EXPERIMENTAL ANALYSIS OF FEMUR BONE BY STRAIN GUAGE METHOD

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***Abstract*— In human body, femur bone is longest bone as per the research. The femur bone is a bone which is located between hip joint and knee joint forming an important bone in a human body. As it is the longest bone in a human body, chances of failure of this bone are more. The exact amount of stress on bone can be calculated and chances of failure of bone can be analyzed according to various extreme conditions. We study models of the bone from computed tomography scan data, as this technique of scanning gives a better idea about the structure of bone in detail. In this paper different test of the femur bone is carried out to analyze stresses and strain experimentally by using 3 point bending method.**

Keywords- Biomechanics, femur bone, 3point bending method.

I. INTRODUCTION

The femur is not just a solid. It consists of cortical (which is the outer bone and also known as compact bone), spongy (which is the inner bone and is also known as spongy bone), bone marrow, Haversian canal, osteocytes, blood vessels and periosteum. The structure itself is complex. This leads to the complexity of bone properties. Therefore, an understanding of bone properties is important so that proper modeling can be performed. The femur connects to the pelvis forming a patella. The head of the femur acts as the ball for the acetabulum on the pelvis and is the corresponding socket for the joint. This joint is known as a hip joint. The hip joint is connected by a round ligament. The cartilage acts as a lubricant between the bullet and the socket.

Biomechanics is the study of the structure and function of biological systems such as humans, plants, animals, organs, fungi and cells using the mechanics method. The term "biomechanics" and the term "biomechanics" refer to the study of the mechanical principles of living organisms, in particular their movement and structure. It is the development and application of mechanics in order to understand the influence of mechanical loads on the structure, properties and function of living beings. It focuses on design and analysis, each of which is the foundation of engineering.

The femur bone is a long bone between hip joint and knee joint of body. The femur bone is located in the human thigh.

Its function is to support the weight of the body and allow the movement of the lower end.

A. *Importance of the femur bone:*

- The strongest bone of the body.
- Acts as a pillar of our leg.
- Allows us to walk, run, jump and do other daily activities.
- One of the main bearings of the lower end.

B. *Importance of Stress Analysis for Femoral Bone:*

The human femur can withstand the force of 1800 to 2500 pounds, so that it does not break easily. A fracture in this bone can be the result of a large amount of force, such as car accidents or falling from great heights. The risk factor for femur fracture includes women over 50, men over 65, smokers. In 2016, in India alone, more than 610,000 cases of femur fractures have been reported. In 2015, the cost of fracture treatment in India was about $ 6 billion. There is only one solution for femur fracture, surgery, but about 1 in 10 has been surgically readjusted because of problems such as:

- Failure of the bone due to stress concentration.
- Failure of the metal fastener.
- The age of the patient.
- The weight of a patient.
- The daily routine of a patient, etc.
- To avoid the next surgery is important.
- By doing stress analysis of femur bone, we can predict the exact strength of bone.

C. *Necessity of Femur Bone:*

It connects to the pelvis at the proximal end of the hip joint and the tibia at the distal end of the knee joint. The femur in the body takes the largest percentage of body weight.

The human skeletal system consists of a large number of organs that support the body, protect the inner body. The femur is the longest, strongest and heaviest bone in the human body and one of the main bone carriers of the lower limb.

Many studies have focused on geometry, biomechanical properties, etc. of a human femur. A typical femur structure includes compact bone, cancellous bone, medullary cavity, yellow marrow, periosteum, articular cartilage, and so on.

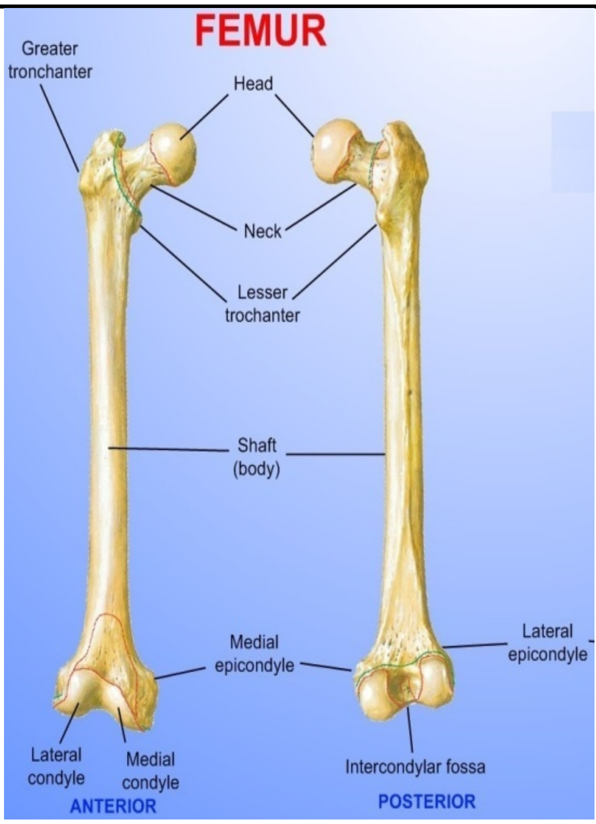

Fig. 1 Anatomy of Femur Bone

The human bone is very heterogeneous and nonlinear in nature, so it is difficult to attribute the properties of the material. On the other hand, the correct assignment of the properties of the material is still under study because of the inherent inhomogeneous and anisotropic nature of the bone tissue. Most previous studies assume the role of inhomogeneous because of the simplicity and limited knowledge of anisotropic behavior. Thus, the anisotropic and inhomogeneous isotropic material, the most isotropic material, we are also considered as (isotropic) material of the femur in our study.

In this research, paper literature is given about the experimentation of femur bone. The femur bone was subjected to three-point flexion tests, comparing the anteroposterior and postero-anterior orientations. The results show that the loading capacity of the femur bone tested in the posterior orientation is greater than that of the anteroposterior bones. The load capacity of the bones tested in the posterior orientation is much higher than that of the bones tested in the opposite direction. This result confirms that the mechanical properties of bone tissue depend on their position in the cross-section when subjected to bending tests [7]. Stress fracture is a type of biomechanical failure caused by intense physical training. This failure occurs in the elderly and athletics. Due to cell death, in some cases after emergency surgery, the injured person may suffer from permanent disability. In this research, a three-dimensional finite element of the human model was created and analyzed. The material is supposed to have isotropic elastic characteristics. The results indicated that the maximum stress occurred at the lower root of the femoral neck [8]. It studied the behavior of human beings. In the analysis, the effect of the femoral bone is neglected to understand the behavior of bone for different loading conditions. If we take into account the muscular effect, the constraints will decrease by 30%. The results obtained in this study can be used to determine what fracture occurs in the bone. It can also be used to decide materials for artificial bones [12]. The analysis of anisotropy has been performed by six sets of models for each specimen of six femurs that have been experimentally investigated by femoral neck. Two different modulus-density relationships were tested, both with and without anisotropy derived from mean intercept length analysis of high-resolution peripheral QCT (HR-pQCT) scan [11].

II. EXPERIMENTAL PROCEDURE

A. Positioning of strain gauges on a sheep femur bone.

Select the installation location of bone and mark the surface. Remove all scale, rust, etc. to provide a shiny surface of the sample. Clean the abraded surface with an industrial grade paper towel or a cloth soaked in a small amount of solvent. Precise mounting of the strain gauge on the component is always necessary. Make a marking where the strain gauge is mounting. Use cellophane tape, mark a slightly larger area than the base of the strain gauge to install. Apply the required amount of adhesive to the back of the strain gauge base. Align the gauge with the positioning marks. Place the polyethylene sheet on the dipstick and apply constant pressure with your thumb. Carefully raise the gauge leads after the applied adhesive becomes hardened. Remove the masking tape. Check the measured resistance with the rating given on "gauge resistance".

B. Assembly of the femur bone in the experimental configuration.

Stress is induced on the surface when the load is applied. For the same purpose, it is necessary to find the value of stress on same surface. There are different methods for determining body surface stress values that are strain gauge, elasticity method, moiré fringe and grid method. But it is flexible and more reliable to use the strain gauge technique for experimental stress analysis.

III. PRINCIPLE OF STRAIN GAUGE:

Strain gauge is a device used to measure strain on an object. As the object is deformed, the foil is deformed, causing change its electric resistance. With elongation or mechanical contraction, most metals undergo a change in electrical resistance. The strain gauge applies this principle to the deformation measurement through resistance changes. Generally, the detection element of the strain consists of a copper-nickel alloy sheet.

Specifications of strain gauge used:

The gauges used for experimentation are made in Japan, and they are very sensitive and reliable. The other details of the strain gauge are as follows.
Manufacturer: LCS Co. Ltd.
Type: FOIL
Length of the gauge: 3 mm
Resistance of gauge: 350Ω
Gauge factor: 2.0

C. *Apply a load on shaft of the proximal femur*

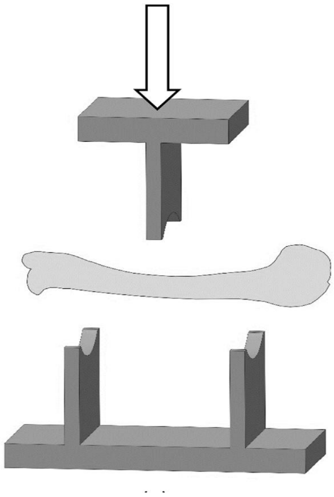

Fig.2 3 Point Bending Test

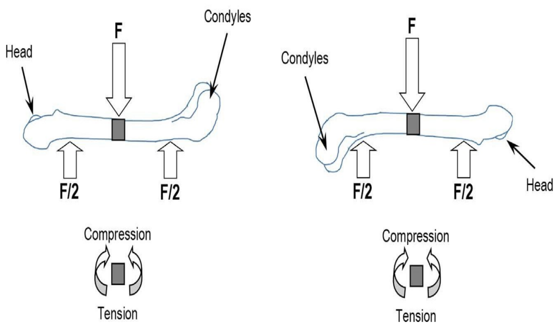

Fig.3 Schematic description (lateral view) of the position of the bones subjected to three-point bending tests. (a) PA loading, (b) AP loading.

The three-point bending tests were carried out with a testing machine, under quasi-static control and displacement conditions, applying a constant flow rate of 0.2 mm/sec until failure of a bone. During the trials, the femurs were immersed in a Hanks solution bath at 37 °C to mimic the physiological environment and prevent dehydration.

Fig. 4 shows the testing is carried in position PA (posteroanterior)

Fig. 5 shows the testing is carried in position AP (anteroposterior)

In these cases, the hardness obtained in the anterior region is larger than in the posterior region. This result confirms that the mechanical properties of the bone tissue depend on its position in the cross-section.

The results show that the loading capacity of the femur bone tested in the posterior orientation is greater than that of the anteroposterior bones [7].

TABLE. 1 LOADING CAPACITY OF FEMUR WITH RESPECT TO POSITION

Position	**Postero-Anterior(N)**	**Antero-Posterior(N)**
Load Capacity	2159	1812

D. *Stress analysis.*

We collect the fresh frozen femur bone of male sheep. The age of sheep is 5 to 7 month respectively. The necessary measurement like head diameter, neck diameter, biomechanical length etc. was taken. Once the specimen is cleaned strain gauge mounted on sheep femur section. Two strain gauges were used on the middle position at shaft. Strain gauge is mounted opposite side to each other at middle of the shaft.

Fig. 6 Strain gauge mounted on femur bone

To find out the stresses and strains induced in femur bone under the applied load some mechanical properties were required of the femur bone. So to find out the mechanical properties like density and Young's modulus etc.CT scan [15] is necessary. From CT scan we found out the grey density in HU unit, but we cannot put this grey density as it is so we have to convert this in density (kg/m^3) and then find out Young's modulus (MPa).

So there is a relation between density and Young's modulus in terms of grey scale density HU and theses are below:

From the basis of grey density obtained from CT scan data find out the density of bone tissue, and Young's modulus.

ρ= 1.122 * *HU* + 47, [13], [15].
E = 1.92 * ρ – 170, [13], [15].
μ = 0.3
For Poisson's ratio a density-independent value of 0.3 was assumed.

After finding out the mechanical properties of femur bone put these values in Lab view program and find out the stresses and strain by applying force until the failure is occurred at the shaft of the bone. For loading configuration the load was applied in the plane containing both neck and proximal shaft axes at middle of shaft. Tests were performed on test rig machine, at a constant flow rate of 0.2 mm/sec until failure. The femoral failure load was defined as maximum load along vertical direction in bending that bone can sustain.

IV. RESULT AND DISCUSSION

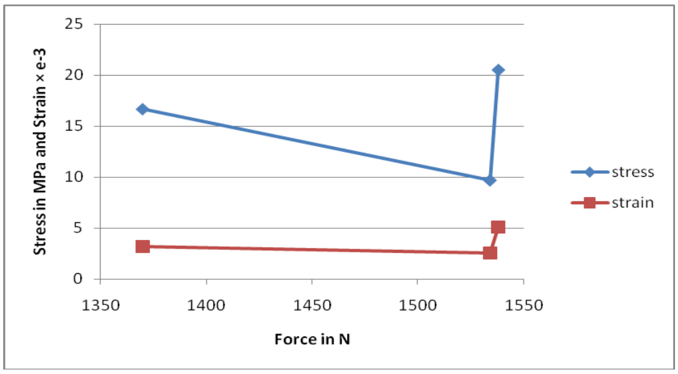

Fig. 7 Graphical representation of force vs stress & strain in femur bone experimentally.

For failure of sheep femur bone of age 5 months the 1370 N force is required and induced stress and strain in this bone is 16.67 MPa and 32.13e-3 respectively, similarly the failure of sheep femur bone of age 6 months the 1534 N force is required and induced stress and strain in this bone is 9.6771 MPa and 25.47e-3 respectively, and failure of sheep femur bone of age 7 months the 1538 N force is required and induced stress and strain in this bone is 20.51 MPa and 51.15e-3 respectively.
So the value of these stress and strain of different age of femur bone is plotted against the respective force for failure in the graph.

V. CONCLUSION

From this study, it is concluded that as age increases the strength of femur bone increases and by using strain gauge method we can find out the failure load of femur bone as well as the maximum load that can resist by the femur. So as age increases the load carrying capacity of femur increases. And the load carrying capacity of the femur is different for different age of group.

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