3D Printed Polylactic Acid Mould for Human Bone Fracture Healing

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Abstract— This paper is focused on use of 3d printing technology for the application of bone fracture healing inside of plater of Paris, the Magnetic Resonance Imaging (MRI) files of the human hand have been collected in the form of Digital Imaging and Communications in Medicine format. The MRI files have been segmented by using 3D slicer software for creating the negative mould of the human hand and saved in stereolethography file format. In order to generate the G-code for 3D printing machine, the STL file has been sliced in to N number of layers, then 3D printed human hand mould has been fabricated by using Fusion Deposition Modeling machine.

Keywords: 3D Printing, Hand Mould, Bone fracture, PLA, MRI

I. INTRODUCTION

PLA is widely used polymer for 3d printing application. Poly lactic acid shows biocompatibility and under ideal conditions, is absolutely biodegradable [1]. PLA's monomer, lactic corrosive, is organically created, while polymerization happens synthetically. Its glass progress temperature Tg relies upon the proportion of L and D enantiomers and normally lies between 45 °C and 65 °C. It shows low water absorption, scraped spot obstruction, a smooth and hard surface just as shading quickness and it is UV-light safe. Its warm extension coefficient is low. Because of these properties, PLA is an effectively taken care of and regularly utilized material in fused deposit modeling. Ongoing progresses in the field of three-dimensional imaging utilizing cone beam processed tomography (CBCT) have prompted the advancement of PC helped OGS, in which point by point introduction of the craniofacial perplexing and upgraded investigation of careful arranging lead to improved consistency of careful results [2]. Magneto resonance image of injury patients can be used for making negative mould of the patient hand. MRI is a medical imaging technique that uses a magnetic field and computer-generated radio waves to create detailed images of the organs and tissues in your body. Now a day's 3D print technology is widely used for the application of creating 3d model from the Digital Imaging and Communications in Medicine (DICOM). DICOM file format is most commonly used for storing and transmitting medical images enabling the integration of medical imaging devices [3-6]. In conventional method plaster of paris is used for treating the bone fracture healing. It causes blister on the skin and weight of the mould also high. And removing the mould also bit difficult. Static and dynamical properties of PLA were studied from Manara et al [7]

II. MATERIALS AND METHODS

The MRI file of the injured patient hand or leg data is collected in the DICOM file format. The collected data is feed in to the 3d slicer software. The software creates a three dimensional model in the graphical window corresponding to the MRI data. The outer structure of the patient hand is marked and segmented by using volume rendering process. In this paper the patient data are collected in the Digital Imaging and Communications in Medicine - DICOM file format or may be in the 2D images and then the collected data is converted in to required stereolithography file format. This file format is supported by many other software packages, it is widely used for rapid prototyping, 3D printing and computer aided manufacturing. The converted file format is edited and separated in to two parts. Then the separated part is sliced and printed in insta bot 3D S2 series.The first challenge is to take the data from imaging studies, isolate the anatomy of interest referred to as segmentation and convert it into a file format readable by CAD and 3D printing software. The final product depends on the quality of the original data. Image resolution, the use of contrast to enhance the anatomy, and sophistication of the software used to perform segmentation can all significantly affect the final product. There are a variety of professional, freeware, and open-source solutions available to perform these steps. This document describes the approach using 3D slicer and Materialise Magics as an example, but the process can be replicated by many available solutions.

The STL is the industry standard file type for 3D Printing. It uses a series of triangles to represent the surfaces of a solid model. All modern Computer Aided Design software allow you to export their native file format into STL. The 3D model is then converted into machine language G-code through a process called "slicing" and is ready to print. The STL file format uses a series of linked triangles to recreate the surface geometry of a solid model. When you increase the resolution, more triangles will be used, approximating the surfaces of the 3D model better, but also increasing the size of the STL file. Industry-grade printers utilize lasers to accurately sinter granular substrates such as metal or plastic powders. On completion of each layer, the printer adds a new layer of unfused powder over the previous one and the cycle continues till the entire model is generated.

Another file format input for 3D printers in G-Code. This file contains detailed instructions for a 3D printer to follow for each slice, like the starting point for each layer and the route that the nozzle or print head will follow in laying down the material. In addition, 3D printer manufacturers may have their own proprietary input file formats that contain instructions specific to the methodology for that make or model, and that are compatible only with that manufacturer software. 3D Printing revolutionized the industry by allows designers to create and the next day see and touch their design. No longer did it take several meetings for everyone to agree on one design to create, and then wait months for the actual part to arrive. This does not create a barrier to printing with these machines, as the proprietary file format is

generated from the user's own STL file. Industry-grade printers utilize lasers to accurately sinter granular substrates such as metal or plastic powders. On completion of each layer, the printer adds a new layer of unfused powder over the previous one and the cycle continues till the entire model is generated.

The process of separating the required structure from the available medial data file using the 3D slicer software. The slicer, also called slicing software, is a computer software used in the majority of 3D printing processes for the conversion of a 3D object model to specific instructions for the printer. This platform for medical image informatics, image processing, and three-dimensional visualization. Built over two decades through support from the National Institutes of Health and a worldwide developer community, Slicer brings free, powerful cross-platform processing tools to physicians, researchers, and the general public. Slicer is made possible through contributions from an international community of scientists from a multitude of fields, including engineering and biomedicine. The outer layer of the hand was separated from the medical data and then the separated data is stored in the STL file format.

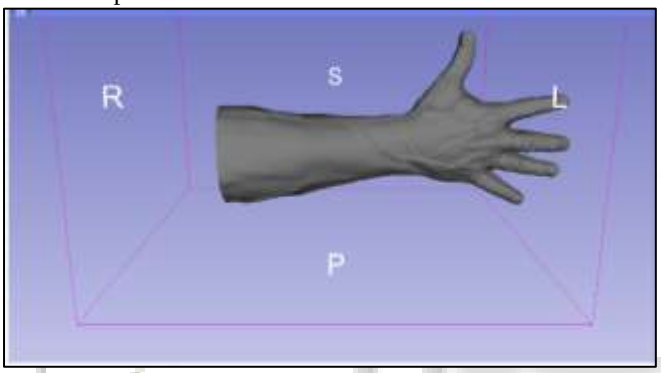

Fig. 1: Segmented Hand - front view

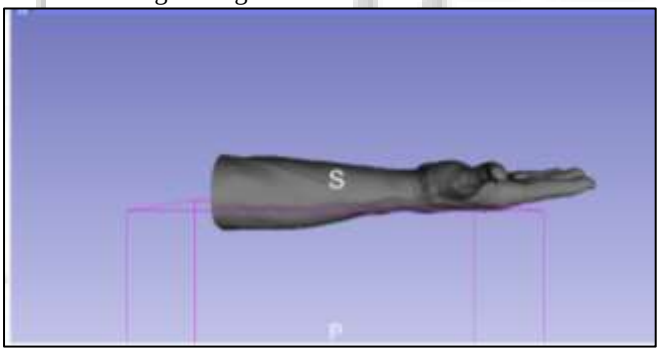

Fig. 2: Segmented Hand - side view

The above figure 1 and 2 show the entire hand mould, which is separated and segmented then stored as the STL file format.

III. STL EDITOR

The hand mould further edited by using Mesh lab to remove the unwanted portion from the converted file. For bone fracture healing process, the mould must be in the two parts so that it can be inserted in to the patient hand. There is no need of finger replica in the mould that cannot be removed in the slicer software. So that this portion are removed by using Mesh Lab. After removing the unwanted portion again, the file is saved as STL file.

Fig. 3: Hand mould part 1

Fig. 4: Hand mould part 2

The edited file is separated in to two equal half in the mid plane of the mould. And then they were stored separately. The above figure 4.3 and 4.4 show the two separated parts of the hand mould. The stored data is used to print the mould. The MRI files have been segmented by using 3D slicer software for creating the negative mould of the human hand and saved in stereolethography file format. In order to generate the G-code for 3D printing machine, the STL file has been sliced by using Ultimaker Cura software.

IV. SLICING

In computer programming, program slicing is the computation of the set of program statements, the program slice that may affect the values at some point of interest, referred to as a slicing criterion. Program slicing can be used in debugging to locate source of errors more easily. The 3D models must be first sliced into layers since the 3D printer prints out model layer by layer. The slicing algorithm plays a very important role in the 3D printing process. The most common technique for slicing is the produce contour data from STL files. The Ultimaker Cura software which is widely used software which help to convert the STL file format to G-code for the given geometry and properties. This mould was printed by using the INSTABOT 3D S2. The bed size of this machine is 240x240x300 mm. The nozzle diameter and layer thickness of this machine is fixed and it cannot be changed.

V. PRINTING PROPERTIES

The following properties are given while generating the G-code in the Cura software.

SL. No.	Properties	Value / attributes
1	Layer height	0.28 mm
2	Infill density	100%
3	Infill pattern	line
4	Bed temperature	40o C
5	Printing temperature	215o C

Table 4.1 Properties of printing material

The layer height in this fused deposited modeling machine is fixed and it varies with respect to the machine to machine. For this insta bot 3D S2 series the layer height is 0.28 mm. Infill density refers to amount of material to be filled while printing. I choose infill pattern as line so that the tool travel like a line format while printing, so that the material covers the entire volume of the mould.

The hand mould is fabricated in two parts which can be coupled using the strippers and covered by woolen cloths. During the fabrication some difficulties were faced. While printing the hand mould it started to warp on one side. So it was interrupted in between the process. In order to rectify the warpage, the bed temperature was adjusted and some extra glue was applied on the surface of the bed. After the solidification of the glue the process was again started from the initial process of printing. To maintain the ambient temperature of the process the printing area is surrounded by glass chamber. While print the component support material is required to hold the original position of the mould. The printing direction plays a major role in generation of support material. While slicing the software itself generate the support according to the orientation of the part. I choose orientation as vertical so that the component gets the accurate shape. But in this type of orientation the support also builds according to the direction. After finishing the support material is removed manually.

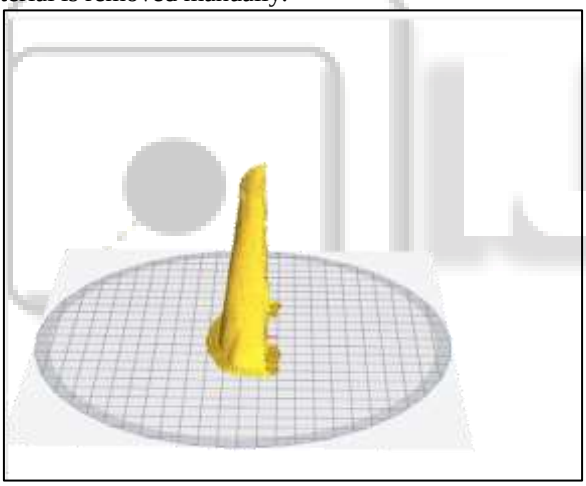

Fig. 5: Left half of hand mould

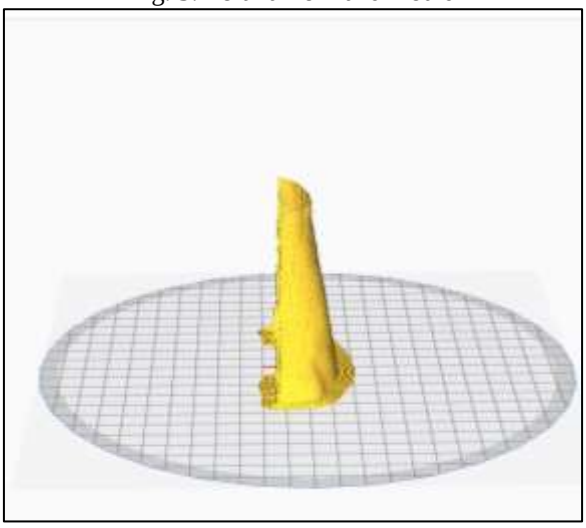

Fig. 6: Right half of hand mould

The figure 5 and 6 represent the software generate preview of the hand mould by using Cura software.

Fig. 7: Fabricated hand mould

VI. Result and Discussion

To compare the mechanical properties of the PLA mould with existing material for the hand mould the following test were conducted

VII. Tensile Test

Tensile test is conducted for the PLA material according to American Society for Testing and Materials ASTM is an international standards organization that develops and publishes voluntary consensus technical standards for a wide range of materials, products, systems, and services. ASTM D638 is selected for the testing process. The mechanical behavior of a part is the reaction of a material to a mechanical stress.

VIII. IMPACT TEST

The purpose of impact strength is to determine materials behavior at higher deformation speeds where the the loss of energy of the pendulum as determined by precisely measuring the loss of height in the pendulum's swing. Notched izod impact strength of 3D printed model for given infill density and infill pattern of 80x10x4 mm 3D printed specimen has been tested and achieved good strength when compared to conventional methods.

This impact test show (42 joules) the properties of the 3D printed material, which is quite higher than the available material plaster of paris.

IX. CONCLUSION

In this project work fabrication of hand mould is done by using the 3D printing technology. For designing patient specific models, instrumentation, implants, orthosis and prosthesis, besides 3D bio printing of bone and hand mould, and the same has been applied for nearly all areas of orthopedic trauma surgery, from head to foot. In convention method the plaster of paris is used for treating the bone fracture healing. In this method calcium sulfate is mixed with water and the applied to the patient hand it takes some time to solidification also it emits some amount of heat when exothermic reaction. But while using plaster of paris the weight of the mould is high when compared to PLA.

The Plaster of Paris Gypsum is the common name of calcium sulfate dehydrate. When it reacts with water it produces heat it affects the human skin. Human skin is normally sweating in nature, because of sweating itself it causes irritation and heat blisters. In order to avoid that PLA is the best solution when compared to other material. It also waters resistance it doesn't react with water, but in calcium sulfate it is not possible. There is no need of changing the mould every week. Ones it printed we can use this mould up to entire healing time. And it can be reused because of it thermoplastic properties.

In earlier day creating a mould is difficult one, first we have to create a die for injection molding, which is costlier when the die is made for one part. But in 3D printing technology there is no need of creating the die. It leads to great advantage in medical field as well as the bone fracture healing. There is no formation of blisters while using polylactic acid in contrary to usage of plaster of paris. The cost of PLA also low when compared to other material. 3D printed Polylatic acid mould is the best alternative for the existing plaster of paris mould for the purpose of healing bone fracture.

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