# Review of Bovine Femur Bone

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***Abstract-*** *Finite element analysis is widely used to describe the biomechanical behaviour of bones. Biomechanical analysis is an interdisciplinary branch which combines biology and mechanical engineering to understand the behaviour of biological materials. The femur bone is the most proximal bone of the leg in vertebrates capable of walking and jumping. The aim of the study finds material properties of bovine femur bone. Study of the interaction of metallic joint with bone material necessitates the mechanical properties of bone to be evaluated. Braces or steel plate permanently fixes to the animal that have fracture to bone or crack bone. Braces or steel plates are fix to bone by screw. In this study a three-dimensional virtual femur bone is modelled and then it is merged with material properties and mesh generation algorithm, then it is analysed using the ANSYS for different stress condition. This analysis will helpfully find stressed region and to select suitable implant material during bone fracture.*

***Keywords***- Biomechanical, proximal bone, metallic joint, meshing, etc.

## I. INTRODUCTION

Finite Element Method (FEM) is widely accepted as a power tool for biomechanics modelling. The biomechanical study deals with the understanding of the mechanical behaviour of biological objects such as bones. The femur bone is the most proximal bone of the leg in vertebrates capable of walking and jumping. In human anatomy the femur is the longest and largest bone but strongest in compression only. Femur bone is important because it supports the body and the whole-body weight is transferred to the legs.

Bone is the second most common transplanted tissue after blood and approximately 5.3 million orthopaedic surgeries are performed yearly worldwide. Femoral stress fractures and partial-thickness fractures are the most common and are reported to be due to chronic overuse injuries and also visible in individuals who take part in physical activities. The mechanical properties of bone evaluation are necessary in case of study of the interaction of metallic joint with bone material. Braces or steel plate permanently fixes to the animal that have fracture to bone or crack bone. Braces or steel plates are used fix to bone by screw. For checking stability of screw, we need to know elastic properties of bone. The aim of present experimental study is to determine the orthotropic behaviour of cortical portion of cadaveric femur bone. The comprehensive items of mechanical properties of cadaveric cortical femur are to be provided through series of mechanical tests.

Biomaterial is defined as "artificial or natural materials used in the manufacturing structure foe replacing the lost or diseased biological structure to restore its form and function". A biomaterial can exhibit specific interaction with cells that will lead to stereotyped response. To know the properties of biomaterial Compression test on bone specimen have been performed to know elastic properties i.e., stress, strain, elastic modulus, poison's ratio and yielding point of bone. These properties may prove useful in studies of implant material. The experimental results are expected to establish orthotropic nature of femur bone. The mechanical properties of bone evaluation are necessary in case of study of the interaction of metallic joint with bone material. Braces or steel plate permanently fixes to the animal that have fracture to bone or crack bone.

## II. LITERATURE REVIEW

The following research work in the field of the application of the composite member and structure has been surveyed at the global level. The brief discussion is as follows.

Mrudula Patil (2020) study attempts at providing comprehensive values of mechanical properties of bovine femur, through series of mechanical tests like elastic properties i.e., stress, strain, elastic modulus, poison's ratio and yielding point of bone. This attempt is to establish orthotropic nature of femur bone of goat and water buffalo using stiffness matrix approach. [1].A. Kalaiyarasan(2020) compare bone joints are made up of dissimilar biomaterials aluminium alloy Al8090 series due to light weight with high strength and silicon carbide to improve the strength. He also observed that Axial strength of femur is almost six times of bending. Human femur bone can withstand ten times the load of its body weight.[2].D. P. Singh (2020)found that the probable fracture of bone occurs near the femoral head and knee joint, but the modal frequency of any of these materials is not exceeding natural femur bone frequency. PMMA/HaP is best suited for bone implants because its modal frequencies are optimal and also it had an optimum weight in comparison with Nylon 6/HaP, and Poly-lactic acid/HaP composite materials.[3].T. Kumaresan (2019) analyses the biomechanical effects of the femur bone implanted with porous scaffold made of polyamide/hydroxyapatite material. Porous scaffolds are temporary load bearing members, consisting of 3D porous geometry to support internal cell growth.[4].K. C. Nithin Kumar(2019) study done using threenatural bone material, AZ31 (magnesium alloy), CP Ti (Commercially Pure Titanium Alloy). By using study stress calculated under different conditions. He suggests suitable alternative material for prosthesis like; AZ31 is the best suited material for Bone implants and as its weight is approximately same as natural bone.[5]S. K. Dey(2018) analysis shows PEEK and HA–PEEK have shown nearer Von-mises stress and directional deformation as compared to that of a natural bone were HA–PEEK had more close value as compared to the pure PEEK.[6] Femur bears most of the stresses produced due to these static and dynamic loads. The stresses observed from the analysis gives an idea about potential zones of damage in the femur. P. B. Kumar (2017)shows the importance of accurate designing of artificial implants that are to be used in case of any damage occurs to the bones.[7]. During different activities load is applied at knee joint and femoral head was fixed and developed stressed level are identified. In analyses muscle effect is neglected, if it is considered then stress will be decreased by 30%.[8]. Sandeep presents the analysis of Femur bone fracture fixation plates using FEM on ANSYS environment. The stress distribution at the fractured site of the femur is obtained when the system is subjected to torsional as well as compressive loadings along with various healing stages.[9]. Kumar (2014) says objective of the femur bone analysis is to know the natural frequencies, natural vibration modes and identify the fracture location of the bone through the computer simulation based on the FEA using ANSYS. He conclude that sudden accident and continuous vibration excitation is the main reason for femur bone failure and the maximum chance of bone cracking is through bone shaft and neck region.[10]. Sameer Jade (2014) investigated the role of longitudinal bone curvature in the design of limb bones. It has been hypothesized that bone curvature results in a trade- off between the bone's mechanical strength and its bending predictability. And result shows longitudinal bone curvature increases bending predictability, but at the expense of bone strength.[11]. Y. Shireesha (2013) done analysis on different materials like structural steel, and Ti-6Al-4V implant materials. Since each femur carries 1/2 the body weight, analysis is done for 550kg,650kg, 750kg load, including the cases of patient carrying certain weight. It shows Ti-6Al-4V is the best material in orthopaedic implant surgeries.[12]

Bone fracture is one of the common traumas, curing of fractured bone can be done by using bone plates. P. S. R. S. Maharaj (2013) compares bone plates made of different biomaterials (Stainless Steel, Titanium, Alumina, Nylon and PMMA. He suggested Further work had been done to find the best material based on comparison of stiffness between bone and plates, corrosion and wear resistance of the materials.[13]. D. Amalraju (2012) analysed the stresses formed in Femur Distal Locking Plate Implant under static loading condition using ANSYS software. Through this static loading condition and material comparison analysis found out the Titanium Implant better mechanical properties while stainless still may fail in cyclic loading in long term effect.[14]. A modified bone plate has been designed with a deformable section to give surgeons the ability to reduce misalignments at the fracture site. Rectangular plates have the highest bending stiffness and proof load, suggesting that they should be used in further experiments with excised biological tissue, animal, or human trials.[15]Huang examined the fundamental dynamic characteristic of both the solid and hollow femur, experimentally and numerically. They used reverse engineering to obtain the outer geometry of synthesis femur. Noble's Canal Flare Index (CFI) is applied to excavated marrow material of the femur canal and to build a more realistic human hollow femoral model.[16]. W. Kajzer (2009) done research to determine displacements, deformations and stresses occurring in a bone depending on the age of the patient and the extent level of osteoporosis. the selection of an appropriate implant should be dependent above all on the age and state of patient’s general conditions of bones.[17]. W. Kajzer done further work to determined stresses, strain and displacement in the inserted screws. The obtained results may be useful in clinical practice. They can be applied in selection of stabilization methods or rehabilitation as well as in describing the biomechanical conditions connected with type of bone fracture obtained from medical imaging.[18]

Bone do not have consistent density; hence results may vary with accuracy range which cannot predict micromotion measurement with accuracy. M. S. Kulkarni (2009) adopted method for micromotion measurement is from X -ray radiograph. The displacement of imported prosthesis is more than that of SMP in proximal zone. In medial zone imported prosthesis appears to displace less as compared to SMP. The prosthesis functions better as the maximum stress levels reached is about 1/12th of failure stress of bone thus stability of prosthesis in body post-surgery is better.[19]. Static analyses were conducted under body load. Dynamic analyses were performed under walking load.[20]. M. Z. Bendjaballah (1997) concludes that Collaterals are the primary load-bearing structures; their absence would substantially increase primary laxities, coupled axial. rotations, forces in cruciate, and articular contact forces.[21]. G. N. Duda (1997) demonstrated that muscles play a substantial role in balancing the loads within the femur. the bone is loaded axially, rather than in bending, with maximum shear forces at the proximal and distal ends. Bending moments are relatively small compared to models which do not consider muscle activity.[22]. Computer-assisted tomography with direct digitization and measurements were used to reconstruct the detailed geometry of an entire human knee joint specimen. These data were then merged with a mesh generation algorithm and material properties reported in the literature to develop a three-dimensional non-linear finite element model of the knee joint. [23]. E. E. Gdoutos(1982) states obtain mechanical behaviour of the human femur bone the work divided into four part. In the first two parts a brief description of the structure and the mechanical properties of the cortical and cancellous bones of the femur determined from the tension, compression, shear, bending, torsion and impact tests takes place. The third part deals with the analysis of the joint and muscle forces acting on the femur. In the fourth part the mathematical and experimental methods for the determination of the stress distribution in the femur are presented in detail. By using this strength characteristic of femur bone is taken under consideration.[24]. The prime function of bone, as an organ, is the structural support of the whole system. It can be safely assumed that bone has a mechanical function in the body.[25]. The remodelling results reproduce the morphologic features of bone and provide evidence of the difference on the bone behaviour when comparing metallic and polymeric nails.[26]. Fracture of often takes place due to complex loading condition which results in combined tensile-shear fracture mechanism. Several parameters such as loading type, applied loading direction relative to the bone axis, loading rate, age and etc., may affect the mixed mode fracture resistance and damage mechanism in such materials.[27].

For the dimensional study of femur bone, Antinea Garmendia utilized 72 unclaimed corpses (20 females and 52 males). The age at death for this sample range from 19 to 91 years. In some cases, they have recorded antemortem data, like sex and age and in some cases name, death cause, and provenance.[28]. Laxman had done cross-sectional study on 60 dry femora. Along with maximum femoral length, four proximal and four distal segmental measurements were measured following the standard method with the help of osteometry board, measuring tape and digital Vernier's calliper. Bones with gross defects were excluded from the study. This data collected may contribute in the analysis of forensic bone remains in study population and to analyse the causal factors for hip fractures.[29]. Sayed used both direct and indirect methods for measurement of femur bone. They take 113 femurs in dissection hall. Samples included persons aged between 20-40 years who were selected randomly. For anthropometric measurements, metallic and plastic tape, goniometer, calliper was used. Different dimensions of the femur such as anterior-posterior and lateral diameter of the femoral head, anterior-posterior and lateral diameter of the body, the minimum length diameter of the neck, superficial longest and shortest femoral height were measured. Usage of anthropometric data in designing a product can reduce human errors and improve public health and qualification of products and efficiency of workplaces.[30].

The objective of this paper study is to finite element analysis of human fracture femur bone fixation with poly-methyl methacrylate thermoplastic (PMMA) prosthesis plate at mid-shaft position in static loading condition. By considering different problem cases of metal like metal compatibility, corrosion, cathode- anode reaction they selected PMMA material. They also done work on Geometry generation and mesh generation on Ansys. Ajay conclude that maximum stress is sustained by the contact area of screw and plate so load is transferred through the femur bone to screws and plate hence fractured femur bone will come in contact of minimum stresses.[31]. Marques suggest that use of this homogenization technique allows to remove subjectivity and reduce the computational cost associated with the iterative process of creating a heterogeneous mesh. Thus, it allows to create simpler homogenized meshes with its mechanical properties defined using information directly from the mesh source.[32]. Two-dimensional finite element models of cadaveric femoral stiffness were developed to study their suitability as surrogates of bone stiffness and strength, using two-dimensional representations of femoral geometry and bone mineral density distributions. Such methods could be clinically applied to estimate patient bone stiffness and strength using simpler and less costly radiographs.[33].

The five automatic meshing generation (AMG) methods considered were: mapped mesh, which provides hexahedral elements through a direct mapping of the element onto the geometry; tetra mesh, which generates tetrahedral elements from a solid model of the object geometry; voxel mesh which builds cubic 8-node elements directly from CT images; and hexa mesh that automatically generated hexahedral elements from a surface definition of the femur geometry. The comparison demonstrated that each tested method deserves attention and may be the best for specific situations.[34].

David C. Kieser considered cortical and medullary diaphyseal diameters, cortical cross-sectional area, bone length, cortical thickness, and bone density for morphological comparison. The four-point flexure tests for bending stiffness, Young's modulus of bending, and ultimate strength in bending tests were conducted as Biomechanical tests. Mid-diaphyseal cortical compressive elastic modulus and strength for torsional stiffness (Nm/degree) was also studied. Three samples of every bone types (a) rear deer femur; (b) rear pig femur, and (c) rear sheep femur was used for tests. Young's modulus and ultimate strength in bending for whole bone samples was determined by a four-point bend test of whole femora. Load was applied through the top rollers, with the lower supporting rollers being self-aligning. The previously reported ultimate strength for deer femora was 174 MPa [16] but they observed lower value 98 MPa. For sheep femur it was 44 MPa.[35]

## III. CONCLUSION

The prime function of bone, as an organ, is the structural support of the whole system. The femur has different states of healing. Hence, selection of implant material depends on age, sex, type of fracture and mammal's general condition. During fracture of femur bone Titanium is the most suitable implant material. In femur bone of bovine species, Compressive strength in longitudinal direction is greater than transverse direction.

During study of femur bone dimension analysis various human femur bone sample taken having different age, sex, death cause, provenance, etc. This data will helpful for forensic study as well as to design femur bone model for further analysis.

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