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Simulation Analysis on Femur Bone Along with Fracture Fixation Plate

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***Abstract*— The Biomechanics is the application of mechanical principles on the living organisms and utilizing the principles of physics, simulation and study of biomechanical structures are carried out. Finite Element Method is one of the widely accepted tools for modelling the biomechanical structures. The femur bone is the most proximal bone of the leg in vertebrates capable of walking and jumping. This paper presents the analysis of Femur bone fracture fixation plates using Finite element method.**

The Femur bone model is taken from online library and analysis is carried out in an ANSYS environment. Different models of fracture fixation plate is modelled using the commercially available Catia V5 software. The stress distribution at the fractured site of the femur is obtained when the system is subjected to compressive loadings along with various healing stages. The effects of the use of different biomaterials for the plates and screws on the stress distribution characteristics are also investigated. In addition to materials from base papers new materials are studied*

***Keywords*— Femur, Fracture, CatiaV5, Biomaterials, Ansys**

I. INTRODUCTION

Medical definition of Prosthetic:

First Referring to a prosthesis, an individual artificial substitute or replacement of a human part of the body such as a tooth, eye, a hip, a facial bone, the palate, a knee or another Body joint, the leg, an arm, etc. A prosthesis is designed for fully functional or cosmetic reasons or both. Typical prostheses for joints are the elbow, ankle, and hip, knee, and finger joints. Prosthetic implants can be used in the parts of the joint such as a unilateral knee. Joint replacement and surgical reconstruction or replacement of a joint.

Design Consideration of Modern Prosthetic: They are many factors that are taken in to consideration, when designing the Prosthetic. Some of the reasons are as Follow

1-Fitness of the Prosthetic Users

2-Weight of the Given Material or Using For the Material

3-Energy Storage and return by the Equipment

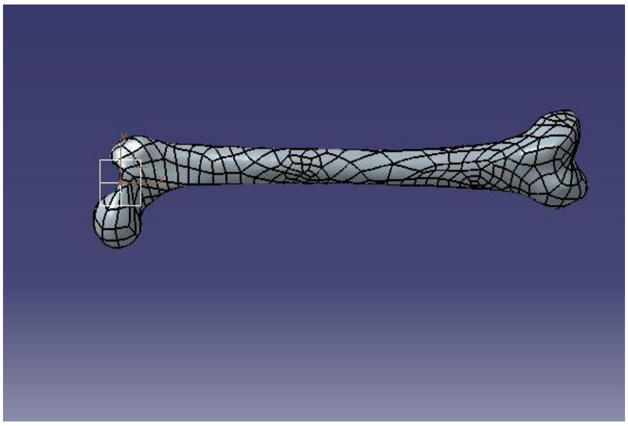
4- Ground compliance

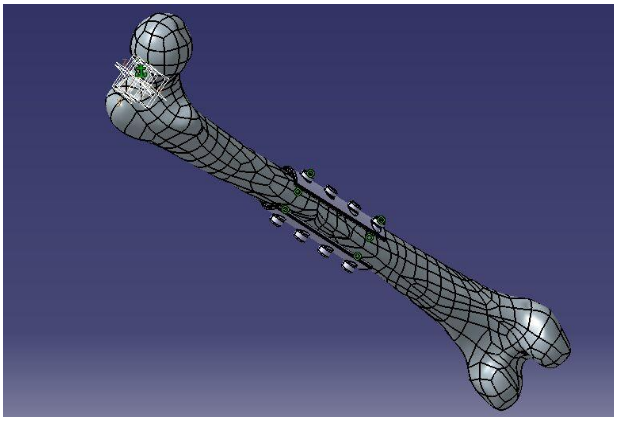
5-Rotation – ease of changing direction

Large segmental defects and non-unions in long bones caused by fracture, infection, tumour or cysts are still a challenging problem in orthopaedic surgery. The stable fixation of an osteosynthesis system is necessary for the bone healing process and the clinical success of the implant. Manufacturers worldwide developed various methods to offer maximum intra operative flexibility (e.g. poly axial screws) and stable screw-plate connection (e.g. angular stable fixations) [1], [2]. The functionality of the mentioned fixation methods has been demonstrated in several experimental studies [3]–[5]. Nevertheless, experiment Besides experimental testing, finite element analysis (FEA) has grown to a powerful tool in order to analyze stresses and strains within structures during static and dynamic load situations. Moreover, it offers detailed information which cannot be determined with experimental methods. Due to the capability to analyse the influence of various parameters on implant components during the preclinical testing, without prototype production, the FEA has become an irreplaceable tool with various applicability. Therefore, it is a common method in mechanical engineering and gains more and more influence in biomechanics.

II. CATIA

CATIA has a unique ability of modelling a product in the context of its real life behaviour. This design software became successful because of its technology which facilitates its customers to innovate a new robust, parametric, feature based model consistently. CATIA provides easy to use solution tailored to the needs of small medium sized enterprises as well as large industrial corporations in all industries, consumer goods, fabrications and assembly, electrical and electronics goods, automotive, aerospace, shipbuilding and plant design





III. PROBLEM DESCRIPTION

Four different materials considered for plates modelling. Those are Titanium, Callus and PLA,HP30CF.

1)Titanium: Titanium is the newest metallic biomaterial. In both medical and dental fields, titanium and its alloys have demonstrated success as biomedical devices. Ti and Ti based alloys are lighter in weight than the other metals and have good mechanochemical properties. Ti has poor shear strength, making it less desirable for bone screws, plates and similar applications. The high strength, low weight, outstanding corrosion resistance possessed by Titanium and Titanium alloys have led to a wide and range of successful applications.

2)Callus: A localized firm thickening of the upper layer of skin as a result of repetitive friction. A callus on the skin of the foot has become thick and hard from rubbing. The Hard new bone substance that forms in an area of bone fracture. Bony callus is part of the bone repair process. Callus Structure stability remodelled overtime to achieve a more effective structure, while the material quality of callus tissue is a very important factor for callus strength.

3)PLA(Poly Lactic Acid):Poly Lactic Acid is Different than most Thermoplastic polymers in that it is derived from renewable resources like corn starch or sugar cane. most plastics by contrast, are derived from the distillation and polymerization of non-renewable petroleum reserves. Plastics that are derived from biomass(ex. poly lactic acid) are known as” bio plastics”

4)HP30CF: Two, different, commercially available polyamide 10.10 products were selected for testing as composite matrices: Hiprolon® 211, Suzhou HiPro (now Arkema), marked further in the text as HP, a plasticized compound for cable applications.

According to the book Human Body Dynamics: Classical Mechanics and Human Movement by Aydin Tozeren, the average percentage of weight for each body part is as follows:

Trunk (Chest, back and abdomen) – 50.80%

• Thigh – 9.88%

• Head – 7.30%

• Lower leg – 4.65%

• Upper arm – 2.7%

• Forearm – 1.60%

• Foot – 1.45%

• Hand – 0.66%

Load calculation

average weight of human being	60 Kg	
upper body weight	50 Kg	84% of body weight
so load on ferum bone	50 Kg	
in dynamic conditions load is 2 times general conditions	100 Kg	980 N

IV. ANALYSIS

The values of Equivalent stress, Equivalent strain, Total Deformation are calculated by using ansys. The finite element Analysis is done in Ansys workbench on the femur bone and plate for four different materials and three different plate models to validate with a dynamic load of 1000N representing a two times of body weight for a average weight of 50Kg is taken i.e 1000N at every point the finite element analysis generate maximum and minimum values. This simulation was conducted on Titanium and Poly lactic acid, Callus and HP30CF

Case Showing Various Fluctuations For model 1 With Callus Material

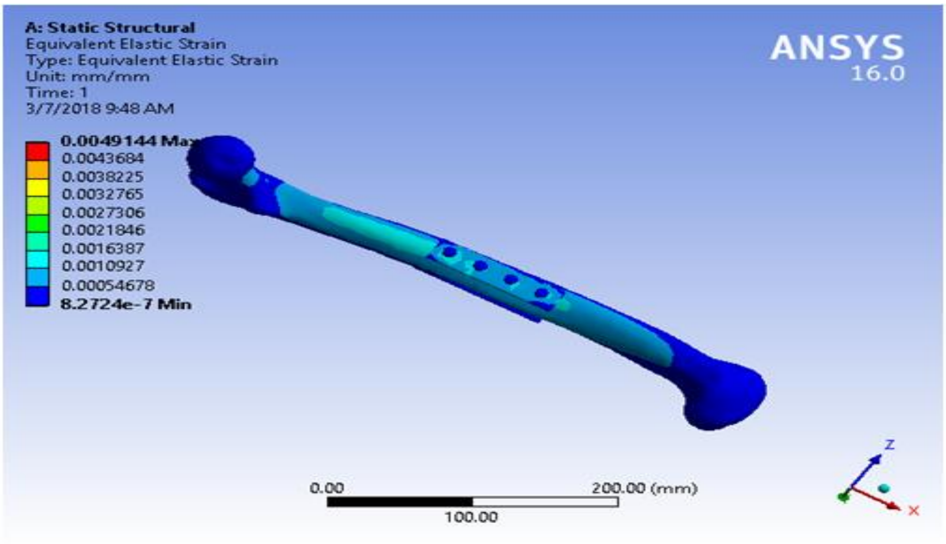


Fig: 4.2.1 picture showing equivalent strain for model 1 with callus(100%)material

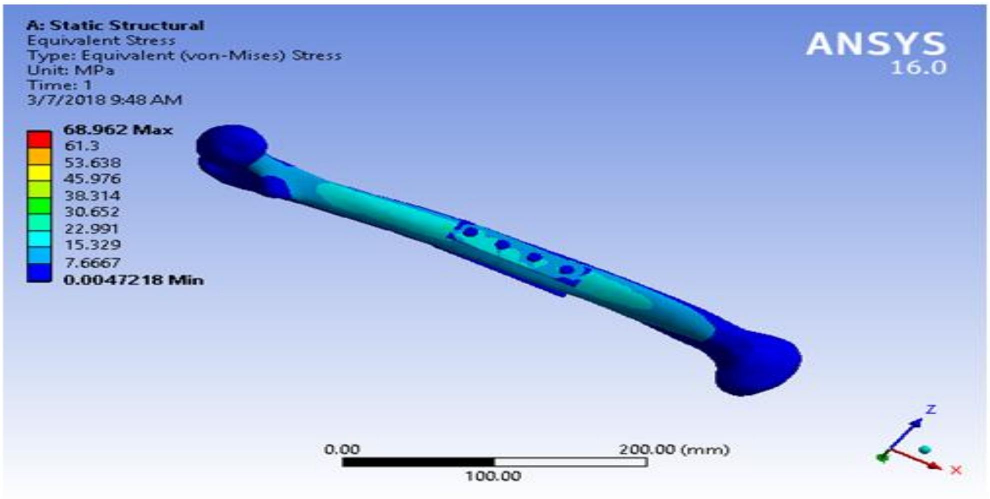


Fig: 4.2.2 picture showing equivalent stress for model 1 with callus(100%)material

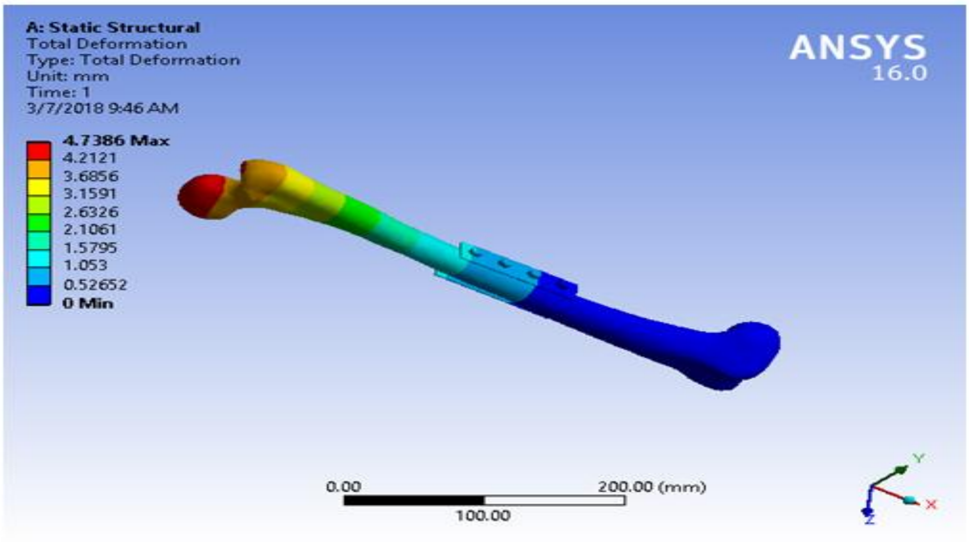


Fig: 4.2.3 picture showing total deformation for model 1 with callus(100%) material

Case Showing Various Fluctuations For model 2 With HP30CF materials

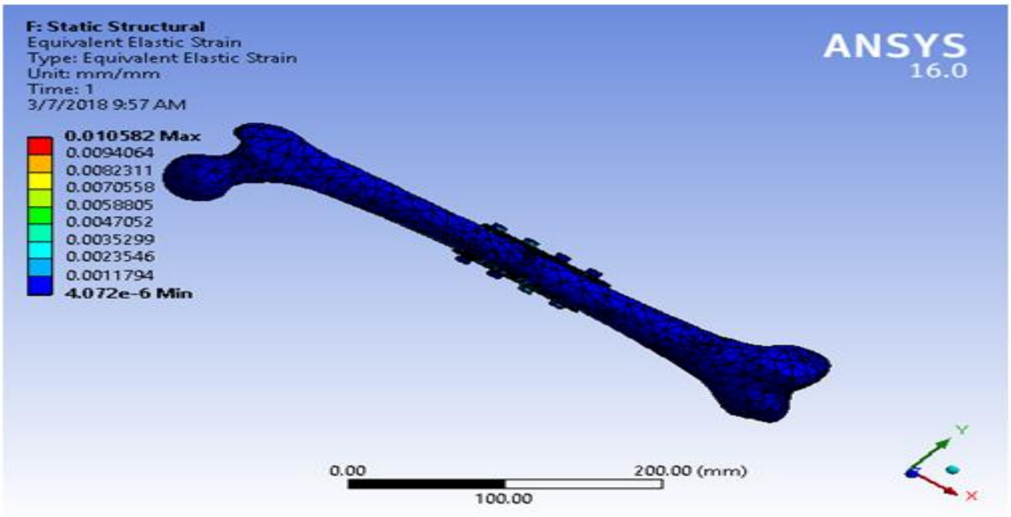


Fig: 4.7.1 picture showing equivalent strain for model 2 with HP30CF material

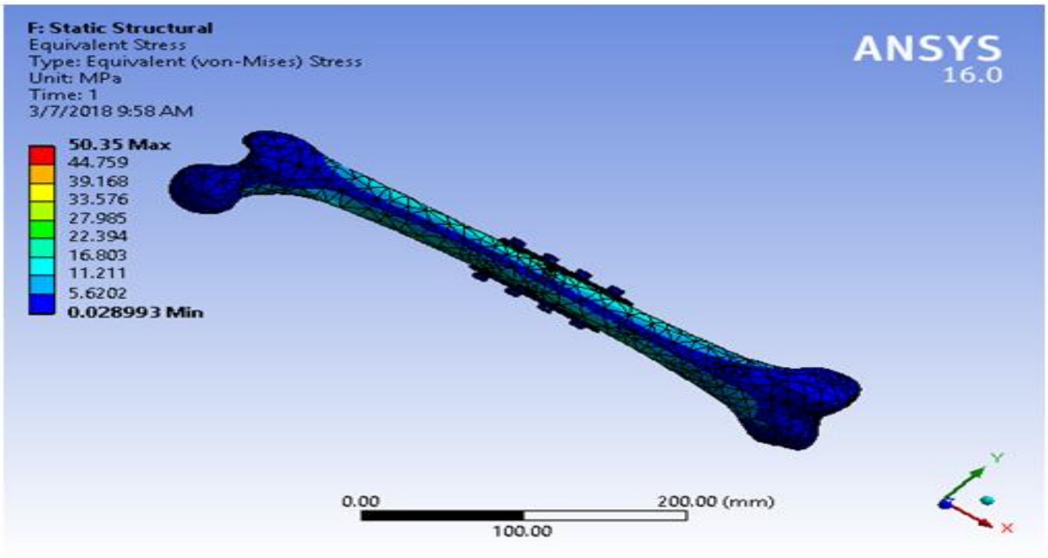


Fig: 4.7.2 picture showing equivalent stress for model 2 with HP30CF material

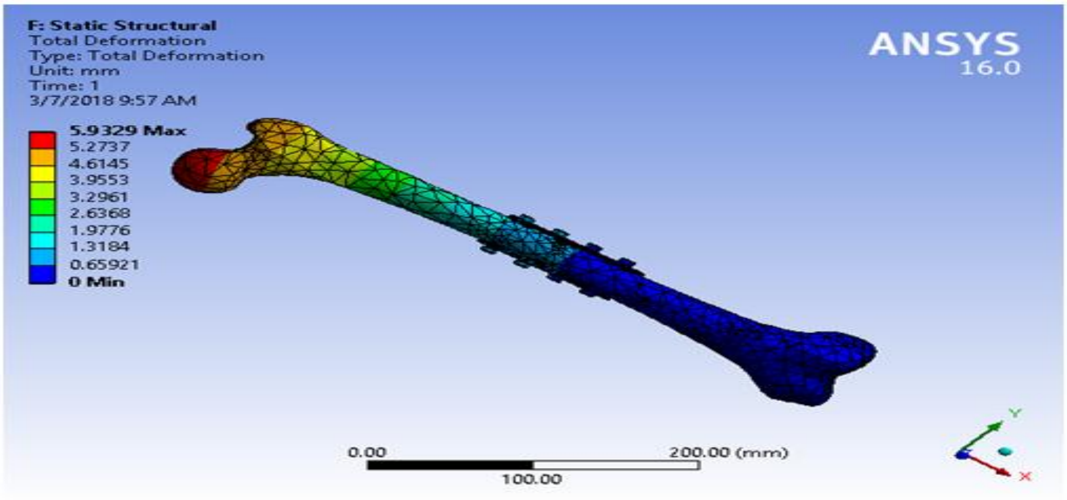


Fig: 4.7.3 picture showing total deformation for model 2 with HP30CF material

Case showing Various Fluctuations For Model 3 with Titanium Material

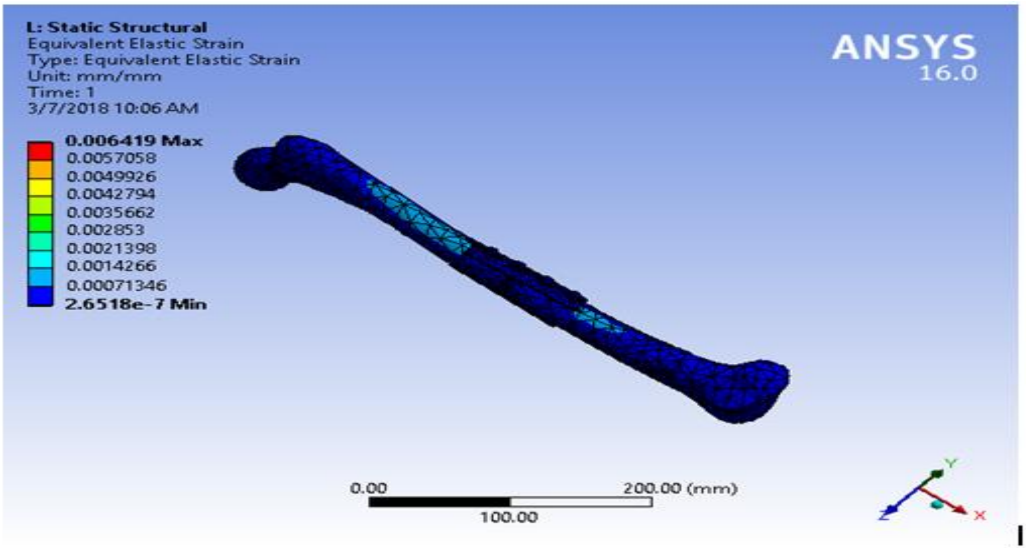


Fig: 4.13.1 picture showing equivalent strain for model 3 with titanium materials

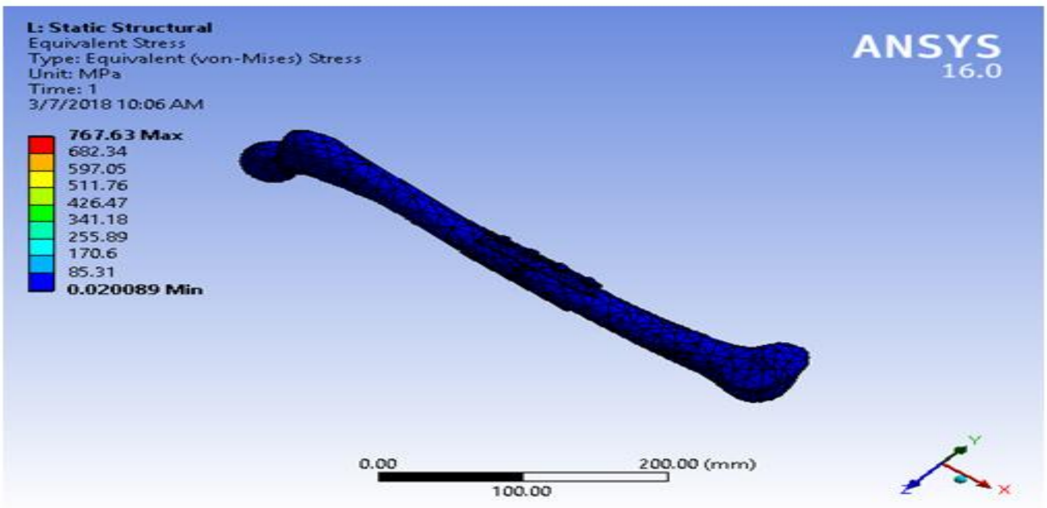


Fig: 4.13.2 graph showing equivalent stress for model 3 with titanium materials

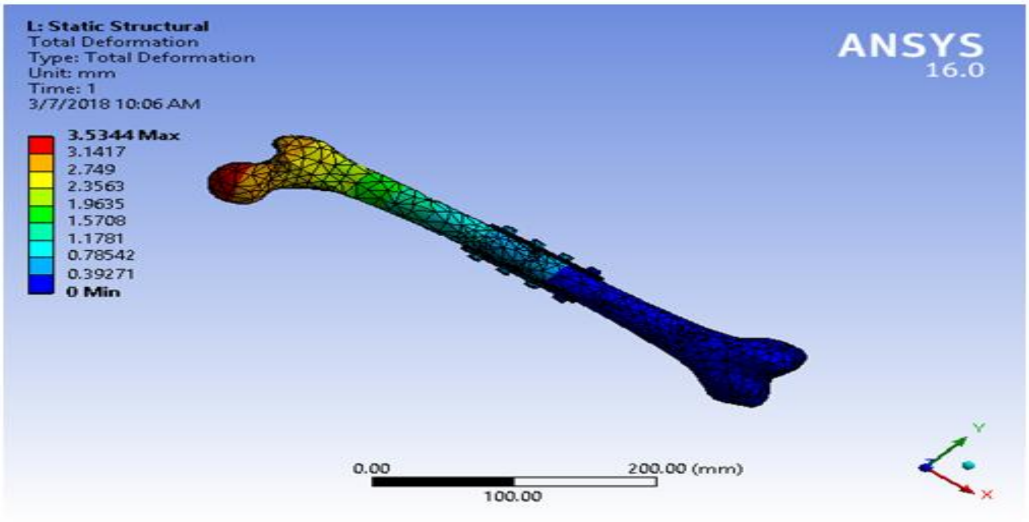


Fig: 4.13.3 Picture showing total deformation for model 3 with titanium materials

1. Table describing simulation results of model 1 with different materials

Model 1	equivalent strain		equivalent stress		total deformation	
	Min(mm/mm)	Max(mm/mm)	Min(Mpa)	Max(Mpa)	Min(mm)	Max(mm)
Callus100 %	8.27E-07	0.004914	0.004722	68.962	0.52652	4.7386
HP30CF	4.46E-06	0.005521	0.016467	32.443	0.59457	5.3511
PLA	3.88E-06	0.004806	0.032345	36.14	0.54438	4.8994
Titanium	1.00E-06	0.002826	0.014544	231.36	0.37944	3.415

2. Table describing simulation results of model 2 with different materials

model 2	equivalent strain		equivalent stress		total deformation	
	Min(mm/mm)	Max(mm/mm)	Min(Mpa)	Max(Mpa)	Min(mm)	Max(mm)
Callus100 %	3.98E-06	0.006138	0.052163	82.965	0.55151	4.9636
HP30CF	4.07E-06	0.010582	0.028993	50.35	0.65921	5.9329
PLA	4.57E-06	0.007671	0.055714	61.446	0.58385	5.2546
Titanium	7.91E-07	0.003489	0.02362	233.66	0.4124	3.7116

3. Table describing simulation results of model 3 with different materials

model 3	equivalent strain		equivalent stress		total deformation	
	Min(mm/mm)	Max(mm/mm)	Min(Mpa)	Max(Mpa)	Min(mm)	Max(mm)
Callus100 %	2.68E-07	0.010237	0.003406	170.77	0.49464	4.4517
HP30CF	7.76E-07	0.016089	0.00156	56.282	0.58621	5.2759
PLA	3.20E-07	0.012126	0.002447	123.61	0.52881	4.7593
Titanium	2.65E-07	0.006419	0.020089	767.63	0.39271	3.5344

4. Table describing simulation results of 100%callus material in different models

Callus 100 %	equivalent strain		equivalent stress		total deformation	
	Min(mm/mm)	Max(mm/mm)	Min(Mpa)	Max(Mpa)	Min(mm)	Max(mm)
Model 1	8.27E-07	0.004914	0.004722	68.962	0.52652	4.7386
Model 2	3.98E-06	0.006138	0.052163	82.965	0.55151	4.9636
Model 3	2.68E-07	0.010237	0.003406	170.77	0.49464	4.4517

5. Table describing simulation results of HP30CF material in different models

HP30CF	equivalent strain		equivalent stress		total deformation	
	Min(mm/mm)	Max(mm/mm)	Min(Mpa)	Max(Mpa)	Min(mm)	Max(mm)
Model 1	4.46E-06	0.005521	0.016467	32.443	0.59457	5.3511
Model 2	4.07E-06	0.010582	0.028993	50.35	0.65921	5.9329
Model 3	7.76E-07	0.016089	0.00156	56.282	0.58621	5.2759

6. Table describing simulation results of PLA material in different models

PLA	equivalent strain		equivalent stress		total deformation	
	Min(mm/mm)	Max(mm/mm)	Min(Mpa)	Max(Mpa)	Min(mm)	Max(mm)
Model 1	3.88E-06	0.004806	0.032345	36.14	0.54438	4.8994
Model 2	4.57E-06	0.007671	0.055714	61.446	0.58385	5.2546
Model 3	3.20E-07	0.012126	0.002447	123.61	0.52881	4.7593

7. Table describing simulation results of Titanium material in different models

Titanium	equivalent strain		equivalent stress		total deformation	
	Min(mm/mm)	Max(mm/mm)	Min(Mpa)	Max(Mpa)	Min(mm)	Max(mm)
Model 1	1.00E-06	0.002826	0.014544	231.36	0.37944	3.415
Model 2	7.91E-07	0.003489	0.02362	233.66	0.4124	3.7116
Model 3	2.65E-07	0.006419	0.020089	767.63	0.39271	3.5344

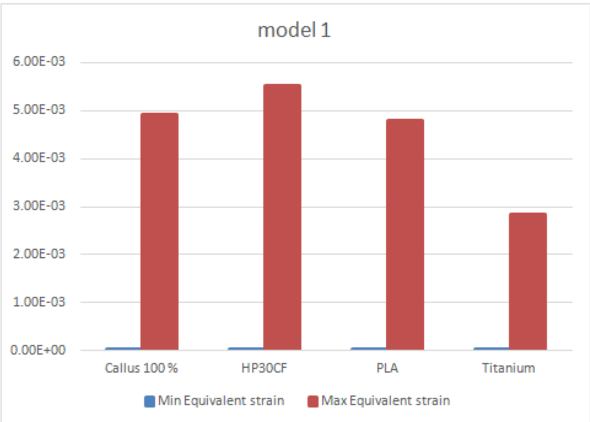


Fig:1 Graph showing Equivalent strain For Model 1 with Different Materials

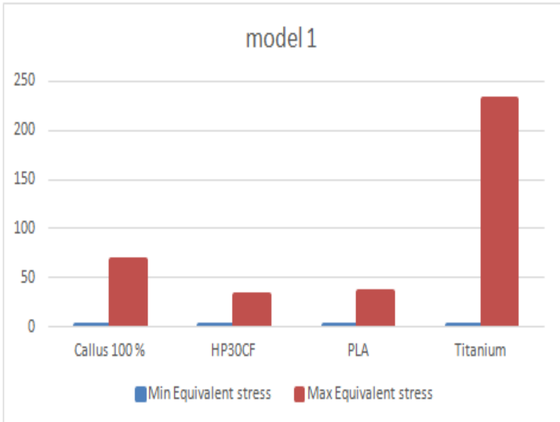


Fig:2 Graph showing Equivalent stress For Model1 with Different Materials

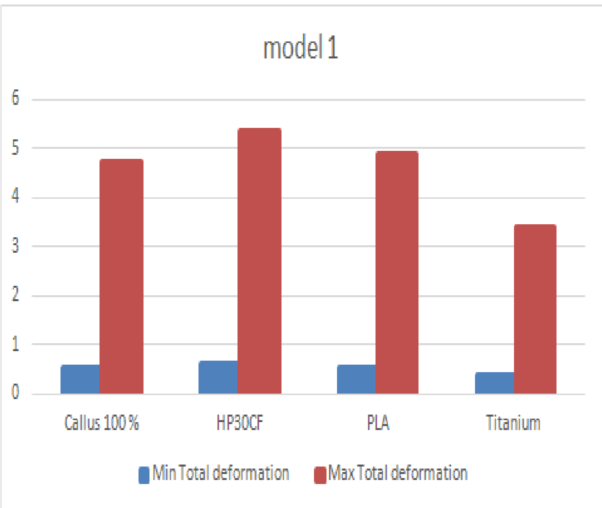


Fig:3 Graph showing Total deformation For Model 1 with Different Materials

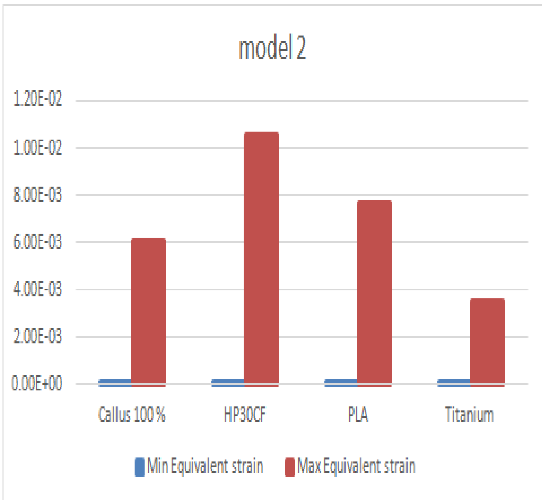


Fig:4 Graph showing Equivalent strain For Model 2 with Different Materials

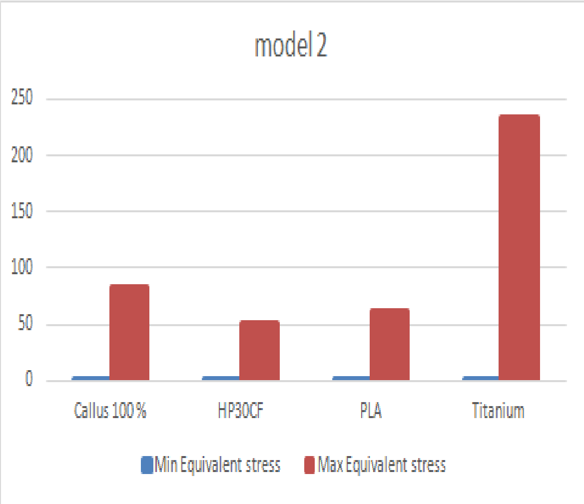


Fig:5 Graph showing Equivalent stress For Model 2 with Different Materials

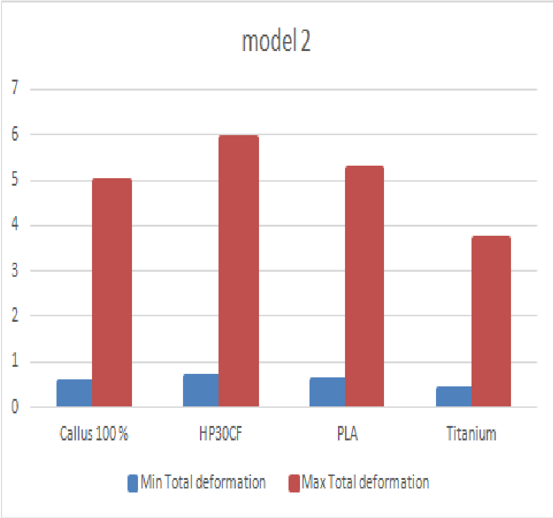


Fig:6 Graph Showing Total deformation For Model 2 with Different Materials

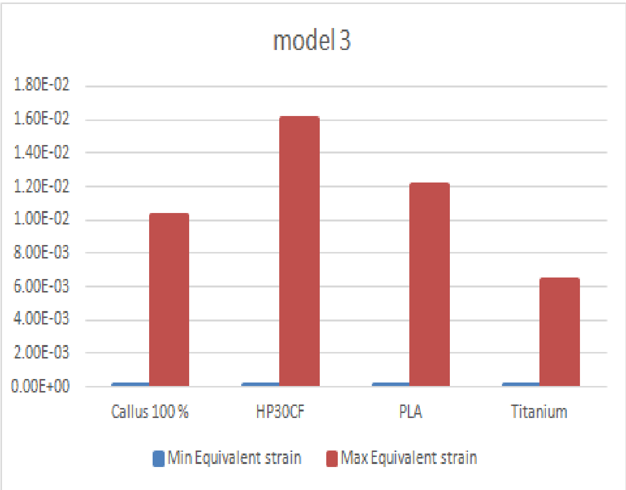


Fig:7 Graph showing Equivalent strain For Model 3 with Different Materials

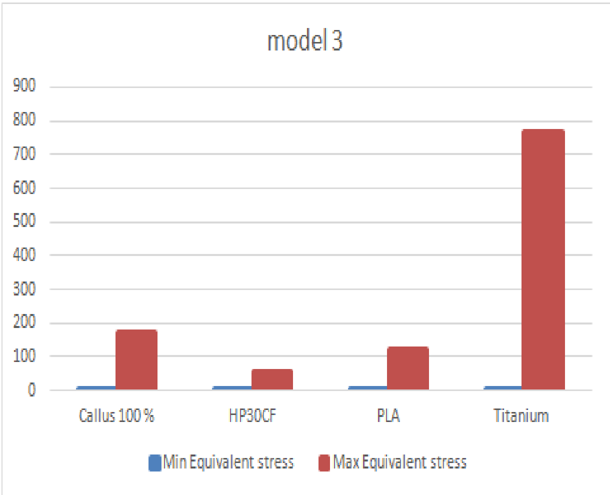


Fig:8 Graph showing Equivalent stress For Model 3 with Different Materials

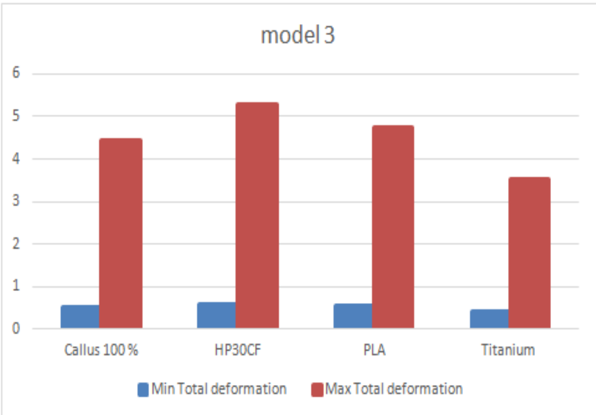


Fig:9 Graph showing Total deformation For Model 3 with Different Material

V. CONCLUSIONS

Now a days prosthetics are became very common for curing fractured and worn-out bone members. In this study different design of plates used to reinforce femur bone in case of fracture or complete detachment are studied, along with that a material study is also done for all models under same boundary conditions. Observations made during study are discussed below

1. From the simulation result it is evident that nonmetal substitutes for prosthetics shows little poor qualities when compared with metals
2. The variations between metal prosthetics and nonmetal prosthetics are around 20-25% repenting on the material
3. Here the conditions taken are completely broken bone under dynamic loading so nonmetallic prosthetics can be used for minor fractures and medium load application
4. Whereas metallic prosthetics can be used any ware except for it weight and need of removal
5. Here callus (100%) showed best results when compared with nonmetallic substances for prosthetics
6. While comparing the designs model 3 has showed best result because of more contact are between prosthetic plats and bone
7. Model 3 is developed by taking the outer profile of the bone cut section at various offsets

Note: the model of the bone in this study is developed from point cloud data generated by 3D scanning a human femur bone by data conversion.

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