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Strength Evaluation Of Bone Implant By Different Mechanical Tests And Analysis

M.A.Godse[1], V. R. Ingle[2], D. S. Koyale[3], Prof. N. T. Manjare[4]

[1,2,3,4]**Department of Mech. Engg , D .Y. Patil College Of Engineering, Pune, Maharashtra, India**

Abstract
The structure and topology of human bones decide the capabilities of human to perform day to day activities. Fracture of bone badly affects the human performance however certain techniques are developed by doctors to cure bone fractures. A suitable metal with required mechanical and chemical properties are used to fabricate the bone implant which is then inserted at fracture junction. The chemical properties of biocompatible metals are evaluated easily without considering actual geometry of the implant however mechanical stress which is function of the geometry and cross sectional area of the implant are to be evaluated carefully. For this purpose it is required to take various tests like bending, torsion, tensile, fatigue tests etc. to know the respective strengths of implant material. For the bending test there is need of advanced four point bending machine to obtain correct bending strength of the implant material. All other test can be conducted as per standard test procedures on respective machines. We evaluated mechanical properties of two most widely used bone implant metals SS316L and Ti Grade 4 Though destructive mechanical tests. The actual tibia implant geometry is modeled and analyzed for stresses using Finite element package. The independent results for both the metals are compared and most suitable metal for such implants is suggested.

Keywords: *Tibia Bone Implant, Biomaterials, Different Mechanical Tests, Testing Machines.*

1. Introduction

1.1 Tibia Bone

The tibia bone is one of the longest and strongest of the two lower leg bones. It connects the knee joint with ankle joint to transmit load to the ground. Healthy tibia is essential for many activities performed by the legs, including standing, walking, running, jumping and supporting the body's weight. The average adult male tibia is 40 to 45 centimeters in length and 2.5 cm in diameter and can support up to 3.5 times the weight of an adult. Tibia works along with fibula to facilitate turning of ankle joint. Tibia is most commonly fractured bone in case of road accidents. Based on locality and severity of fracture a supporting plate with the nails is used temporarily for natural healing of fractured bones. However in case if whole tibia bone is missing or cannot be cured with plates then an artificial leg made of suitable metal is permanently implanted in the patient's body.

1.2 Metals Used For bone implants

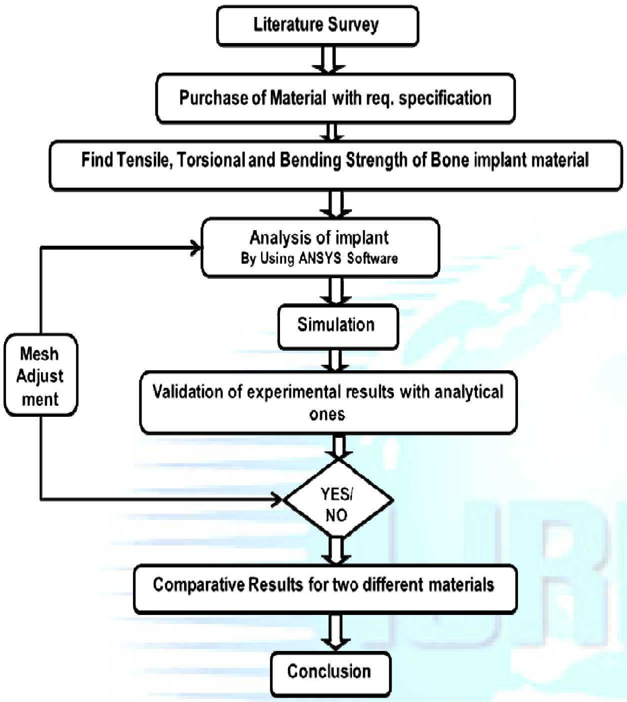
1.2.1 Titanium alloy(Grade 4):

Grade 4 the strongest and lighter of all commercially pure titanium. It is not harmful to the human body and highly corrosive resistance. Titanium resists corrosion, non toxic, long lasting, and elasticity rivals that of human bone, biocompatible and has an innate ability to form implants. Titanium alloy has good chemical properties and salient features for implant application. it is in unalloyed form and proves to be a best metal with no chemical reactions with human body fluids.The joint replacement continue to grow as people live longer or damage themselves more through serious injured in road traffic and other accidents. Titanium is one of Lighter, stronger and totally biocompatible materials that naturally fulfill the requirements for implantation in the human body.

1.2.2 Stainless steel(316L):

stainless steel 316L as a potential implant material. SS316L has good corrosion resistance, biocompatibility, tensile strength and suitable density for load-bearing purposes thus making this material a desirable implant material. SS316L is a widely used economical orthopaedic implant material for internal fixation because of its mechanical strength and the possibility of bending and shaping the implant. In recent years, stainless steel has been recognized as one of the main directions of implant material development and various methodologies and techniques have been tried. SS316L surgical steel is used in the manufacture and handling of food and pharmaceutical products where it is often required in order to minimize metallic contamination. It is also used in the manufacture of body piercing jewelry and body modification implants.

2. Methodology



3. Objectives

3.1 To conduct various mechanical tests on the two independent bone implant materials on UTM, Four pt. bending, and torsion testing machine.

3.2 To find out strength (bending, torsional, tensional etc) of bone implant materials through mechanical testing.

3.3 To carry out analysis of bone implant material using finite element package (ansys).

3.4 Validation of experimental results with analytical ones.

3.5 Suggest the most suitable implant metal out of two.

4. Mechanical Testing

4.1 Tensile Test

Mechanical testing plays an important role in evaluating fundamental properties of materials as well as in developing materials and in controlling the quality of materials for use in design. The most common type of test used to measure the mechanical properties of a material is the Tension Test. Tension test is widely used to provide basic design information on the strength of materials and is an acceptance test for the specification of materials. The major parameters that describe the stress-strain curve obtained during the tension test are the tensile strength (UTS) elastic modulus (E), Percentage elongation (ΔL %) etc other mechanical properties can also be found by the use of this testing technique. Tensile test can be used for precise measurements of bone implant materials, but test specimens must be prepared carefully as per respective test standards. Tensile test specimens are designed so that the highest strains will occur in the central portion or gauge region of the specimen. Strain measurements can be obtained by providing a stain gauge based measuring instrument attached to the specimen. Stress is calculated as the applied axial tensile force divided by the specimen cross sectional area measured at the mid span of specimen.

Fig. 1 Tensile Test of bone implant material

4.2 Four point bending test

With ever increasing demand for high quality and reliable materials, flexural tests have become an important test method in both the manufacturing process and research and development to define a material's ability to resist deformation under load. A component's or material's flexural strength provides critical insight into the modulus of elasticity in bending, flexural stress and flexural strain. The test specimen is placed on two supporting pins placed at a known distance apart and two loading pins placed at a equal distance around the centre are lowered from above at constant rate until sample fails. In four point bending a uniform maximum moment and area of tension at the bottom of the specimen is achieved. This test is more accurate than the conventional three point bending machine.

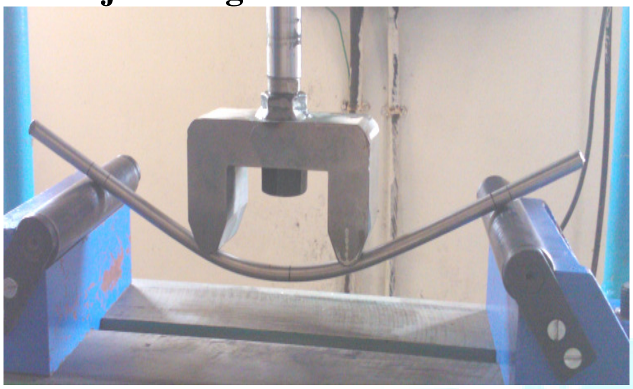


Fig. 2 Bending Test of bone implant material

5. Analytical Testing

5.1 Modelling the implant geometry:

A 2D sketch of tibia implant is obtained from doctors and it is drawn in modeling software the model is saved as .IGS file format, for analysis purpose.

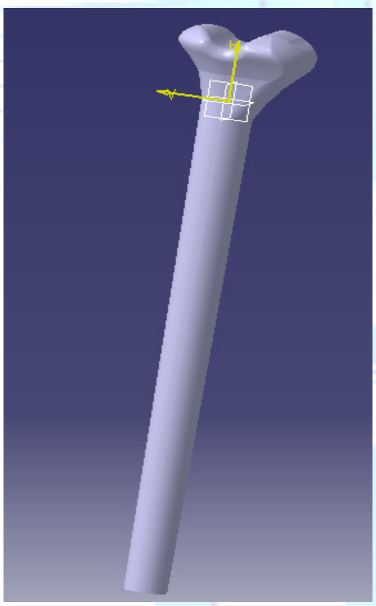


Fig.3. Tibia Implant model

5.2 Stress analysis (static):

Imported the IGES model to FEA software and updated the required engineering data for each material. For meshing the model Tetrahedron was chosen as the element type. The model was meshed by choosing automatic patch conforming method and the lower end was constrained. Load was applied on the head along centre of tibial head bearing groove. The Model was solved and von mises stresses and total deformations were plotted for both the materials.

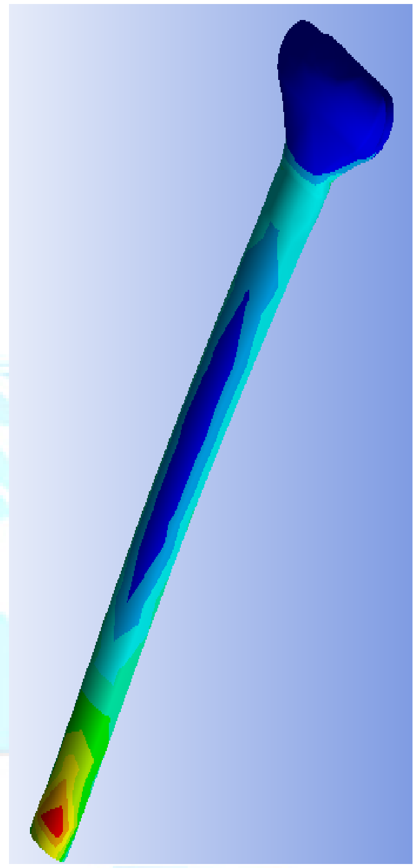


Fig.4. Stress analysis for axial loads

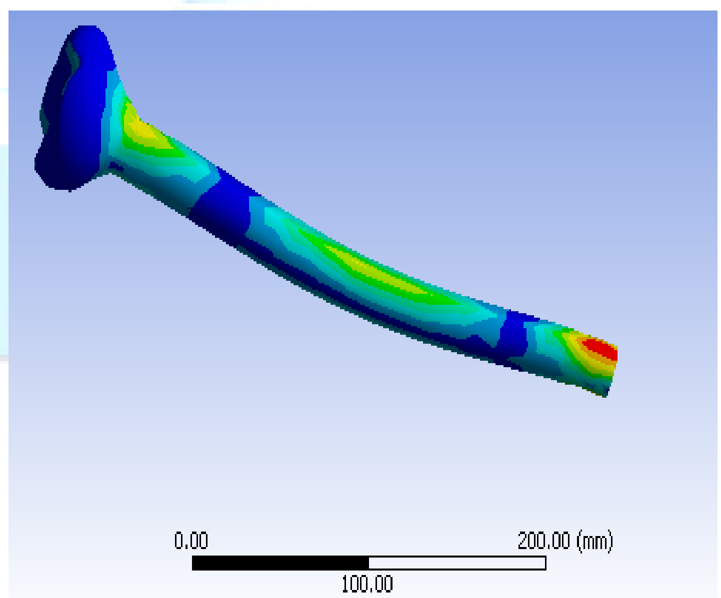


Fig.5. Stress analysis for bending loads

6. Results and Discussion

6.1 Tensile Test (SS316L)
Specification:
Diameter: Ø 10 mm
Total Length: 300 mm
Gauge Length: 50 mm

Table 1: Tensile Test results for SS316L

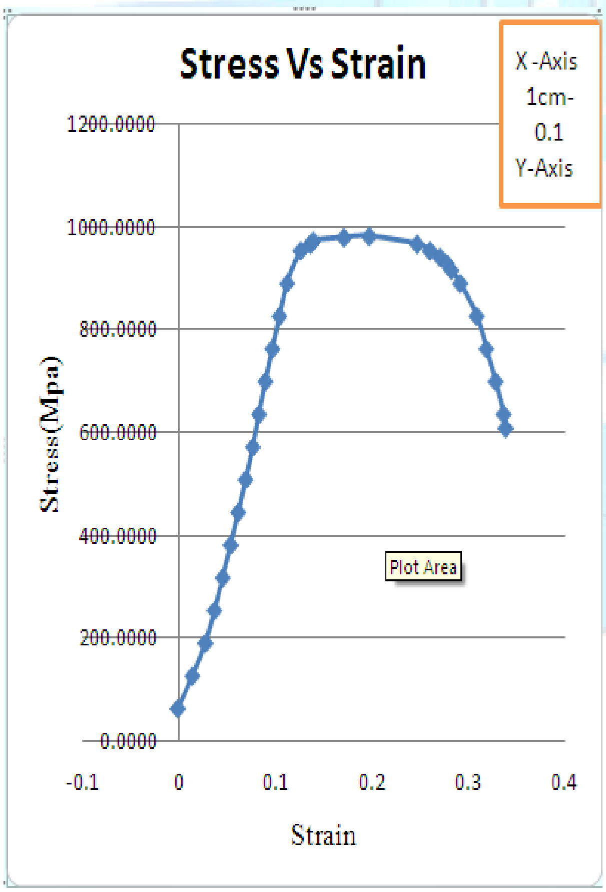
Specimen	Ultimate Load (KN)	Elong. (mm)	UTS (N/mm2)	Average UTS
Sample-1	77.18	16.93	982.6862	982.2618
Sample-2	76.24	18.83	970.718	
Sample-3	78.02	19.12	993.3816	

6.2 Tensile Test (Ti grade 4)

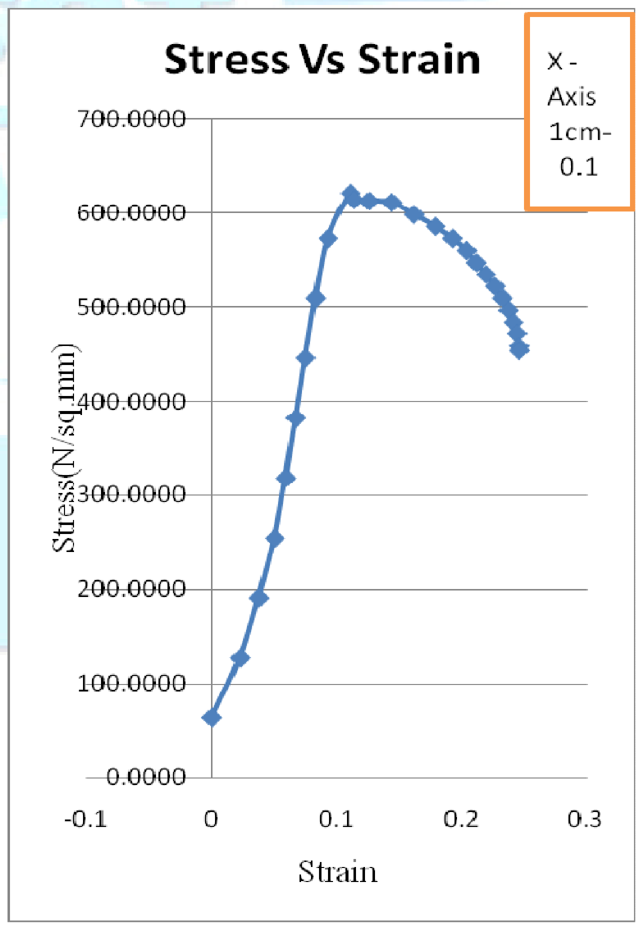
Specification:
Diameter: Ø 10 mm
Total Length: 300 mm
Gauge Length: 50 mm

Table 2: Tensile Test results for Ti Grade 4

Specimen	Ultimate Load (KN)	Elong. (mm)	UTS (N/mm2)	Average UTS
Sample-1	48.79	12.30	621.2137	619.1764
Sample-2	49.13	12.50	625.5425	
Sample-3	47.97	12.71	610.7731	



Graph 1: Stress Vs Strain curve for SS316L specimen-1



Graph 2: Stress Vs Strain curve for Ti grade 4 specimen-1

6.3 Four Point Bending Test (SS316L)
Specification:
Diameter: 10 mm
Total Length: 300mm

Table 3: Bending Test results for SS316L

Specimen	Distance between two supports (mm)	Bending Strength (N/mm^2)	Avg Bending Strength (N/mm^2)
Sample 1	300	2252.9	2209.8
Sample 2	300	2166.7	
Sample 3	200	1560.2	1581.85
Sample 4	200	1603.5	

6.4 Four Point Bending Test (Ti Grade 4)
Specification:
Diameter: Ø 8mm
Total Length: 400mm

Table 4: Bending test result for Ti grade 4

Specimen	Distance between two supports (mm)	Bending Strength (N/mm^2)	Avg Bending Strength (N/mm^2)
Sample 1	300	2370.1	2370.1
Sample 2	300	2370.1	
Sample 3	200	1354.3	1396.65
Sample 4	200	1439	

6.5 implant model analysis for tensile loads:
Table 5: Implant model Analysis results for Stainless Steel

LOAD [N]	MAX STRESS [MPa]	MAX DEFO.[MM]
250	3.92	0.043
500	7.85	0.086
1000	15.70	0.172

Table 6: Implant model Analysis results for Ti Grade 4

LOAD [N]	MAX STRESS [MPa]	MAX DEFO.[MM]
250	1.14	0.016
500	2.29	0.032
1000	4.59	0.065

7. Discussion

We conducted different destructive mechanical tests on both implant materials (SS316L & Titanium alloy Grade 4) to evaluate ultimate properties. From model analysis it is observed that stress developed in implant model of SS316L was higher than the Ti grade 4.

8. Conclusion

Thus we have successfully conducted important mechanical tests on Bone Implant materials on advanced UTM as well as on Four-point bending machine.
The following conclusions are reported:
6.1 For stainless steel (316 L)

- Tensile strength= 982.26 N/mm^2
- Bending strength (300 mm dist.)=2209.80 N/mm^2
- Bending strength (200 mm dist.)=1581.85 N/mm^2

6.2 For Titanium alloy (grade 4)

- Tensile strength= 619.17 N/mm^2
- Bending strength (300 mm dist.) = 2370.1 N/mm^2
- Bending strength (200 mm dist.)=1396.65 N/mm^2

6.3 The following conclusions are reported from analysis:

- The maximum values of von mises stress for titanium tibia implants range from 1.14 MPa to 4.59 MPa are much lower when compared to the yield strength of Titanium Grade 4 alloy, 552 MPa. The maximum von mises stress was observed near the constrained end of the implant.
- Stress induced in SS316L alloy is always found greater than the Ti Grade 4 for each load.
- Ti Grade 4 alloy being extremely light with less density as compared to SS316L alloy does not have any adverse effect on the patient and his movements.
- From the experimental results and implant analysis it is suggested to use Ti Grade 4 alloy effectively as compared to SS316L Alloy for tibia bone prosthesis.

9. References

[1] Prof. N.T.Manjare, Prof. S.N.Khan, and Prof. A.V.Naik 'Strength Evaluation of Bone Implant' IJREAT International Journal of Research in Engineering & Advanced Technology, Volume 2, Issue 3, June-July, 2014.

[2] Yuehuei.H.An & Robert.A.Draughn, Mechanical Testing of Bone and the Bone-Implant Interface, CRC Press, Washington, 2000, PP. 3-219.

[3] Yoshihiro Noyama, Noriyuki Nagayama, Koichi Kuramoto & Takayoshi Nakano, "The optimal design of an implant to improve bone quality of implant surroundings based on stress analysis", Journal of Physics, 2009, pp. 1-5.

[4] Raviraj Havaldar, S.C.Pilli and B.B.Putti Paper Enti tled "Effects of Magnesium on Mechanical Properties of Human Bone" IOSR Journal of Pharmacy and Biological Sciences (IOSR-JPBS) E-ISSN: 2278-3008, P-ISSN: 2319-7676. Volume 7, Issue 3 (Jul. – Aug. 2013), Pp 08- 14.

[5] Wiley, New York, 1980, Ch. 36. G. F. Howden, Mechanical Properties of Biomaterials (eds G. W. Hastings & D. F.)

[6] David Bombač1 et.al Characterization of titanium and stainless steel medical implants surfaces RMZ – Materials and Geoenvironment, Vol. 54, No. 2, pp. 151-164, 2007

[7] M S.Ramakrishna, J. Mayer, E. Wintermantel, Kam W. Leong, paper entitled "Biomedical application of poly-mer-composite materials: a review", Composites science and technology journal, 61 (2001), pp (1189-1224), ELSEVIER.

[8] Hendra Hermawan et.al Metals for Biomedical Applications "Faculty of Biomedical Engineering and Health Science, Universiti Teknologi Malaysia"Malaysia,Theory to Applications, Prof. Reza Fazel (Ed.), ISBN: 978-953-307-637-9.

[9] Faisal Wahib Adam, Joshua Ampofo & Raphael Kumah–Ametepey, "Bending Properties of Implants, Rate of Femur Fractures and Implants Failure in Ostoesynthesis, Reported at the Komfo Anokye Teaching Hospital, Kath, Kumasi- Ghana", International Journal of Engineering and Technology, 2013, pp.265-268.

[10] Damien Subit, Eduardo del Pozo de Dios, Juan Velazquez- Ameijide,Carlos Arregui-Dalmasesa & Jeff Crandall, "Tensile material properties of human rib cortical bone under quasi-static and dynamic failure loading and influence of the bone microstructure on failure Characteristics", Physics.bioph,pp.1-22,2013.

[11] P.-I. Brånemark et al., "Osseointegrated TitaniumFixtures in the Treatment of Edentulousness,"Biomaterials, 4 (1983), pp. 25–28.

[12] Dallari D, Savarino L, Stagni C, Cenni E, Cenacchi A, 63. Fornasari PM, et al. Enhanced tibial osteotomy healing with use of bone grafts supplemented with platelet gel or platelet gel and bone marrow stromal cells. J Bone Joint Surg Am 2007; 89 : 2413-20

[13] Bucholz RW, Carlton A, Holmes R. Interporous 199. hydroxyapatite as a bone graft substitute in tibial plateau fractures. Clin Orthop Relat Res 1989; 240 : 53-62.

[14] Doursounian L, Cazeau C, Touzard RC. Use of tricalcium 96. phosphate ceramics in tibial plateau fracture repair: results of 15 cases reviewed at 38 months. Available from: http:// bhd. online.fr/framensus.htm, 1999.