



Single Stage Cranioplasty Following Benign Calvarial Tumor Resection using Anatomised Three Dimensional Printed Model

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Abstract

In prehistoric era archeological evidences suggest that cranial defect (Trephination) reconstruction was done with gold, silver and shells. The next advancement was the use of bone grafts in late 19th century. In 20th century alternative of bone graft, metals and plastics were used. Cranial reconstruction can be done by autografts, allografts, distinct biomaterials, and even osteoinductive growth factors. Polymethylmethacrylate (PMMA) is one of the most popular materials used for cranioplasty. But attainment of desired shape, size and cosmesis is difficult. This problem can be solved with the help of 3 dimensional printing technology, using prefabricated model (template) to prepare implant preoperatively. In this case report, we developed a computer-generated model (template) using the 3D Object printer. A mould (template) was created and it was used intra-operatively to produce a PMMA-alloplastic cranial implant that was well fitted into the anatomical defect. A well-fitted implant improves cosmetic outcome, self confidence and reduces the risk of implant movement or extrusion. 3D printed model helps us to provide exact dimensions of the bony defect along with good cosmesis, accuracy and strength of the anatomic replacement.

Keywords: Skull bone tumor; Single stage Calvarial reconstruction; 3D model (template); Poly methyl methacrylate

Introduction

Cranioplasty is the surgical repair of acquired or congenital defects of cranium [1]. Archeological evidences suggest that in pre historical era, cranial defect reconstruction was done with gold, silver and shells. Later it was followed by the use of bone grafts, metal and plastics [2,3]. Apart from metals like titanium, Poly Methyl Methacrylate (PMMA) is the latest material being used for cranioplasty. It was first utilized in 1940 and can be moulded intra operatively by hands or using 3D printed models into the shape of a cranial defect [4]. Prefabricated Titanium implants have been successfully solving this purpose of cranioplasty, but are quite expensive especially in developing countries. In modern era, for getting desired shape, size and better cosmetic results, the use of Three-Dimensional (3D) printing technology has come into existence with evolution of this technology; its application has expanded, to various aspects of surgeries especially craniofacial. Implants can be prepared intra operatively by PMMA, with the help of 3D moulds which are generated using 3D printer technology. These are quite cost effective and a good alternative to costly titanium implants. In our case, we developed a computer-generated model (template) using the 3D Object printer. A mould (template) was created and it was used intra-operatively to produce a PMMA-alloplastic cranial implant that was well fitted into the anatomical defect. A well-fitted implant improves cosmetic outcome, self confidence and reduces the risk of implant movement or extrusion. The 3D printed model helps us to provide exact dimensions of the bony defect along with good cosmesis, accuracy and strength of the anatomic replacement.

Case Presentation

A 13 years female presented with complaints of painless, slowly progressive, bony hard swelling in the right parietal region since one year. On examination swelling was fixed, bony hard, immobile with ill defined margins, non pulsatile and non tender. It was approximatey 5 cm x 5 cm in size. CT brain with 3D reconstruction suggested of osteolytic bony tumour reaching to the midline (Figure 1). MRI brain was suggestive of no dural or any parenchymal invasion (Figure 2). Patient was planned for single stage excision of calvarial mass and reconstruction. Pre operatively a 3D model (template) was constructed using 3D CT brain. 3D printing technology used to manufacture the

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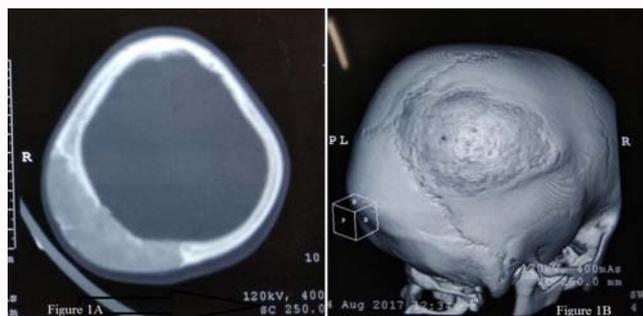


Figure 1: (A+B): Non contrast CT Brain with 3D reconstruction - showing osteolytic expansile calvarial lesion involving right posterior parietal bone extending to sagittal and lamdoid suture with intact inner table.

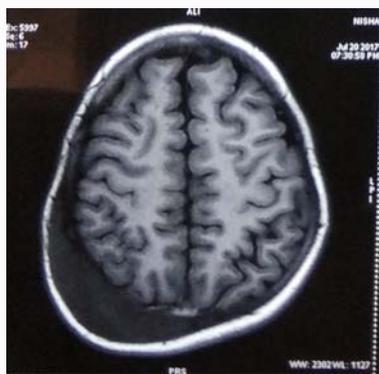


Figure 2: MRI Brain - T1W image showing extradural right parietal bony lesion with no infiltration of brain paranchyma.



Figure 3: Per operative excised bony tumor *in situ*.

model (template) was “Selective Laser Sintering (SLS)”. The material used was nylon pa 2200 which is biocompatible and autoclavable. Intra operatively the area of resection was outlined with the help of previously prepared template, but the area of resection was crossing midline. To prevent sinus injury craniectomy was done leaving some tumor tissue in midline which was later removed via bone nebular. Tumour free margin was achieved and it was reassessed with the help of template (Figure 3). The calvarial graft was prepared using poly methyl metha acrylate (bone cement). This alloplastic graft was moulded in exact dimensions and evenly distributed thickness by using previously prepared 3D printed model. The graft was re analyzed and margins were drilled to make them non traumatic. It was applied on the cranial defect and fixed with the help of titanium miniplates (Figure 4). Exact shape and contour of parietal bone was achieved as that of the opposite side (Figure 5).

Discussion

The history of cranial reconstruction goes back to 3000 BC, where archeological evidences suggest that head trephination repair was done with the use of metals, shells, and gourds. In subsequent years the practice of cranioplasty was done by using moistened linen, which was applied over wounds and regular dressings were performed to promote wound granulation [4-8]. In 1505, the Ottoman surgeon Ibrahim bin Abdullah published the first case of cranioplasty in his book, “Wonders of Surgeons” and he used canine-derived xenografts. In 1668, a Dutch surgeon Job Janszoon van Meekeren reported the first successful bone graft cranioplasty [9,10]. Autogenous bone grafts are preferred over alloplastic materials to reconstruct the cranial defects. Alloplastic material is required when autogenous bone is not available as in calvarial tumour resections, bone infections or bone discarded during craniectomies. Now a day’s PMMA and titanium are most widely used alloplastic materials. Preparation of implants can be done in two ways - by hands and by computer generated 3D models [11,12]. Hand fabrication is cheaper and less time consuming technique but desired outcome with respect to shape and size is difficult. The 3D printing technology helps us to prepare prefabricated implants or models to mould grafts intra operatively. This method has become immensely popular as it does not require original bone flap and has produced superior fitting and cosmetic results [13]. 3D printing technology is an evolving branch and its clinical application is growing rapidly. The convenience and affordability of this technology have spurred its adoption in variety of medical fields, especially in planning complex craniofacial reconstructions [14,15].

The procedure for the fabrication of medical models (templates) consists of multiple steps:

- Acquisition of high-quality volumetric 3D image data of the anatomical structure to be modeled.
- 3D image processing to extract the region of interest from the surrounding tissues.
- Mathematical surface modeling of the anatomic surfaces.
- Formatting of data for rapid prototyping.
- Model building Quality assurance of the model and its dimensional accuracy [6,7,8].

Pre operatively computer generated models are very helpful in management of large full thickness defects of cranium. These large defects preclude the use of autogenous tissue for reconstruction and also pose difficulty in shaping the bone graft. In these cases computer generated models allow pre operative analysis and perfect shaping of the alloplastic implants. Advantages include less operative time and simplification of procedure.

Conclusion

Hand-fabrication of PMMA prostheses is an excellent alternative but it does not provide desired cosmetic results especially in large cranial defects such as following decompressive craniectomy or after excision of calvarial tumors. Prefabricated Titanium implants that are generated with the help of 3D printing technology are costlier. To solve this problem, PMMA mould was prepared intra operatively using model or template developed preoperatively by same

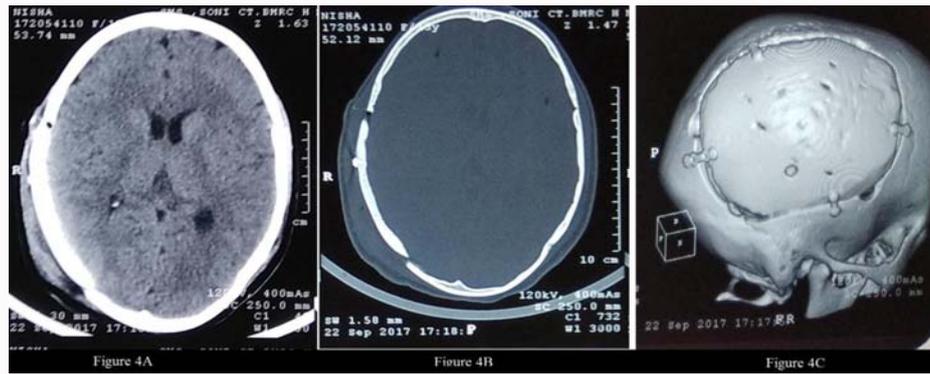


Figure 4: (A+B+C): Post operative non contrast CT brain with 3D reconstruction– Properly fitted calvarial graft in situ fixed with titanium plates.



Figure 5: Anatomised 3D model (Template).

technology. It provides same cosmetic results and is quite cheaper. Hence this technique has proven to be safe and has yielded excellent results with cost effectiveness.

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