International Journal of Mechanical Engineering and Robotics Research

ISSN 2278 – 0149 www.ijmerr.com
Vol. 2, No. 4, October 2013

Review Article

REVIEW OF THE APPLICATION OF FINITE ELEMENT ANALYSIS AND ITS RELATION WITH THE ANTHROPOMETRY IN CASE OF THE HUMAN FEMUR AND TIBIA

Ramanpreet Singh[1]*, Rasmeet Kaur[1] and Vijay Shanker[1]

*Corresponding Author: Ramanpreet Singh, ✉ ramanpreet.gurdutta@hotmail.com

Femur also known as the thigh bone is considered to be the strongest, heaviest and largest amongst all the bones. Femoral shaft fractures are very common major injuries that an orthopedic surgeon will require to treat. The possible cause of the shaft fracture may be the high energy sudden forces which creates heavy stress in the femur shaft that can cause failure of the shaft. This may be the case for tibia also. Anthropometrical variations are also present which plays a vital role in the stress variation. Anthropometric data varies from a set of population to other set of population. The method that can be used in order to analyze any femoral bone and tibia bone is the finite element analysis for number of samples because that will help in analyzing the heterogeneous material and complicated shapes.

Keywords: Femur, Tibia, FEM, Anthropometry, Stress analysis, Biomechanics

INTRODUCTION

The term human anatomy consists of the study of the various structures of body and deals with the relationship of its constituent parts with each other.

Bone Material Constituents: Majorly bone is composed of calcium carbonate, calcium phosphate, collagen and water. Generally calcium carbonate and calcium phosphate constitute 60%-70% of dry bone weight. These minerals play an important role in determining its compressive strength. Collagen is protein that takes care of the flexibility and tensile strength of the bone. Water contributes 25% to 30% of the total bone weight.

Bone in thigh area is known as femur. The longest bone in the body is femur (Figure 1) For the formation of hip joint it articulates with acetabulum and from here bone inclines medially to the knee, where it articulates with

[1] Lovely Professional University, Jalandhar-Delhi GT Road (NH-1), Phagwara, Punjab, India.

Figure 1: Tibia Model

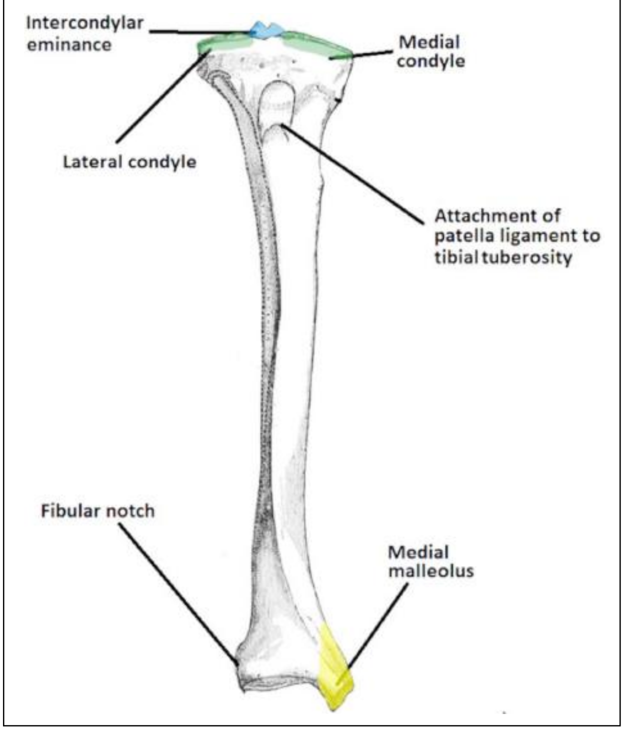
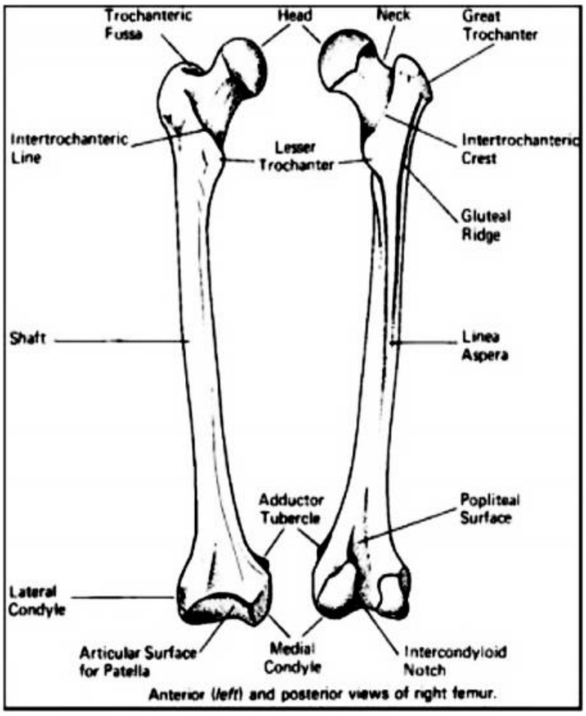


Figure 2: Femur Model



tibia. It has a long bone with two extremities and a shaft.

The upper extremity: It has the head covered by the two third of the sphere which has an ovoid depression know as a roughened pit for the ligamentum teres attachment. Neck is located below the head which is long and flattened. Shaft of femur: It is smooth, cylindrical, rounded in front and at the sides. It has a marked ridge behind as it curves forward that ridge is linea aspera to which a number of muscles are attached. Lower extremity: It is wide and has two condyles, intercondylar notch, a popliteal surface and a patellar surface.

Shin bone or tibia (Figure 2) forms main skeleton of leg. It lies medial to fibula. It also has a long bone with a shaft and two extremities. Upper extremity: It has the medial and lateral condyles. The upper and the most expanded portion of the bone was formed by condyles. The lateral condyle has the facet posteriorly for the articulation with the head of the fibula. The shaft: It has the triangular cross section. The anterior border forms the crest of tibia and lies subcutaneously in its middle third. The medial surface forms the useful area to take a tibial bone graft. Soleal line marks the posterior surface which is a strong ridge of bone running downwards and medially. Lower extremity: marks the entry into the formation of the ankle joint. It provides a joint between femur, talus and fibula.

LITERATURE REVIEW

Francis and Kumar (2012) performed the three dimensional finite element modeling using Computed Tomography (CT) data that accurately predicts information about bone morphology and tissue density. Modeling of the proximal femur of the three samples (17 yr, 32 yr, 40 yr) was done using CT data for their individual weights. When half of the load of the body was applied on the head of the right proximal femur it was discovered that safety factor was highest in case of the middle aged (32 yr) sample. Same was the case when the data for the bone mineral density was observed.

Yousif and Aziz (2012) had done the biomechanical analysis of human femur bone during normal walking and standing conditions. They modeled a human femur bone of a 40 year old healthy individual whose weight is 75 kg and which was reconstructed from DICOM (CT) images. They had fixed the distal end of the femur and on the head of the femur the hip contact forces had been applied for the calculation of the normal stresses in normal walking and standing up conditions. After that the boundary conditions were interchanged and the result average was considered. It was observed maximum normal stress for both normal walking and standing up conditions was observed at the neck of the femur.

Yazar *et al.* (2012) in their study, associated the distal morphometry of femur with femur height and width. CT data of 66 caucasians were taken for the measurement of femur. Then all the measurements were thoroughly checked for the correlation with the femur height and width. They concluded that Femur height is the basic parameter instead of sex or race discrimination as difference of distal femur morphometry as per the race and sex depends on the other morphometric measurements of femur.

Nareliya and Kumar (2012) reviewed some papers related to the finite element analysis and elaborated the anatomy of the femur bone. In all 47 technical papers were reviewed and explanation of FEA was well written and it was concluded that, for modeling the human femur bone computational techniques were used and for observing the response FEM was used. In most of the research articles CT data of dry, frozen or moist bone had been used to get the 3D well dimensioned model. In case of the THR (total hip replacement) and effect of nailing research was carried by using FEM. It was also observed that the angle of inclination varies between 7° to 28° for different individuals under loading conditions for analysis of stress and deflections. In various articles it was found that the in-homogenous models of femur predicts good accuracy for the measured stress field and homogenous material femur gave less accurate results.

Bokariya *et al.* (2009) prepared a report on anthropometric study of femur in central Indian population collected 106 femora (58 right and 48 left) of adult from bone bank of Anatomy Department of MGIMS, sevagram. First they had evaluated the morphometry of the femur of central Indian population, then bilateral difference between the right and left bone was estimated. Ultimately a comparative statistical study was performed. In their study they found that the mean value of the length of the right and the left femora was statistically similar (there was difference which was insignificant). They concluded that as the number of bones taken was small so significant differences were shown in the result.

Kubicek and Florian (2009) studied the stress strain analysis of the normal tibio-femoral joint in its basic position (extension).

They described the geometry of tibia and femur by computer tomography and shape of cartilage and meniscus with aid of literature. They obtained the contact pressure between a femoral and tibial cartilage and femoral cartilage and meniscus from the analysis which was performed using ANSYS 10.0. Pressure at different joints like hip joint, elbow joint and knee joint was also compared.

Popa *et al.* (2006) presented the method and steps to model a virtual bone. The model was prepared with the help of the CAD software and it was attached to the other bones. Finite element method can be used for stress analysis and model prepared can be used for kinematic and dynamic simulation. In their study all the important steps explaining all the features required for the modeling of a human femur was explained in detail. That detailed explanation could be utilized for the model development.

Shi *et al.* (2006) developed the dynamic model of the knee joint after total knee replacement and stress analysis of the distal femur was done. MSC/ADAMS and MSC MARC software was used for the modelling of the knee joint. Bones of the knee joint were modelled as mixed cortico- cancellous bone. Femur distal part had been modelled as flexible body with springs for simulation of the ligaments. On simulation it was found that higher stresses were observed in the bone adjacent to the femoral component peg.

Züylan and Murshid (2002) prepared a report on the femoral anthropometry two different age groups from Anatolian population. In this study a sliding caliper, osteometric board, tapeline and goniometer were used for measurements. The data obtained in this research was statically analyzed with the students t-test and pearson correlation coefficient. After the analysis they concluded that there is no significant difference between the left and right femora except the head vertical diameter. Significant differences in collo-diaphyseal angle of the femora of contemporary and Chalcolithic Age was also observed. Also, there were differences in the anthropometric measurements of the individuals of different ages belonging to different age groups.

Rajani (1995) observed that cars design are such that during an accident upper part was protected by air bags and the lower limb were left free for injuries. So, he created the 3D model of the tibia and fibula using a software OPTIMAS on analysis it was ascertained that maximum compressive stress of 43.96 N/mm^2 occurred approximately 70 mm from the distal end. It was coincident that the same area where most of the tibial fractures were known to occur. Indications of tibial plateau fractures were also present due to the low tensile stress patterns on the lateral and medial side of the tibia plateau.

CONCLUSION

Human femur is considered to be the strongest and the heaviest part of the body and it is largest among all the bones. It has a very important part in the functioning of the human body and so is Tibia, both the parts are connected at the patella. In the present scenario the study and computational analysis is the need of the hour to overcome some severe problems. Material properties of the bone are not homogenous and it varies from individual to individual and it directly affects the stress state in the bone (Femur and tibia). In this review ten research papers related to femur modeling, tibia stress analysis, femur stress analysis and their anthropometry were thoroughly studied. From all the above papers it may be concluded that for the analysis of either femur or tibia, model is needed. That model can be real model (man-made) or the computational model with the help of any software like CATIA, Solid works etc. The other way to model it is to scan the CT/MRI images and use any medical imaging software that converts 2D model into 3D model. In all the above literature it has been observed that all the analysis was done with the help of FEA software. Analysis can be done after modeling, for the analysis any FEA software can be used like (ANSYS, PATRAN, etc.). In the series of papers observed here, it was seen that when the model was done as mixed cortico-cancellous bone higher stresses are observed in the femoral component leg. From the anthropometrical point of view when the femoral anthropometry two different age groups from Anatolian population when statically analyzed, no significant difference was observed in the right and left femora except the vertical head diameter but the results may vary depending on the numbers of the sample taken. The same analysis can be made for the Tibia bone. When anthropometrical analysis was done in the sample taken from the Indian population (sample size 106)[6] it was observed that length of both the right and left femur was same but there may be some difference if number of samples are increased. As it was observed that in Indian population the length of the right and left femur was same when analyzed for small number (106)[6] of samples, so number of samples may be taken from different age groups and that can be analyzed for the safety in the normal walking, standing up and playing situations when the femur and tibia are making different angles with each other like 45°, 60°, etc. Variation in the bone mineral density may also be made for the same analysis that can help in imitating the artificial bone which can be replaced by the original one as in case of TKR (total knee replacement). The results can be compared with the same research carried out with the 2 or 3 samples.

REFERENCES

1. Bokariya P, Kothari R, Waghmare J E, Tarnekar A M and Ingole I V (2009), “Anthropometric Study of Femur in Central Indian Population”, *J. MGIMS*, Vol. 14, No. ii, pp. 47-49.
2. Francis A and Kumar V (2012), “Computational Modeling of Human Femur Using CT Data for Finite Element Analysis”, *International Journal of Engineering Research & Technology (IJERT)*, Vol. 1, No. 6.
3. Hall S J (2003), *Basic Biomechanics*, 4th Edition, Mc-Graw Hill.
4. Kubicek M and Forian Z (2009), “Stress Strain Analysis of Knee Joint”, *Engineering Mechanics*, Vol. 16, pp. 315-322.
5. Nareliya R and Kumar V (2012), “Finite Element Application to Femur Bone: A Review”, *Journal of Biomedical and Bioengineering*, Vol. 3, No. 1, pp. 57-62.

6. Pearce E C (2003), *Anatomy and Physiology for Nurses*, 7th Edition, Jaypee Brothers.

7. Popa D, Gherghina G, Tudor M and Tarnita D (2006), "A 3d Graphical Modelling Method for Human Femur Bone", *JIDEG*, Vol. 1, pp. 37-40.

8. Rajani (1995), "3-D Modeling and Finite Element Analysis of the Tibia".

9. Shi J F, Wang C J, Laoui T and Hall R (2006), "A Dynamic Model of Simulating Stress Distribution in the Distal Femur After Total Knee Replacement", *JEIM Proc. IMechE*, Vol. 221, pp. 903-912.

10. Yazar F, Imre N, Battal B, Bilgic S and Tayfun S (2012), "Is There Any Relation Between Distal Parameters of the Femur and its Height and Width?", Springer-Verlag.

11. Yousif A E and Aziz M Y (2012), "Biomechanical Analysis of the Human Femur Bone During Normal Walking and Standing Up", *IOSR Journal of Engineering (IOSRJEN)*, Vol. 2, No. 8, pp. 13-19.

12. Züylan T and Murshid K A (2002), "An Analysis of Anatolian Human Femur Anthropometry", *Turk. J. Med. Sci.*, pp. 231-235.