Original Article

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The Efficacy of Monomeric Acrylic in Cranioplasty Surgery Five-Year Follow-up

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ABSTRACT

Background: Cranioplasty refers to the surgical repair of a defect or deformity of skull that may result from trauma, growing skull fracture, congenital encephalocele, neoplasm.
Objectives: To evaluate the efficacy of monomeric acrylic implant material in cranioplasty
Patients and methods: Retrospective analyses of (64) patients undergoing cranioplasty over five years from January 2010 to December 2015 were performed in AL- Kadhimiya teaching hospital Baghdad, Iraq. Monomeric Acrylic was used in all patients and cranioplasty were performed under general anesthesia. 26 RTA, 19 bullet injuries, 7 FFH, 5 fan injuries, 4 congenital encephalocele, 3 brain tumors.
Results: A total of 64 cranial defect patients, 48 males and 16 females, were studied. Surgery had been conducted on all using monomeric acrylic designed in the hospital. Wound infection occurred in one patient, postoperative seizure in two cases, and dizziness post operatively in one case.
Discussion: The monomeric acrylic implant is considered the most compatible material as it can be easily used and prepared in a dental laboratory, is cheap, light weight, radiolucent, requires no thermal production, is malleable, sterilizable, and non-magnetic.
Conclusion: The monomeric acrylic implant designed in a dental laboratory is a new material used in cranioplasty which is malleable, sterilizable, nonmagnetic, radiolucent, light weight, inexpensive with easy and short surgical procedure and less post-operative complications**.**
Recommendation: Monomeric acrylic is the ideal synthetic material for cranioplasty; it is relatively safe, provides an acceptable aesthetic reconstructive option and contributes to neurological improvement in the treatment of cranial defect.

Keywords: Cranioplasty, Monomeric Acrylic, Cranioplastic

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INTRODUCTION

Indications of cranioplasty

The cosmetic restoration of external skull symmetry, protection from trauma (blunt or penetrating) in the area of post craniotomy or post traumatic skull defect is done to relieve **Trephine syndrome**, which manifests as headaches, dizziness, intolerance of vibration and noise, irritability, fatigue, loss of motivation and concentration, depression and anxiety. There is a large selection of possible materials for repair of skull defects, which may be categorized into auto grafts, allografts, xenografts, and bone substitutes.

The ideal material for cranioplasty

The ideal material would have the following features:

- Viable and thereby capable of growth and resistant to infection;
- Radiolucent;
- Thermally nonconductive and with coefficient of expansion identical to that of the surrounding skull;
- Non ionizing and non-corrosive;
- Stable (durable, non-bio degradable);
- Inert (non-reactive, non-antigenic, non-sensitizing, non-carcinogenic);
- Esthetically pleasing;
- Protective, with biomechanical properties same as that of the skull;
- Malleable and easily contoured;
- Inexpensive;
- Readily available;
- Sterilizable.[1]

Cranioplasty material alternatives

Autologous Bone Graft

Autologous bone flap replacement using the previously removed bone flap is traditionally performed. Autologous bone grafts are preferred because this method reduces foreign materials being introduced into the body, and because the bone flap can be readily accepted by the host and integrated back into the skull. Further experimentation with the tibia was performed; however, it was noted that the need for two operative fields, the risk of tibia fracture, and the undue discomfort for the patient made tibia grafts not optimal. Many other bone harvest sites were experimented with, including the ilium, ribs, sternum, scapula, fascia, and fat.[2] The replacement of the original bone removed during craniotomy is optimal as no other graft or foreign materials are introduced (Fig. 1). Autologous bone can be preserved either by cryopreservation or by placement in a subcutaneous abdominal pocket. However, in a traumatic brain injury setting, the subcutaneous pocket may be the preferred method of storage because cryopreservation may have a higher surgical site infection rate.[3] A common complication in pediatric patients is bone flap resorption, which results in structural breakdown. [4]

Methyl methacrylate

The methacrylate is polymerized ester of acrylic acid that exists in powdered form and is mixed with liquid monomer and benzoyl peroxide. In an exothermic reaction, methyl methacrylate slowly cools from a paste-like substance into a translucent material with strength comparable to that of the native bon[5] During this cooling phase, methyl methacrylate may be shaped to fit any skull defect. Methyl methacrylate may be used for technically challenging areas of the skull and reconstruction and growth from the native bone edge adjacent to the prosthesis that will secure it to the skull. Disadvantages of methyl methacrylate include postoperative infection, at a rate of approximately 5% to 10%, and plate breakdown or fracture[6] Methyl

methacrylate prosthesis presents a higher risk of infection compared to autologous bone flap.[7]

Calcium phosphate

Bone cement, which like methyl methacrylate exists as a powder and forms a malleable substance when it is mixed with liquid sodium phosphate. The most commonly used calcium phosphate material is hydroxyapatite, shown to be ideally suited for small craniofacial defects.[8] When it is used directly against exposed Dura, titanium mesh is recommended as an underlay to prevent small fractures in the hydroxyapatite plate from duralpulsations.[9] In contrast to methyl methacrylate, which does not allow further expansion of a growing skull, hydroxyapatite bone cement is often used for skull defects in the pediatric population.[9]

Titanium mesh

Either alone or a combination of titanium mesh and methyl methacrylate is another useful material for cranioplasty. Titanium is non-ferromagnetic and noncorrosive, and it does not elicit an inflammatory reaction. Several series have reported a low incidence of infection while still achieving excellent cosmetic results.[10] Most commonly, titanium exists as a metallic alloy with other metals to improve its strength and malleability. Titanium is also employed to preform prostheses on the basis of three-dimensional computed tomographic reconstructions of the skull base defect.[11]

Computer-designed implants

Computed tomographic reconstructions are expensive but effective for complex skull defects.[12] Anatomic models may be formed by polymerization of ultraviolet light-sensitive liquid resin with the use of a laser, based on computed tomographic data. These stereo lithographic models are then used to manufacture customized titanium plates Hydroxyapatite implants, or methyl methacrylate prostheses.[13]

Porous polyethylene implants

Are composed of high-density polyethylene microspheres that create interconnected pores, allowing the ingrowth of native bone. This unique implant structure rapidly incorporates fibro vascular tissue from the patient and decreases the infection rate of the implant. Porous polyethylene implants may be shaped to cover a large variety of skull defects and secured with titanium screws to the native bone. A distinct advantage of this material over titanium is that it does not produce artifacts on postoperative computed tomographic scans and magnetic resonance images.

Monomeric acrylic implant

The monomeric acrylic implant is semi-crystalline polymer that is radiolucent, chemically inert, and can be sterilized by use of cidex for at least one day preoperatively.[14] The implants have strength, thickness, and elasticity compatible to the cortical bone and can be incorporated accurately with the defect without use of miniplate.[14] Newer technologies such as monomeric acrylic implants are commonly used today because they can be designed specifically to a patient's craniotomy defect.[14]

The monomeric acrylic implants advantages

They do not create artifact on CT. Or MRI. Because they are translucent to X-Ray, monomeric acrylic implant are more comfortable because the material is less dense for lighter weight. They do not conduct temperature unlike metallic implants which can have negative ramifications on the brain.[14] Monomeric acrylic implant like other foreign

implants may have a higher infection rate risk than expected because of being dislodged or extruded since it does not incorporate with the surrounding native bone.

MATERIALS AND METHODS

A retrospective and prospective study of total 64 patients undergoing cranioplasty over five years from January 2010 to December 2015 was conducted in AL-Kadhimiya teaching hospital, Iraq. Monomeric acrylic was used in all patients and cranioplasties were performed under general anesthesia. 64 patients were operated on (48 males and 16 females). The age distribution was between 2–47 years. The cause of bone defect: 29 patients with head trauma due to road traffic accident (RTA), 10 cases were bullet injuries, seven cases present with depressed skull fracture due to falling from a height, five cases presented with fan injury with depressed skull fracture, four cases with congenital encephalocele, and three cases of brain tumor with skull defect. All patients had a skull defect with cosmetic problem. Headache presented in 40 patients, generalized fit in 14 patients, sided weakness in 10 patients. Frontal bone defect in 20 patients, frontal temporal in four, temporal 22, temporal parietal 13 and occipital five patients, one protection and cosmetic cause for 60 patients and four due to chronic headache**.** Cranioplasty is typically performed approximately three months after traumatic brain injury, early cranioplasty after 5-8 weeks may aid recovery. In our study timing of cranioplasty surgery was decided at least after one year from first insult.

Preparation of the patient

Preoperative antibiotic active against Staphylococcus species and continue them for 10 days postoperative. All scalp hair should be shaved. After inducing general anesthesia, position with plane of skull defect horizontally in order to facilitate molding of congealing plastic later. The patient is usually positioned on foam donut or horse shoe head holder. The incision follows the prior incision with care taken to stay directly on the previous scar to avoid necrosis of scalp. The blood loss in these operations is significant because of the neovascularization of scar tissue that is re-incised and it is important to alert the anesthesiologist to avoid injury to the dura as the cranial defect is entirely exposed. Dura defect are repaired with water tight sutures or with pericardial fossa per cranial incision is made near the defect margin and reflected about 1–2 cm away, in order to obtain good approximation of the cranioplasty plate 3–5mm of outer table of defect edge is often rimmed.

Post-operative care

There are different standards of practice in postoperative management of cranioplasty patients, some surgeons routinely place patients in intensive care settings for at least one night to monitor their neurological status closely. CT scan should be obtained postoperatively and subgaleal drain removed on postoperative day one. Cranioplasty is typically performed approximately three months after traumatic brain injury. Early cranioplasty after 5–8 weeks may aid recovery. Several reports indicate that communicating hydrocephalous occurs at a high incidence after decompressive hemicraniectomy. Early cranioplasty combined with implantation of programmable shunt improved patient outcome and reduced complications.

Surgical procedure

The incision is done at the site of the previous scar or may be performed on a new flap of scalp in order to avoid ischemia and for cosmetic reasons, hemostasis and dissection of scalp layer separation of native bone edge from the dura, and to avoid dural injury. Followed by insertion of monomeric implant and fixed in periosteal layer by using absorbable suture material such as vicryl (1/0) to hold cranioplasty plate in position. Subgaleal drain is placed and the flap closed in two layers. Improvement in neurological status after early cranioplasty depends on restoration of normal CSF. flow dynamic. Monomeric acrylic implant designed preoperatively in dental laboratory molding on the bone defect and sterilized by using cidex (activated aldehyde solution) sterilizing and disinfecting solution, for at least one day before surgery. In our study the complications reported during the follow-up study are: low wound infection (1), seizure (2), dizziness (1) (Fig. 4). Steps of preparation Monomeric Acrylic Implant in Dental Laboratory.

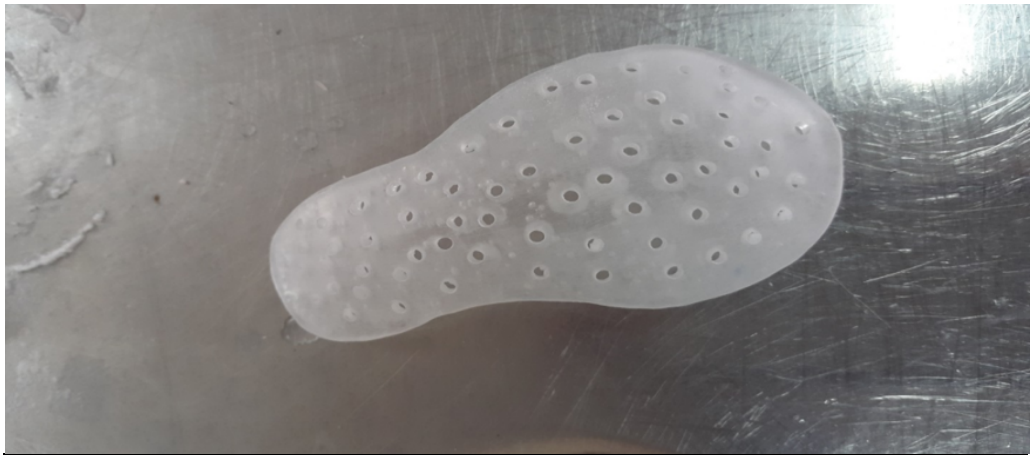
Step (1) Make marker on edge of skull defect.

Step (2) Place the molding on the skull defect

Step (3) Prepare the powder and solution of monomeric acrylic

Step (4) Mix the two formula in molding

Step (5) Molding of implant according to skull defect



Step (6) The implant ready for surgery.

Result

A total of 64 cranial defect patients presented with skull bone defects – 48 males (75%) and 16 females (25%).

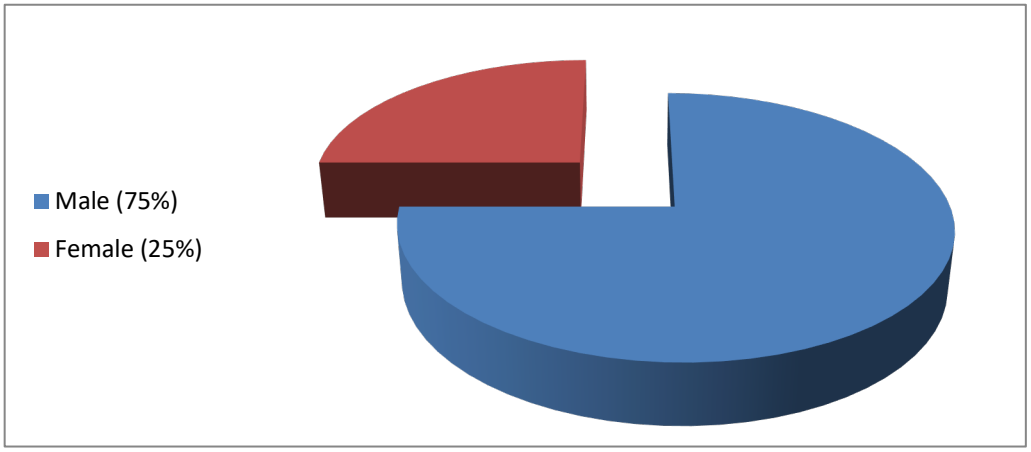


Figure 5. Males to Females ratio 3:1.

There were a total of 26 patients (41%) with head trauma due to road traffic accident, out of which 18 were males (28.12%) and eight were females (12.5%); 19 (30%) bullet injuries of which 17 were male (26.56%) and two were female (3.12%); seven (11%) presented with head trauma due to a fall from height of which five were males (7.81%) and two were females (3.12%); five (8%) presented with head trauma due to fan injury of which four were males (6.25%) and one female; (1.56%), four (6%) presented with encephalocele with skull defect all of them males; three cases (4%) with skull defect due to brain tumor (meningioma) of which one was male (1.56%) and two were females (3.12%).

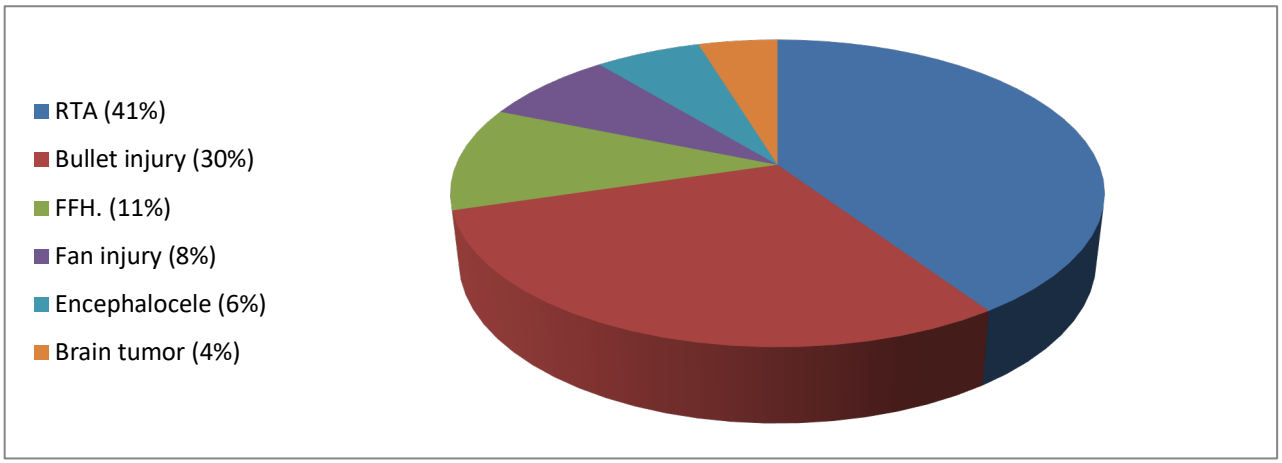


Figure 6. Percentage of Etiology in cranioplasty regarding age distribution. Less than 10 years…(8) patients,11–20 years (13) patients, 21–30 years (19) patients, 31–40 years (15) patients, 41–50years (9) patients.

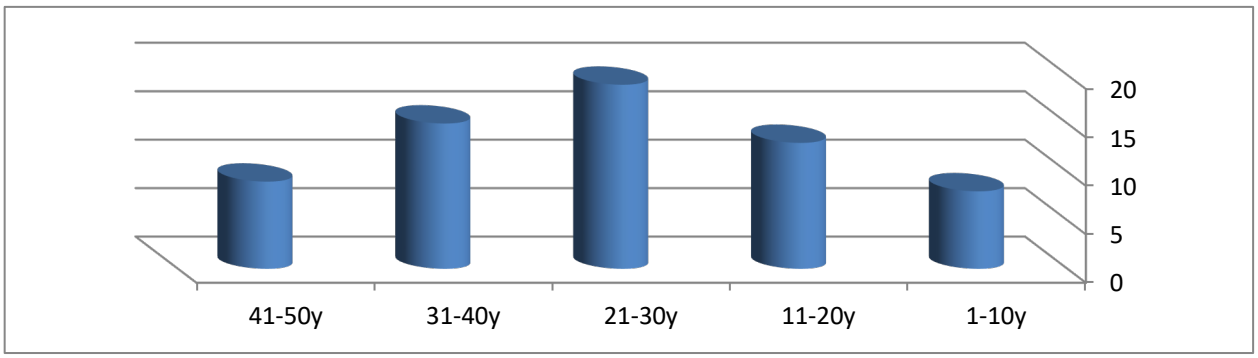


Figure 7. Number of patients according to age distribution. Regarding presentation of patient: 40 patients (62%) present with headache, 14 patients (21.8%) present with generalized fit, 10 patients (15.62%) present with body sided weakness. Total 64 patients presented skull defect.

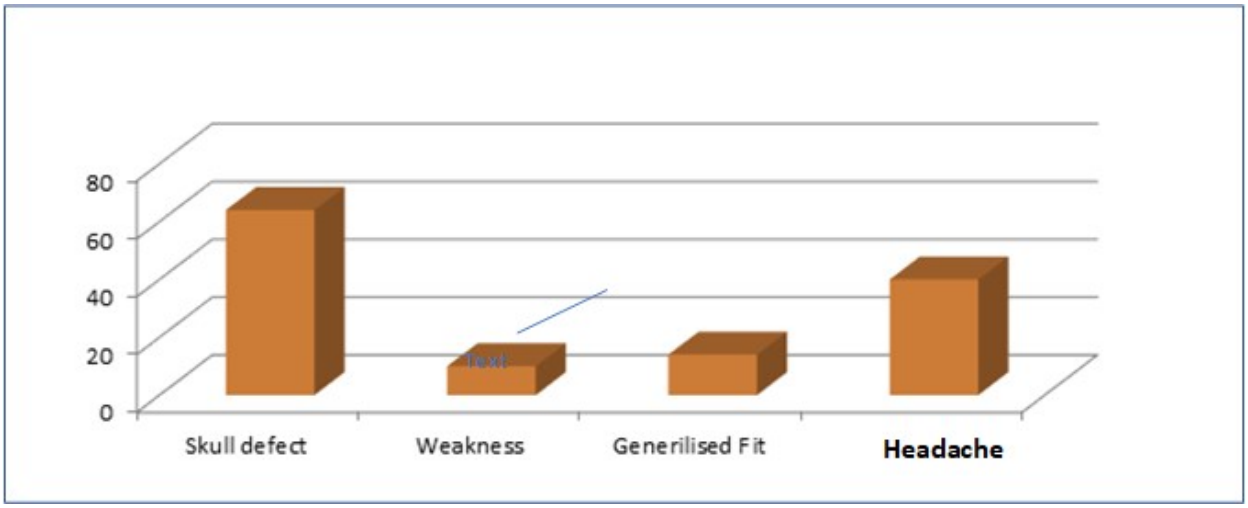


Figure 8. Presentations of patient in cranioplasty. Regarding site of skull defect: Frontal (20) 31.25%, Frontotemporal (4) 6.25%, Temporal (22) 34.37%, Temporal-parietal (13) 20.31%, Occipital (5) 7.81%.

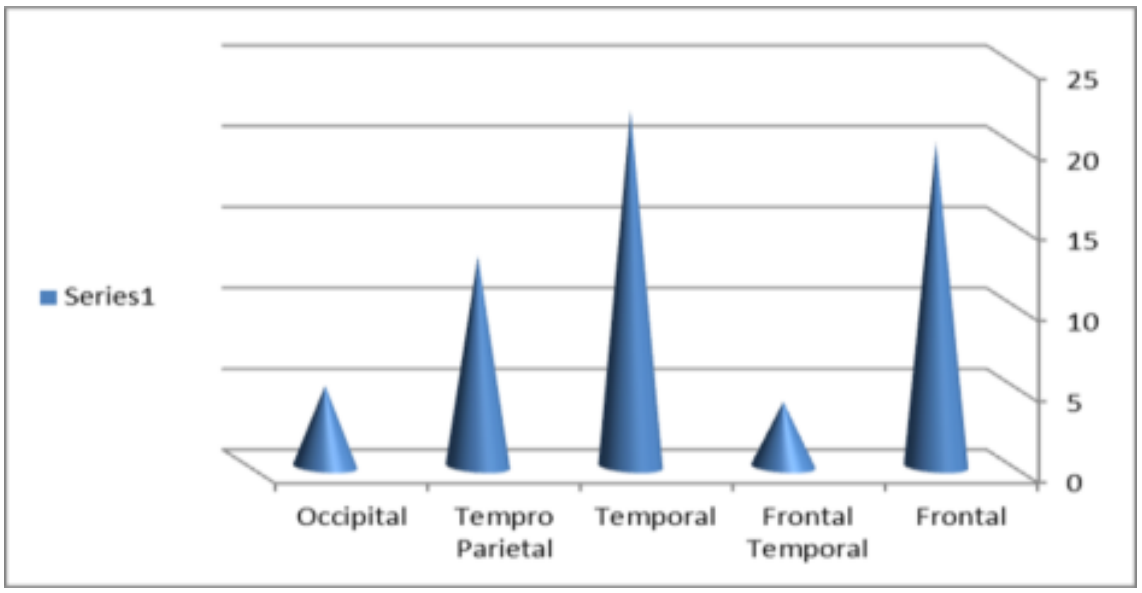


Figure 9. Site of cranial injury.

Regarding complications of surgery due to monomeric acrylic implant, the complications are low. Apart from post-operative wound infection (1) cases 2%, seizure (2) cases 3%, dizziness (1) 2%. In fact, the headache may persist as a result of post-operative complications in craniotomy. Mechanism of neurological recovery after cranioplasty is unclear, but this improvement is an important indication for the cranioplasty procedure.

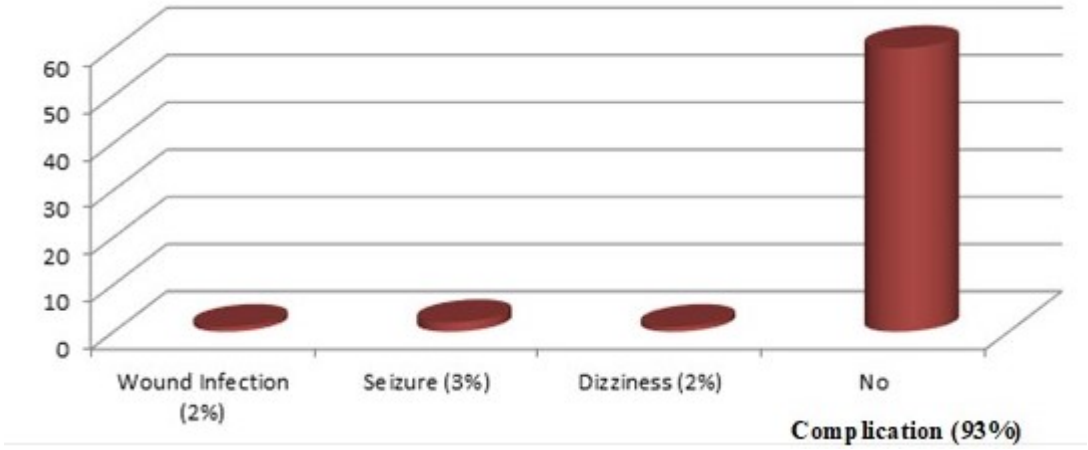
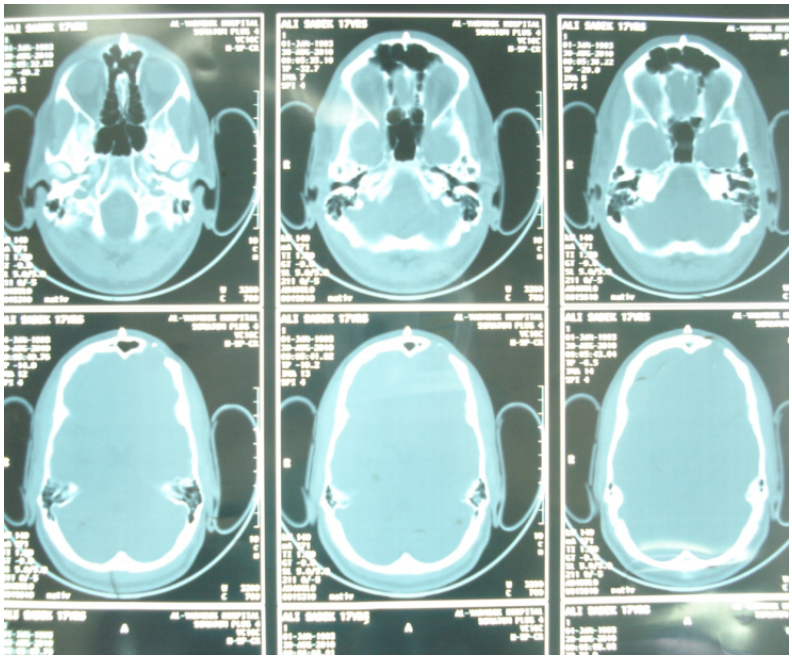
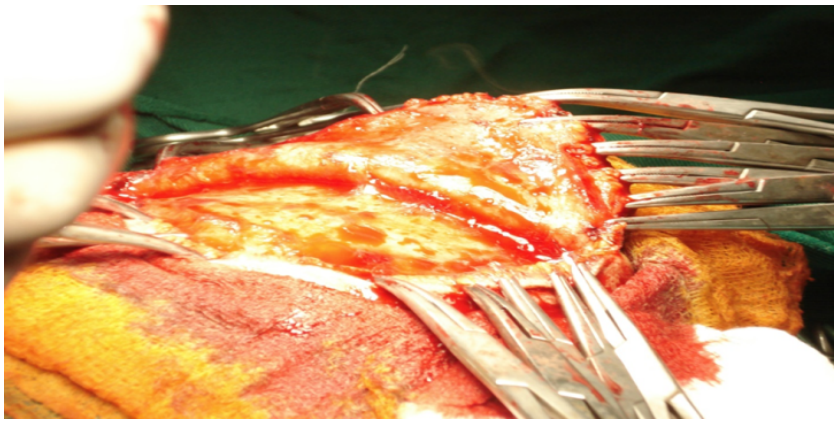


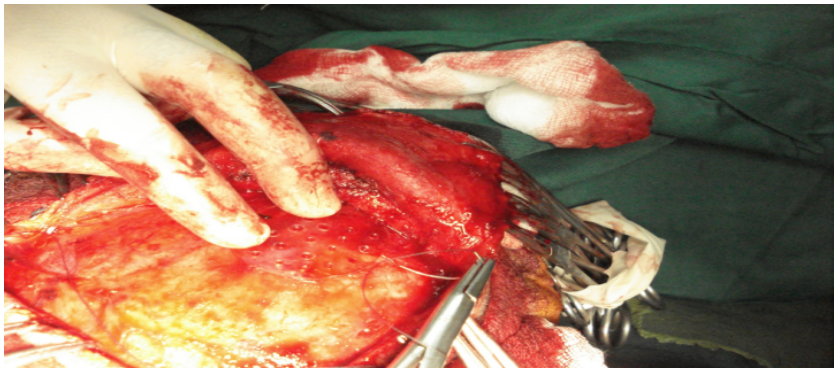
Figure 10. Postoperative complications.



Brain CT scan showing bone defect in left frontal area due to previous trauma



Intraoperative exploration of bone edge



Monomeric implant fit on the cranial bone defect.

DISCUSSION

The monomeric acrylic implant is considered as the most compatible material as it can be easily used and prepared in dental laboratory, is cheaper, more lightweight, radiolucent, not thermally produced, malleable, sterilizable, and non-magnetic. Regarding the most common cause of cranial defect, which needs repair by cranioplasty, 10 cases presented with compound depressed fracture due to head trauma, three cases presented with skull defect resulting from brain tumor and four cases presented with osteomyelitis.[15] In our study, the common causes of skull defect in 64 cases with cranioplasty was mostly due to road traffic accident—26 patients (41%) 18 males (28.12%) and eight females (12.5%); 19 patients with bullet injury (30%)—17 males (26.56%) and 2 females (3.12%); seven FFH patients (11%) five males (7.81%) and two females (3.12%); five patients with fan injury (8%)—four males (6.25%) and one female (1.56%); four patients with encephalocele (6%)—four males(6.25%); three patients (4%)—one male (1.56%) with osteomyelitis and two females (3.12%) present with meningioma and osteoma. The age distribution range from 1–50years with mean age of 26 years were treated. Average time between craniotomy and cranioplasty is typically performed approximately three months after traumatic brain injury. Early cranioplasty after 5–8 weeks may aid recovery.[16] In our study, median time of cranioplasty surgery is 18 months, with range of 12–24 months. In other studies of 51 patients, cranioplasty is conducted using methyl methacrylate, the sites of skull defect frontal (8) cases, frontotemporal (7), temporal (12), tempro-parietal (21), occipital (1).[17] In our study frontal (20) 31.25%, fronto-temporal (4) 6.25%, temporal (22) 34.37%, tempro-parietal (13) 20%, occipital (5) 7.81%. The auto polymerization of methyl acrylate during its preparation can cause thermal damage to underlying brain due to its exothermic reaction.[17] While in our study, the monomeric acrylic implant designed in dental laboratory before surgical procedure, using dental molding and the sterilization of this material by using of cidex (Activated aldehyde solution Sterilizing Disinfecting solution) for one day before the surgery and used directly to fit cranial defect without any thermal reaction, then fixed on the region of defect intra operatively, suturing it in the periosteum by using absorbable suture like vicryl 1/0. The time required for operation in monomeric acrylic implant is shorter in other materials of cranioplasty. The postoperative complications include infection, bone resorption, poor cosmoses in autologous bone. In methyl methacrylate complications include infection, plate fracture, no growth potential, inflammatory reaction, calcium phosphate bone cement complications include brittle and fragile, difficult to contour, can't bear stress. Titanium mesh complications include high cost, poor malleability, possible poor cosmoses, looseness over time image artifact on magnetic resonance images and computed tomographic scans rendering resolution of adjacent tissue difficult.[16] While the complication in Monomeric implant is low infection or wound infection post operatively, good cosmoses, no fracture plate, low cost, malleable, sterilizable and decrease the headache, postoperative seizure (2) cases 3%, wound infection (1) case 2%, and dizziness (1) case 2%, postoperative neurological recovery is important indication for cranioplasty.

CONCLUSIONS

(1) The most common causes of skull defect are road traffic accidents, bullet injuries, falls from height, fan injuries, and less cranial defects in congenital encephalocele and brain tumors. (2) Cranioplasty is required more for males than females because the head trauma is higher in males. (3) It contributes to neurological recovery with excellent cosmoses and no inflammatory reactions as well as low infection rate; so, it is economically superior.

RECOMMENDATIONS

Monomeric acrylic is the ideal synthetic material for cranioplasty and is relatively safe, provides an acceptable aesthetic reconstructive option and contributes to neurological improvement in the treatment of cranial defects. The monomeric acrylic implant can be prepared easily in dental laboratory, with an easy and short surgical procedure.

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