Conference Paper

3D Printed Medical Model to Resolve Cleft Alveolus Defect: A Case Study

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Abstract

3D printing or Additive Manufacturing (AM) technology has been in existence for more than 30 years. The footprint of this technology has been entered into almost each and every industry such as medical, dental, aerospace, construction, automobile, etc. One of the most benefited industries using AM is medical industry. In case of medical or maxillofacial surgical field, each and every patient has a unique anatomy. The traditional way of analyzing the patient anatomy was by using X-ray with single layer or CT scans with multiple layers information is available that too as soft data. 3D printing technology provides a physical model from virtual data of the patient anatomy using CT/MRI/CBCT information with the help of medical software. The physical 3D printed medical model is very useful for pre planning complex surgeries. The current case study is regarding a 35 years male patient, who presented with a defect in maxillary anterior alveolar region and nasal regurgitation of fluids. Based on chief complaint, history and clinical examination, a diagnosis of cleft alveolus was made. CT scan was advised to see the defect in all the 3 planes. The surgery was planned for reconstruction of the bony defect and to prevent escape of oral fluids into nasal cavity. Treatment planning and mock surgery were performed on the 3D printed medical model, which reduced about 30% of total surgery time thereby decreasing the complications.

Keywords: Additive Manufacturing, Cleft Alveolus, Medical model, Pre planning Surgery, Complex Surgery

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1 Introduction

Additive manufacturing is being used for various applications over the past 30 years. This technique is very useful and convenient for mass customization. This technology makes use of data from source such as Computed Tomography(CT Scan), Magnetic Resonanace Imaging(MRI), Cone Beam Computed Tomography (CBCT), Computer Aided Designs (CAD) or from any Reverse Engineering Techniques [1]. AM technology is now expanding its goal posts and its use is now increased in industries like automobile, aerospace, dental, medical industries [2,3]. AM is one of the recognized technologies

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for providing customization for patient specific implants in the medical industry. This is very important in medical application because in every case, anatomy differs and so requires tailor made solution. So this technology is beneficial for the diagnosis, accurate treatment plan and perfect execution of the surgical plan prior to the surgery. In the recent years, the use of AM technology is gaining good popularity in the medical industry for its promising results. In some of the cases, the information is used for pre-planning and in some of them the final implant is also fabricated using one of the AM techniques.

Traditional presurgical planning is based on the manipulation of 2-dimensional data obtained by means of traditional radiography and photography. This approach limits the full appreciation of various bony structure movements [4,5]. But the Digital radiographic technology or physical medical models and techniques have significantly raised the possibilities for accurate, noninvasive visualization and measurement of intra corporeal morphology and function during the last four decades. However, three dimensional imaging has emerged as a beneficial option in recent times replacing the conventional method of radiographs[6]. The technological advances in hardware and software led to development of 3D printed medical models. 3D printing in craniofacial surgery was first used by Brix & Lambrecht in 1985 for surgery planning [7]. 3D printed medical models has plethora of applications in maxillofacial surgical field for diagnosing congenital malformations, craniomaxillofacial defects, maxillofacial pathologies, reconstruction of facial defects, maxillofacial trauma, orthognathic surgery, facial asymmetry, surgical planning, custom prosthesis design and even professional-patient communication [8]. In cases of complex surgeries, the prototype ensures proper surgical planning, determination of the osteotomies and also the adaptation of osteosynthesis plates prior to surgery. As a result, there was decrease in surgical time, improving the patient security, decreasing blood loss and enriching the treatment outcome were noticed [9].

2 Methodology

2.1 Conversion of CT data

The patient was subjected to 128 slice CT scan under optimized CT parameters [10]. The CT scan data is stored in the Digital Imaging and Communications in Medicine (DICOM) format. With help of Materialize MIMICS software the DICOM data was processed in to the Computer Aided Model (CAD). MIMICS software provides option to perform multiple operations on the CT data. From the entire CT data the region of interested is selected with operations like edit mask, cut, split, threshold and segmentation etc. The patient MIMICS data is shown in the [figure 1] below. The CAD data is saved in stl file format, which is globally accepted by all the AM machines.

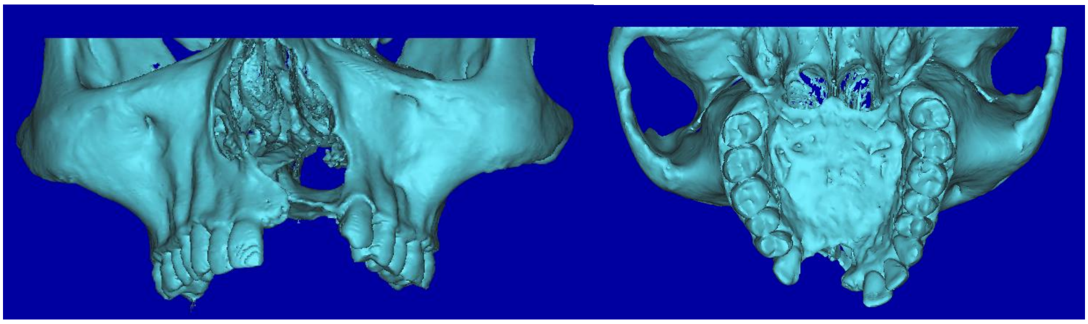

Figure 1: The CAD MODEL OF THE PATIENT.

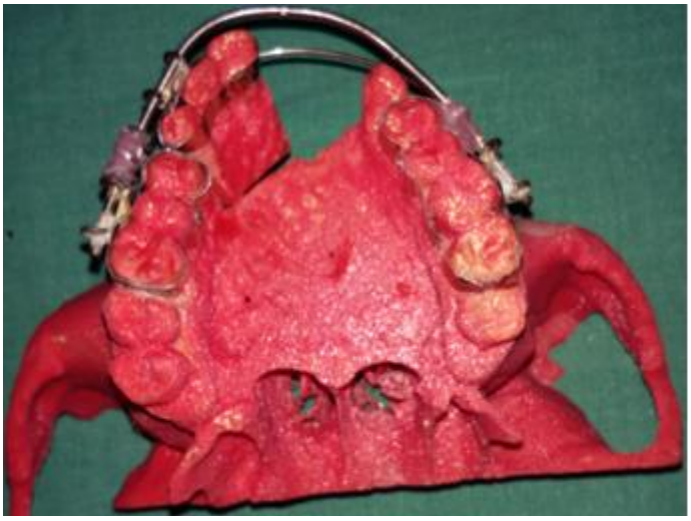

Figure 2: PLA MODEL WITH OSTEOYOMY PERFORMED AND DISTRACTOR FIXED.

2.2 Fabrication of medical model

As per the ASTM classification the AM technology is classified in to 7 techniques. Out of the 7 techniques Fused Deposition modelling (FDM) process falls under the material extrusion technique. In the current case study the FDM process was used to fabricate the physical medical model. The stl file was processed through flashprint software to generate the g codes for the flashforge finder machine. In the falshprint software the orientation, speed, fill density, printing temperature and many other printing parameters can be controlled. For the current case medical model is fabricated using poly lactic acid (PLA) material. The PLA medical model has enough strength to fix the distractors and screws for mock surgery as shown in [figure 2].

2.3 Case description

The patient presented with a defect in maxillary bone which has been diagnosed as cleft alveolus based on history and clinical evaluation. It is associated with regurgitation of food and fluids into nose on consumption. Figure 3 – Preoperative clinical picture. On

Figure 3: SHOWING CLEFT IN THE ALVEOLUS AND MISSING TEETH.

Figure 4: MOCK SURGERY ON 3D PRINTED MODEL.

examination of CT Scan, the size of the defect has been recorded as 28mm based on radiographic evaluation on CAD Model [Figure 1].

2.4 Mock surgery

Before posting the case for surgery 3D printed medical model has been prepared. Distractor was designed, which are of tooth borne type. Teeth are marked into three different segments based on anchoring and distracting units [Figure 4]. Mock surgery is conducted over the 3D printed model. A 3D printed model was used to plan and execute the Mock Surgery. Cleft was present on left side of the alveolus. Three teeth adjacent to the cleft on the contralateral side were banded together and was selected as the transport segment for distraction [Figure 4]. Four teeth present adjacent to the cleft on the same side were banded together and was selected as anchor unit on left side. Three teeth on the contralateral side distal to the transport segment were selected as anchor segment on right side.

A 2.5 mm threaded K wire was used to adapt on the bands, and was welded on anchor segments on either side and a miniplate was used to fix the transport segment to the bands and K wire such that, the transport fragment moves on the threads on the K wire. Nuts were on either side of the miniplate of the transport segment in such a way that, as the nuts move over the threaded K wire. The mock surgery was performed on the model and the segment mobility was checked on the model.

Figure 5: TRANSPORT SEGMENT FOR DISTRACTION.

2.5 Actual surgery

The case was operated under General Anesthesia. During surgery incision is given in the buccal vestibule followed by sub periosteal dissection. Bone segments are exposed along with the defect. Horizontal and vertical cuts are given as shown in the model [Figure 5]. Mobilisation of segment is done followed by placement of distractors. Closure is done and distraction of 1mm per day has been carried out after the latency period of 5 days. Distraction phase has been finished recently and consolidation phase is under progress.

3 Discussion

Although 3D printing technology is under evolution, its clinical applications are actually sprouting more rapidly. The affordability and convenience of this technology have spurred its adoption in a variety of medical fields as well as surgeries. The clinical success in applying AM technology for patient management and surgical procedure simulation is largely dependent on the accuracy of the replica model made available for diagnosis and treatment planning [11]. From the surgeon's analysis, 3D printed models play a vital role in the diagnosis and treatment planning. The drawbacks of the 3 D printed models were time taken for the printing, cost and soft tissue anatomy was not being obtained in the model. However, combination of images (eg, CT scan) and medical models would facilitate assessment of the extent and site of defect [12]. These models are also more useful as a teaching tool in distraction osteogenesis cases. Though producing the models is expensive, using them for preoperative planning substantially reduces operative time during surgical procedure. Saving operative time is important because operating room costs average 30% to 40% of hospital expenses when these surgeries are carried out [13,14]. The accuracy of the models also allows preoperative planning of bone grafts and surgical resection procedures, shows the location and orientation of bone fragments, and allows the preoperative modifications of reconstruction plates which can be adapted precisely to the model before carrying out surgeries.

4 Conclusion

3D printing technology enables more effective patient consultations, increases diagnostic quality, improves surgical planning, and provides a template for surgical resection causing in carrying out surgery with greater ease. For the current case the 3D printed model saved 30% of the operating time with help of mock surgery inputs. The placement of the screws and distractor angle was analyzed in at the time of mock surgery. The blood loss and to the patient is reduced since the surgery time is reduced. The overall cost to the surgery is also reduced due to the reduction in surgery time. Still there is a scope for better connection between the preoperative simulations and the real surgery environment should be made over the model.

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