ORIGINAL RESEARCH

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Finite Element Analysis of Fractured Femur Bone with Prosthetic Bone Plates Using ANSYS Software

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Abstract

Bones are living tissues made of calcium and phosphorus among other elements. In the early years, they replenish themselves and expand quickly. The bone is viewed as a homogenous, isotropic, linear-elastic material. The foundation of the human skeleton are the bones. It aids in supporting the body's softer areas. Trauma is a significant factor in both industrialised and developing nations in terms of mortality and disability. According to the World Health Organization (WHO), trauma will account for the majority of years of life lost in both developed and developing countries by the year 2020.One of the frequent traumas is a bone fracture. Using bone plates to connect the fractured bone is one way to treat the broken bone. This study compares bone plates constructed of several biomaterials (Stainless Steel, Titanium, Alumina, Nylon, and PMMA) to determine which one is the best. SOLIDWORKS is used to model the femur bone, while ANSYS is used for analysis. Also modelled, attached to a fractured bone, and examined are the fracture fixation plates.

Keywords

Biomaterials, FEMUR, ANSYS, Trauma, Fracture.

Imprint

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Introduction

Biomaterials have been around for thousands of years, with archaeologists discovering metal dental implants as early as 200 A. D. However, they have advanced tremendously since World War II. The performance of biomaterials is determined by two factors: bio functioning and biocompatibility. Bone are most important tissues, consists of raw materials like calcium and phosphorus. They develop rapidly during one of early years and make good themselves. The bone is particular as a linear-elastic, isotropic process and uniform material. [11] This examination researches the diversion and the stressful appropriation in a length, thin cantilever beam or bar light emission rectangular cross section segment made of straight versatile the material behavior and mechanical properties that are homogeneous mixture. [12] Bone are most important tissues, consists of raw materials like calcium and phosphorus. They develop rapidly during one of early years and make good themselves. The bone is particular as a linear-elastic, isotropic process and uniform material. Bones are an essential part of the human skeleton. It helps to maintain the softer parts of the body.

Trauma is a chief cause of death and disability in both developed and increasing countries. [13]

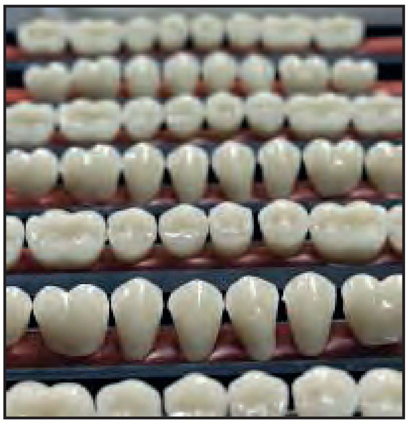
Nomenclature

ρ	Density
E	Young's Modulus
γ	Poisson Ratio
G	Shear Modulus
σ_{eq}	Equivalent stress
δ	Directional deformation

Prosthesis

A prosthesis is a device that is used to replace a lost bodily component. It is a branch of biomechatronics, which is the study of combining mechanical devices with human muscle, bone, and neurological systems to help or increase motor control lost due to accident, disease, or malfunction. Prostheses are often utilised to repair or augment body components that have been lost due to injuries or congenital defects. Artificial heart valves are widely used within the body, whereas artificial hearts and lungs are less frequent but still under active technological development. Hearing aids, bone plates, artificial eyes, palatal obturator, gastric bands, and dentures are examples of prosthetic medical equipment and aids.

a



b

Fig. 1. (a) Prosthetic hip joint; (b) Prosthetic teeth.

Human Bone

As a component of the endoskeleton of animals, bones are stiff organs. They create red and white blood cells, store minerals, and support and shield the body's numerous organs. Dense connective tissue includes bone tissue. Bones occur in a variety of forms, are lightweight yet strong and hard, and have many functions. They also have a complicated internal and exterior structure. The mineralized osseous tissue, commonly known as bone tissue, is one of the tissue types that makes up bone and gives it its stiffness and coral-like three-dimensional interior structure. Bones also contain marrow, endosteum, periosteum, nerves, blood vessels, and cartilage as well as other forms of tissue. A baby human has more than 270 bones at birth, but as the kid develops, many of them fuse together, leaving an adult with just 206 distinct bones.

Femur

The most proximal (closest to the body's centre) bone in the leg is the femur, sometimes known as the thigh bone.

such as the majority of terrestrial mammals, birds, numerous reptiles like lizards, and amphibians like frogs, are capable of walking or leaping. The femur is only present in the back legs of animals with four legs, such as dogs and horses. The biggest bone in the human body is the femur. The femur is one of the body's strongest bones by most standards. The longest, heaviest, and by far the strongest bone in the human body is the femur. In anthropology, this ratio is helpful because it provides a foundation for a realistic estimation of a subject's height from an incomplete skeleton. Its length is 26% of the person's height The head, neck, the two trochanters, and other nearby structures are located at the upper or proximal extremity, which is close to the torso. The femur's body, also known as the shaft, is long, thin, and almost cylindrical in shape. It is somewhat wider above than in the centre, and below it is the broadest and most flattened from the front. It is slightly arched, with a concave back and a convex front. The linea aspera, a conspicuous longitudinal ridge, which divides into a medial and lateral ridge at the proximal and distal ends, strengthens the concave back. The femur's lower extremity is bigger than its upper extremity. Although its shape is relatively cuboid, its transverse diameter is larger than its anterior and posterior (front to back). There are two oblong eminences in it.

Prosthetic bone plates

Bone plates are surgical devices that aid in the repair of shattered and broken bones. When casts cannot be placed to the wounded region, the breaks are first fixed and then secured in place using bone plates. Fractures of the nose, jaw, or eye sockets are frequently treated using bone plates. This type of repair belongs to the field of medicine known as osteosynthesis.

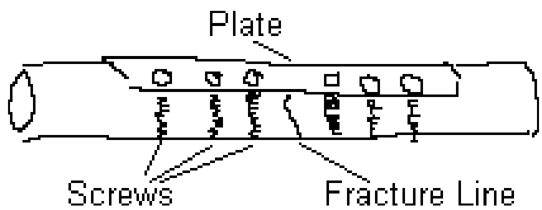


Fig. 2.Fractured bone with plate

2. Selection of Materials

The biomaterials I have selected for this study are Stainless steel

- Stainless steel
- Aluminum
- Titanium
- Graphite
- Nylon PMMA

Table 1

Mechanical properties of material.

Material	(g/cm^3)	E Gpa	Y
Stainless Steel 316L	8000	193	0.30
Titanium	4430	895	0.342
Alumina	8.5	240	0.31
Nylon	3.72	300	0.21
PMMA	1.18	2.2	0.20

3. Modelling and Analysis of Femur bone

In order to simulate the human femur bone, Solidworks software was used. The Journal [3] made reference to the bone's measurements. The ANSYS WORKBENCH® is used to analyse human bone. Fig. 3 displays the SOLIDWORKS-modeled femur bone. The following is a description of the analysis's steps.

Material Assignments

Assigning material attributes in each direction of a bone model is challenging due to the significant degree of heterogeneity and nonlinearity in human bone. Either in a Mimics module or a Finite Element Module, material may be assigned in two different ways. Here, ANSYS is used to assign the material attributes directly.

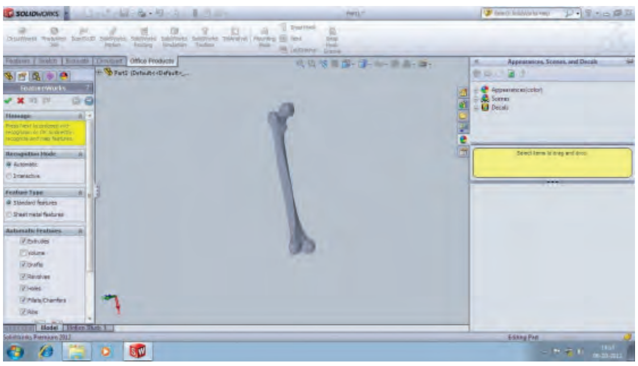


Fig. 3.Modeling of femur bone

Import of Geometry

The SOLIDWORKS software's file is saved in the. IGS format. The create option is selected when it is loaded into the ANSYS programme. The model may now be examined. Figure 4 displays the imported geometry in ANSYS.

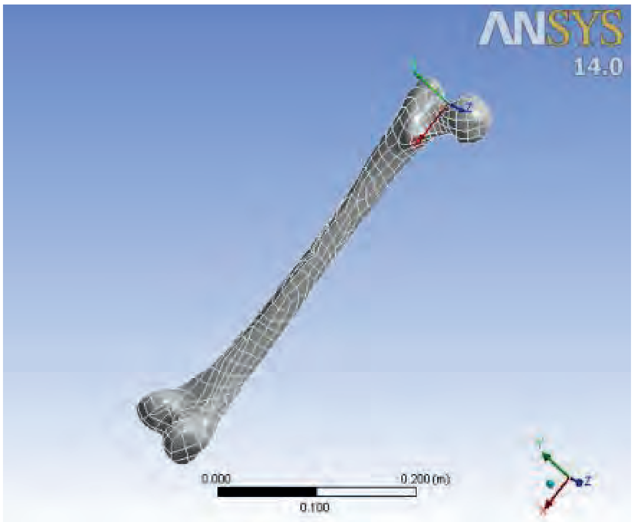


Fig. 4. Imported geometry;

Meshing

For further Finite element analysis (FEA), a surface mesh is constructed for the femur bone model once it has been created. The mesh size is specified as fine mesh. There are 40397 nodes and 23353 items total that have been produced. Figure 5 in ANSYS displays the Femur bone's mesh model.

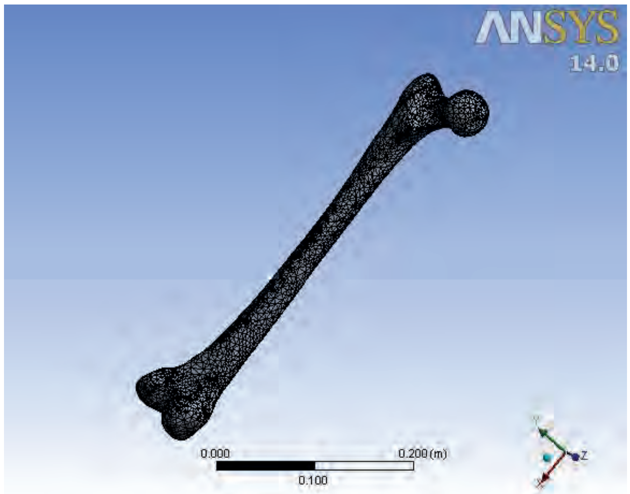


Fig. 5. Imported geometry;

Boundary conditions

The femur bone is rigid and unyielding. The volumetric mesh-based three-dimensional Finite element model of the femur bone was loaded into ANSYS. A 750 Pa eccentric and concentrated load is supplied to the head of the femur bone, and fixed support is offered at the lateral, medial, and lower surfaces of the patella. Fig. 6 displays the boundary conditions provided by ANSYS for the femur bone. The femur bone's material characteristics are listed in Table 2.

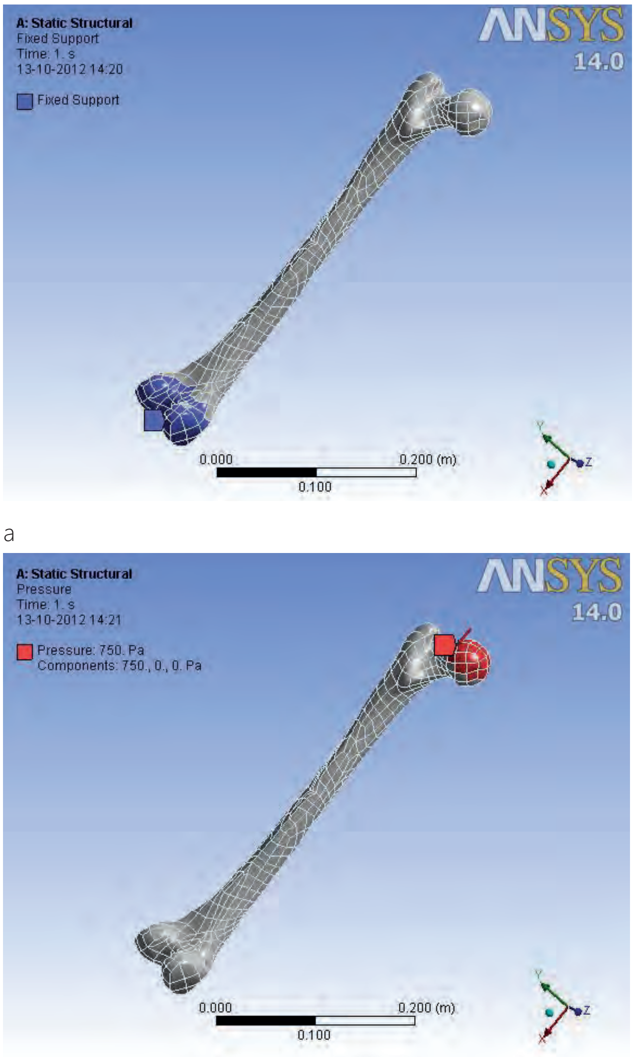


Fig. 6.(a) Fixed support in the lower surface; (b) Load at the head surface of femur

Table 2

Mechanical properties of Femur Bone.

Material	Bone
ρ	2000 g/cm^3
E	2.13 GPa
γ	0.3
G	70 MPa
Material	Bone

Results & Discussions

In this study, a 75 kg male subject is used to analyse stress distribution, total deformation, and fatigue failure of the femur in the usual posture. Maximum Directional deformation of 0.000040462m was achieved for eccentric load. According to the findings, the femur's head has the greatest deformation, while its lower end experiences the least. Minimum principle stress is 35.98 Pa and Maximum equivalent stress is 6534 5 Pa. The central portion of the femur experiences the highest level of principal stress. There is a corresponding (Von Misses) stress of 6534 Pa.

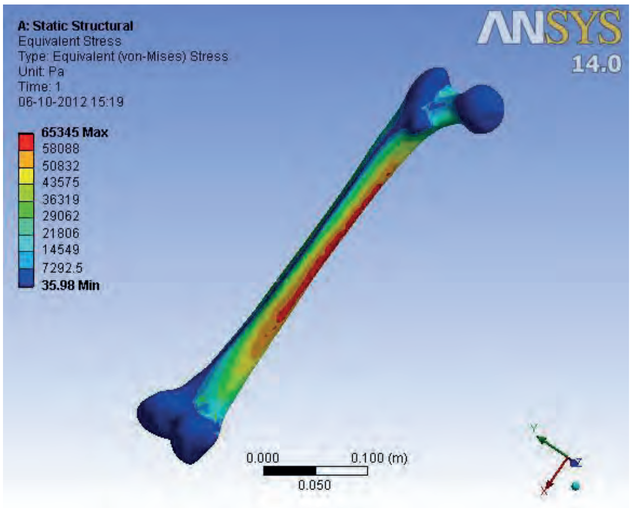


Fig. 7.Equivalent stress of femur bone

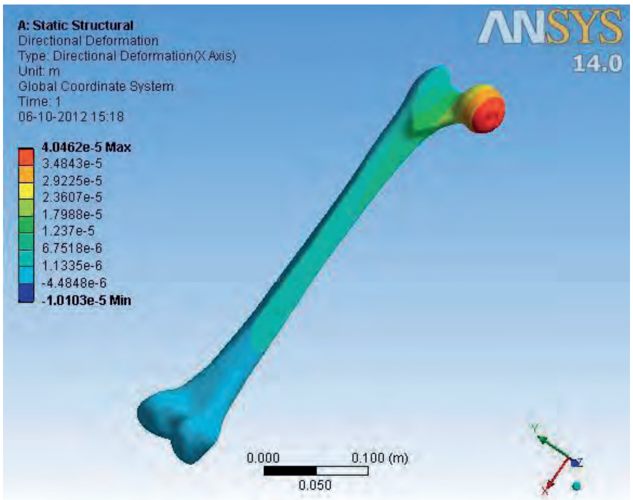


Fig. 8.Directional deformation of femur bone

4. Analysis of fractured femur bone joined with bone plates

SOLIDWORKS software is used to simulate the femur's bony plate. By purchasing a femur bone plate constructed of SS316L, the measurements for this bone plate are referenced. This type of bone plate will be created in the future for use in the experiment. Fig. 8 displays the bone plate for the broken femur bone that was modelled in SOLIDWORKS.

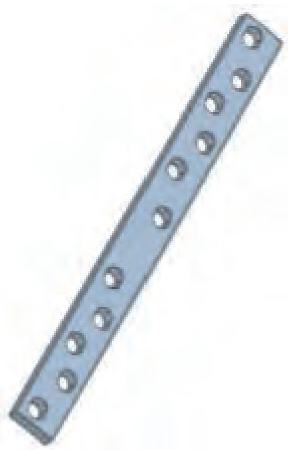


Fig. 9. Bone plate modeled using SOLIDWORKS

The previously modelled femur bone has been divided into two halves. SOLIDWORKS software is used to construct the bone plate and the damaged femur bone. A screw, which is also modelled in SOLIDWORKS software, holds them together. The analysis is carried out after importing the assembled model into the ANSYS programme. The analytical process is the same as it was for the last femur study. The usage of two materials in this instance, however, necessitates the assignment of material attributes to each of them. For attaching the bone, bonded joints are provided, and friction joints are provided for fastening the screws to the plate. The femur bone was broken. Fig. 9 displays how the bone plate is linked.

Fig. 10.Assembly of broken bone and plate using SOLIDWORKS

The analysis is carried out after importing the assembled model into the ANSYS programme. The analytical process is the same as it was for the last femur study. The usage of two materials in this instance, however, necessitates the assignment of material attributes to each of them. For attaching the bone, bonded joints are provided, and friction joints are provided for fastening the screws to the plate.

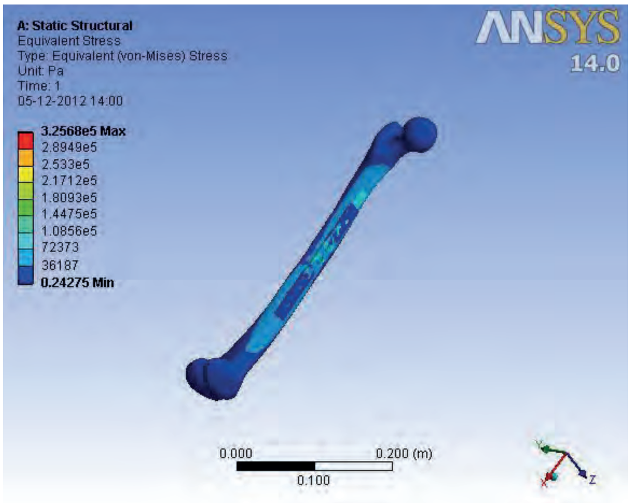


Fig. 11.Equivalent stress of femur with titanium plate assembly;

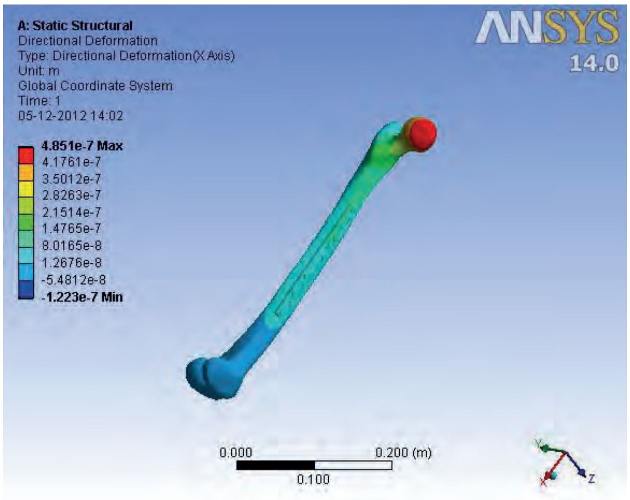


Fig. 12.Directional deformation of femur with titanium plate assembly

Table 3

Finite Element Results

Material	σ_{eq} (pa)	δ (m)
Stainless Steel 316L Titanium	3.2906e6 3.2568e5	0.0061501 4.851e-7
Alumina	1.8259e6	0.0063721
Nylon	5.0434e6	0.0051529
PMMA	5.3459e6	0.0059465

5. Conclusion

The femur bone is modeled and examined in this study. Then, five different substances are chosen to create bone plates. A shattered femur bone is joined with the aid of a simulated bone plate. The completed model is subjected to analysis. By doing this, it is possible to identify the material that is least affected by loading-related stress. Titanium is discovered to have less equivalent stress in the materials utilized. To compare the stiffness of bone and plates, as well as the materials' resistance to corrosion and wear, further research must be done in order to determine the optimal material. Finally, by doing this, the ideal substance for making bone plates will be discovered.

References

1. Thomas M.Cervantes, Alexander H.SlocumJr, Edward B.Seldin, 2011. Design and Experimental evaluation of adjustable bone plates for mandibular fracture fixation. Journal of Biomechanics 45 (2012) 172 178.
2. Ali, M.S., French,T.A.,Hastings,G.W.,Rae,T.,Rushton,N.,Ross,E.R.,1990.Carbon fibre composite bone plates: development, evaluation and early clinical experience. Journal of Bone and Joint Surgery British Volume72,586 591.
3. Taner Zuylan, Khalil Awadh Murshid, 2001. An Analysis of Anatolian Human Femur Anthropometry. Turk J Med Sci 32 (2002) 231-235© T.BUTAK.
4. Choueka, J.,Charvet,J.L.,Alexander,H.,Oh,Y.H.,-Joseph,G.,Blumenthal,N.C., Lacourse,W.C.,1995. Effect of annealing temperature on the degradation of reinforcing fibers for absorbable implants. Journal of Biomedical Materials Research29,1309 1315.
5. Chandra Mohan Devarajan, Marimuthu Krishnaswamy, Natural fiber bone plates as substitutes for orthopaedic alloy plates, (2011) Biotechnol.Bioinf. Bioeng. 2011, 1(4):405-413 © 2011 Society for Applied Biotechnology.
6. Computers & Structures, vol. 17, no. 5/6, pp. 845-855, 1983.
7. Cheung, G.; Zalzal, P. ;Bhandari, M.; Spelt, J.K. ; Papini, M. (2004) : Finite Element Analysis of a Femoral Retrograde Intramedullary Nail Subject to Gait Loading, Medical Engineering and Physics, 26 93 108.
8. Coelho, P. G.; Fernandes, P. R.; Rodrigues, H. C.; Cardoso, J.B. ; Guedes, J.M. (2009) Numerical modeling of bone tissuea daptation A hierarchical approach for bone apparent density and trabecular structure ,Journal of Biomechanics, 42 830 837.
9. Fouad H. Effects of the bone-plate material and the presence of a gap between the fractured bone and plate on the predicted stresses at the fractured bone. Med Eng Phys 2010;32:783 9.
10. Alkan, A., Celebi, N., Ozden, B., Bas, B., Inal, S., 2007. Biomechanical comparison of different plating techniques in repair of mandibular angle fractures. Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology & Endodontics 104, 752 756.
11. A Kalaiyarasan, K Sankar, M Madheswaran, C Harish Finite Element Analysis of Femur Bone under Different Loading Conditions 2021 International Conference on Computational Performance Evaluation (ComPE) DOI: 10.1109/ComPE53109.2021.9752266
12. A Kalaiyarasan, S Sundaram Finite element analysis of beam with different loading condition Volume 43, Part 2, 2021, Pages 2189-2193
13. A Kalaiyarasan, K Sankar, S Sundaram Finite element analysis and modeling of fractured femur bone Volume 22, Part 3, 2020, Pages 649-653
14. Enhancements of leach algorithm for wireless networks: A review.M Madheswaran, RN Shanmugasundaram Economy of Industry 4 (4)
15. Analysis and implementation of LLC-T series parallel resonant converter using fuzzy logic controller C Nagarajan, M Madheswaran International Journal of Engineering, Science and Technology 2 (10)