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Customization of Patient Specific Distraction Device using Additive Manufacture Technology

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Abstract

Additive Manufacturing (AM) technology is an engineering technology which has a wide scope in medical field. Individual planning of complex maxillofacial surgical procedures require 3D models for the precise outcome and reduction in the surgical time and thereby complications. AM technology can be used for the manufacture of patient specific models using Computed Tomographic (CT) Scan data for the complex surgical procedures. Design method for personalized Mandibular Transport Distraction device manufacturing by using medical Additive Manufacturing (AM) is presented in this paper. The present work explains the use of AM models for planning of a case of mandibular defect secondary to tumour ablation. The surgical method used to correct the deformity is called Distraction Osteogenesis (DO). It involves new bone formation between fractured bony segments which are separated by gradual, controlled incremental traction. This results in simultaneous expansion of soft tissue and bone volume. The Transport DO procedure of mandible involves creation of a transport segment which is separated from the residual bone to be distracted to the other side of the bone present. The outcome depends on an important principle called as Distraction Vector where the direction and magnitude dictates the outcome. The use of Additive Manufactured models made to plan the Distraction vector precisely and made the operation easier and more accurate. Moreover preoperative preparation reduced the operating time.

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*Keywords:*Additive manufacturing, 3 D printing, Residual Defect; Distraction Osteogenesis; Distraction Vector.

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1. Introduction

Recent advances in three-dimensional imaging techniques, advanced computer programming and Additive Manufacturing (AM) technology provided an extra tool for the fine outcome for the craniomaxillofacial defects and deformities. Technological development from 3D imaging techniques to Additive Manufacturing brought about a big revolution in assessing physically than virtually. This gave an extra hand for the clinician to perform trial and errors on the models for the precise outcome.

AM applications have generated increased interest in recent years. Many countries are trying to apply AM technique to various fields round the globe. Among various fields which applied AM technology, medical field is one of the most benefited industries. As the medical field requires patient specific medical models, it is easy to get it by using AM technology [1]. For approximately 25 years, individual three-dimensional (3D) models have been used for the planning of craniomaxillofacial corrections [2, 3].The gold standard for the fabrication of individual 3D models remains DICOM (Digital Imaging and Communication in Medicine) datasets that have been acquired by conventional high-resolution multi-slice computed tomography (MSCT) [4]. The DICOM images can be achieved by Cone Beam CT Scan or traditional CT scan. In the present case, the scans were obtained from traditional CT scan at less than 1mm slice thickness. There are many techniques for generating three dimensional models. These techniques include stereolithography (SL), selective laser sintering (SLS), fused deposition modeling (FDM), 3D printing (3DP), and polyjet modeling [5].

Mandibular defects can range from isolated segmental defects to large extensive areas of bone involving the entire jaw. These defects are often congenital, as a result of trauma, infection or resection of benign and malignant tumors [6]. Reconstruction of mandible poses a challenge to the maxillofacial surgeon. Though there are variety of options available for reconstruction the mandible, the decision to choose the treatment depends on various factors like age of the patient, extent of the defect, site of the defect etc,. In this case, we opted for reconstruction using custom made plate guided transport distraction osteogenesis with the help of patient specific mandibular model manufactured by AM technology.

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2. Material and Method

Here we demonstrate a case of a young female who underwent resection of a tumor on right side of the lower jaw followed by reconstruction with a reconstruction plate. The reconstruction plate was fractured at a later date. With the above mentioned scenario, 3D CT scan [Figure 1] of the facial bones was advised to the subject. DICOM images were obtained for the CT scan data. The DICOM files were converted into .stl stile (Stereolithographic file). 3D model was prepared by using Additive Manufacturing technology in 1:1 scaling. A plate guided distractor was planned for the above scenario. Two models were prepared, one for stock [Figure 2a] and the other or surgical planning [Figure 2b]. The bony defect was measured [Figure 3] and the appropriate size distraction of bone required was assessed. By using the AM model, the exact angulation, the vector for distraction and the placement of the osteotomy cut for the transport segment was planned over the model Figure 4 and Fig 5.

Once the variables of the distraction procedure were obtained, the appropriate unidirectional stock distractor was selected. The parts of the device are as follows. Figure 3

a. Distractor of sufficient length
b. Plate to guide the distractor
c. Reconstruction plates to connect the bone segments on either side of the defect
d. Long “L” plates – Transport segment plates

All these parts are assembled as custom made transport distraction device by using models prepared by Additive Manufacturing technology. This technology provided accurate measurements of the defect and aided in planning the distraction vector in a precise manner. The printed models decrease a majority of surgical time.