamics: evaluation with transcranial Doppler sonography. *Neurology India*, *51*(4), 479.
5. Abhay, S., & Haines, S. J. (1997). Repairing holes in the head: a history of cranioplasty. *Neurosurgery*, *40*(3), 588-603.
6. Grant, F. C., & Norcross, N. C. (1939). Repair of cranial defects by cranioplasty. *Annals of surgery*, *110*(4), 488.
7. Durand, J. L., Renier, D., & Marchac, D. (1997, February). The history of cranioplasty. In *Annales de chirurgie plastique et esthetique* (Vol. 42, No. 1, pp. 75-83).
8. Grant, G. A., Jolley, M., Ellenbogen, R. G., Roberts, T. S., Gruss, J. R., & Loeser, J. D. (2004). Failure of autologous bone—assisted cranioplasty following decompressive craniectomy in children and adolescents. *Journal of Neurosurgery: Pediatrics*, *100*(2), 163-168.
9. Shah, A. M., Jung, H., & Skirboll, S. (2014). Materials used in cranioplasty: a history and analysis. *Neurosurgical focus*, *36*(4), E19.
10. Bowers, C. A., Riva-Cambrin, J., Hertzler, D. A., & Walker, M. L. (2013). Risk factors and rates of bone flap resorption in pediatric patients after decompressive craniectomy for traumatic brain injury. *Journal of Neurosurgery: Pediatrics*, *11*(5), 526-532.
11. Zanotti, B., Zingaretti, N., Verlicchi, A., Robiony, M., Alfieri, A., & Parodi, P. C. (2016). Cranioplasty: review of materials. *Journal of Craniofacial Surgery*, *27*(8), 2061-2072.
12. Matsuno, A., Tanaka, H., Iwamuro, H., Takanashi, S., Miyawaki, S., Nakashima, M., ... & Nagashima, T. (2006). Analyses of the factors influencing bone graft infection after delayed cranioplasty. *Acta neurochirurgica*, *148*(5), 535-540.
13. Goldstein, J. A., Paliga, J. T., & Bartlett, S. P. (2013). Cranioplasty: indications and advances. *Current opinion in otolaryngology & head and neck surgery*, *21*(4), 400-409.
14. Aydin, S., Kucukyuruk, B., Abuzayed, B., Aydin, S., & Sanus, G. Z. (2011). Cranioplasty: review of materials and techniques. *Journal of neurosciences in rural practice*, *2*(02), 162-167.
15. Scolozzi, P., Martinez, A., & Jaques, B. (2007). Complex orbito-fronto-temporal reconstruction using computer-designed PEEK implant. *Journal of Craniofacial Surgery*, *18*(1), 224-228.
16. Spetzger, U., Vougioukas, V., & Schipper, J. (2010). Materials and techniques for osseous skull reconstruction. *Minimally invasive therapy & allied technologies*, *19*(2), 110-121.
17. Szpalski, C., Barr, J., Wetterau, M., Saadeh, P. B., & Warren, S. M. (2010). Cranial bone defects: current and future strategies. *Neurosurgical focus*, *29*(6), E8.
18. Lee, S. C., Wu, C. T., Lee, S. T., & Chen, P. J. (2009). Cranioplasty using polymethyl methacrylate prostheses. *Journal of clinical neuroscience*, *16*(1), 56-63.
19. Sahoo, N., Roy, I. D., Desai, A. P., & Gupta, V. (2010). Comparative evaluation of autogenous calvarial bone graft and alloplastic materials for secondary reconstruction of cranial defects. *Journal of Craniofacial Surgery*, *21*(1), 79-82.
20. Hern, J., Hamann, J., Tostevin, P., Rowe-Jones, J., & Hinton, A. (2002). Assessing psychological morbidity in patients with nasal deformity using the CORE® questionnaire. *Clinical Otolaryngology & Allied Sciences*, *27*(5), 359-364.
21. Kucur, C., Kuduban, O., Ozturk, A., Gozeler, M. S., Ozbay, I., Deveci, E., ... & Kaya, Z. (2016). Psychological evaluation of patients seeking rhinoplasty. *The Eurasian journal of medicine*, *48*(2), 102.
22. Honigman, R. J., Phillips, K. A., & Castle, D. J. (2004). A review of psychosocial outcomes for patients seeking cosmetic surgery. *Plastic and reconstructive surgery*, *113*(4), 1229.
23. Moss, T. P., & Harris, D. L. (2009). Psychological change after aesthetic plastic surgery: a prospective controlled outcome study. *Psychology, health & medicine*, *14*(5), 567-572.
24. Bradbury, E. (1994). The psychology of aesthetic plastic surgery. *Aesthetic plastic surgery*, *18*(3), 301-305.
25. Shridharani, S. M., Magarakis, M., Manson, P. N., & Rodriguez, E. D. (2010). Psychology of plastic and reconstructive surgery: a systematic clinical review. *Plastic and reconstructive surgery*, *126*(6), 2243-2251.
26. Carr, T., Moss, T., & Harris, D. (2005). The DAS24: A short form of the Derriford Appearance Scale DAS59 to measure individual responses to living with problems of appearance. *British journal of health psychology*, *10*(2), 285-298.
27. Terkawi, A. S., Tsang, S., AlKahtani, G. J., Al-Mousa, S. H., Al Musaed, S., AlZoraigi, U. S., ... & Altirkawi, K. A. (2017). Development and validation of Arabic version of the Hospital Anxiety and Depression Scale. *Saudi journal of anaesthesia*, *11*(Suppl 1), S11.
28. Zigmond, A. S., & Snaith, R. P. (1983). The hospital anxiety and depression scale. *Acta psychiatrica scandinavica*, *67*(6), 361-370.
29. Bjelland, I., Dahl, A. A., Haug, T. T., & Neckelmann, D. (2002). The validity of the Hospital Anxiety and Depression Scale: an updated literature review. *Journal of psychosomatic research*, *52*(2), 69-77.
30. Ishigooka, J., Iwao, M., Suzuki, M., Fukuyama, Y., Murasaki, M., & Miura, S. (1998). Demographic features of patients seeking cosmetic surgery. *Psychiatry and Clinical Neurosciences*, *52*(3), 283-287.
31. Goin, M. K., & Rees, T. D. (1991). A prospective study of patients' psychological reactions to rhinoplasty. *Annals of plastic surgery*, *27*(3), 210-215.
32. Blum, K. S., Schneider, S. J., & Rosenthal, A. D. (1997). Methyl methacrylate cranioplasty in children: long-term results. *Pediatric neurosurgery*, *26*(1), 33-35.
33. Chiarini, L., Figurelli, S., Pollastri, G., Torcia, E., Ferrari, F., Albanese, M., & Nocini, P. F. (2004). Cranioplasty using acrylic material: a new technical procedure. *Journal of cranio-maxillofacial surgery*, *32*(1), 5-9.
34. Wiggins, A., Austerberry, R., Morrison, D., Ho, K. M., & Honeybul, S. (2013). Cranioplasty with custom-made titanium plates—14 years' experience. *Neurosurgery*, *72*(2), 248-256.
35. Wiggins, A., Austerberry, R., Morrison, D., Ho, K. M., & Honeybul, S. (2013). Cranioplasty with custom-made titanium plates—14 years' experience. *Neurosurgery*, *72*(2), 248-256.
36. Cabraja, M., Klein, M., & Lehmann, T. N. (2009). Long-term results following titanium cranioplasty of large skull defects. *Neurosurgical focus*, *26*(6), E10.
37. Hanasono, M. M., Goel, N., & DeMonte, F. (2009). Calvarial reconstruction with polyetheretherketone implants. *Annals of plastic surgery*, *62*(6), 653-655.
38. Wind, J. J., Ohaegbulam, C., Iwamoto, F. M., Black, P. M., & Park, J. K. (2013). Immediate titanium mesh cranioplasty for treatment of postcraniotomy infections. *World neurosurgery*, *79*(1), 207-e11.
39. Leao, R. D. S., Maior, J. R. S., Lemos, C. A. D. A., Vasconcelos, B. C. D. E., Montes, M. A. J. R., Pellizzer, E. P., & Moraes, S. L. D. (2018). Complications with PMMA compared with other materials used in cranioplasty: a systematic review and meta-analysis. *Brazilian oral research*, *32*.
40. Al-Tamimi, Y. Z., Sinha, P., Trivedi, M., Robson, C., Al-Musawi, T. A., Hossain, N., ... & Towns, G. (2012). Comparison of acrylic and titanium cranioplasty#. *British journal of neurosurgery*, *26*(4), 510-513.

41. Fingeret, M. C., Yuan, Y., Urbauer, D., Weston, J., Nipomnick, S., & Weber, R. (2012). The nature and extent of body image concerns among surgically treated patients with head and neck cancer. *Psycho-Oncology*, *21*(8), 836-844.
42. List, M. A., Stracks, J., Colangelo, L., Butler, P., Ganzenko, N., Lundy, D., ... & Vokes, E. E. (2000). How do head and neck cancer patients prioritize treatment outcomes before initiating treatment? *Journal of Clinical Oncology*, *18*(4), 877-877.
43. Brunton, G., Paraskeva, N., Caird, J., Bird, K. S., Kavanagh, J., Kwan, I., ... & Thomas, J. (2014). Psychosocial predictors, assessment, and outcomes of cosmetic procedures: a systematic rapid evidence assessment. *Aesthetic plastic surgery*, *38*(5), 1030-1040.
44. Sarwer, D. B., Gibbons, L. M., Magee, L., Baker, J. L., Casas, L. A., Glat, P. M., ... & Young, V. L. (2005). A prospective, multi-site investigation of patient satisfaction and psychosocial status following cosmetic surgery. *Aesthetic Surgery Journal*, *25*(3), 263-269.
45. Wildgoose, P., Scott, A., Pusic, A. L., Cano, S., & Klassen, A. F. (2013). Psychological screening measures for cosmetic plastic surgery patients: a systematic review. *Aesthetic surgery journal*, *33*(1), 152-159.
46. Broers, D. L., van der Heijden, G. J., Rozema, F. R., & de Jongh, A. (2017). Do patients benefit from orthognathic surgery? A systematic review on the effects of elective orthognathic surgery on psychosocial functioning and patient satisfaction. *European journal of oral sciences*, *125*(6), 411-418.
47. Thompson, A., & Kent, G. (2001). Adjusting to disfigurement: processes involved in dealing with being visibly different. *Clinical psychology review*, *21*(5), 663-682.
48. Mulkens, S., Bos, A. E., Uleman, R., Muris, P., Mayer, B., & Velthuis, P. (2012). Psychopathology symptoms in a sample of female cosmetic surgery patients. *Journal of plastic, reconstructive & aesthetic surgery*, *65*(3), 321-327.
49. Collins, B., Gonzalez, D., Gaudilliere, D. K., Shrestha, P., & Girod, S. (2014). Body dysmorphic disorder and psychological distress in orthognathic surgery patients. *Journal of Oral and Maxillofacial Surgery*, *72*(8), 1553-1558.
50. Harhay, M. O., & King, C. H. (2012). Global burden of disease in young people aged 10–24 years. *The Lancet*, *379*(9810), 27-28.
51. Kessler, R. C., Ruscio, A. M., Shear, K., & Wittchen, H. U. (2009). Epidemiology of anxiety disorders. *Behavioral neurobiology of anxiety and its treatment*, 21-35.
52. Cook, S. A., Rosser, R., & Salmon, P. (2006). Is cosmetic surgery an effective psychotherapeutic intervention? A systematic review of the evidence. *Journal of Plastic, Reconstructive & Aesthetic Surgery*, *59*(11), 1133-1151.
53. Neto, M. S., Silva, A. L. A. L. D., García, É. B., Freire, M., & Ferreira, L. (2007). Quality of life and self-esteem after breast asymmetry surgery. *Aesthetic surgery journal*, *27*(6), 616-621.
54. Eufinger, H., Rasche, C., Wehmöller, M., Schmieder, K., Scholz, M., Weihe, S., & Scherer, P. (2005, May). CAD/CAM titanium implants for cranioplasty—an evaluation of success and quality of life of 169 consecutive implants regarding size and location. In *International Congress Series* (Vol. 1281, pp. 827-831). Elsevier.
55. Zegers, T., ter Laak-Poort, M., Koper, D., Lethaus, B., & Kessler, P. (2017). The therapeutic effect of patient-specific implants in cranioplasty. *Journal of Cranio-Maxillofacial Surgery*, *45*(1), 82-86.
56. Corallo, F., De Cola, M. C., Lo Buono, V., Marra, A., De Luca, R., Trinchera, A., ... & Calabrò, R. S. (2017). Early vs late cranioplasty: what is better? *International Journal of Neuroscience*, *127*(8), 688-693.

Ethical Considerations

All procedures were carried out complying with the ethical standards of the institutional research committee and with the Declaration of Helsinki of 1964 and its subsequent modifications or comparable ethical standards.

Disclosures

The authors report no conflict of interest concerning the materials or methods used in this study or the findings specified in this paper.

Author Contributions

Conception and design: All authors. *Drafting the article:* Youssef. Critically revising the article: Youssef, Seleem. *Reviewed submitted version of manuscript:* Youssef. *Approved the final version of the manuscript on behalf of all authors:* Youssef

Correspondence

Essam Mohamed Youssef, Lecturer of Neurosurgery, Neurosurgery Department, Faculty of Medicine, Zagazig University, Egypt, PO 44519. E-mail: dr.essam.m.youssef@gmail.com, ORCID ID: https://orcid.org/0000-0003-4702-4192