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ROLE OF 3D PRINTING TECHNOLOGY IN PLASTIC SURGERY

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ABSTRACT

Pre operative assessment and planning is essential part of plastic surgery practice. As many patients present to the plastic surgeon with defect or deformities are concerned about their functional and cosmetic outcomes hence accurate planning is necessary for optimum result in plastic surgery. Conventionally visual assessment and two dimensional pictures were used for pre operative planning. Later 3-D CT scan was used for planning and mock surgery of complex craniofacial deformities. Limitation to this modality is that the planning was limited to computers and there is no physical model for better understanding. 3D printer has remove this limitation and physical model printed from 3D printer provides better understanding and assessment of craniofacial deformities. Through this article we present the use of 3D printing technology in pre operative planning of complex craniofacial deformity.

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INTRODUCTION

3D printing refers to a process used to synthesize a three dimensional model from a 3D model or other electronic data source. It uses successive layers of material under computer control to create a physical model. Additive manufacturing (AM) is another term which is broadly used for 3D printing [1].

Printable models are created by computer aided design (CAD) via digital camera or 3D scanner and photogrammetry software. CAD is helpful in reduction of errors and also one can crosscheck multiple times before final print. The medical imaging data stored in the form of 3D CT scan or ultrasound can be used for printing. The data is converted in to CAD by using medical software Mimics or 3D doctor. A 3D model from STL (STereoLithography) file format is examined for errors before printing. The 3D modeling software slices the final model into several horizontal layers and produces a G code file to prepare a digital file. The sliced file is uploaded in a 3D printer, the G code file is used by 3D printer to create and the objects layer by layer [2].

Formation of physical model by 3D printer may take several hours to days depending on the size and complexity of the object to be printed.

Need of 3D printer in plastic surgery

Complexity of deformities, high expectations of the patients and surgeon's responsibility to provide both form and function makes the management more challenging. Plastic surgery is a branch where pre operative planning is as important as surgery itself. Practice of surgery is traditionally performed on animal models, mannequins, simulation models or virtual surgery [3, 4]. There are several limitations of such modules as most of the deformities cannot be learned in animal models and due to case to case variations it may not be possible to learn all the steps in conventional mannequins. 3D

reconstructed image software and virtual surgery can help in planning the surgery but again it is limited to computers and is not suitable for assessment of post operative outcome. Physical models created from 3D printer can solve these problems as it provides exact template of the deformity. It can be utilized for learning the nature of deformity, performing the procedures (mock surgery) and assessing the post operative outcome after proposed surgery.

Methodology

3 year old child attended outpatient department of plastic surgery with complaints of deformity of face and skull. She underwent ventriculo-peritoneal shunt at 2 years of age for raised ICT by neurosurgeons. On examination she was diagnosed as a case of Crouzon syndrome with Bicoronal craniosynostosis (Figure 1a, 1b). Patient was thoroughly evaluated to rule out other congenital anomalies. Necessary investigations were done and patient was found to be fit for anaesthesia. Skull remoulding surgery (Cranioplasty) was planned by fronto-orbital advancement. Pre operative assessment and surgical planning was performed by physical model obtained from 3D printer. First 3D CT scan of skull and facial bones was done. The CT images were obtained to develop CAD design. The CAD design was converted to a stereolithograph (STL) model. The obtained model of the skull was depicted. The deformity was assessed again on the printed 3D model and operative planning was performed. Mock surgery of Front-orbital advancement was done in the model to plan the surgical steps and to assess the post operative outcome (Figure 2). The sites of osteotomy, number of ostoetomies and the amount of advancement needed were recorded at the time of mock surgery. Satisfactory outcome was noticed after fronto- orbital advancement of the model. Now the child was prepared for surgery

under GA. Surgery was performed in the same way as in mock surgery.

Figure 1a: Showing Frontal view

Figure 1 b: profile view showing fronto temporal recession

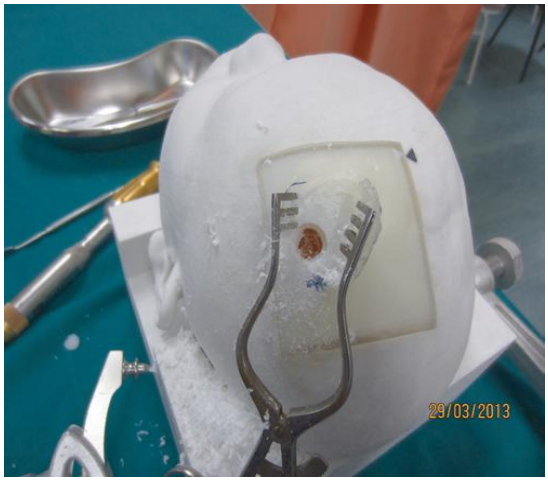

Figure 2: 3D printed model being used for mock surgery

Patient was positioned supine with head elevation. A Bicoronal zigzag skin incision was made (Figure 3). Skin flap was raised over bilateral frontotemporoparietal region (Figure 4).

Figure 3: Pre operative skin marking

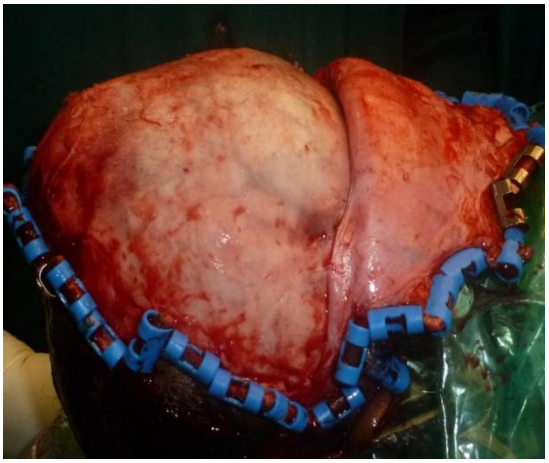

Figure 4: Showing raised skin flaps

Osteotomy incisions were marked by using Osteotomised bony pieces from the printed model (Figure 5, 6).

Osteotomy was performed over marked areas, frontal bandue and bilateral temoroparietal bones taken out (Figure 7, 8). Osteotomised bones were rearranged ex situ and fixed with mini plates and screws (Figure 9). Resulting recreated bony vault fixed to the skull with miniplates and screws at multiple points (Figure 10). Skin flaps closed primarily without tension (Figure 11).

Figure 5: Osteotomised piece from printed model being used for bony marking

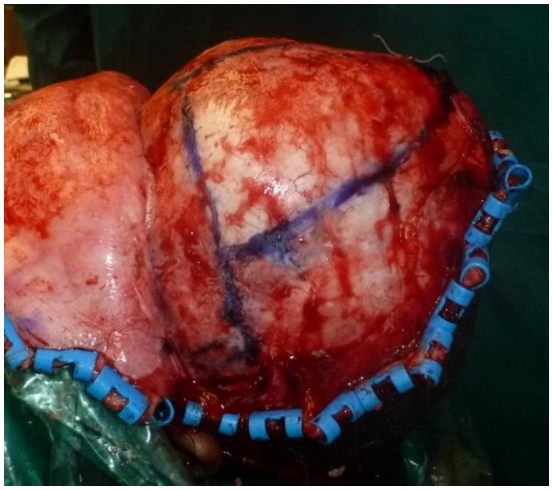

Figure 6: Showing complete osteotomy marking

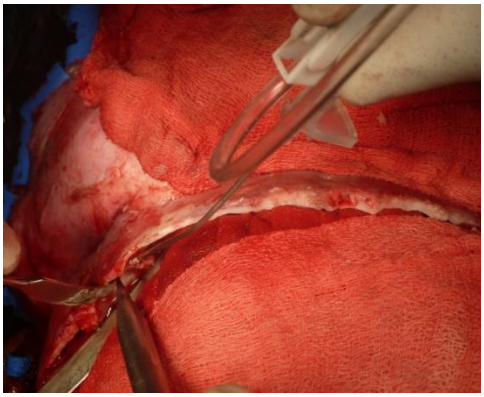

Figure 7: Frontal osteotomy being done

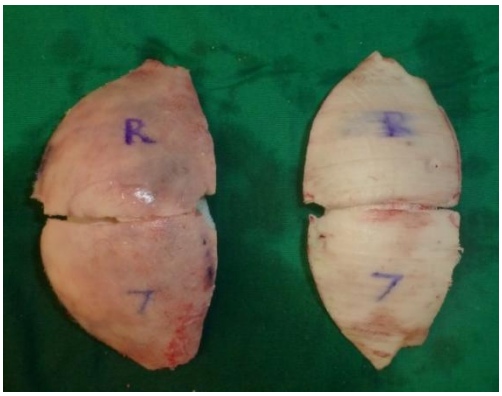

Figure 8: Temporo parietal osteotomy done

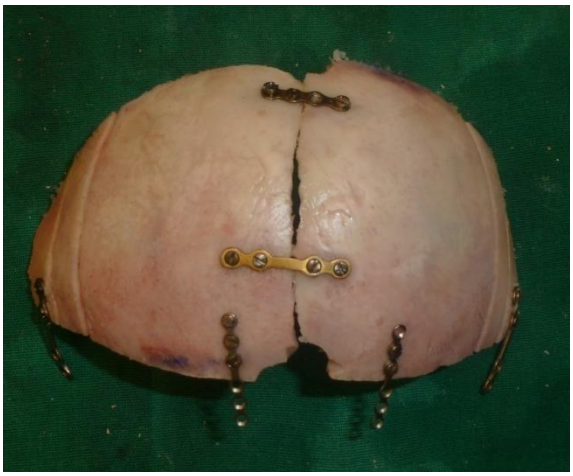

Figure 9: Osteotomised bones re oriented and fixed with mini plates and screws

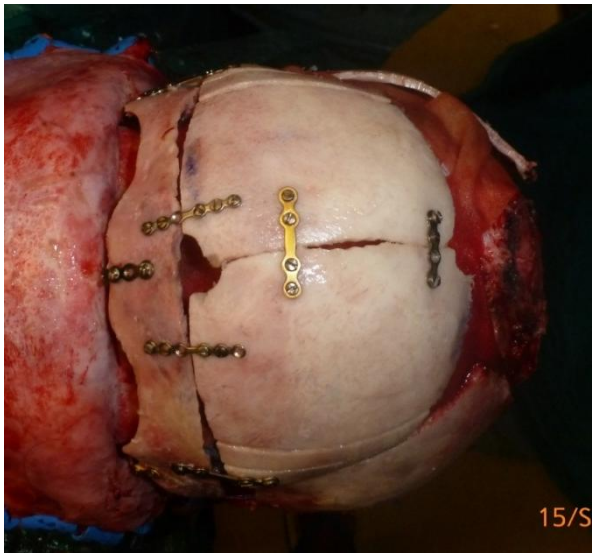

Figure 10: Showing bony vault fixed on the skull

Figure 11: Post operative picture showing significant fronto temporal advancement

Result

A good intra-operative correlation of the finding was observed between actual and the mock surgery. Procedure was completed without complications. Operating surgeon was more comfortable, intra operative planning was avoided and hence anesthesia time was reduced. Significant fronto orbital advancement was noticed post operatively.

Discussion

3D Printing (Rapid Prototyping) is the process of conversion from 3D Computer Aided Design (CAD) virtual models into physical models without the need for specialised tooling or fixtures. 3D printing was developed in 1980s. Hideo Kodama of Nagoya Municipal Industrial Research Institute developed two additive manufacturing fabricating methods of 3D plastic model in 1981 [5].

In 1984 Chuck Hull from 3Dsysttem corporation developed the design of STL(STereoLithography) file format which was found to be very useful to digital slicing and 3D printing technique [6]. In the mid 1990s Stanford and Carnegie Mellon University developed new methods of material deposition including microcasting and sprayed materials [7]

Additive manufacturing gained wider currency in 2000s as various additive processes were introduced and the term “Substractive manufacturing” was used for large family of machine processes where metal removal was common theme. However the term 3D printing is referred to polymer technologies [8].

In 2002 a working 3D kidney was created in animal model while the first 3D printed prosthetic leg was created in 2008. Later in 2009 Organovo used the first Bio 3D printer to prepare blood vessel. With the help of modern technologies, in 2011 University of Southampton engineers fly the first 3 D printed aircraft and later 3 D printed cars was

designed. First 3D printed prosthetic jaw was implanted in 2012.

Various types of 3D printers are

- Stereolithography(SLA)
- Digital Light Processing(DLP)
- Fused deposition modeling (FDM)
- Selective Laser Sintering (SLS)
- Selective laser melting (SLM)
- Electronic Beam Melting (EBM)
- Laminated object manufacturing (LOM)

Commonly used materials for 3D printing now a days are ABS (Acrylonitrile Butadiene Styrene) PLA (Polylactic acid or Polylactide) PVA (PolyVinyl Alcohol).

Uses of 3D printer in medical field

Printing patient specific implants, prosthesis and devices for medical use. Titanium pelvic implant was successfully performed followed by implantation of titanium jaw in a Belgian patient. Tracheal implant for infant, various hearing aids and devices, dental devices and implants, bioprinting and implantation of stem etc are other uses. Swansea's surgeons reconstructed face of a trauma victim by using 3D printed parts. Use of chemical inks to print medicines another use of 3D printing technology. Formation of exact replicas of organs form CT scan or MRI images. 3D print technology is also useful in the field of Education and research Conduction of mock surgery, surgical training and surgical practice. It is a relatively low cost investment in the training and education as it obviates the need of purchase of multiple simulation models for each body parts whereas a single printer can print any organ or body parts in any number [9, 10].

Uses of 3D printer in other fields

Industrial applications includes printing dresses, 3D printed jewelleries, 3D printed shoes for footballers, household items, on-demand customized glasses, making computers, laptops and robots [11, 12]. First 3D printed car was formed by Local motors in collaboration with Oak Ridge national Laboratory and Cincinnati incorporated. In

the field of Architecture and Construction this technology is being used to create physical models of samples. In Firearms industry in 2012, the U.S. based group designed a working 3D printed plastic gun. Latter in 2013 3D printed rifle and metallic gun were made. Various limitations of this technology are limited availability, limited prototypes, limited availability of multiple ingredients feeders and questionable acceptability

Conclusion

3D printing technology is an emerging concept in the field of plastic surgery. It is an important adjunct to simulation models for performing mock surgeries. Through this article we present use of 3D printer in planning strategy for complex craniofacial deformities. On literature review (internet search) no study has been reported from India on use of 3D printer technology for planning of Craniofacial Surgery. Our article demonstrates successful use of 3D printer in planning and management of complex craniofacial deformity. However a large sample study may be helpful to draw more significant conclusion.

Conflicts of interest- none

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