Finite Element Analysis of Tibia Bone Model

G Narayanaswamy, Bindu A Thomas

Abstract*: *In this Paper tibia bone is generated and analyzed using finite element method by applying static load on it and various stress concentrated regions in tibia bone is identified and analyzed for stresses at various locations by taking Von Misses stress and displacement. The body of the human being consists of many bones and muscles and many instances, the application of different loads leads to the damage in the bone. So it is necessary to evaluate the effect of applied loads on the bone of human body. In most of the cases whole body weight is carried by the tibia bone which is below the knee roll. So it's necessary to estimate the strength of the tibia bone to carry the body weight. The behavior of the tibia bone under dynamic and static load is necessary for the orthopedic doctors during the treatment of ankle trauma and fractures, but in this paper the study is limited to only static and find out the aspects like Von Misses stress and displacement of tibia bone model under different forces of 800N, 810N, 820N &830N and from the result its understood that both Von Misses stress and displacement are directly proportional to the applied force and the value of Von misses stress in result is less than the maximum value i.e 18MPa for calcium, hence its concluded that generated bone model can withstand the applied force in the range of 800 to 850N

Keywords* : *Von Misses stress, Tibia bone, COMSOL Multiphysics, Calcium, Human body

I. INTRODUCTION

The body of human being is supported and protected by the skeletal system and also give shape and form. The connective tissues are present in this systems are bone, cartilage, tendons and ligaments. The blood vessels present in the canal are helps to provide nutrients to this system. Another functionality of the system is storing of minerals and fats and blood cell production. It helps in providing mobility also. The movement of the systems is the consolidated working of Tendons, bones, joints, ligaments, and muscles. The bone are play a very important role in the skeletal systems and its considered to be major components, there are two class of the bones are present in skeletal systems they are axial skeletal bones and appendicular skeletal bones. There are 206 bones are there in an adult human skeletal systems out of which 80 of which are from the axial skeleton and 126 from the appendicular skeleton. Its necessary to understand the capacity of the various bones of our body can withstand at what forces or stress in order to study this behavior of the bone in the current paper tibia bone model is created and applied various forces to the model and study the behavior of the model. Tarnita et al. [13] have done created the FE model of tibia bone by using CAD tool for studying the behavior of the model for various stresses applied on it. For the creation of the tibia bone model author used computed tomography (CT) images, in this work the researcher are not considered Von misses stress and displacement. Sepehri *et al.* [2] worked on the study of mechanical properties of stress induced tibia bone model. In this work researcher considered only cortical bone but not spongy bone. Taheri et al. [3] have done comparing the result of the mechanical response of experiments on human cadaveric tibia and PE model on the same tibia bone. Consisting of anisotropic material properties with cortical and trabecular. Ruchirabha, Puttapitukporn and Sasimontonkul [4] have worked on stress distribution in the tibia bone during stance phase running. Aroonjarattham and Suvanjumrat [5] have worked on the effect of strain distribution on tibia bone after knee replacement. The FE model of tibia bone consisted of the solid diaphysis formed by the compact bone. According to the author the FE model is made up of compact bone and the distal and proximal ends made by spongy. Gonzalez-Carbonell et al. [6] studied the tibial torsion correction in 3D patient-specific model of the tibia constructed from CT-images. The author assumed the material properties of FE model is non homogeneous in nature.

II.METHODOLOGY

Procedure to build a model using COMSOL MULTIPHYSICS is as shown in Figure 1.

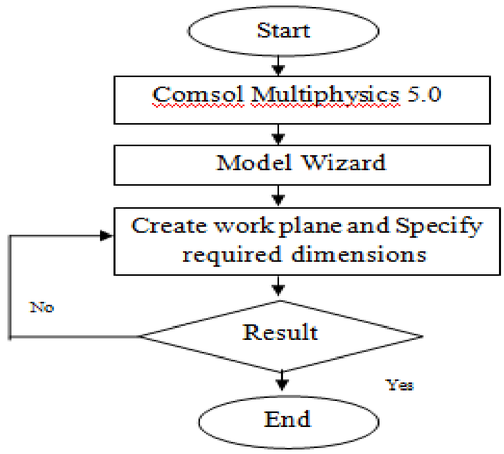

Figure 1: Flow chart of COMSOL Multiphysics.

The analysis of the tibia bone model is started by generating 3D model of tibia bone using Auto CAD and its imported into COMSOL Multiphysic finite element tool for analysis purpose. After importing the model various processes has to be carried out in COMSOL by selecting the boundaries as per the requirement both at the top and at the bottom. To determine the aspects like Von Misses Stress and Total displacement for various stress or force applied. The flow of proposed work is as shown in Figure 1.

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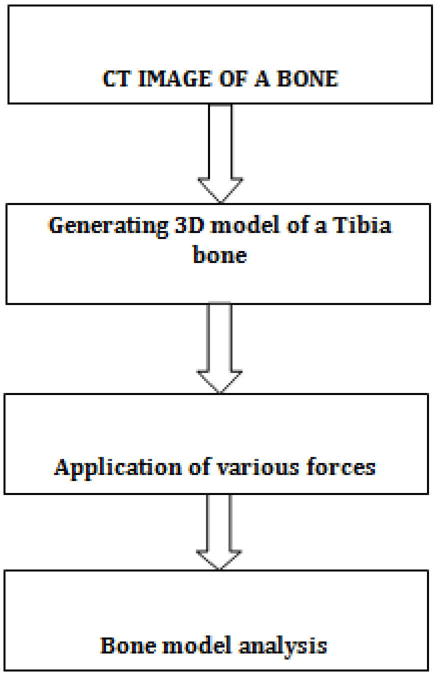


Figure2.Flow chart of the proposed work

The flow chart in the Figure 2 explain the flow of research work carried out and it started with creating a 3D model of tibia bone by using Auto CAD software with the help of CT image of an tibia bone and importing the model into COMSOL Multiphysics5.0. Once the model is imported lot of preprocessing operation has to be carried out such as meshing and applying various forces at various places of tibia bone model. In this model meshing is used as basic meshing i.e. free tetrahedral mesh with course element size.

III. IMPLEMENTATION

The Dimensions of the tibia bone in CT image is considered for the development of tibia bone model and its observed that tibia bone length is 300 to 450mm in case of male and 250 to 400mm length for female and thickness will be 20-30mm in both the cases, the Figure 3 shows the length and thickness of the tibia bone. All these aspects of tibia bone in CT image used to construct the actual tibia model bone using CAD software, later its imported into COMSOL Multiphysics for analysis purpose.

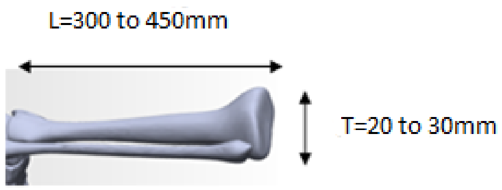


Figure 3: Dimension of the tibia CT image

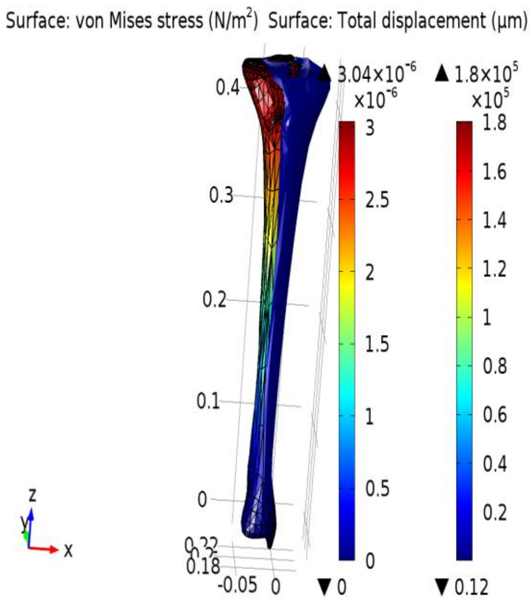
The human body bones are composed of compact (cortical) and spongy (trabecular) bone[3], and assigning the material properties to these bone is highly difficult because making homogenize material assignment to each bone together [5]. By considering all these aspects it is assumed that the tibia model is made up of calcium and the table1 gives the properties of the material assigned to the model.

Table 1: Properties of the calcium and human bone materials

Sl. NO	Property	Properties of calcium	human bone materials
		Value	Value
1	Heat capacity at constant pressure	384[J/(kg*K)]	1313[J/(Kg*K)]
2	Thermal conductivity	401[W/(m*K)]	0.32[W/(m*K)]
3	Density	8960[kg/m^3]	1600[Kg/m^3]
4	Young's modulus	120e9[Pa]	10-15e9[Pa]
5	Tensile strength	110[Mpa]	90-130[Mpa]
6	Compressive strength	60[Mpa]	130-200[Mpa]

IV. RESULTS and ANALYSIS

The Finite Element Analysis calculates the Equivalent Von-Misses stress, total displacement of the tibia bone model. By varying the force applied to the model its observed that both Von Mises Stress and displacement varies linearly with applied force. Figure 4 shows the variation of Von Misses Stress and displacement with applied force on the top surface of the model and fixing the bottom end of the model.



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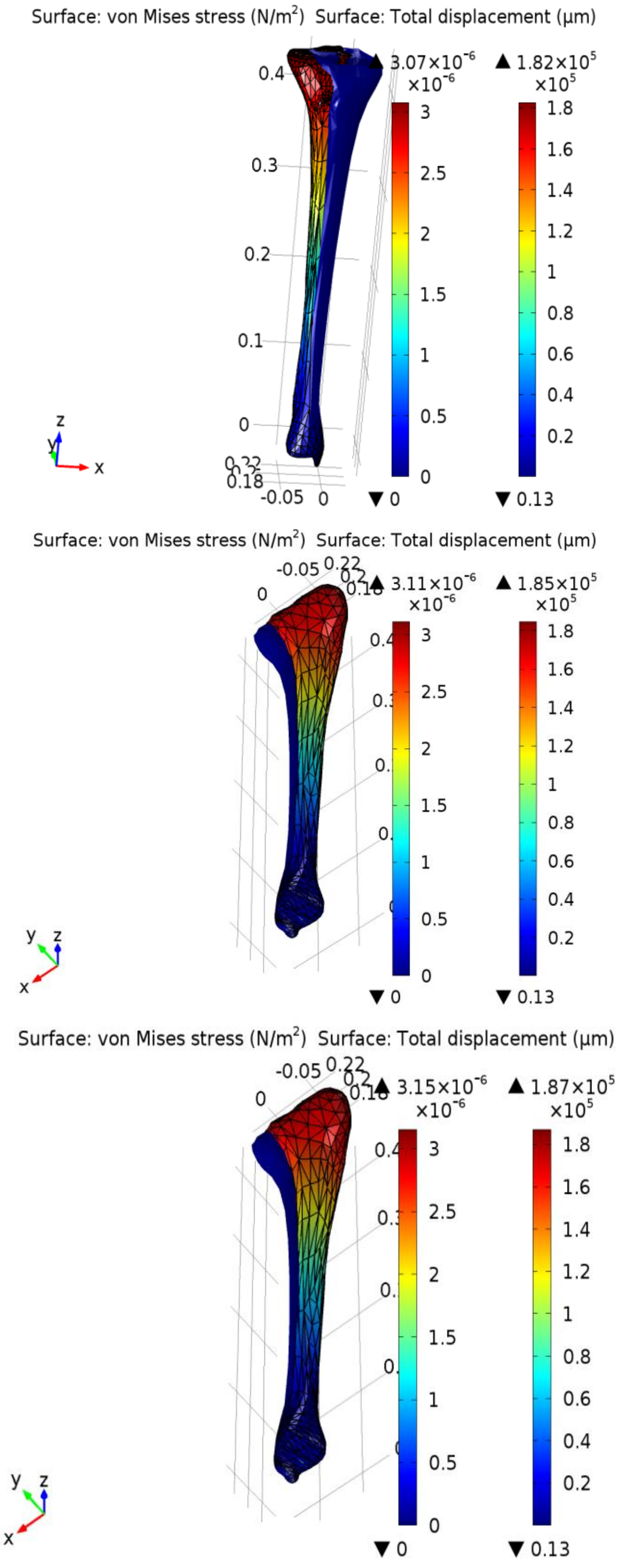
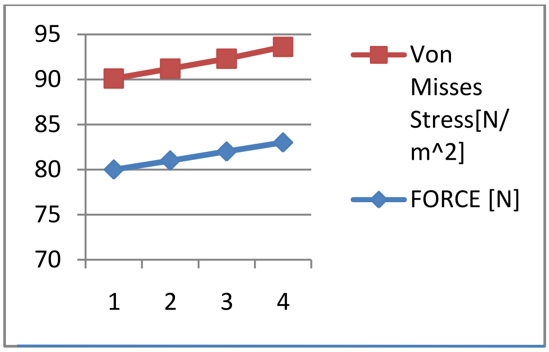


Figure 4.Von Misses stress and Total displacement for various pressures

Figure 4 indicates the value of Von Misses stress and total displacement due to the application of the force on the top surface of the tibia bone model and the values of Von Misses stress and total displacement for various forces are tabulated in the table 2.

Table2.Von –Misses stress and displacement for various Forces

Sl No	Force in Newton(N)	Von-Mises Stress in N/m^2	Total Displacement in um
1	800	1.8X10^5	3.04
2	810	1.82X10^5	3.07
3	820	1.85X10^5	3.11
4	830	1.87X10^4	3.15



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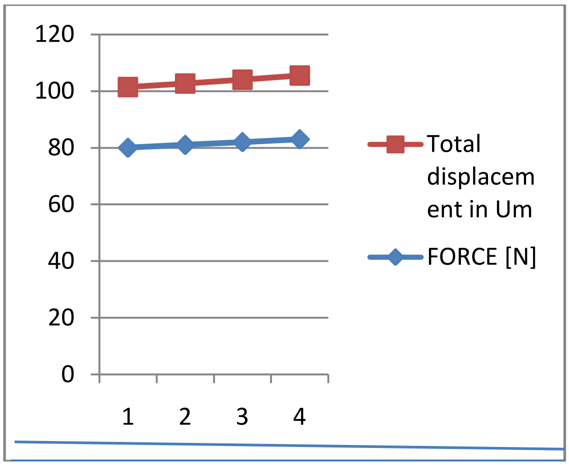

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Figure 5: Variation of the Von-Misses stress and Total displacement with force

The variations of both Von Misses stress and Displacement with applied force is as shown in the Figure5a and figure 5b,The graph shows that the variation of Von Misses stress and total displacement is directly propositional to the applied force ,there are four trails carried out for the force 800N,810N,820N and 830N assuming the human body weight is around 80 Kg,81Kg,82Kg and 83 Kg, so the same amount of forces is applied on the tibia bone on the top surface by fixing the bottom end. In all the cases the Von Misses stress is around 1.8x10^{5}N/m^2, 1.82x10^{5}N/m^2 etc, which is less than the Von misses stress of calcium its 18.1MPa.

V.CONCLUSION

The objective of the research aims at development of tibia bone model by considering the CT image of a tibia bone and same model can be used for the stress analysis purpose by using COMSOL Multiphysics5.0, by applying various amount of forces on the tibia model. Its possible to analyze the stress and displacement for various load applied on it and from the analysis it's understood that Displacement and Von Misses stress are directly proportional to the force applied on the bone model and from the von misses stress value obtained is less than the Von misses stress of the calcium which is used as a model material, this ensure that the model can withstand the applied force of around 800N under different conditions. The outcome of the paper helps orthopedic doctors to analyze the tibia bone for proper diagnosis. Future works involves in testing of real bone by applying various forces on it and comparing the results. Based on the outcome it's possible to comment on the strength of the tibia bone.

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