Structural Analysis of Hip Joint from 3D model Generated from DICOM File using Slicer 3D

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Abstract:- In this paper, we will walk people through the steps from creating a 3D model to analyzing the hip joint. So we browsed a lot of sites for a CT scan of the hip joint before we zeroed in on the scanned file. Then the scanned file is converted to a 3D model by the use of Slicer 3D software. Further, along with the paper, we would have discussed the difficulties encountered to prepare a solid model from the 3D model for analysis purposes and how to overcome it via the use of various software. Software like Mesh Mixer and Mesh Lab were used to reconstruct the model before transferring to Solid Works to convert to the appropriate file type for use in the ANSYS software for analysis. This is done by first uploading a CT scan of the hip joint downloaded from the 3D Slicer. The 3D Slicer software offers three views which help in deciding the correct part which we particularly want. The CT scan used contained the pelvis of the body, which can be adjusted to display the complete hip joint specifically. To start generating the 3D model, the editor option helps in highlighting the particular portion of the scan via different colors which represent different parts- the tissues, bones, organs, etc- of the body. After this, the 3D model is generated using the 3D Slicer software and exported to ANSYS for determining the force distribution over the hip joint.

Keywords:- *Hip Joint, ANSYS, 3D Model Generation using DICOM File, Mesh Mixer, SOLIDWORKS 2018, Slicer 3D.*

I. INTRODUCTION

The idea was to work on a cost-effective device for helping paralyzed (in the legs) people with rehabilitation. While browsing through research papers we found that not many papers offered an explanation and solution on the difficulties they faced during the analysis of hip joints and how they overcame that. The previous approaches carried out only offer a minuscule explanation of the model and the software they used to generate it but do not appraise the readers of the method they undertook [1]. We have taken a CT scan file [3] of the hip joint from the internet and generated a 3D model to help us visualize the force distribution over it. Our project has dealt with the possible difficulties one can face while trying to obtain the 3D model and we have elucidated our work by stating which software can be used to tackle a particular hurdle and how we can overcome it, from repairing a damaged file to obtaining the finished and flawless 3D model. This analytical work will prove to be particularly useful for future work as various studies can be carried out with this as the basis. In the coming sections, we will explain how to convert the scanned data to a 3D model, how to repair it and how we carried out the analytical work in ANSYS.

II. 3D MODEL GENERATION USING SLICER3D

A. Conversion of CT Scanned data into 3D Model using 3D slicer Software

The 3d model used for the analysis was first created with the use of 3D Slicer software. 3D Slicer is free open-source software that is flexible and a modular platform for the analysis of an image and its visualization. 3D Slicer provides the ability to develop both batch processing and interactive tools for various applications.
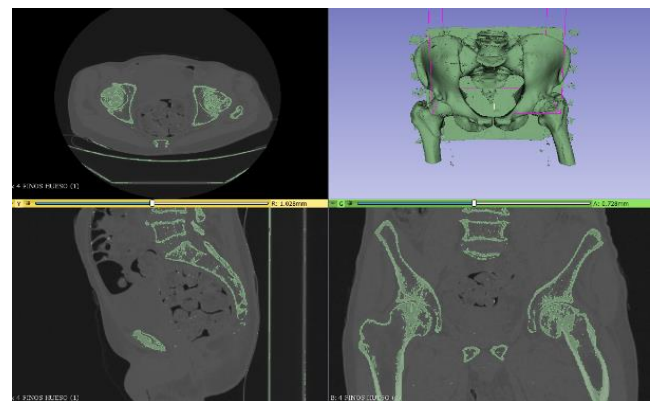

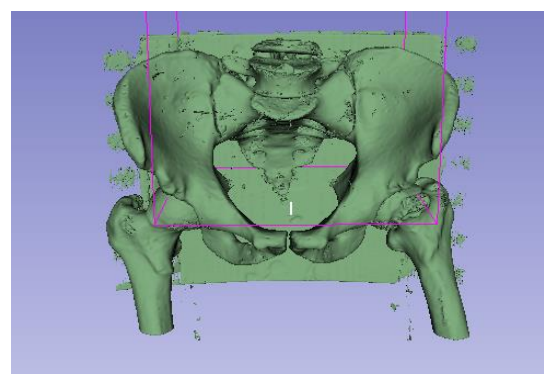Fig 1: 3D Model Generated Using DICOM File

Fig 2: Generated 3D Model in Slicer 3D

After this, the apply button is pressed which generates the 3D model of the hip joint and is displayed on the second frame, on the right, from the top. To apply this model for analysis, an STL file version of this is required, which can be seen in the save options tab.

III. REPAIRING ERRORS IN 3D MODEL

A. Repairing and Editing STL into a solid model

Having seen the generation of a 3D model of hip joint using 3D Slicer, we proceed to the analysis. Before the process of analysis, there are certain criteria of the model required which will work in the ANSYS software for analysis. The model thus to be analyzed is obtained via a series of determination of errors and are rectified to obtain a flawless solid model from the 3D model. [5]

The first error that was tackled was the rough and complex surface obtained via the 3D model. [7] A rough surface during analysis has a deleterious effect on obtaining a fine outcome. To overcome this obstacle software, called MeshMixer was used.

B. Repairing Errors in the 3D Model Using MeshMixer

The MeshMixer, a free 3D modeling software, allows us to easily create and correct 3D models. It is an ideal software for creating 3D models based on the current volumes available, which are combined via easy-to-use tools. We imported a 3D model of the hip joint to MeshMixer.
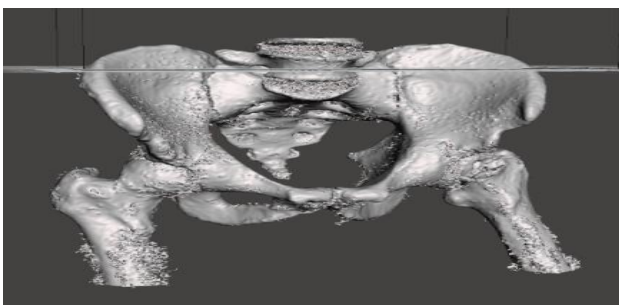

Fig 3: Imported 3D MODEL in Mesh Mixer Software

Our research work is only on one-half of the hip joint. The 3D model also provides a complete and complex surface of the hip joint which proved to be a surplus for our work. To reduce the complexity, the hip joint was sectioned into representing only one half. Since the 3D model contains some holes and cracks, we repair it using MeshMixer. [7]
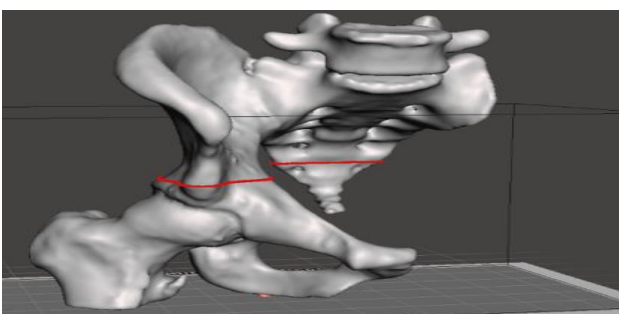

Fig 4: Sectioned STL hip joint.

The red line, visible in Fig 4. Indicates the cracks and errors in the STL files. These cracks can be removed by the remove cracks option in Mesh Mixer. After removing the holes and cracks we exported the STL file as .ply/.obj files.[10] The 3D model of the hip joint generated via the 3D Slicer is converted into an STL file for analysis purposes. For performing analysis on the hip joint we need to convert the STL file into a solid model because an STL file only contains a graphical representation of 1.

C. Problems faced in converting STL file into Solid model

The .obj file/.ply files for this study contained more than 40,000 triangular facets, which when imported directly to SolidWorks but it takes a very huge amount of time while importing it as a solid model. A solid model containing 20,000 triangular facets provides a faster working rate (as per data from the SolidWorks website), [7] thereby increasing efficiency. To reduce the complexity we used a software called MeshLab, where we can reduce the triangular facets to the required number.

IV. MESH GENERATION USING MESH MIXER

A. Meshing the 3D Generated Model using MeshLab

MeshLab is an open-source system for the processing and editing of 3D triangular meshes. We are provided with a set of tools for editing, cleaning, healing, inspecting, rendering, texturing, and converting meshes. It also offers features, which help in the processing of raw data produced by 3D digitization tools/devices and for preparing models for 3D printing. So we imported the model to MeshLab and reduced 40,000 triangular facets to 10,000 triangular facets. [2]
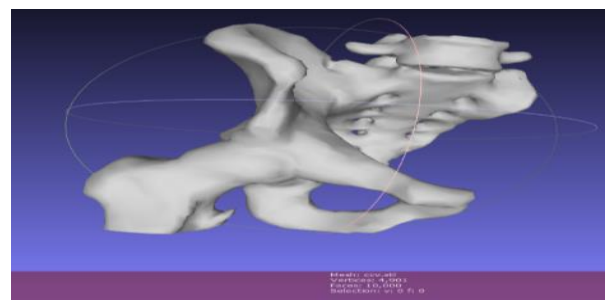

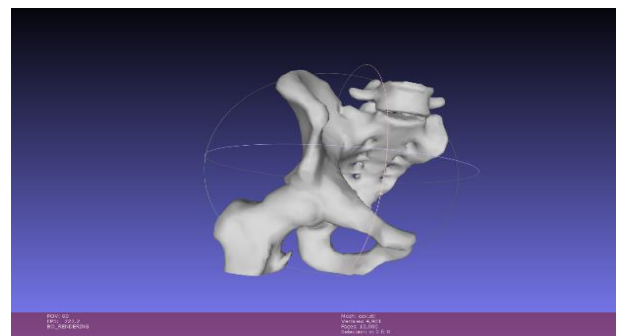Fig 5: Imported .ply model into MeshLab contain 40,000 facets.

Fig 6: Converted .ply model in MeshLab contain 10,000 facets.

V. CONVERTING SOLID MODEL INTO 3D MODEL

After reducing the triangular facets we import a solid model of the hip joint into SolidWorks and export it as a . STEP/.IGES file format.
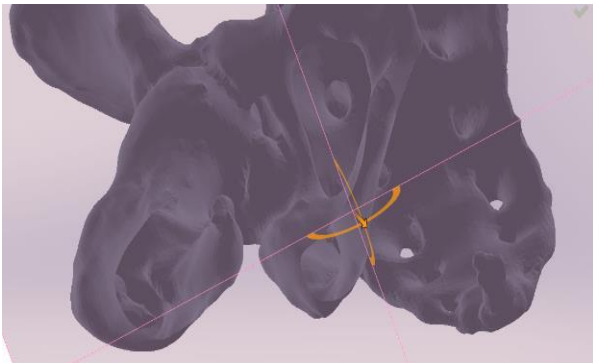

Fig 7: Cross-section of imported Hollow Model.

Fig 8: Cross section of imported Solid Model.

VI. SIMULATION RESULTS

A. Structural Analysis of Hip joint using ANSYS Workbench

The .IGES file was imported to ANSYS for force analysis. We wanted to perform a real-time analysis, which was done by taking into account one of the materials the bone was made up of- Calcium Phosphate. [5,11,12] Its properties were referred from. Since ANSYS does not offer this material in one of its in-built list of materials, we decided to add this as new material. [8,9] This was done with the help of an option called Engineering Data under the Static Structure Tab. On selection of this option, we added Calcium Phosphate as bone and provided it with Isotropic Elasticity properties listed in the table [5,11,12]. After this, the force was applied to the femur keeping the rest of the hip joint fixed. The Equivalent Stress was obtained as the final solution, which projected the stress distributed throughout the hip joint.[6]
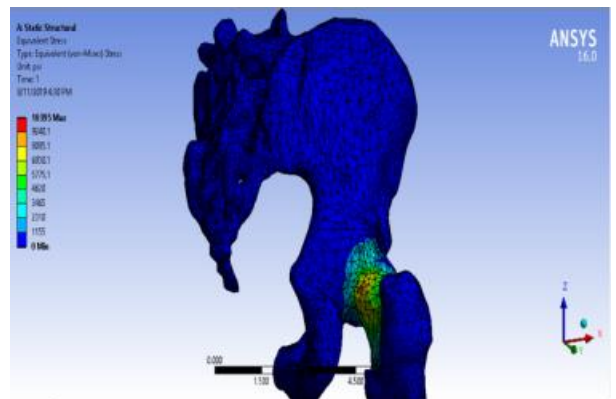

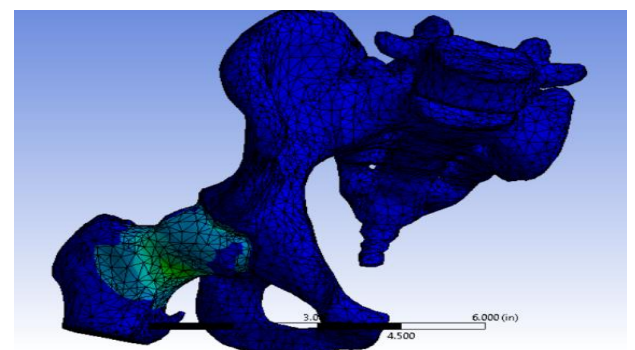Fig 9: Static Structural Analysis of Hip Joint

Fig 10: Static Structural Analysis of Hip Joint

VII. CONCLUSION

In this paper, we created a new methodology to analyze hip joints using the 3D model generated using DICOM File. A lot of research and works are underway to make assistive devices for helping paralyzed people with rehabilitation. This paper can be used to generate a 3D model and feed it as input to the 3D printer and produce a 3D printed model to conduct real-time analysis. The results obtained can be used for design and find an appropriate torque to run the motor for a rehabilitation device for a paralyzed leg. Other works can include helping people understand if there is a fracture in the joint and the important parameters that were responsible for the fracture.

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