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Design Process for Rapid Manufacturing of Maxillofacial Prosthesis: A Case Study

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Abstract—***Maxillofacial prosthetics is a specialised profession that seeks to meet the needs of patients with various degrees of facial deformity by restoring aesthetic and functional portions of missing tissue using artificial materials. The objective of this study is to streamline the process of fabrication of facial prosthetics with the help of the 3D scanning, CAD/CAM and 3D Printing (Rapid Prototyping). Thus reducing the time and cost to make prosthetics. Further making the whole process a lot easier for doctors. The case was taken from the Oral Science Department of PGIMER, Chandigarh. A case of orbital defect was reconstructed.***

Keywords— CAD/CAM, 3D Scanning, Rapid Prototyping,Orbital prosthesis, Prosthesis fabrication, Modelling.

I. INTRODUCTION

The unfortunate loss or absence of an eye may be caused by a congenital defect, irreparable trauma, or a tumour. As the human face constitutes the center of attention in human relationships, the emotional pressures caused by facial disfigurement can cause great distress. Rehabilitation is of primary importance in restoring self-confidence and a normal life. Fabrication of aesthetic maxillofacial prostheses is traditionally a challenging process. A non-aesthetic maxillofacial prosthesis will create even more psychological trauma for the patient than not having a prosthesis at all. The practice of restoring lost tissue with prosthetic replacements precedes surgical attempts and even with recent advances in surgery there still remain many cases where prosthetic rehabilitation is more suitable and desirable to the patient involved. These devices provide the majority of patients with a satisfactory facial match that resolves their aesthetic concerns [Carter KD]. When the clinician is faced with maxillofacial defects, conventional prosthetic methods often lead to problems that require substantial skill and experience to overcome; these include the risk of aspiration while the impression is being made, difficulties relating to whole tissue undercut impression, and impaired impression because of reduced mouth opening after scar contracture or radiotherapy [Tanaka Y]. However, the conventional method of fabricating this type of prosthesis includes a variety of complex production steps. It is a labour intensive and time-consuming task, and the end results are heavily dependent on the experience of the clinician [Hooper SM]. Since the conventional impression technique may cause discomfort to patients because of the pressure of the impression material [INRIA, 2010; Ciocca et al., 2010; De et al., 2011], and increasing number of patients select computer-aided design/computer-aided manufacturing (CAD/CAM) techniques [Cheah et al., 2003a, b, 2005; Ferrario et al., 2001; Reitemeier et al., 2004; Sansoni et al., 2009; Ciocca et al., 2010; Benz et al., 2002; Evans et al., 2004]. This study describes a universal approach to fabricate maxillofacial prosthesis using the CAD/CAM and RP.

II. METHODOLOGY AND MATERIALS

2.1 Methodology

The patient's specific alignment characteristics are included in the model, allowing for the development of a biomechanically correct geometry that improves the fit, comfort and stability. There are always patients outside the standard range, between sizes or with special requirements caused by disease or genetics. With the aid of 3D Scanning, CAD/CAM and RP (Rapid Prototyping), it becomes possible to design and manufacture a custom prosthesis that precisely fits a patient at a reasonable cost.

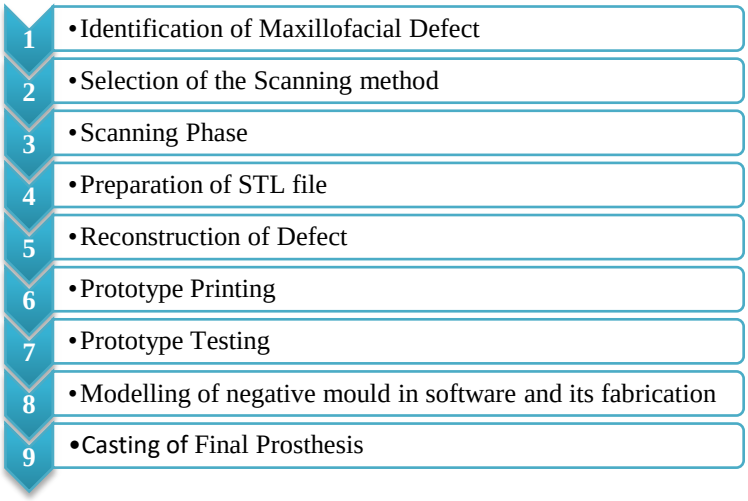

Fig. 1 Methodology

2.2 Materials

The Artec Eva Handheld Scanner and GOM Atos Core 300 were used to scan the defects, Artec Studio and GOM Inspect software were used make STL files. The Materialize 3-Matic Software is used to reconstruct the defects. The Stratasys Fortus 400mc and Stratasys Eden260V™ 3D Printer were used to 3D print the prostheses and Stratasys Insight software to assist the 3D printing. The prosthesis pattern was printed in ABS-M30i thermos-plastic material.

2.3Implementations of proposed methodology on maxillofacial prostheses

Case: Orbital Defect, the patient presented with a continuation defect post orbital exenteration and oro-nasal communication post maxillectomy.

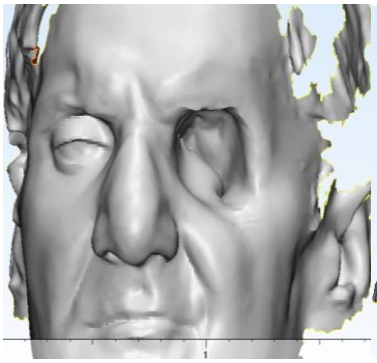

Fig.2 Orbital defect

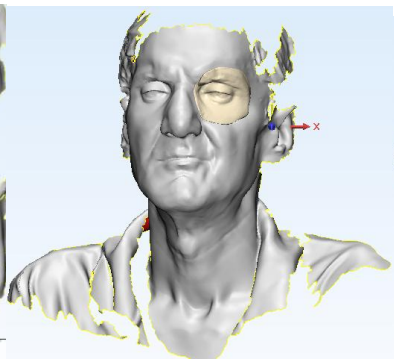

Fig. 3 Reconstruction of defect

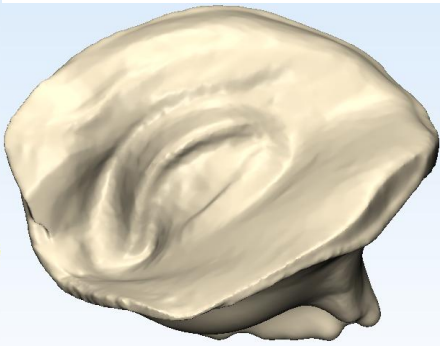

Fig. 4 Orbital prosthesis CAD model

Steps involved: -

1. This defect was identified as a mirror-able,extra-oral, medium in size and volume.
2. Depending upon the geometry of the defect the CBCT scan was chosen for the data acquisition. (we can write: surface scanning as it was a medium size defect to justify the methodology more appropriately)
3. The surface scanning was performed by using the Artec Handheld Scanner and the data was first saved in the SCAN format.
4. Later, the SCAN file was converted into the STL format in Artec Studio.
5. The STL file was exported to the 3-Matic to design the prosthesis. First, the number of triangles was reduced. Then a mid-plane was constructed using the face landmarks. The mid-plane is used as a mirror plane to mirror the healthy side on the defected side to fill up the missing part. Then the mirroring plane was adjusted so thatboth the sides become identical. After that, by superimposing the defect on the healthy mirrored side we took out the shape of the prosthesis to be made.

6. The digital model of the prosthesis was imported into the INSIGHT software and was printed in ABS-M30i with the FDM machine.
7. The printed prototype was used for a direct trial on the patient and relined with impression material for all the undercuts and under extended areas. All additional and necessary modifications were done by selective trimming and addition of wax.
8. This refined model was then eventually used for flasking and final prosthesis fabrication in a conventional manner.

Fig. 5 Orbital prosthesis printed by FDMFig.6Trial of the pattern on the patient at PGIMER

III. CONCLUSIONS

3-D Scanning, CAD/CAM and 3-D Printing techniques were extremely helpful in the field of prosthesis fabrication. Our study concludes that:

1. The proposed methodology for the prosthesis fabrication was found to be fast, reliable and effective.
2. It was found to be helpful with patients who are claustrophobic or unable to cooperate while making traditional full face impression.
3. Laboratory work is significantly reduced than the conventional methods because positive models can be automatically fabricated and later invested for casting.
4. Prosthesis fabrication and insertion can be accomplished in 2-4 days which is a lot faster than the conventional methods.
5. It allows for digital storage of mould and prosthesis design. Therefore, new moulds can easily be fabricated if the initial mould was damaged.
6. It was found that the surgical time reduces because of the minimization of the need for decision making at the time of surgery.
7. The fabricated prostheses are found to be more accurate than the conventional methods.
8. Greater patient satisfaction because of improved prosthesis conformity and shortened surgical period.

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