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EXPERIMENTAL AND ANSYS ANALYSIS OF STRESSES IN REAL PRESERVED INTACT HUMAN TIBIA BONE UNDER STATIC BODY LOAD TO ENHANCE THE DESIGN OF IMPLANT FOR ORTHOPEDIC SURGERY.

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Abstract -*The tibia is a long hollow leg bone, which has an expanded metaphysic and an epiphysis at both ends of a thick walled tabular diaphysis. The proximal end of the human tibia displays very special characteristics; it is form the superior base of a truncated cone. Tibia has most statistics in skeleton bone fracture. Injuries to the human lower extremities are mostly due to the collision of a vehicle and pedestrian, which results in fractures of long bone, injuries to the knee and ankle. In tibial fractures a plate and screws may be the ideal method of fixation. The tibia 3 D CAD model is required for FEA analysis, it was obtained by using industrial 3D scanner. The obtained results are most useful for providing information to doctor for the risk of possible fractures location in human tibia bone.*

Key words- *Human tibia bone, Strain gauge, FEA, Stress, CAD model*

I. INTRODUCTION

The tibia is also known as the shinbone is larger and stronger of the two bones in the leg below the knee in fibula, and it connects the knee with the ankle bones. The tibia is found on the medial side of the leg next to the fibula and closer to the median plane or centre line. The tibia is connected to the fibula by the interosseous membrane of the leg, forming a type of fibrous joint called a syndesmosis with very little movement. It is the second largest bone in the human body next to the femur. The leg bones are the strongest long bones as they support the rest of the body. Bone is a composite material consisting of both fluid and solid phases. Two main solid phases, one organic and another inorganic, give bones their hard structure. The organic material gives bone its flexibility, while the inorganic material gives bone its resilience. Calcium and phosphate account for roughly 65–70% of a bone's dry weight. Fig.1 shows position of tibia bone.

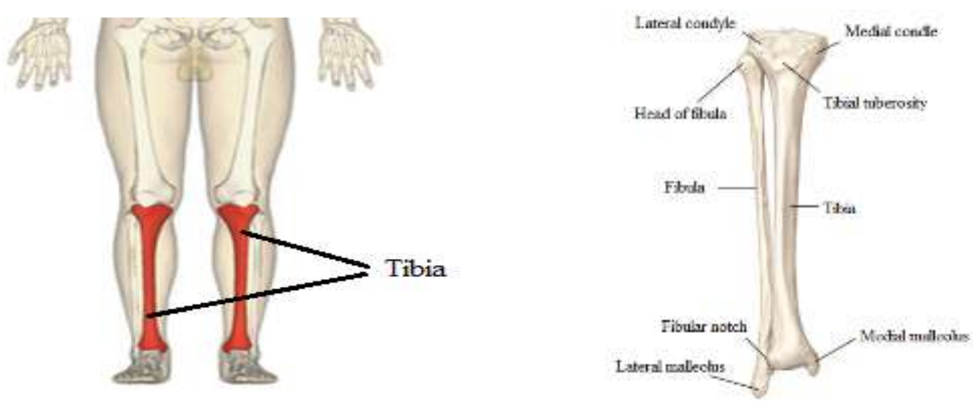


Fig.1 Position of Tibia bone

II. LITERATURE REVIEW

Brief review of some selected reference on this topic is presented here-

Han A .Gray et.al [1] have studied the principal strains and displacements at selected points, measured by experiments on a human cadaveric tibia, to those predicted by an FE model based on the same bone. Only surface strains were compared as the measurement of internal strains is experimentally difficult; however, it is reasonable to assume that the internal strains will be accurate if the external strains and the material property assignment were accurate.

M.O .Kaman et.al. [2] have conducted a numerical simulation which uses finite element methodology, to estimate the von Mises stress subjected to the plate and screw which is used in tibia fracture treatment. A titanium plate and 4 screws on it are used for treatment of the fracture.

EhsanTaheri et. al. [5] have analysed Von Mises stresses and stiffnesses measured by experiments on a human cadaveric tibia and composite ones compared to those predicted by a FE model based on the same bone. Modeling of exact geometrical tibia including cortical and spongy bone using human bone CT scan images and mechanical validating of obtained model is the aim of this study.

III. EXPERIMENTAL ANALYSIS

Experimental analysis has been carried out using strain gauge analysis. The procedure for strain gauge analysis as follows:

A. Selection of strain gauge:

The strain gauge is one of the most important sensor of the electrical measurement technique applied to the measurement of mechanical quantities. As their name indicates, they are used for the measurement of strain. A Strain gauge is a sensor whose resistance varies with applied force; It converts force, pressure, tension, weight, etc., into a change in electrical resistance which can then be measured. When external forces are applied to a stationary object, stress and strain are the result. The strain gauge model and gauge length were selected which meet the requirements of the measuring object and purpose. For tibia bone, the foil type electric resistance type of 110 ohm is selected.

An ideal strain gauge should have the following basic characteristics:

1. The gauge should be of extremely small size so as to adequately estimate strain at a point.
2. The gauge should be easy to attach to the member being analyzed and easy to handle.
3. The strain sensitivity and accuracy of the gauge should be sufficiently high.
4. The gauge should be unaffected by temperature, vibration ,humidity or other ambient conditions.
5. The calibration constant for the gauge should be stable over a wide range of temperature and time.
6. It should be possible to read the gauge either on location or remotely.

B. Bonding of strain gauge:

Accurate strain measurement requires a clean surface to bond the strain gauge on it. So, the bone surface was prepared using polish paper. After preparing the bone surface, the strain gauges were bonded with the help of adhesive cynoacrylate by following standard procedure. The strain gauges mounted on the bone at various positions are as showing in fig.2.

Fig.2 Bonding of strain Gauges at Various Positions

C. Application of load:

The prepared bone was mounted on the loading frame and loads were applied on it. Connect the all connections as per procedure and take the readings at different loads. Fig.3 shows the application of load on the tibia bone.

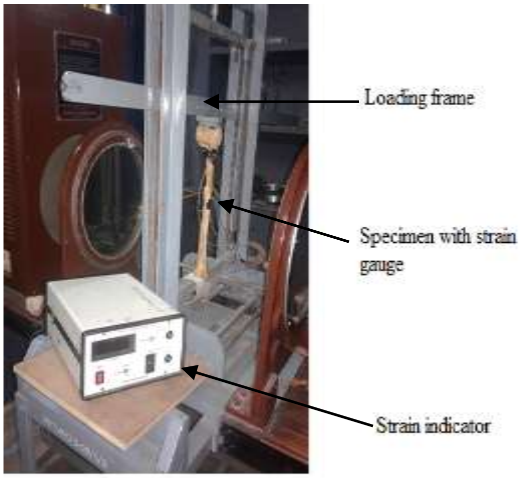


Fig.3 Experimental Set up

D. Stress Calculation:

Sample Calculation

Stress is given by formula

$\sigma = [E / (1 - V^2)] * (\varepsilon a + V \varepsilon b)$……………………….(1)

Where,

Strain at X direction = $\varepsilon a = 0$

Young's Modulus = E = 18400 MPa

Poisson's ratio = V = 0.12

At 20Kg. load and position no.2 strain is 0.0010

After putting values in equation 1

$\sigma = [18400 / (1 - 0.12^2)] * (0.12 * 0.0010)$

$\sigma = 2.24$ MPa

IV. FEA ANALYSIS

It is not always possible to obtain the exact analytical solution at any location in the body, especially for those elements having complex shapes or geometries. Always matters are the boundary conditions and material properties. In such cases, the analytical solution that satisfies the governing equation or gives extreme values for the governing functional is difficult to obtain. Hence for most of the practical problems, the engineers resort to numerical methods like the finite element method to obtain approximate but most probable solutions. CAD model of the tibia bone is developed by using 3D scanner. The fig 4 shows model of tibia bone.

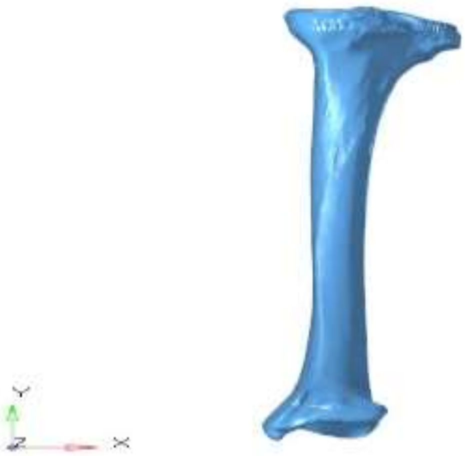


Fig.4 CAD Model of Tibia Bone

The procedure for finite element analysis

- Geometry has been imported in ANSYS using ANSYS workbench.
- Meshing
  - ➢ Element Type : Solid92
  - ➢ Mesh type : Tetrahedral

Fig.5 shows meshed model of tibia bone.

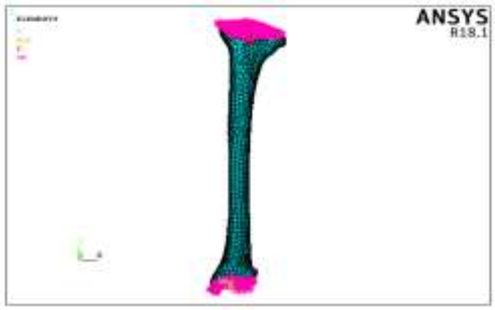


Fig.5 A Meshed Model of Tibia Bone

- Assigning the material properties
  - ➢ Young's Modulus 18400 Mpa
  - ➢ Poison's Ratio 0.3
- Applying boundary conditions

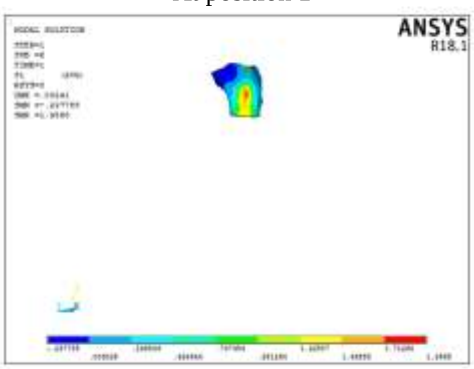
Both ends are fixed i.e. all dof is zero and load is applied on top of tibia bone.

- Solution: The problem now has been well defined in preprocessor .This problem is then solved using ANSYS solver.
- Post processing: After getting the solution from solver, the results are processed in post processor. The stresses in the bone have been obtained at various positions and shown in fig.6

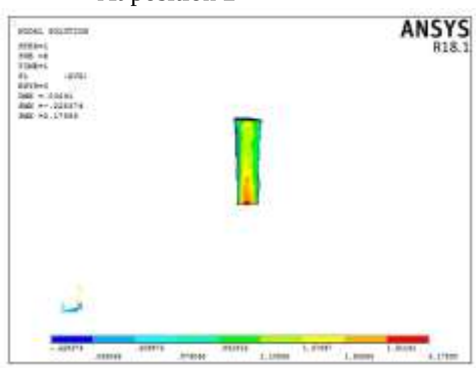
FEA Results

At 20 Kg load

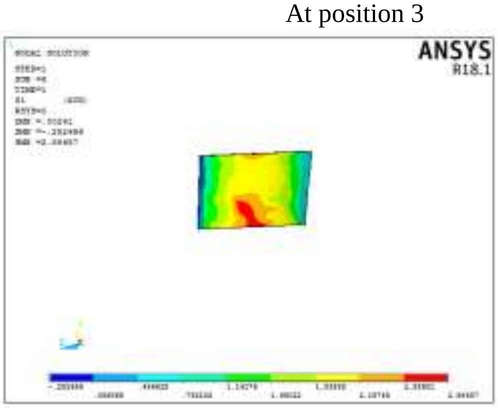
At position 1



At position 2



At position 3



At position 4

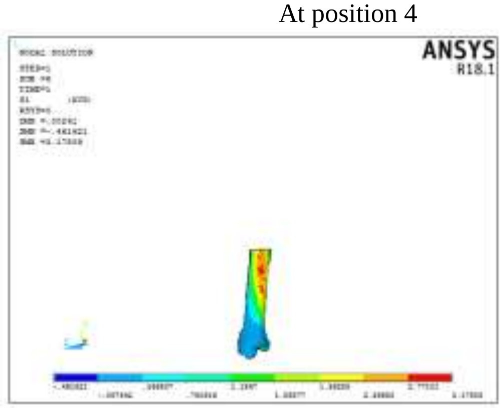


Fig.6 Stresses At Various Positions

V.RESULTS

The results obtained by various methods are tabulated in Table 1.

Sr. No.	Position No.	Load in Kg.	Experimental stress in MPa	FEA stress in MPa	% Error bet. Expt. and FEA
1	1	20	2.02	1.96	3.1
2		25	2.68	2.44	9.8
3		28	2.91	2.73	6.6
4		30	3.14	2.93	7.16
1	2	20	2.24	2.17	3.22
2		25	2.91	2.72	7
3		28	3.14	3.05	2.9
4		30	3.36	3.26	3
1	3	20	2.91	2.88	1.04
2		25	3.81	3.6	5.83
3		28	4.25	4	6.2
4		30	4.48	4.32	3.7
1	4	20	3.36	3.17	6.03
2		25	4.03	3.96	1.76
3		28	4.7	4.44	5.85
4		30	4.91	4.72	4.23

Table 1 Result at Various Points

VI. CONCLUSION

Following conclusions have been drawn from experimental and FEA analysis of tibia bone

- Maximum stresses occur at shaft lateral i.e. position No. 4 for all corresponding loads.
- The minimum stresses are shown below the shaft condyle i.e. position No. 1.
- The strain gauge method is one of the best method for finding of stresses for human tibia bone.

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