Experimental & ANSYS Stress Analysis of Real Human Femur Bon

Pranjal P. Farakte [1], Rohini N. Gaikwad[2], Priyanka S. Chavan[3]

[1]*Assitant Professor, D. Y. Patil college of Engineering and Technology, Kolhapur, Maharashtra, India*
[2]*Assitant Professor, D. Y. Patil college of Engineering and Technology, Kolhapur, Maharashtra, India*
[3]*Assitant Professor, D. Y. Patil college of Engineering and Technology, Kolhapur, Maharashtra, India*

---***---

Abstract - *The human femur is the leg bone that experiences the most deformation. The femur bone, which is the largest and longest bone in the body, is the most likely to fail, especially in women. In the event of failure, orthopedic implantation is performed. Sometimes implanting a new synthetic femur is necessary following femoral bone loss.Therefore, in order to compare with a synthetic femur, we must see how the real and actual femur behaves. Analysis of the material's properties, size, form, surface treatment, load resistance, and failure probability is required prior to implantation.*

Key Words: *Femur, bone, resistance, Orthopaedic, skull , Titanium*

1. INTRODUCTION

The femur, or thigh bone, is the most proximal (closest to the body) bone of the leg invertebrates capable of walking or jumping. The word femur is Latin for thigh. In medical Latin its genitive is always femoris, but in classical Latin its genitive is often feminis, and should not be confused with case forms of femina, which means "woman".

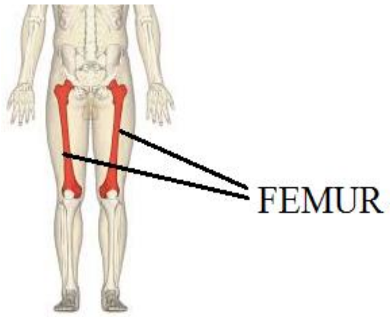

Fig.1.1 Position of Femur Bone

Femur fractures rank in the top ten of all injuries in terms of residual functional impairment for people over age 50. Due to increasing life spans, this number is consistently growing. Risk factors for femur fractures include women over age 50, men over age 65, smokers, certain blood pressure medications, diseases such as osteoporosis, epilepsy, obesity, poor vision and more. Today, with technological medical inventions, means of bone fixation such as screws, metal Prostheses and implants can allow full weight bearing a few days after bone fixation surgery. However, approximately 1 out of every 10 fixations must be surgically readjusted due to problems such as: failure of the bone due to stress concentration, fatigue of bone cemented rarely, a failure of the metal fixation device. A common tool in engineering for the prediction of stress, strain and deformations is the finite element method. The purpose of these studies was to predict the mechanical response of the preserved human femur, and validated by experiments on the same.

2. PROBLEM DEFINITION

"Femur is leg bone of the human body undergoing more deformation. Being longest and heaviest in size, failure of femur bone is the most common among bone failures especially in woman. Orthopedic implantation is done in case of failure. After failure of femur bone sometimes it is necessary to implant a new synthetic femur .So that we must check the behaviour of real and actual femur to compare with synthetic femur. Before implantation it is necessary to analyze the perfectness in case of its material property, size and shape, surface treatment, load resistance and chances of failure.''

Fig.3.1Real Titanium Femur Bone

3. INTRODUCTION OF FEMUR BONE

3.1 HUMAN ANATOMY

In human anatomy, the femur is the longest and largest bone. Along with the temporal bone of the skull, it is one of the two strongest bones in the body. The average adult male femur is 48 centimeters in length and 2.34 cm in diameter and can support up to 2 times the weight of an adult .It forms part of the hip joint and part of the knee joint, which is located above. There are four eminences, in the human femur: the head, the greater trochanter, the lesser trochanter, and the lower extremity. They appear at various times from just before birth to about age 14.Initially; they are joined to the main body of the femur with cartilage, which gradually becomes ossified until the protuberances become an integral part of the femur bone, usually in early adulthood. The shaft of femur is cylindrical with a rough line on its posterior surface.

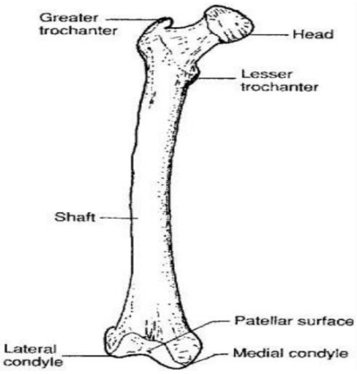

Fig.32 Nomenclature of femur bone

3.2 TYPES OF FEMUR BONE FRACTURE:

In order for a femur fracture to occur, either a large force must be applied or something is wrong with the bone. In patients with normal bone strength, the most common causes of femur fractures include:

- Car accidents
- Falls from a height

Patients may also have bone that is weakened by osteoporosis, tumor, or infection

3.3Proximal Femoral Fracture

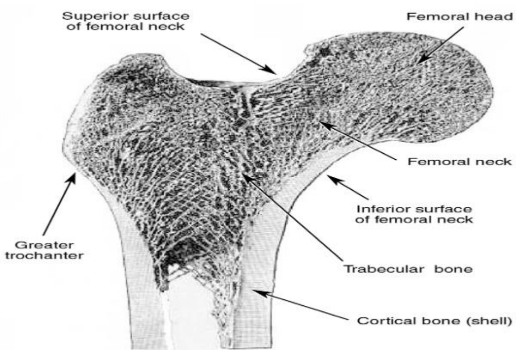

Fig.3.3 Femoral fracture

Figure shows the anatomy of the human proximal femur (upper third of the human femur bone), which includes the femoral head, femoral neck, greater trochanter, and upper portion of the femoral stem. The femoral neck is the narrowed region directly below the femoral head. Cortical bone is the outer (hard) shell of a bone having higher material density. Trabecular bone is the relatively soft, sponge-like bone residing inside the hard cortical shell. Proximal femur fractures, or hip fractures, involve the upper-most portion of the thigh bone, just adjacent to the hip joint. A hip fractures a fracture in the proximal end of the femur (the long bone running through the thigh), near the hip joint. The term "hip fracture" is commonly used to refer to four different fracture patterns and is often due to osteoporosis; in the vast majority of cases, a hip fracture is a fragility fracture due to a fall or minor trauma in someone with weakened osteoporotic bone. Most hip fractures in people with normal bone are the result of high-energy trauma such as car accidents

3.4 Sub-Types: Many subtypes of fractures about the hip joint are colloquially known as 'hip fractures'. Although a true hip fracture involves the joint, the following four proximal femur fractures are commonly referred to as hip fractures. The differences between them are important because each is treated differently.

Femoral head fracture denotes a fracture involving the femoral head. This is usually the result of high energy trauma and a dislocation of the hip joint often accompanies this fracture.

Femoral necks fracture is adjacent to the femoral head in the neck between the head and the greater trochanter. These fractures have a propensity to damage the blood supply to the femoral head, potentially causing vascular necrosis.

Intertrochanteric fracture denotes a break in which the fracture line is between the greater and lesser trochanter on the Intertrochanteric line. It is the most common type of 'hip fracture' and prognosis for bony healing is generally good if the patient is otherwise healthy.

Sub trochanteric fracture actually involves the shaft of the femur immediately below the lesser trochanter and may extend down the shaft of the femur. A femoral shaft fracture is a severe injury that generally occurs in high-speed motor vehicle collisions and significant falls. These injuries are often one of several major injuries experienced by a patient. The treatment of a femoral shaft facture is almost always with surgery. The most common procedure is to insert a metal rod down the center of the thigh bone called an intramedullary rod. This procedure reconnects the two ends of the bone, and the rod is secured in place with screws both above and below the fracture. The intramedullary rod generally remains in the bone for the life of the patient, but can be removed if it causes pain or other problems. Other less commonly used treatments of a femur fracture include a plate and screws or an external fixator. These treatment options may have to be used if an intrameduallary rod cannot be used for some reason. In certain patients, depending on the fracture type and associated injuries, an intramedullary rod may not be an option; in these cases one of the other treatments (plate and screws, external fixator, etc.) will be selected.

In this project, the analyses are mainly concerning about how does the stress distributed over the proximal femur bone during the standing position of human being. The main purpose in this project is to study the stresses carried by the proximal femur before total hip replacement.

4. WHY FEMUR BONE?

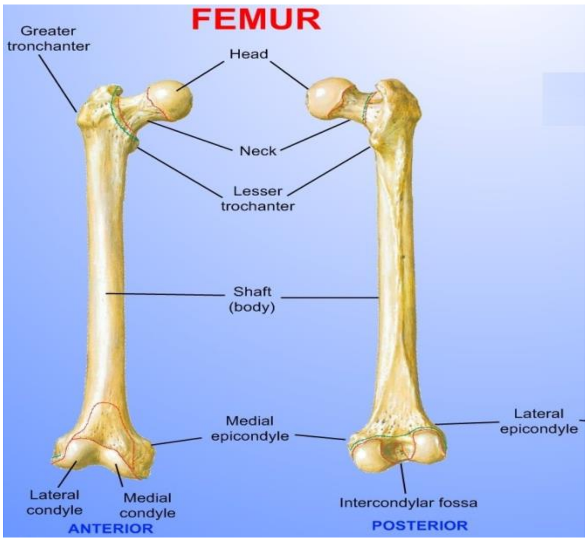

Fig.3.4 Femur

With the above problems, the following are the reasons because of that we were interested in stress analysis of real human femur bone.

1. Largest Human Bone: It connects to the pelvis at the proximal end to form the hip joint and to the tibia at the distal end to form the knee joint. The femur in the body takes the largest percentage of the weight of the body. The shaft of the femur is cylindrical with approximately circular cross section shape.

2. Single Support Member: The human skeletal system consists of a large number of bones that fill roles such as support for the body, protecting inner body organs, allowing movement and producing red blood cells. The femur is the longest, strongest, and heaviest bone in the human body and one of the principal load bearing bones in the lower extremity.

3. **Less** Flexible (Stiff): Many studies have focused on geometry, biomechanical properties, etc. of a human femur. A typical femur structure includes compact bone, sponge bone, medullar cavity, yellow marrow, periosteum, articular cartilage, etc. The average adult male femur is 48 centimeters in length and 2.84 cm in diameter at the mid-shaft, and has the ability to support up to 30 times the weight of an adult.

4. Anisotropic Material: Human bone is highly heterogeneous and non-linear in nature, so it is difficult to assign the material properties. The proper assignment of material properties on the other hand, is still under active research because of the inherent inhomogeneous and anisotropic nature of bone's tissue. Most past studies assumed the bone to be inhomogeneous isotropic due to simplicity and the limited knowledge of the anisotropic behavior. Thus, the bone is known to be anisotropic and inhomogeneous, most studies simplify these difficulties by considering an isotropic material so we have also considered same (i.e. Isotropic) femur bone material in our study.

5. ASSUMPTIONS

2. The load acting on the femur is assumed to be a point load acting at the top of the femur head.

3. Motions considered are for a flat ground.

4. Four arbitrary loads 490N, 540N, 588N and 640N were assumed.

5. Self-weight of the femur bone is neglected.

6. Small modifications were made to the dimensions as ANSYS was unable to import

7. The model.

8. Muscle forces were neglected:

There are a lot of muscle forces acting on the femur. The muscle forces move the hip joint by a system of levers. The resultant forces acting on the hip joint when a person moves are few times higher than the body weight. Basically, there are two major kinds of forces, which are bending force and twisting force.

6. METHODOLOGY USED:

1. In the present work, experimental and finite element analysis of stresses in real proximal human femur bone under static body load was carried out.

The work focuses on:

- FEM analysis :

a) Modeling of human femur bone.

b) Meshing of human femur bone.

c) ANSYS calculations of the stresses.

d) Experimental analysis:

e) Positioning of strain gauges on real human femur bone.

f) Mounting of human femur bone.

g) Applying a load on proximal human femur bone head.

h) Stress analysis.

2. To check the validity of FEM analysis results by using the obtained experimental results.

3. To carry out comparative study of experimental and FEM analysis results to decide the high stress concentration areas of the femur bone which are extremely responsible for fractures and damages.

7. CONCLUSIONS

[1] These analyses will provide information to medical doctors about risk of possible fracture areas in human femur bone.

[2] The results of proposed analysis will be helpful for orthopedic surgeons for clinical and experimental interest.

[3] This research work will be aimed to make available guideline in relation to the importance of medical treatment once fracture has occurred for the femur.

[4] The results of this analysis are helpful to design an implant, which is called hip prosthesis, to replace the failed femur part.

8. REFERENCES

1. Royi Fedida, Zohar Yosibash, Charles Milgrom and Leo Joskowicz 2005. Femur Mechanical Simulation Using High-Order Fe Analysis with Continuous Mechanical Properties. In Proceedings of the II International Conference on Computational Bioengineering.

2. Nir Trabelsi, Zohar Yosibash, "Patient-specific FE analyses of the proximal femur with orthotropic material properties validated by experiments", Journal of Biomechanical Engineering. Received November 29, 2010; Accepted manuscript posted May 6, 2011. doi:10.1115/1.4004180 Copyright 2011 by ASME.

3. P.E. Galibarov, P.J. Prendergast, A.B. Lennon, "A method to reconstruct patient-specific proximal femur surface models from planar pre-operative radiographs", Elsevier Journal of Medical Engineering & Physics, 2010 (1180-1188).

4. Adeeb Rahman, Shirin Selmi, Chris Papadopoulos, and George Papaioannou, "CT-Scan based FEA for the Assessment of the Effect of Bone Density on Femur's Fracture", In Proceedings of the 9th International Conference on Information Technology and Applications in Biomedicine, ITAB 2009, Larnaca, cyprus, 5-7 November 2009.

5. A. Ramos, J.A. Simoes, "Tetrahedral versus hexahedral finite elements in numerical modelling of the proximal femur", Science Direct Journal of Medical Engineering & Physics 28 2006 (916–924).

6. Fulvia Taddei, Saulo Martelli, Barbara Reggiani, Luca Cristofolini, and Marco Viceconti, "Finite-Element Modeling of Bones from CT Data: Sensitivity to Geometry and Material Uncertainties", IEEE Transactions on Biomedical Engineering, Vol. 53, No. 11, November 2006.

7. A.S. Dickinson1, A.C. Taylor, H.Ozturk1 and M. Browne, "Experimental Validation of a Finite Element Model of the Proximal Femur Using Digital Image Correlation and a Composite Bone Model", Journal of Biomechanical Engineering. Received May 24, 2010; Accepted manuscript Papaioannou, "CT-Scan based FEA for the Assessment of the Effect of Bone Density on Femur's Fracture", In Proceedings of the 9th International Conference on Information Technology and Applications in Biomedicine, ITAB 2009, Larnaca, cyprus, 5-7 November 2009.

8. A. Ramos, J.A. Simoes, "Tetrahedral versus hexahedral finite elements in numerical modelling of the proximal femur", Science Direct Journal of Medical Engineering & Physics 28 2006 (916–924).

9. Fulvia Taddei, Saulo Martelli, Barbara Reggiani, Luca Cristofolini, and Marco Viceconti, "Finite-Element Modeling of Bones from CT Data: Sensitivity to Geometry and Material Uncertainties", IEEE Transactions on Biomedical Engineering, Vol. 53, No. 11, November 2006.

10. A.S. Dickinson1, A.C. Taylor, H.Ozturk1 and M. Browne, "Experimental Validation of a Finite Element Model of the Proximal Femur Using Digital Image Correlation and a Composite Bone Model", Journal of Biomechanical Engineering. Received May 24, 2010; Accepted manuscript posted November 29, 2010. doi:10.1115/1.4003129 Copyright 2010 by ASME.

11. Raji Nareliya et al., "Biomechanical Analysis of Human Femur BoneInternational", Journal of Engineering Science and Technology (IJEST) ISSN: 0975-5462 Vol. 3 No. 4 Apr 2011 3090-3094.

BIOGRAPHIES

Assistant professor Pranjal P. Farakte at Department of Electronics & Telecommunication Engineering, D. Y. Patil College of Engineering & Technology, Kolhapur, Maharashtra, India.

Assistant professor Rohini N. Gaikawad at Department of Electronics & Telecommunication Engineering, D. Y. Patil College of Engineering & Technology, Kolhapur, Maharashtra, India.

Assistant professor Priyanka S. Chavan at Department of General Science Engineering, D. Y. Patil College of Engineering & Technology, Kolhapur, Maharashtra, India