Design And Weight Optimization of Solid Stainless Steel Tibia Rod

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Abstract- *Intramedullary rod, also known as Intramedullary nail which is a metal rod forced in to the human bone when it is broke (due to accidents or any high impact) Not necessarily it is related to humans only but for animals (pets) have been also used. In this paper we will limit our work to Tibia bone rod. Tibia bone, is the bone situated between knee and the foot ankle.Tibia rod is mainly made of two materials, Stainless steel and titanium. Both the rods are extensively used and available in the market. As stainless steel is cheap in price as compared to titanium, we will be considering stainless steel rod for our research. Different diameter and length rods are been used as per requirement. Primary goal of this project is to reduce/optimize the weight of the rod to 12 to 15% from the existing rod of same diameter and length. This can be achieved by changing the cross section. The new rod design, stresses and deflection will be compared with the existing rod to see whether it can sustain the human load. Different rod diameters and lengths will be considered for the design. The less weight of a foreign material in a human body can make walking, running and other day to day work easy for the humans.*

Keywords- Tibia Rod, Unreamed Intramedullary Tibial Nails, Tibial Fracture

I. INTRODUCTION

Human skeletal system is the system of bones, associated cartilages and joints of human body. Skeleton is defined as the hard framework of human body around which the entire body is built. Almost all the hard parts of human body are components of human skeletal system. Joints are important because they help the skeleton system to move at different locations. The skeleton system serves 6 major functions to human body.

1. Support: The skeleton provides the framework which supports the body and maintains its shape. The pelvis and the associated ligaments and muscles gives a floor for the pelvic structure. Without the ribs, costal cartilages and the intercostals muscles the heart would collapse.
2. Movement: The joints between bones permit movement, some allowing a wider range of movement than others, e.g. the ball and socket joint allow a better range of movement than the pivot joint at the neck. Movement is powered by skeletal muscles, which are attached to the skeleton at various sites on bones. The muscle, bone, and joints provide the mechanics for the movement, all coordinated by the nervous system.
3. Protection : The skeleton protects many vital organs like, the skull protects the brain, eyes, and the middle and inner ears, the vertebrae protects the spinal cord, the rib cage, spine, and sternum protect lungs, heart and blood vessels, the clavicle and scapula protect the shoulder, the ilium and spine protect the digestive and urogenital systems and the hip, the patella and the ulna protect the knee and the elbow respectively, the carpals and tarsals protect the wrist and ankle respectively.
4. Blood cell production: The skeleton is the site of hematopoiesis, which takes place in red bone marrow.
5. Storage: Bone matrix can store calcium and is involved in calcium metabolism, and bone marrow can store iron in ferritin and is involved in iron metabolism. However, bone is not completely made of calcium, but a mixture of chondroitin sulfate and hydroxyapatite, the latter making up 70% of a bone.
6. Endocrine regulation: Bone cells release a hormone called osteocalcin, which contributes to the regulation of blood sugar (glucose) and fat deposition. Osteocalcin increases both insulin secretion and sensitivity, in addition to boosting the number of insulin-producing cells and reducing fat storage.

1.1 Components of Human Skeleton

Human skeleton is composed of three main components, namely, bones, associated cartilages and joints.

- Bones: Bone is a tough and rigid form of connective tissue. Bone is the weight bearing organ of human body and is responsible for almost all strength of human skeleton.
- Cartilages: Cartilage is a type of connective tissue composed of special cells known as chondrocytes along with collagen or yellow elastic fibers. The fiber and the cell is embedded in a firm gel like matrix rich in

mucopolysaccharide. Cartilage is not as hard and rigid as bone. It is much more flexible and elastic.

- Joints: are important components of human skeleton because they make the human skeleton mobile. Joints occur between the “two or more bones”, “bone and cartilage” and “cartilage and cartilage”. Joints can be classified either by structure or by function. The functional classification is based on the amount of movement allowed at the joint and are classified as synarthroses (no movement), amphiarthroses (small amount of movement) or diarthroses (variety of movements). The structural classification focuses on the material binding the bones together, as well as the presence or absence of a joint cavity. They are classified as fibrous (no movement), cartilaginous joint (small amount of movement), synovial joint (variety of movement).

1.2 Divisions of Human Skeleton

Human skeleton can be divided into two divisions, namely, Axial and Appendicular skeleton (Figure 1.1). Axial skeleton forms the axis of human body. It consist of Skull, vertebral column and thoracic cage. Appendicular Skeleton is the skeleton of appendages of human body. It consists of Shoulder girdle, Skeleton of upper limb, Pelvic girdle and Skeleton of lower limb.

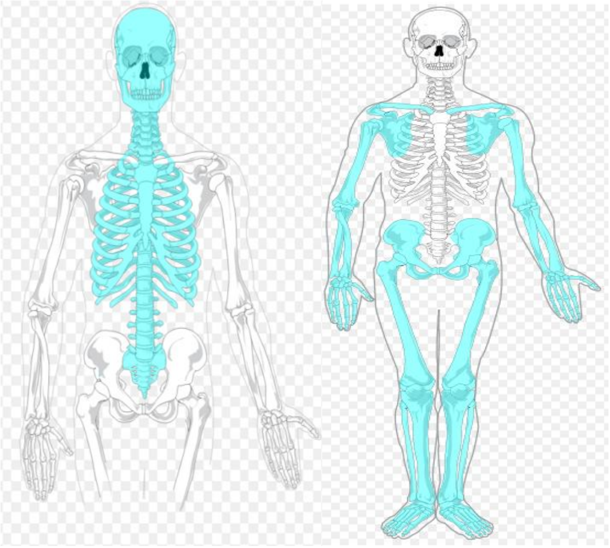


Fig: 1.1 - Axial and Appendicular Skeleton

Bones

Bone is a dense type of connective tissue impregnated with inorganic salts, especially the salts of calcium such as calcium phosphate, calcium carbonate etc. The organic portion of the bone constitutes one third (1/3) and the inorganic salt component constitutes two third (2/3). The inorganic salt is specially responsible for rigidity and hardness, which make bone resist compression caused by the forces of weight and impact. The organic connective tissue portion of the bone makes it resilient and thus the bone can afford resistance to tensile forces. In strength bone is comparable to iron and steel.

Total of 206 bones make bone structure of the human body. It helps body retaining its shape, protection of soft organs, and providing structural rigidity to the body. In different parts of the body, bone is organized in both ways, macroscopically and microscopically. Despite their strength, bone fractures sometimes occur.

1.3.1 Basis of Shape

On the basis of shape, bones are classified into five different types, namely, long bones (arms, legs, hands, and feet), short bones (wrist and ankles), flat bones (Ribs, shoulder blades, hip bones and cranial bones), irregular bones (Vertebrae and facial bones) and sesamoid bones (special short bones, patella). An example for each type is shown in Figure 1.2.

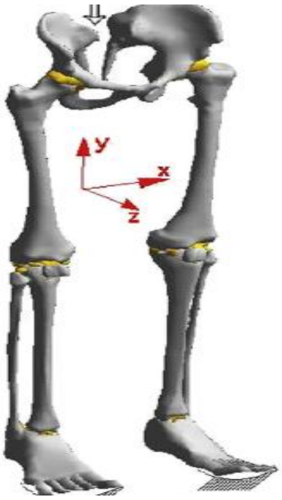


Fig. 1.2: Basic Types of Lower Half Bone shapes

Fractures

Bone form the skeleton of the body and allows the body to be supported against gravity and to move and function in the world. A typical bone ailment is the fracture, which occurs when the bone is not able to withstand outside force like direct blows, twisting injuries and falls. Fracture is crack in bone and is defined as a medical condition in which there is a break in the continuity of the bone. Fractures can happen in a variety of ways, Trauma fractures (Accidents), Osteoporosis and Stress or overuse

Types of Fracture

In general, bone fractures can be categorized as simple or multifragmentary. Simple fractures describe a single fracture line through a bone with the broken parts still in their normal anatomical position and minimal damage to surrounding tissue, whereas the term multifragmentary refers to a fracture in which there are two or more bone fragments present. All fractures can be broadly described as closed or open. A fracture is considered open, if the skin over the break is disrupted, else it is closed.

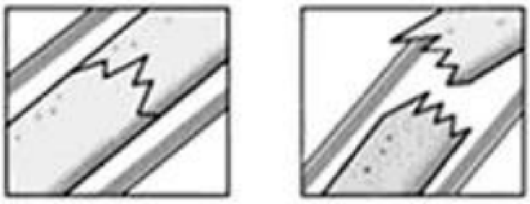


Fig. 1.3: Closed and Open Fracture

A fracture line is the description of the crack. It can be transverse (parallel to bone), oblique (at an angle) and spiral.

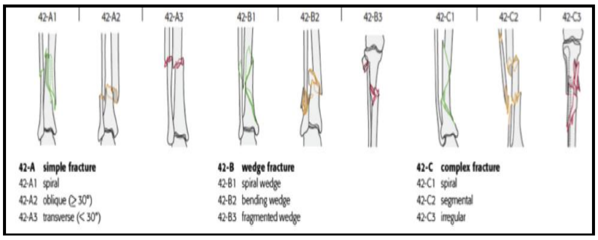
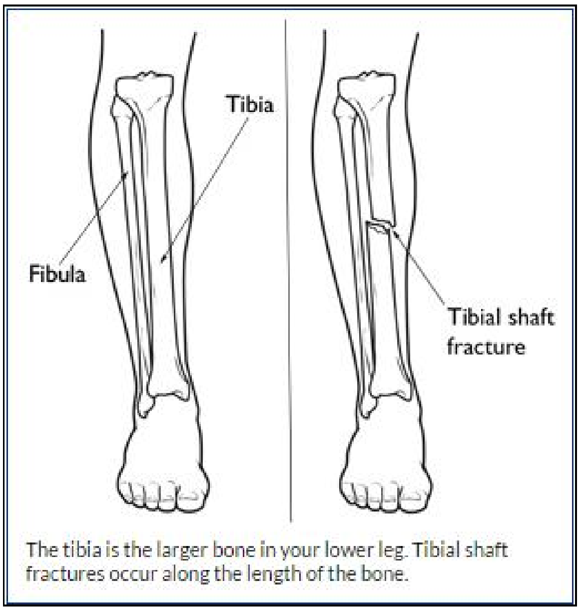


Fig. 1.4: Types of long-bone Fractures

Fracture alignment – This gives a description as to whether the fracture fragments are displayed or in normal anatomic position.

Tibial Fracture

The Tibia, or shinbone, is the most common fractured long bone in our body. The long bone includes femur, tibia and fubula. A Tibial shaft fracture occurs along the length of the bone, below the knee and above the ankle. The lower leg is made up of two bones: the tibia and fibula. The tibia is the larger of the two bones. It supports most of your weight and is an important part of both the knee joint and ankle joint.



The tibia is the larger bone in your lower leg. Tibial shaft fractures occur along the length of the bone.

Fig. 1.5: Tibia Fracture

Types of fixators for the healing of the tibia rod:

1) Insertion of rod
2) External fixtures

1. Intramedullary rod, also known as intramedullary nail which is a metal rod forced in to the human bone when it is broke (due to accidents or any high impact) Not necessarily it is related to humans only but for animals (pets) have been also used

2. External fixation is a surgical treatment used to stabilize bone and soft tissues at a distance from the operative or injury focus. They provide unobstructed access to the relevant skeletal and soft tissue structures for their initial assessment and also for secondary interventions needed to restore bony continuity and a functional soft tissue cover.

Minimally Invasive Percutaneous Plate Osteosynthesis

The MIPPO (Minimally invasive percutaneous plate osteosynthesis) technique was recently introduced to preserve periosteal blood supply and minimize surgical trauma adjacent to a fracture. Intramedullary rods (IM rods), which revolutionized fracture treatments, stabilize fractures and allow micro-movement in bone rehabilitation. Blood flow rate is improved in fractured bones when IM rods rather than bone plates are applied. Reamed and non-reamed IM rods each offer their own advantage s: non-reamed rods promote blood supply in the cortex and reamed rods accelerate callus generation and promote early bone union. Also, reamed IM rods are associated more with high structural stability and reduced complications. Based upon above pros and cons, a reamed IM rod was chosen for our study in tibial fracture healing. Fracture healing is a proliferative physiological process in which the body facilitates the repair of a bone fracture. [1]

Biophysical environment is a fundamental consideration in the regulation of the healing process of fractured bones. Appropriate forces on a bone are essential for the successful healing of osseous fractures. Several mechano-regulation theories have been re- ported based on the type of mechanical stimulus, and in all these theories, deviatoric strain is one of the simplest and most efficient mechanical stimuli for use as a criterion in the estimation of bone healing process. In orthopedic surgery, there has been ongoing research on the development of bio-compatible materials with similar mechanical properties as those of bones. Flexible composite fixation devices provide the desired biophysical environment during bone healing that allows micro-movement in soft tissues (Callus) to enhance the fracture healing efficiency. [1]

II. LITERATURE REVIEW

Work done on the steel Tabia Rod using Finite Element Analysis and testing methods for the actual physical testing of the Tabia Rod .Following statements are observed from that work.

Dae-Sung Son and Seung-Hwan Chang [1] presented a paper “Finite element analysis of tissue differentiation process of a tibia with various fracture configurations when a composite intramedullary rod was applied “In this study, authors investigated the healing performance of composite intramedullary rods (IM rods) used for tibia diaphyseal fractures. A three-dimensional tibia model was developed for various fracture gap sizes and oblique angles. To evaluate the types and material properties of the healing tissues, a mechano regulation algorithm with deviatoric strain was implemented in the finite element analysis. The results showed that the healing performance of a tibial fracture was affected by the modulus of the IM rod according to the fracture gap size and oblique angle. This study suggested the best IM rod modulus for bone fractures.

Leopold Berger & Johannes Eichler [2] presented a work “Advanced interlocking systems to improve heavy-load-bearing characteristics of flexible intramedullary nailing “Flexible intramedullary nailing (FIN) is a minimally invasive and widespread standard method for osteo synthesis of pediatric long bone fractures. In the case of unstable fractures of the lower extremity, interlocking systems need to be used to prevent axial shortening and subsequent perforation of the nail at its insertion site. In the present study, four different screw-fixed interlocking systems for FINs (Hofer Twin Plug with two3-mm titanium interlocking screws, Hofer Fix Plug with 3-mm titanium interlocking screw, Hofer Plug with3.5-mm titanium interlocking screw, and Hofer Plug with 3-mm titanium interlocking screw) in comparison with the commonly used Ender stainless steel nails (locked with 3.5-mm screw) were experimentally investigated in cadaveric lamb tibiae, regarding their load characteristics and failure modes in the case of heavy loading. The specimens were subjected to sequential axial cyclic loading of 5000cycles with stepwise increase of the load amplitude until failure. Migration of the locking screws and the internal damage of the bone tissues were quantified by micro-computed tomography (CT) imaging. Ender nails failed on average at a peak load of 800 N, Twin Plugs at 1367 N, Fix Plugs at 1222 N, Plugs 3.5mm at 1225 N and Plugs 3.0mm at 971 N Twin Plugs, Fix Plugs, and Plugs 3.5mm failed in a slow manner over several hundred loading cycles, whereas Ender nails and Plugs 3.0mm exhibited abrupt failure without any prior indication. Our results confirm that axial stability of FIN can be further improved by screw-fixed plugs by simultaneously avoiding shortcomings of an eye-locked system, which the Ender nails are. Considering biomechanical results, plug interlocking systems with 3.5 mm screws should be favored over conventional Ender nails and plugs with 3 mm screws.

Vincenzo Filardi [3] presented a work “The healing stages of an intramedullary implanted tibia: A stress strain comparative analysis of the calcification process” in this paper Three different conditions were analyzed the initially healthy tibia, the A2 type 1 fractured tibia with the Expert tibial nail implanted, and the follow up stage after complete healing of tibia. Non-linear finite element analysis of the models were performed with Abaqus version 5.4 (Hobbit, Karlsson and Sorensen, Inc., Pawtucket, RI) using the geometric non linearity and automatic time stepping options.The obtained results reveal interesting consequences deriving by taking into account how the stress shielding can influence the integrity and resistance of bones, in order to identify the mechanical reasons for the unfavorable clinical results.

Todd Dodge, Mina Wanis et.al [4] published paper on “Mechanical loading, damping, and load-driven bone formation in mouse tibiae “In this study they investigated the damping capacity of bone, joint tissue, muscle, and skin using a mouse hind limb model of enhanced loading in conjunction with finite element modeling to model bone curvature. Their hypothesis was that loads were primarily absorbed by the joints and muscle tissue, but that bone also contributed to damping through its compression and natural bending. To test these hypotheses, fresh mouse distal lower limb segments were cyclically loaded in axial compression in sequential bouts, with each subsequent bout having less surrounding tissue. A finite element model was generated to model effects of bone curvature in silico. Two damping-related parameters were determined from the output of the loading experiments. Interestingly, the experimental results revealed that the knee joint contributed to the largest portion of the damping capacity of the limb, and bone itself accounted for approximately 38% of the total phase shift angle. Computational results showed that normal bone curvature enhanced the damping capacity of the bone by approximately 40%, and the damping effect grew at an accelerated pace as curvature was increased. Although structural curvature reduces critical loads for buckling in beam theory, evolution apparently favors maintaining curvature in the tibia. Histomorphometric analysis of the tibia revealed that in response to axial loading, bone formation was significantly enhanced in the regions that were predicted to receive a curvature-induced bending moment. These results suggest that in addition to bone's compressive damping capacity, surrounding tissues, as well as naturally-occurring bone curvature, also contribute to mechanical damping, which may ultimately affect bone remodeling and bone quality.

DanielJ.Stinner & Hassan Mir [5] presented "Techniques for Intramedullary Nailing of Proximal Tibia Fractures" they say that Despite poor early results within tramedullary nailing of extra-articular proximal tibia fractures, improvements in surgical technique and implant design modifications have resulted in more acceptable outcomes. Prevention of the commonly encountered apex anterior and / orval gus deformities remain sachaenge when treating the se injuries.

Will Rudge etl [6] presented a paper "Fractures of the tibial shaft in adults" work concludes Closed fractures of the tibial shaft are common and can have a multitude of anatomic characteristics that must be considered. Various methods exist to treat them definitively with no single modality shown to be overwhelmingly preferential. All methods of treatment have their surgical nuances and a thorough understanding of these is required for optimum results. Complications, including compartment syndrome, must be at the forefront of one's mind when treating these patients either operatively or in a cast.

Dae-sung Son etl [7] presented "The finite element analysis for endochondral ossification process of a fractured tibia applied with a composite IM-rod based on a mechano-regulation theory using a deviatoric strain" paper says The bone healing process of fractured tibias applied with various composite IM rods, respectively, was analyzed using finite element analysis. Based on a mechano-regulation theory with a deviatoric strain as a mechanical stimulation the process of tissue differentiation was simulated by a user's subroutine programmed by a Python code for an iterative calculation. Several representative composite IM rods (fabric composites made of a carbon/epoxy and a glass/polypropylene) were investigated to find the rod modulus appropriate for healing bone fractures. It was found that the initial loading condition was the most sensitive factor of healing performance and that the flexible composite IM rod (WSN3k [±45]nT) was able to accelerate tissue differentiation under a reasonable initial loading condition (3 point gait after surgery), resulting in early bone union.

Ji Wang et,l [8] worked on "Trabecular plates and rods determine elastic modulus and yield strength of human trabecular bone" in this study plate–rod (PR) finite element (FE) models were constructed completely based on ITS-identified individual trabecular plates and rods. We hypothesized that PR FE can accurately and efficiently predict elastic modulus and yield strength of human trabecular bone. Human trabecular bone cores from proximal tibia (PT), femoral neck (FN) and greater trochanter (GT) were scanned byμCT. Specimen-specific ITS-based PR FE models were generated for each μ CT image and corresponding voxel-based FE models were also generated in comparison. Both types of specimen-specific models were subjected to nonlinear FE analysis to predict the apparent elastic modulus and yield strength using the same trabecular bone tissue properties. Then, mechanical tests were performed to experimentally measure the apparent modulus and yield strength. Strong linear correlations for both elastic modulus (r2=0.97) and yield strength (r2= 0.96) were found between the PR FE model predictions and experimental measures, suggesting that trabecular plate and rod morphology adequately captures three-dimensional (3D) microarchitecture of human trabecular bone. In addition, the PR FE model predictions in both elastic modulus and yield strength were highly correlated with the voxel-based FE models (r2= 0.99, r2= 0.98, respectively), resulted from the original 3D images without the PR segmentation. In conclusion, the ITS-based PR models predicted accurately both elastic modulus and yield strength determined experimentally across three distinct anatomic sites. Trabecular plates and rods accurately determine elastic modulus and yield strength of human trabecular bone.

III. PROBLEM STATEMENT

Due to budgetary constraints most of the times cost effective solution for the insertion rod while performing Tabia bone surgery is used. Steel is the cheaper of the two available alternatives which are steel and titanium. Weight of the insertion rod is very important aspect as high weight might induce fatigue to the patient. It is area of research to reduce the weight of the insert without losing the usefulness for the application. Optimization technique using multiple FEA analysis is needed to be applied to the insert rod and weight reduction should be attempted to the current design used for rod.

IV. SCOPE AND OBJECTIVES

1. The scope of this Project is to reduce the weight of SS rod with a new design.
2. The Material of Rod Will be used is 316L SS
3. Comparing the new design with the current in market design of same length and dia.
4. Objective is to achieve the new design without compromising the load carrying capacity of rod and failures with reducing the weight by 12 to 15% compared to the available design in market.

V. FINITE ELEMENT ANALYSIS

The basic idea in finite element method is to find the solution of a complicated problem by replacing it with a simpler one. Since, in finding the solution, the actual problem is replaced by a simpler one; I will be able to find only an approximate solution rather than the exact solution. The existing mathematical tools will not be sufficient to find the exact solution (and, sometimes, even an approximate solution) of most practical problems. Thus in absence of any other convenient method to find even an approximate solution of a given problem, we have to prefer the finite element method. Moreover, in the finite element method, it will often be possible to improve or refine the approximate solution by spending more computational effort.

A static analysis calculates the effects of steady loading conditions on a structure, while ignoring inertia and damping effects, such as those carried by time varying loads. A static analysis is used to determine the displacements, stresses, strains and forces in structures or components caused by loads that do not induce significant inertia and damping effects.

A static analysis can however include steady inertia loads such as gravity, spinning and time varying loads. In static analysis loading and response conditions are assumed, that is the loads and the structure responses are assumed to vary slowly with respect to time.

The kinds of loading that can be applied in static analysis includes, externally applied forces, moments and pressures. Steady state inertial forces such as gravity and spinning imposed non-zero displacements.

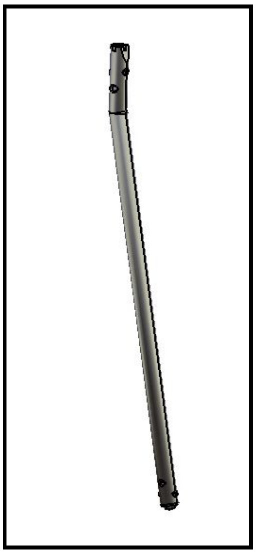
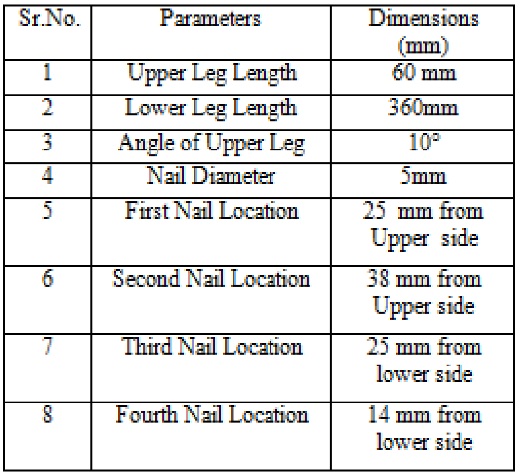


Fig1.6: - Design for Basic 15 mm diameter Rod as Steel Insert

Table 1.0:Dimensions for Base line 1



Sr.No.	Parameters	Dimensions (mm)
1	Upper Leg Length	60 mm
2	Lower Leg Length	360mm
3	Angle of Upper Leg	10°
4	Nail Diameter	5mm
5	First Nail Location	25 mm from Upper side
6	Second Nail Location	38 mm from Upper side
7	Third Nail Location	25 mm from lower side
8	Fourth Nail Location	14 mm from lower side

Steel insert of 15 mm diameter and 420 mm of length is chosen as a baseline 1design for research work and static analysis with the maximum loading is performed on the same to find out high stress regions and highest value of the stress. Boundary condition of 70 kg load and in worst case scenario it is assumed that all 70 kg load is on the broken leg and through which it is on rod. Boundary conditions applied on the rod are given in the image below.

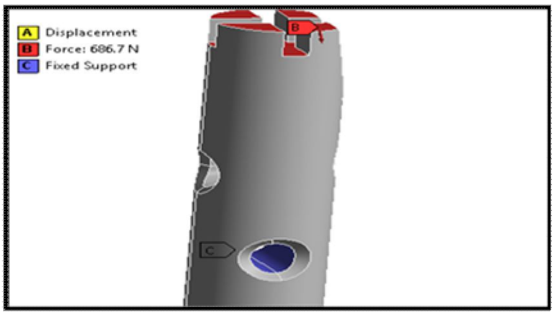


Fig. 1.7: Boundary conditions for the FEA analysis on the Rod

Results for the same boundary conditions are provided below

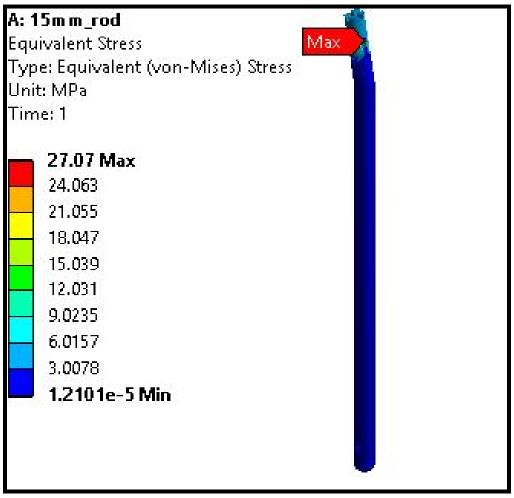


Fig. 1.8: Von Mises Stress Plot @ Baseline 1

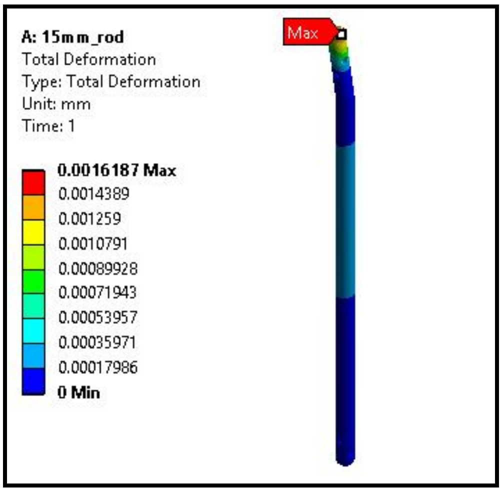


Fig. 1.9: Deformation Plot @ Baseline 1

In iteration 1.1 Radial cut of 1mm is taken with leaving the material at nail portion

Fig 2.0: -Iteration 1.1 geometry

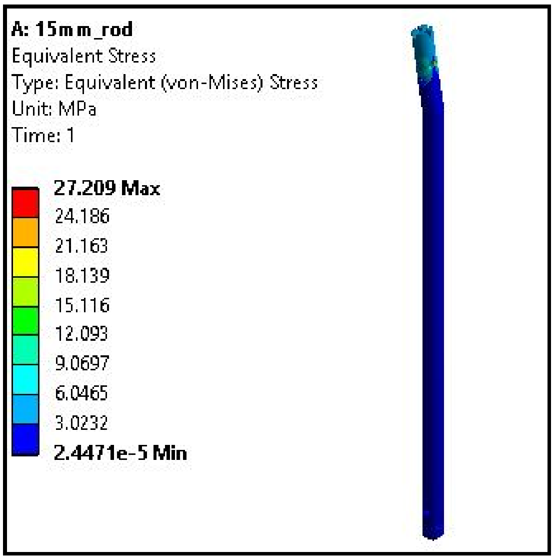


Fig.2.1: von Mises Stess plot @ Iteration 1.1

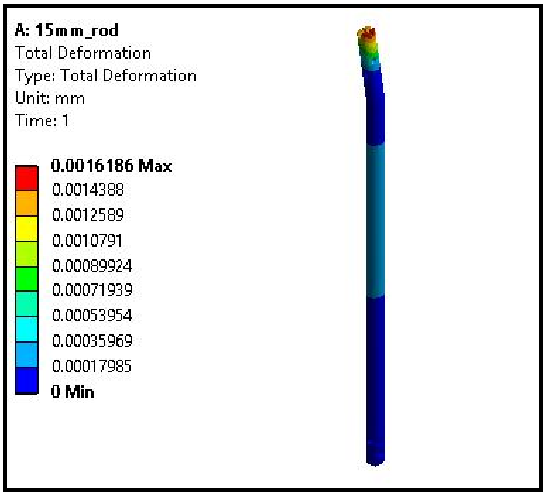


Fig.2.2: Total deformation plot @ Iteration 1.1

In iteration 1.2 Radial cut of 2mm is taken with leaving the material at nail portion

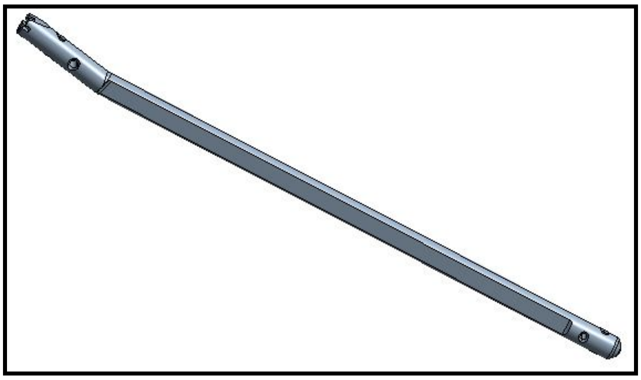


Fig 2.3: -Iteration 1.2 geometry

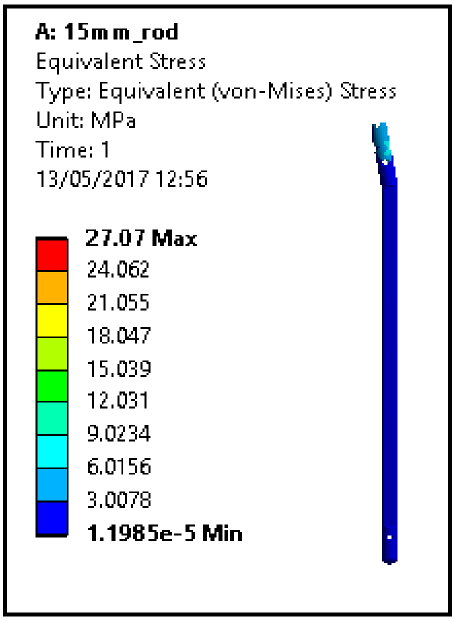


Fig.2.4: von Mises Stess plot @ Iteration 1.2

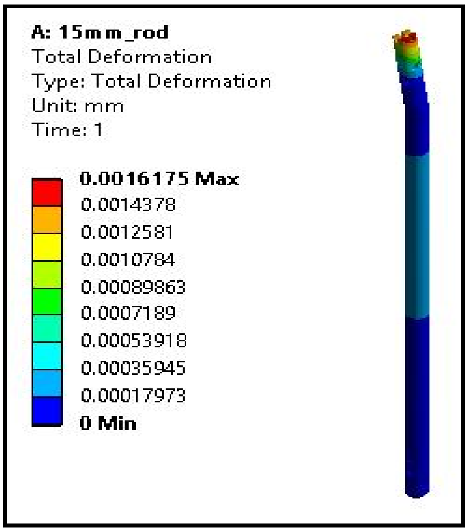


Fig.2.5: Total deformation plot @ Iteration 1.2

Baseline model 2 is prepared for the Tibia Rod insert with 14 mm diameter of the rod, Same FEA procedure that was conducted on the 15 mm diameter Tibia rod is redone on the Baseline 2 model. Results for the same are given below.

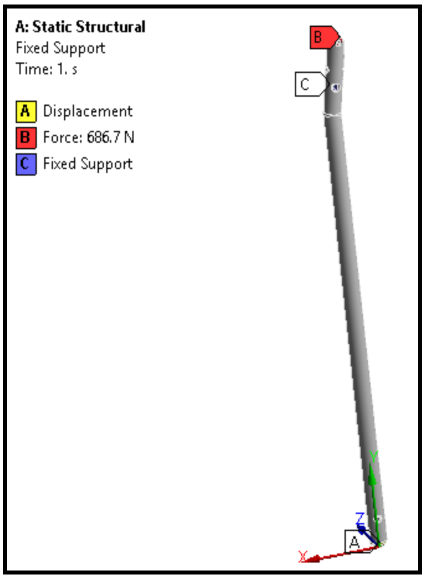


Fig. 2.6: Boundary conditions for the FEA analysis on the Rod

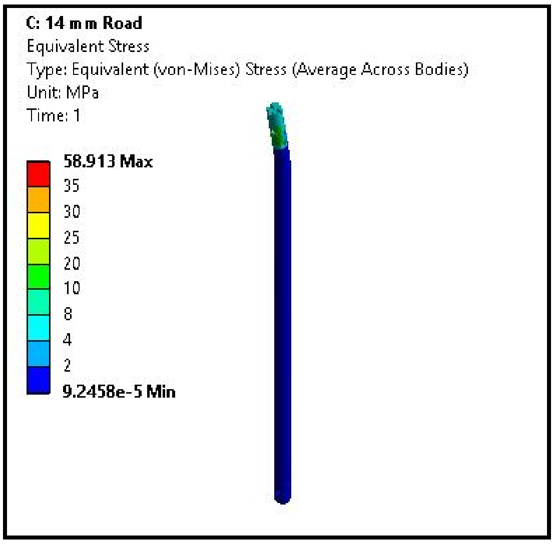


Fig. 2.7: Von Mises Stress Plot @ Baseline 2

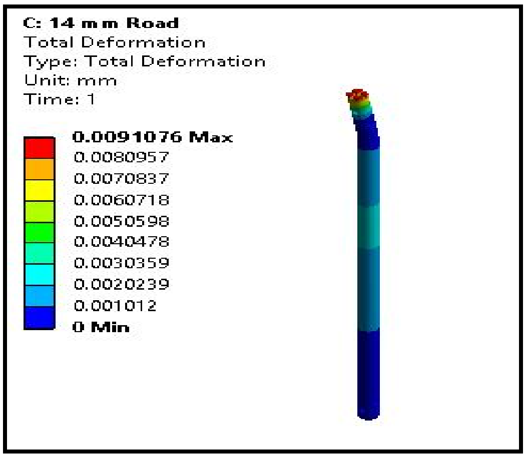


Fig. 2.8: Deformation Plot @ Baseline 2

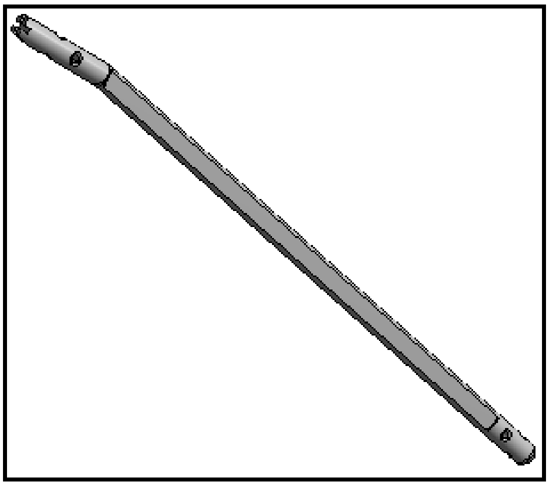


Fig 2.9: -Iteration 2.1 geometry

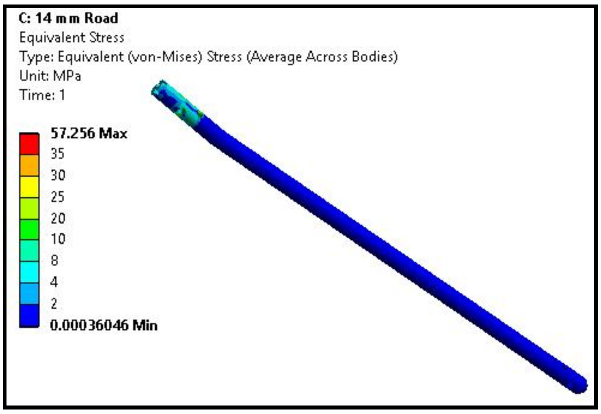


Fig.3.0: von Mises Stress plot @ Iteration 2.1

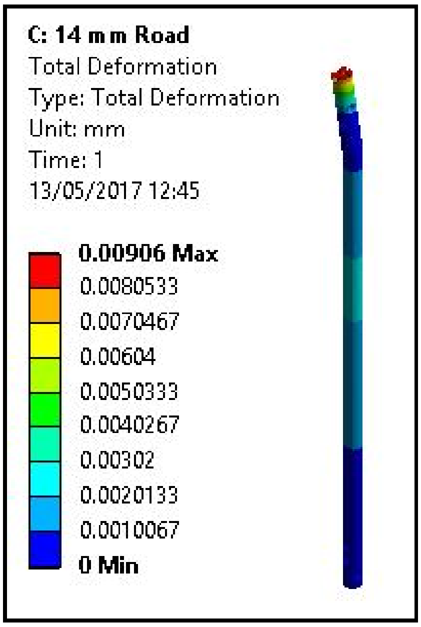


Fig.3.1: Total deformation plot @ Iteration 2.1

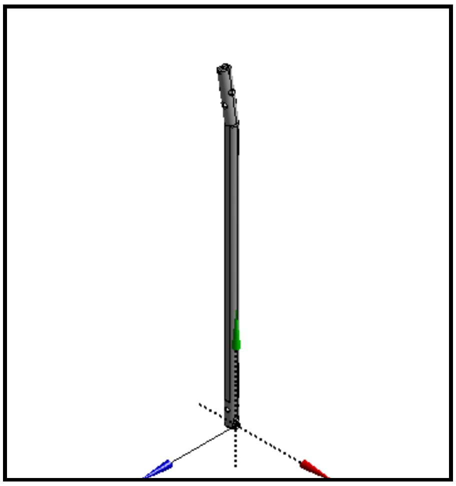


Fig 3.2: -Iteration 2.2 geometry

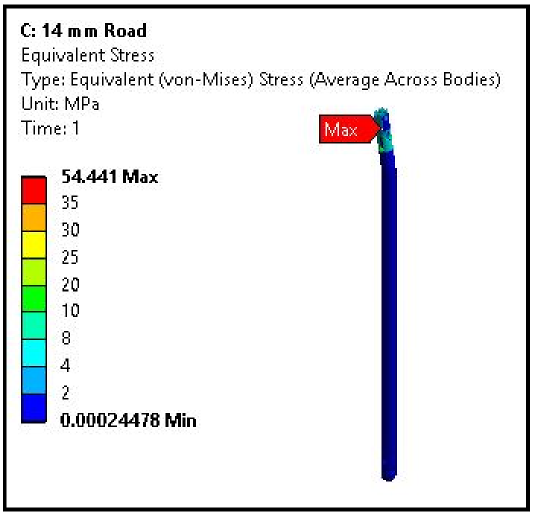


Fig.3.3: von Mises Stress plot @ Iteration 2.2

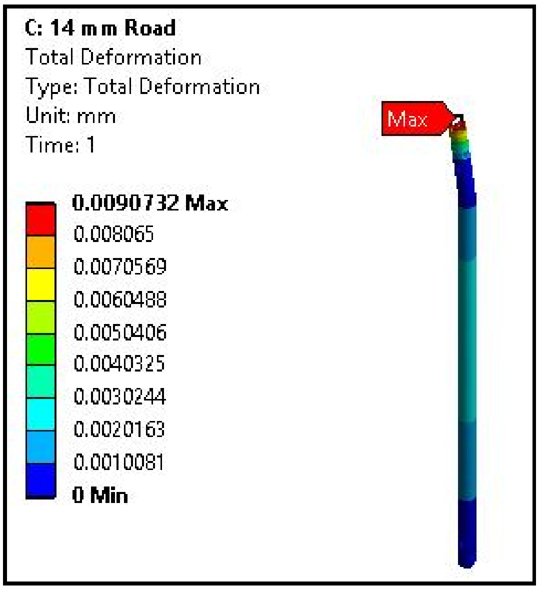


Fig.3.4: Total deformation plot @ Iteration 2.2

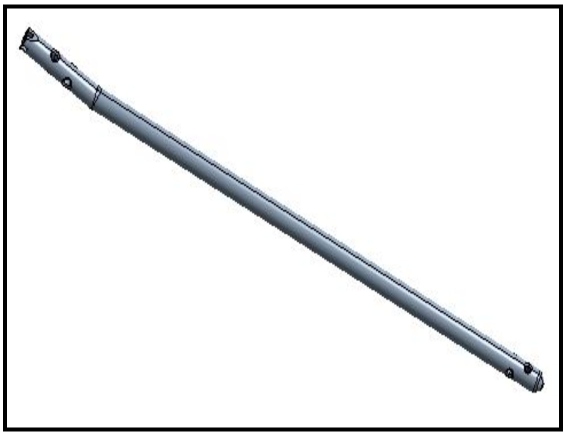


Fig 3.5: - Iteration 3.0 Geometry

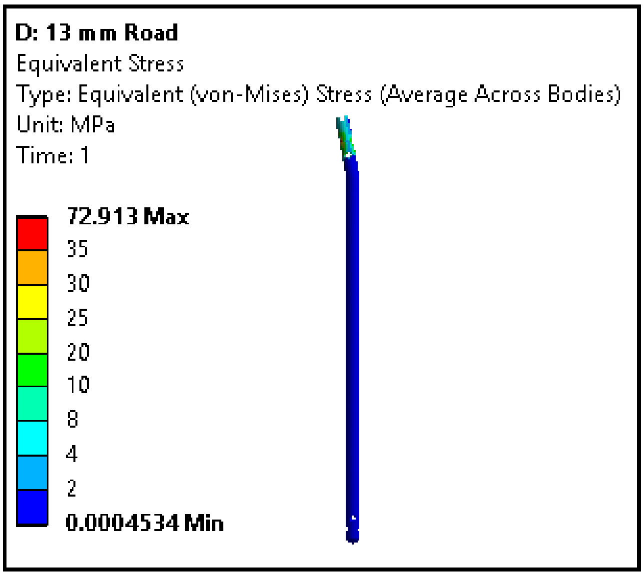


Fig 3.6: Von mises stress plot @ iteration 3.0

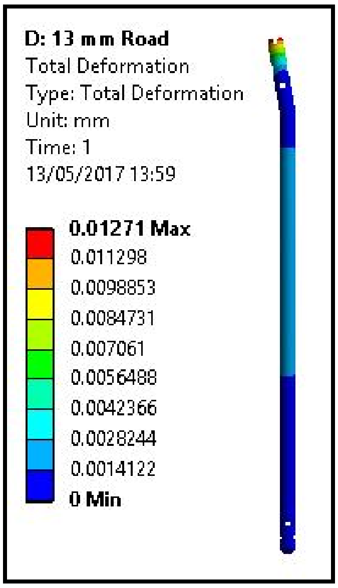


Fig. 3.7: total deformation @ iteration 3.0

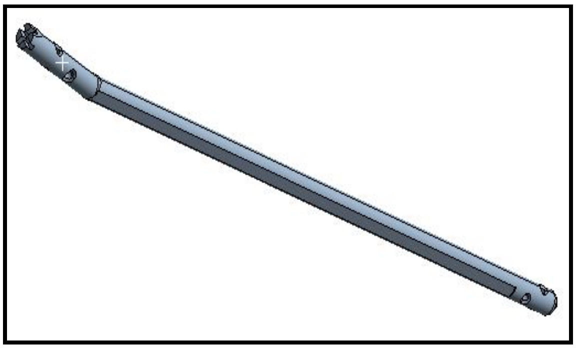


Fig 3.8: - Iteration 3.1 geometry

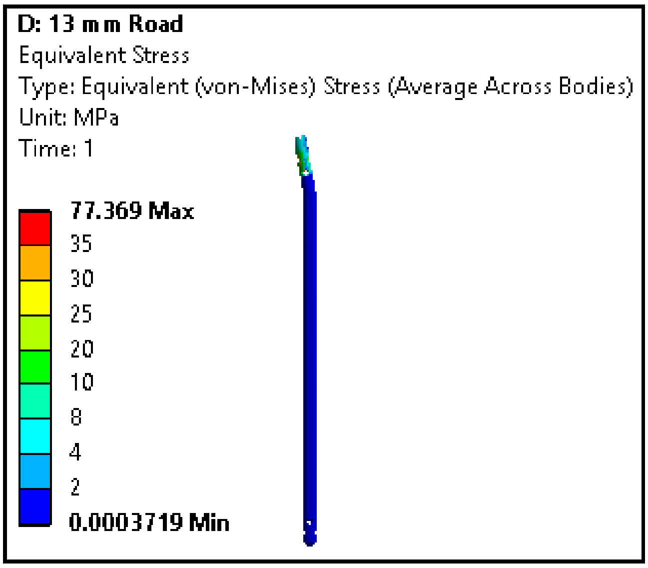


Fig 3.9 :- Von mises stress plot @ iteration 3.1

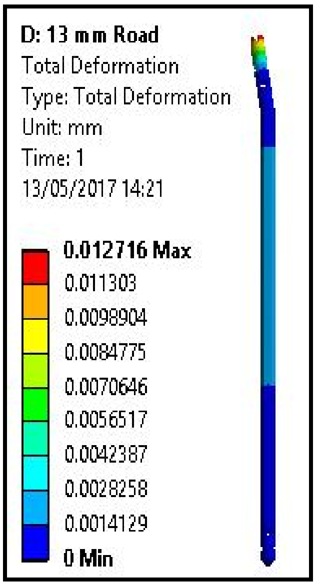


Fig 4.0 :- Total deformation @ iteration 3.1

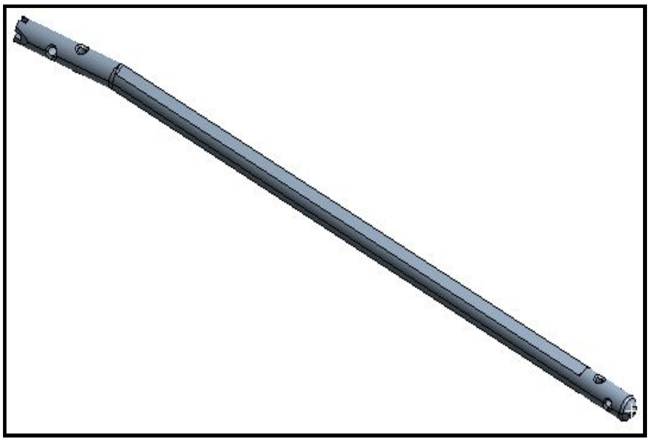


Fig 4.1: - Iteration 3.2 geometry

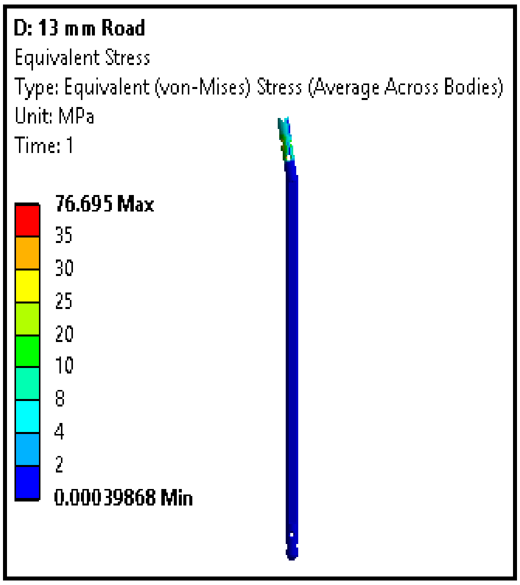


Fig 4.2:- Von mises stress plot @ iteration 3.2

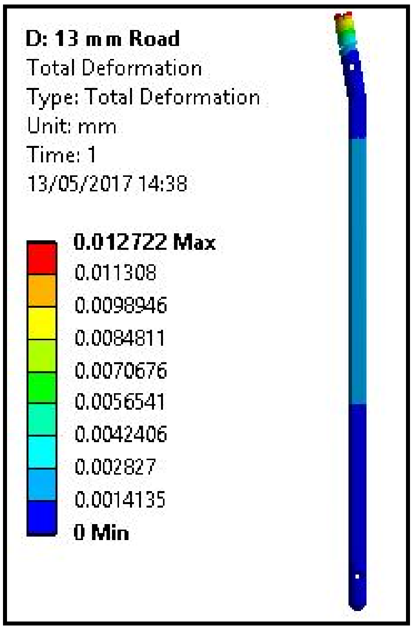


Fig 4.3:- Total deformation @ 3.2 iteration

VI. EXPERIMENTAL ANALYSIS

For experimental analysis part manufactured as per the iteration no.3.2 and tested over the universal testing machine.

Fig 4.4:- Universal Testing Machine

Specification of UTM-

Company Made- Micro Control Systems
Capacity- 400 KN
Test Lab- Om Meta Lab-Pisoli

Load test is carried out on universal testing machine for bending load it's observed that the optimized part FEA results agrees with the experimental results.

Fig 4.5:- Compression testing set up

Fig 4.6:- Compression Loading

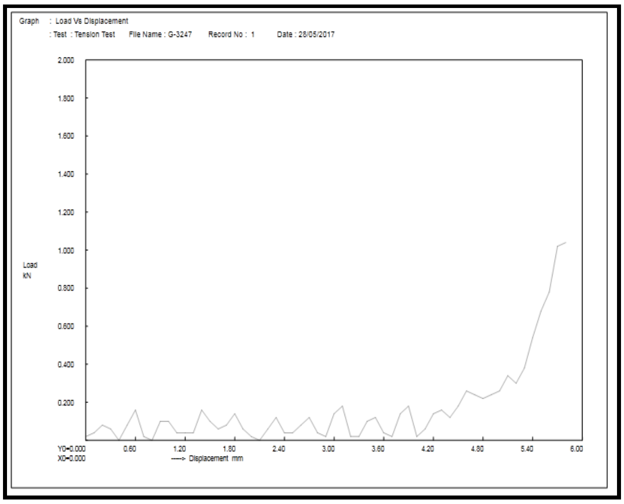


Fig4.7:-Load vs. Displacement Graph

In the above graph of Experimental Load vs Displacement, it can be seen that the rod has taken a compression load of 70 kg and deformed only 0.0023 mm.

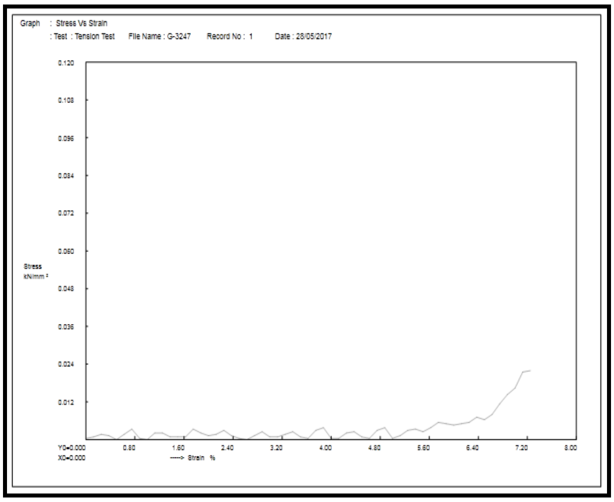


Fig4.8:-Stress Vs. Strain Graph

From the above graph obtained from UTM Testing, it is visible that the stress at the given load is 0.024 KN/mm^2 i.e. 24 N/mm^2 which is within the safe limits

VII. RESULT

Table2.0:- FEA Result Summary 15 mm Dia Tibia Rod

Design	Weight (gm)	Maximum Stress(Mpa)	Total Deformation (mm)
Baseline 1	569	27.07	0.00161
Iteration 1.1	543	27.209	0.00162
Iteration 1.2	497	27.07	0.00161

Table 3.0:- Result Summary for FEA 14 mm Dia Rod

Design	Weight (gm)	Maximum Stress (MPa)	Total Deformation (mm)
Baseline 2	495	58.91	0.0091
Iteration 2.1	470.3	54.44	0.00906
Iteration 2.2	426.5	57.256	0.00907

Table 4.0:- Result Summary for FEA 13 mm Dia Rod

Design	Weight (gm)	Maximum Stress (MPa)	Total Deformation (mm)
Baseline3	426.3	72.913	0.01271
Iteration 3.1	402	77.369	0.01271
Iteration 3.2	360	76.695	0.01272

Table 4.0: Comparison of FEA and Experimental Validation

	FEA	Experimental
Stress	27.07 Mpa	24 Mpa
Displacement	0.00161 mm	0.0023 mm
Weight	497 gm	500 gm

VIII. MANUFACTURING DATA

For manufacturing of Tibia rod iteration 1.2 is selected. In which 2mm radial cut is given. For manufacturing of Tibia rod SS 316L material is selected.

After selection of material the machining is done on milling machine for upper leg slots and nail holes, then bending operation is done for 10° bend at the upper leg side. The manufacturing is done from SS 316L material. The properties are as follows:

Material	UTS (Mpa)	0.2% YS (Mpa)
316L	558	290

IX.CONCLUSION

Statics analysis on the steel insert of TBL bone is successfully conducted and results from the ANSYS software shows us that Stresses are within the acceptable limit . Mass reduction iterations are performed on the TBL rod component to reduce weight without losing strength in static load condition. Multiple design iterations performed on the model shows us that Iteration 1-12.6%, Iteration 2-13.8%, reduction in the mass is possible without loss of static load carrying capacity.

X. SCOPE FOR FUTURE WORK

- There still much work can be pursued in the biomedical are in terms of design and material changes.
- Composite material plays an important role for faster healing and recovery. Carbon/Epoxy, Glass/Polyethylene ETC are some materials are used.
- Flexible implant are also taking up pace to replace ss rods. Flexible implants are inserted in the bone because of low weight and high yield strength the body weight can be taken up. Because of flexible implants healing rate is faster and quicker.

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