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MANUFACTURING OF DENTAL PROSTHESES BASED ON RAPID PROTOTYPING TECHNOLOGY

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Abstract: *Rapid prototyping (RP) technologies are the most widely applied and known fabrication methods that are based on additive fabrication principles. As the result of the development in modern imaging, computerized three dimensional data processing and advanced engineering techniques, medical prostheses like dental prostheses can be accurately designed from computer aided design (CAD) technique and the physical model of prostheses can be produced through rapid prototyping (RP), rapid tooling (RT), and computer aided manufacturing (CAM) technology. This paper discusses the methods of design and fabrication of dental prosthese by using RP technologies.*
Key words: *Dental Prostheses, Rapid Prototyping*

1. INTRODUCTION

Recently, Rapid Prototyping (RP) technology has been used not only in general industries, but also in fabricating of medical models. However, working with RP technologies in the medical field differs radically from using them in the manufacturing environment. Building medical models essentially starts with acquiring data such as computed tomography (CT) cross sectional images. Prior to part building, this highly complex data needs to be pre-processed to provide a format that a CAD package or a RP system can recognize. It can be seen that data scanning and processing technologies must be linked with RP technologies to obtain the desired physical models. The data has to undergo a number of processes: data acquisition, image processing and model fabrication.

The corresponding research covers the method of design and fabrication of dental prostheses using RP technologies and manufacturing process via RP technologies of several case studies.

2. METHOD

The procedure for making 3D medical models using RP technologies implies few steps (Fig.1):

- 3D digital image;
- Data transfer, processing and segmentation;
- Evaluation of design;
- RP medical model production;
- RP medical model validation.

3D digital image can be obtained by using computer tomography - CT scanner or MRI data. These imaging technologies are used for modeling internal structures of human's body.

After saving CT or MRI image data, they should be transferred to RP laboratory. The next step is processing these data, which is a very complex and important step, which the quality of the final medical model depends on it.

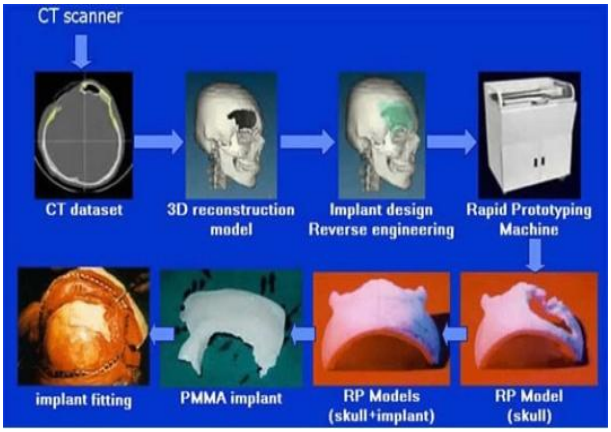

Fig. 1. Generalized procedure for creating medical models

For this step engineers need software package (Mimics) in which they can make segmentation of this anatomy image, achieve high resolution 3D rendering in different colors, make 3D virtual model and finally make possible to convert CT or MRI scanned image data from DICOM to STL (Stereolithography) file format, which is universally accepted RP file format. Surgeons have a very important roll in validation of the created virtual model. It is even more important in some cases of errors which are made because of the misunderstanding of anatomical structures by engineers or because of some disturbances in the scanned images. After evaluation of design, the right RP technology must be choosed according to the purpose of model itself as well as demanding accuracy, surface finish, visual appearance of internal structures, number of desired colors in the model, strength, material, mechanical properties, etc. When the RP medical model is manufactured it should be validated by surgeons. If there are no errors the model is ready for application.

3. CASE STUDIES

3.1 Case 1: Dental Implant

How to construct a CAD model for dental prostheses precisely and easily is a major issue. The process of manufacturing via SLA constitutes of the model design using CAD modeling software such as SolidWorks and transforming the model into STL format known by SLA. Next the preparation process including STL file verification, orientation, support generation, slicing and setting build parameters are performed. The final step after fabrication includes cleaning, postcuring, and finishing. Therefore for fabrication of dental implant, the above steps are carried out via SLA5000 machine using WaterShed^{TM}11120 resin where the RP model of dental implant is shown in figure2 (Rahmati et al., 2009). These models must be used as sacrificial patterns in precision investment casting process for fabrication of final implants using ceramic shells.

Fig. 2. RP model of dental implant (Resin Pattern) for investment casting

3.2 Case2: Design of mandible model

SLA models have been used for the fabrication of mandible titanium trays, which are implanted in the patient as a replacement of the actual bone that was lost or removed due to a tumor. The implant SLA model served as the casting pattern for the construction of a silicon mould and the subsequent casting of an identical wax model, which was finally used as an expendable pattern for the production of the titanium part by investment casting. In this case the design of a custom-made mandible based on data acquired from the patient mandible via Cone-Beam Computed Tomography (CBCT) using RP technology that has designed by Kheirollahi et al (Kheirollahi et al., 2009a) is discussed. The custom design phase is initiated by the acquisition of the CBCT scan of the patient's mandible. The image data was imported into Mimics version 10.01 for editing and three-dimensional reconstruction. Figure 3 illustrates the data processing in Mimics software. In figure 4 the STL model of mandible after processing of Patient's image is shown.

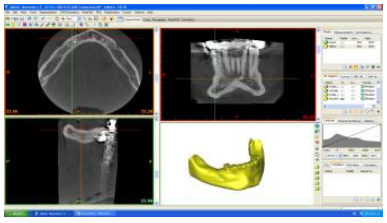

Fig. 3. CBCT data processing

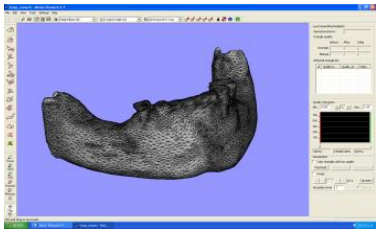

Fig. 4. STL model of mandible

3.3 Case3: Design of lingual orthodontic appliance

In this case a novel lingual orthodontic technique based on custom-made brackets and custom-made series of pre-bent wires using rapid prototyping technologies is discussed (Kheirollahi et al., 2009b). For many adults, the stigma in common orthodontic appliance discouraged them from undergoing orthodontic care. A solution to this problem is to hide the braces on the inside of the teeth (Fig. 5). The manufacturing process of the new appliance differs fundamentally from any other lingual appliance or laboratory procedures. The whole appliance is made by using CAD/CAM technology (Wiechmann, 2003, Mujagic et al., 2005). The set-up model is scanned with a 3D scanner and the brackets are designed on the computer. RP technology is used for the actual manufacturing of the lingual brackets. Bending arch wire is one of the most difficult part in orthodontic. In this system, computer-operated bending of arch wire using robots is used to manufacture precise-shaped arch wires.

Fig. 5. Lingual braces are mounted on the inner surface of the tooth to conceal them

4. DISCUSSION

For case 1, it can be seen that with the help of various RP techniques, the fabrication of dental objects like implant can be done easily and rapidly. It is otherwise difficult to generate them by other techniques because of features like overhangs, sharp corners, and undercuts. In case 2, CBCT image of Patient's mandible was imported into Mimics version 10.01 for editing and three-dimensional reconstruction and making of STL model for the fabrication of mandible titanium trays. In the final case, a novel lingual orthodontic technique based on custom-made brackets and custom-made series of pre-bent wires using RP technologies has discussed.

5. CONCLUSION

RP techniques have been substantially employed in medicine; however, the applications of RP in dental area are relatively rare. This paper also discussed the application of rapid prototyping techniques in fabrication of dental prostheses. With the help of various RP techniques, the fabrication of dental prostheses can be done easily and rapidly that otherwise is difficult to generate them by other techniques.

6. REFERRING

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