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TITANIUM CRANIOPLASTY BY 3D PRINTING OF SKULL DEFECT AFTER DECOMPRESSIVE CRANIECTOMY (DECRA)

Neurosurgery

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ABSTRACT

INTRODUCTION: All cases of decompressive craniectomy (DECRA) eventually require second surgery for cranioplasty. Most people believe that cranioplasty is only for cosmetic purpose but the primary goals of cranioplasty after DECRA are to protect brain, achieve a natural appearance of head and to prevent sinking skin flap syndrome. **METHODS:** Thirty two patients underwent cranioplasty with computer assisted titanium models. With the aid of visual analogue scale (VAS), patient's pain, cosmesis and related complications were evaluated for 6-24 months after titanium cranioplasty. **RESULTS:** None of the implants had to be removed. Of all the patients, 65% declared their outcomes as excellent, 25% as good, 10% as fair and zero percent as poor. There was no resulting pain in 86% of the patients and 92% were satisfied with cosmetic results. Only 2 patients developed CSF leak which subsided by conservative means. Temporalis muscle atrophy was most prevalent complication compromising the cosmetic outcome. **CONCLUSION:** Complications associated with cranioplasty are variable, however post-surgical infections and temporalis muscle atrophy is most common. Many new materials and techniques can result in different outcomes from different healthcare centres.

KEYWORDS

Decompressive craniectomy, Cranioplasty,Titanium.

INTRODUCTION

Cranioplasty refers to restoration or correction of a defect or deformity of skull bone. Trauma, Infections, neoplasm and congenital causes like encephalocele, meningoencephalocele, large parietal foramina, aplasia cutis congenita, cranium bifida, sphenoid wing defects are few causes of cranial defects which require cranioplasty. A satisfactory cranioplasty should employ an on lay technique with a simple method of attaching prosthesis to the skull. The material used should be inert to the tissues, radiolucent, easily and accurately shaped, capable of being adjusted at the time of insertion and should have mechanical strength to resist fracture or deformation under severe impact loading. After[1] 1914- 1918 war autogenous bone was the material of choice for cranioplasty, but repair of large defect requires a major operation to harvest the graft. Reproduction of the correct skull contour often proves difficult, and the patient often has postoperative pain from donor site than grafted site. Some of skull defects from the 1939-1945 were repaired with auto polymerised acrylic resin plates. Spence (1954) described form fitting plastic cranioplasty in which the plastic was moulded into the defect during hardening process. When the defect is large, however, a smoothly contoured plate is difficult to shape and fit accurately. Metals and alloys including tantalum, titanium, stainless steel and chrome–cobalt are not widely used because of difficulty in forming the plate to the compound complex curvatures of the skull. For treating smaller defects plastic or metal or bone grafting usually proves satisfactory, larger defects however create special problem of contouring and fixation which is difficult to sort out by any of the available techniques.

Ideal time of cranioplasty to be done is 3 to 6 months after compound wound, one year in case of wound infection or if frontal sinus is opened, 3 months with autograft or after 1 year in paediatric patients. Few contraindications to procedure include hydrocephalus, cerebral oedema, infection, compound wound and contiguous functional sinus.

Critical size of defect is defined as, defect of more than 2cm over cerebral convexity or defect of glabrous frontal region. There is no need of repair in defects below the temporal and occipital muscles, very elderly patients and in children less than 6 years of age where dura is not damaged. Paediatric cranioplasty is done in children above 3yrs of age after waiting period of 1 year. Autogenous bone is preferred in children, however, alloplasty is not done in children less than 8 years of age. In infants even split bone grafts are not indicated.

An ideal material for cranioplasty should be malleable, easy to sterilise, strong, light weighed, easily securable, non-ferromagnetic, inexpensive, biocompatible, chemically inert, radiolucent and should be readily available. However at present no such material exists. In our study we used titanium as graft material which is non-corrosive, radiolucent, light weight, fatigue resistant, non-allergic, biocompatible with thermal expansion similar to bone and undergoes minimal fibrous encapsulation.

OBJECTIVE

The aim and objectives of the study was to analyse associating factors and clinical outcome of titanium cranioplasty after DECRA.

METHODOLOGY

A prospective clinical study was done during the period of June 2016 to June 2019. In this study all the patients were pre-operatively clinically assessed and non-contrast computed tomography (NCCT) of head with 3D reconstruction of skull was done. All the patients above 18 years of age with skull defects due to traumatic depressed fracture, DECRA or after enblock meningioma excision were included. However, those less than 18 years of age with associated hydrocephalus, infection, compound wound or open sinus were excluded. Patients underwent titanium cranioplasty around 3 months to 2 years after the first surgery and were followed up for next 6 months. Factors analysed were aetiology of defect, potential complications, aesthetic outcome and patient's satisfaction. Patient's satisfaction was analysed by Likert's scale. Clinical outcome was analysed by Glasgow coma scale (GCS), scar visibility and cosmetic improvement by visual analogue scale (VAS).

All the patients with cranial defect underwent 0.5mm cuts of skull defect and 3D reconstruction of defect was done by software. Based on reconstruction images afibre material model of skull delineating defect is created. Afterwards a model of titanium plate or mesh of accurate cranial contour is developed by software. This titanium mesh or plateis applied over the defect by surgery and fixed with screws.

Preparation Of Cranial Defect: After ensuring cleanliness of surgical bed and rich vascularisation of both the surgical bed and overlying flap, sinuses were exenterated and pericranium brought up as second layer, keeping the pedicle intact. Bony edges were freshened and haemostasiswas maintained. Absolute haemostasis and maintenance of dural integrity is key to success.

RESULTS

Thirty two patients were included in the study with mean age of 36.5 years. Male: Female ratio in our study was 3:1. Twenty patients had cranial defect following depressed fracture, eight due to DECRA, two due to traumatic loss of bone and two following enblocktumour excision.

In the follow up period, temporalis muscle atrophy was observed in eight patients leading to cosmetic compromise. Two patients presented with CSF leak which was managed successfully by conservative means. None of the patients presented with wound infection, plate

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exposure, post operative haematoma, seizures or with displacement of plate.

It was observed that following the procedure ninety two percent of patients were aesthetically pleasant. There was minimal scar visibility and significant clinical improvement. All the patients were satisfied or highly satisfied as documented on Likert scale.65% patients reported excellent outcome, 25% good, 10% fair outcome and none of them reported poor outcome. Also 86% patients had significant improvement in the pain.

Figure 1

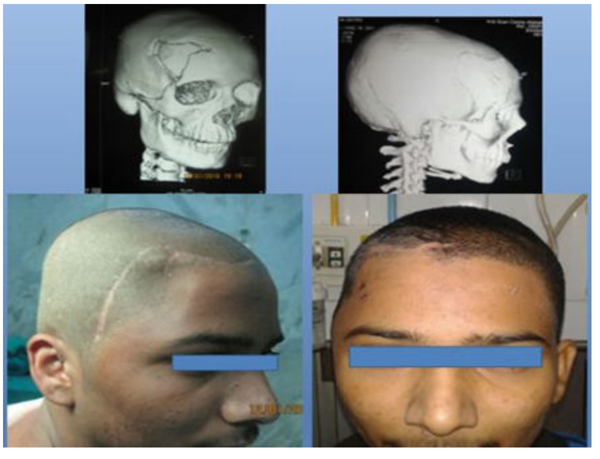

Figure 2

Figure 3

Figure 4

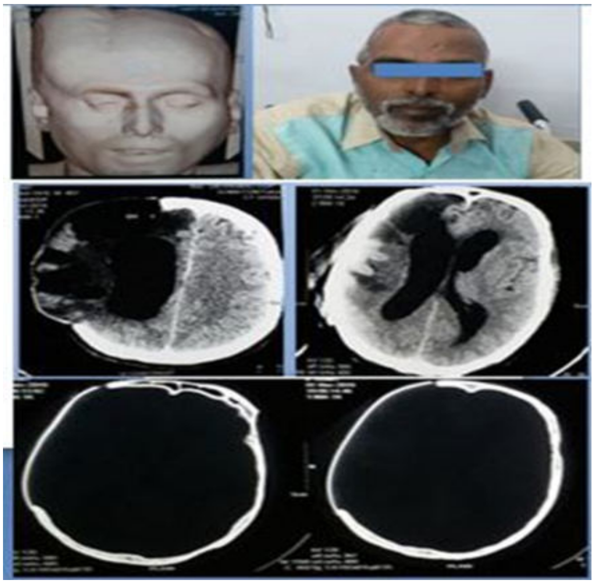

Figure 5

Discussion

Thirty two patients with skull defect were included in thisstudyand reconstruction of skull defect (cranioplasty) with titaniumwas done. Apart from cosmesis, primary goal of cranioplasty is protection of brain and prevention of sinking skin flap syndrome.

Studies suggest that cranioplasty contributes to neurological recovery in craniectomy patients. Neurological signs and symptoms of the patient with post-craniectomy[2] defect may be due to traumatic brain injury or the absence of bone. The lack of bone is related to changes in the circulation of cerebrospinal fluid, direct effect of atmospheric pressure compressing the cortex, and to the reduction of venous return caused by the obliteration of the subarachnoid space[6]. Almost all patients surviving a decompressive craniectomy require cranioplasty, the complications of this second operative intervention should be acknowledged. Most reports in the literature regarding cranioplasty have focused on technical aspects of the procedure and have not emphasized overall surgical complications.

complications	Our study	Noufal Basheeret al[3]	Zanaty et al[4]	Broughton et al[5]
over all complications	35.5% CSF leak(25%) Temporalis atrophy(12.5%)	62.5 %	31.32%,	30%
Over all infection	None	22.7%	26.43%	10.3%
Hematoma formation	None	5.2%	6.90%	6.82%
Reoperation	None	61.5%	None	None
Death	None	None	3.16%	2.3%

Other than autologous bone(craniotomy bone flap), Polymethylmethacrylate (PMMA) eitherhandformed orprefabricated, titaniumPlate and mesh,hydroxyapatite (HA), polyetheretherketone (PEEK), polyethylene (PE) and calcium Phosphateis used as cranioplasty material.[8]

Titanium is considered the most compatible material and can be easily integrated in the human body.Another property of titanium is the non-ferromagneticnature whichmakes it MRIcompatible.Titanium dynamic mesh prosthesis covers the whole area and is perfectly connected between bone and the basal region of bifrontal convexity. Because of its natural osseo-integration factor, it promotes active bone growth into the implant.[9]

In our study we noticed 25% of patients had temporalis muscle atrophy, 12.5% patient had CSF leak and none of the patients needed re-exploration, had wound infection, plate exposure, post-operative haematoma, seizures or displacement of implant. 92% patients were aesthetically pleasant and had minimal scar visibility.

Maricevich et al[6]using PMMA implants reported that infection rate was 3.2%, 4.8% of extrusion, 1.6% of prosthesis fracture, 7.9% of extradural haematoma, 17.4% of reoperation, 5% of wound dehiscence and 4.8% of prosthesis removal.

Our study supports the statementby Cabraja et al[10]that CAD/CAM titanium implants provide the lowest rate of complications, reasonable cost, and acceptable post-operative imaging. Polymethylmethacrylate (PMMA) is suited for primary cranioplasty (at the time of first surgery) or for long-term follow-up imaging of tumours. Titanium implants seem to be the material of choice for secondary cranioplasty (second surgery) of large skull defects resulting from decompressive craniectomy after trauma or infarction. Expensive HA-based ceramics show no obvious advantage over titanium or PMMA.

3D reconstruction of skull defect using platinum is a technique with functional gains improving aesthetic appearance and quality of life of patient with least complications and better results but a costly affair.

Conclusion

In the study, we concluded that titanium cranioplasty is an effective procedure for reconstruction, however, there are various complications associated with the procedure that includes, temporalis muscle atrophy which is the most common cause of cosmetic compromise and CSF leak or infection which is less prevalent.Cosmetic results are best over convexities however poor over temple region.The procedure is a costly affair and it's a dictum that, earlier the cranioplasty, better the results.

Thus, further studies and trials need to be done on exploring possibility of using bone morphogenic protein (BMP), recombinant BMP, PDGF, EGF and IGF as ideal graft material.

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