©2016 Published in 4th International Symposium on Innovative Technologies in Engineering and Science 3-5 November 2016 (ISITES2016 Alanya-Turkey)

The Modeling of 3D Tibia Bone Using the CT Images and Printing

[1]Gözde Rabia Aktaş, [2]Mustafa Kürşat Erbaş, [3]Sevda Şanver, [4]Eylül Demir, [5]İhsan Toktaş, [6]M. Tolga Özkan
[1,2,3,4,5]Faculty of Engineering and Natural Sciences, Department of Mechanical Engineering, Yıldırım Beyazıt University, Ankara/Turkey
[6]Faculty of Technology, Industrial Design Engineering Department, Gazi University, Ankara, Turkey

Abstract

Three Dimensional (3D) printing technology is an useful method for the manufacturing of computer models and is used in many different areas. This study is focused on modeling of human bones such as humerus, tibia, femur etc. used in biomedical and medicine field. The main steps of this study includes to create 3D printing models of the human bones from two dimensional (2D) computerized tomograhy (CT) images and printing of those. Some computer softwares are used to create 3D models and to make the geometrical corrections over them. After modeling, the data is sent to the 3D printing machine for production in the STL (Surface Tesselation Language) format that is commonly used. 3D printers provide to save the processing time and cheap production for the human body parts used for training and experimental studies. Besides, this method satisfies the individual requirements and can be suggested as an alternative way to the conventional manufacturing technologies.

Key words: Tibia bone, 3D modeling, computerized tomography (CT), printing.

1. Introduction

Biomechanics is the study of the structure and function of biological systems by using the methods of mechanics (statics and dynamics), and it is also the science concerned with the internal and external forces acting on the human body and the effects produced by these forces [1]. Biomechanics covers a wide field including tissue engineering and biomaterials, artificial organs and sports therapy. Research objectives of biomechanics are controlling, determining of mechanical and anatomical factors, improving of our movements, preventing from injuries, and determining of characteristics of artificial organs [2]. The concrete models of these parts plays an important role over the knowledge of biomechanics for many number of fields as mentioned above. Nowadays Rapid Prototyping (RP) technology is used to create the concrete models required especially for the experimental studies and training in the medicine and health sciences. Production of anatomical parts with RP becomes an evolving area [3]. This technology provides the 3D printing of specialized implants or planning models before operation [4]. In the past, the production of medical models are difficult due to the complex geometry of them. Some techniques including pressing, forging, machining and casting were expensive and time-consuming for production of anatomical parts [5]. Nowadays 3D printing and printers supports easy way to RP especially in the offices except from heavy industry and allow to us different type of materials. Many different areas like jewellery, footwear, industrial design, architecture, automotive, aerospace, dental and medical industries started to use these technique [6]. The one

*Corresponding Author: **Murat Tolga OZKAN**, Gazi University, Faculty of Technology, Industrial Design Engineering, 06500, Ankara, TURKEY. E-mail address: tozkan@gazi.edu.tr, Phone: +90 312 2028622
Ihsan TOKTAS Faculty of Engineering and Natural Sciences, Department of Mechanical Engineering Yıldırım Beyazıt University, 06020, Ankara TURKEY. E-mail address: itoktas@ybu.edu.tr, Phone: +90 312 3786861/4020

of the most important applications are the design development, and manufacturing of medical models and by means of this, the production of virtual and physical anatomical models is aimed before surgery planning [7]. This study includes the all steps of 3D model creation of human tibia bone and printing process of it.

2. Materials and Method

In this study, modeling of 3D tibia bone with the image processing method and printing of it will be approached as an example. Tibia has two different bone types called as cortical and spongy bone. While the cortical bone is denser and have higher strength, spongy bone is surrounded with the cortical bone and has lower density and strength.

2.1. Steps of the 3D model creation

There are some types of imagining techniques used in medical area. The most used one is them is CT which is a non-invasive medical scanning technique. A CT scan uses modified X-ray technology to obtain geometric data of a body from different positions. Before performing segmentation of the anatomy, CT data in a DICOM format is loaded into Mimics. The image is firstly processed by the thresholding value to differentiate regions of interest [8]. The bone can be separated from soft tissue by changing theresholding range. Unnecessary parts or unwanted adjacent segments are cleaned with dimensional selection and editing tools. 3D model corrections are made in Solidworks as CAD program. For 3D printing process, final models are exported to STL format. General steps of RP process can be seen in Fig.1.

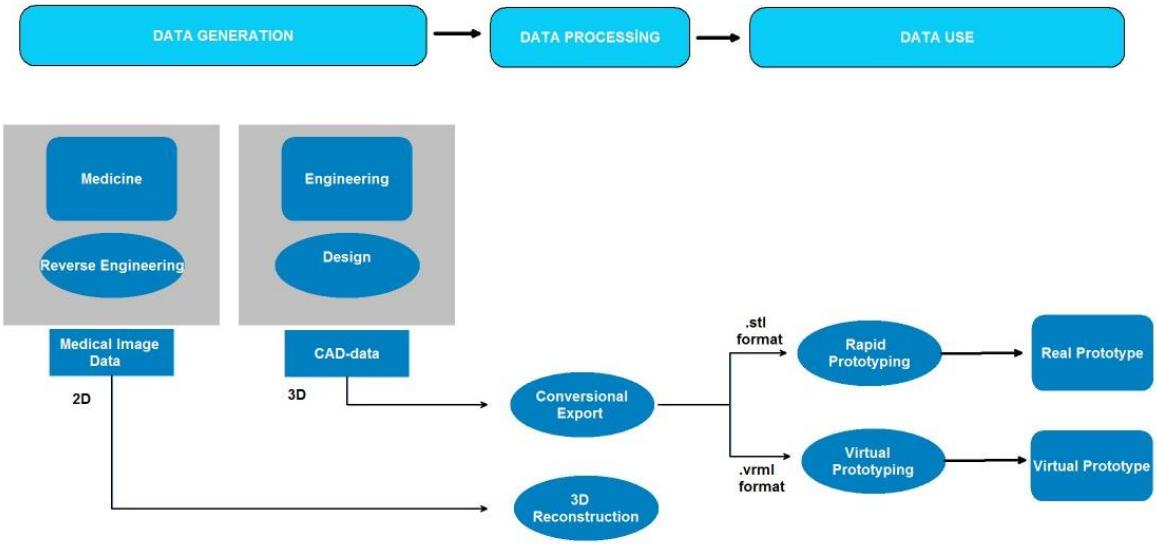


Figure 1. General steps of RP [9]

The Mimics screen is cut into quarter views. These planes are known as coronal (front view), axial (top), and sagittal (right) and 3D view (Fig. 2). The axial view is occured by 2D cross-sectional images. Coronal and sagittal views are obtained by Mimics as shaping of axial images into their associated location. The accuracy of 3D model is depend on the slice thickness and quality of the 2D images pixels.

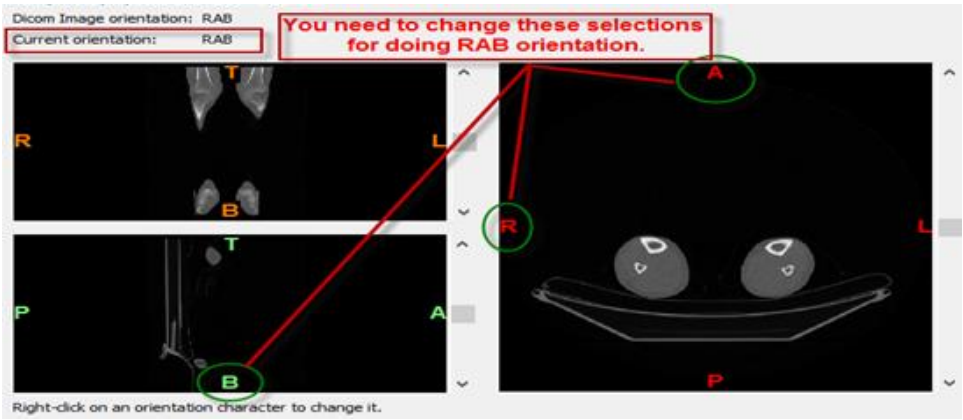
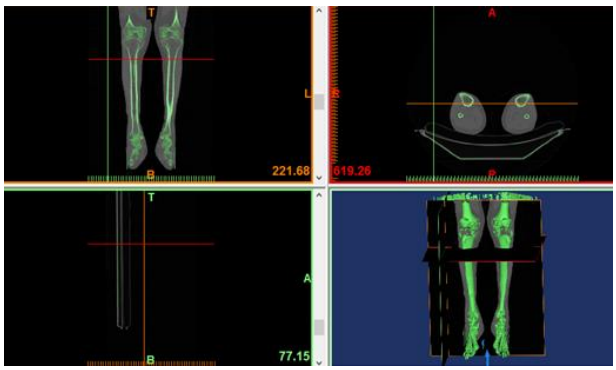


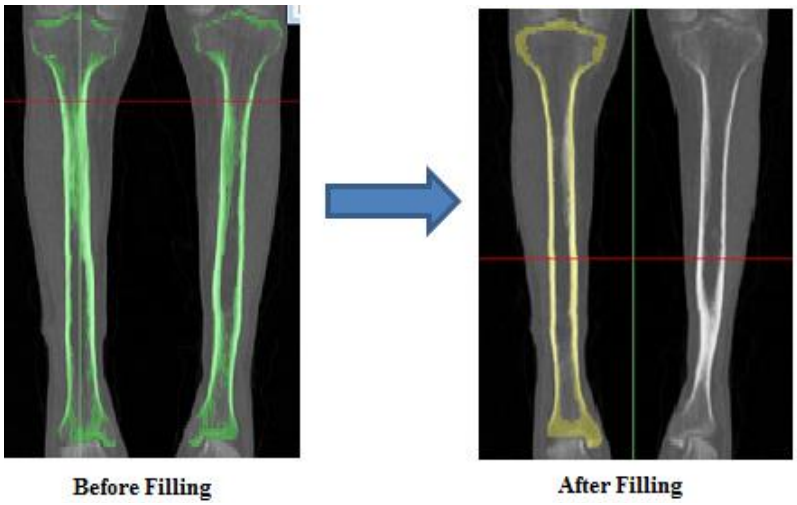
Figure 2. Plane orientation in Mimics

In Fig. 3 (a), mask creation for the cortical bone is seen. Missed parts after mask creation is filled and corrected by the mask edit tools as seen in the Fig. 3(b) and (c).



(a)

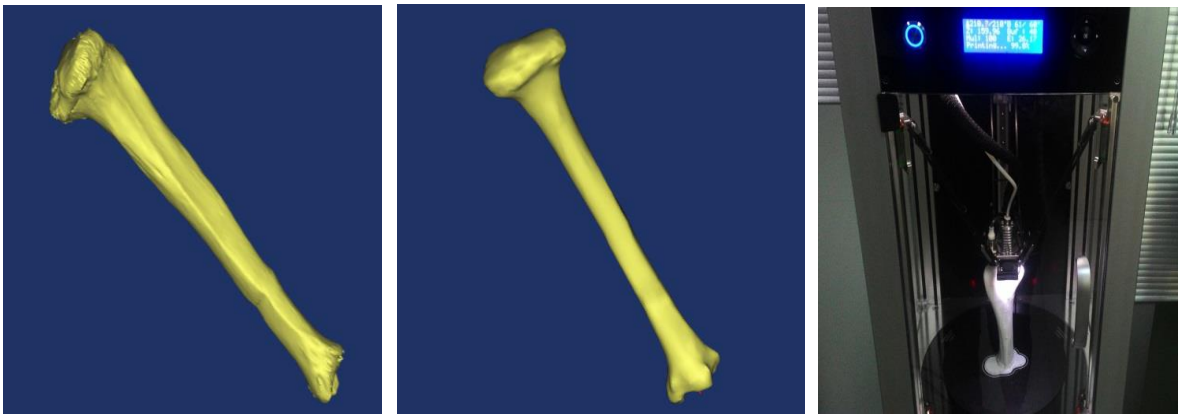
(b)



(c)

Figure 3. (a) 3D mask creation (b), (c) Editing of the bone part

3D model of tibia has the unwanted irregular surface in Fig. 4 (a), and it is required surface smoohting operation in the Fig. 4 (b). After ready 3D model, STL data can be transferred to the another software Simplify 3D for preparing the printing properties. This software plays a role as an intermediary to send the 3D model data to the printer (Fig. 4 (c)).



(a) (b) (c)

Figure 4. (a) Obtained bone (b) Surface smooting of bone (c) Printed objects which are tibia

The file is saved in G-Code format before being sent to the printer. The printing process is carried out with Mass Portal Pharaoh ED Printer machine. Fused deposition modeling (FDM) method is used to print that FDM is an RP technique that creates the 3D model by depositing layers of thermoplastic material [10]. FDM allows the material to pass through a heated nozzle that makes the material as semi-melted and solidifies on the surface. The extruder head moves around x-y plane and upwards in the z plane to make the another layer. As a material, PLA (Polylactic Acid)

thermoplastic is used in this study. The printing parameters are 0.2 primary layer height, 3 outline shells, 15% infill percentage, full honeycomb internal fill pattern. The bone is printed by dividing into two part because of the printing machine capability. After then these two parts are assembled as seen in Fig.5.

Figure 5. Tibia after printing

Conclusions

In this study, creation of 3D anatomical model and printing of it are carried out. It is aimed to show the steps of how modeling and printing process of anatomical parts can conduct. As an example, 3D tibia is printed in the exact scale that can be used in the laboratory applications of Medicine and Health Science. We can have an opportunity to construct human body's anatomical parts and printing of them as real parts by using RP technology. For the biomedical field, it is so substantial to create something with respect to individual problems directly, different design options should be carried out in limited time and RP provides time consuming and cheap production. Having a visual model has been considered as a notable method to simplify concepts and permit individuals to understand the reason of problems and create the solutions before operations. It also helps to learn the human anatomy in Medicine and Health Science trainings. RP technique has still some limitations but it will be used more widely in the future.

Acknowledgement

We would like to thank Faculty of Technology/Kocaeli University for providing us Mimics software.

References

[1] Maughan RJ, An IOC Medical Commission Publication, The Encyclopaedia of Sports Medicine. 2nd ed., Vol. XIX, Wiley-Blackwell; 2013.
[2] Knudson D, Fundamenteals of Biomechanics, 2nd ed., New York: Springer; 2007.

[3] Lantada AD, Morgad PL, Rapid Prototyping for Biomedical Engineering: Current Capabilities and Challenges. Annual Review of Biomedical Engineering 2012; 14:73-96.
[4] Ventola CL. Medical applications for 3D printing: current and projected uses. Pharmacy & Therapeutics 2014; 39:704-11.
[5] Brennan J. Production of Anatomical Models from CT Scan Data. Master Thesis. Faculty of Technology De Montfort University. England, 2010.
[6] Biggins P, Hiltz J, Kusterbeck A. Bio-inspried Materials and Sensing Systems. Cambridge: RSC Pub; 2011.
[7] Milovanović J, Trajanović M. Medıcal applications of rapid prototyping. Mechanical Engineering 2007; 5:79 – 85.
[8] Gibson I. Advanced Manufacturing Technology for Medical Applications: Reverse Engineering. Software Conversion and Rapid Prototyping. West Sussex:John Wiley & Sons; 2005.
[9] Mallepree T. An advanced prototyping process for highly accurate models in biomedical applications. Von der Fakultät für Ingenieurwissenschaften. Abteilung Maschinenbau der Universität Duisburg-Essen. genehmigte Dissertation. 2011.
[10] Lee CS, Kim SG, Kim, HJ, Ahn SH. Measurement of anisotropic compressive strength of rapid prototyping parts. Journal of Materials Processing Technology 2007; 187–188:627–630.