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A Review on Finite Element Analysis of Different Biomaterials used in Orthopedic Implantation

Aparna G. Kadam[1], Sanjay A. Pawar[2], Smita A. Abhang[3]

[1]*Assistant Professor, Dept. of Mechanical Engineering, Fabtech Technical Campus, College of Engineering and Research, Sangola, Maharashtra, India*

[2]*HOD, Dept. of Mechanical Engineering, Fabtech Technical Campus, College of Engineering and Research, Sangola, Maharashtra, India*

[3]*Student, Dept. of Mechanical Engineering, NBN Sinhgad School of Engineering, Ambegaon, Pune, Maharashtra, India*

Abstract - *Biomechanics involves modeling and simulation of biological objects using mechanical laws. Femur bone is the largest and strongest part of human body and each femur bone carries half weight of human body. But in recent years, breakage of femur bone becomes most common especially in women and older peoples. Nowadays the biomaterials used in the biomedical industry for a bone plate application. Implantation of artificial bone which is made up of using different materials such as metals, polymers, composites etc. is widely used technique. But as this artificial bone is inserted into the human body, much care should be taken to avoid problems like corrosion, anode-cathode reaction, magnetism effect, increase in bone porosity etc. also selected material should have more strength as good as natural human femur bone. Researchers have suggested different materials for human femur bone implantation. The main aimofthis paper is to do study in brief on different materials suggested by researchers for orthopedic implantation by considering different parameters like mechanical strength, stresses, corrosion, cost, life. FE analysis was carried out for different biomaterials used as femur bone while implantation to study mechanical properties of these materials and check its biocompatibility.*

Key Words: Femur, FE analysis, Implantation, Magnetism, Porosity, Orthopaedic, etc.

1. INTRODUCTION

An artificial or natural material like metals, polymers, ceramics, composites etc. used to replace diseased or fractured biological structures to restore its form and function is called as biomaterials. Before using these biomaterials it must be necessary to see whether these satisfies required function and mechanical properties i.e. Bio functionality. Also most important these must be compatible with human body i.e. Biocompatibility [1].

Femur bone is longest and strongest bone in human body. It has to carry half weight of human body. It extends from hip to knee. Femur bone is weak in neck point. Fracture of femur bone is more common nowadays especially in elderly people, women those suffering from osteoporosis. Because of fracture in femur bone it causes more pain in the hip and it cannot bear human bodyweight.

Orthopaedic implantation is new technique used by surgeons to replace fractured femur bone with new artificial bone. There are different types of materials used for artificial bone like metals, polymers, composites, and ceramics. In present paper brief review was carried out to study finite element analysis done by researchers on different biomaterials like titanium alloy, stainless steel, carbon chrome. Modelling of femur bone in CAD software is little complex. CT scan, Mimic software's can be used to model femur bone easily. Analysis was done in past by applying different loads on femur bone, by comparing artificial femur bone made up of different alloy material with natural femur bone, on the basis of materials used in intramedullary nailing, on the basis of materials biocompatibility to human body etc. and suggested suitablematerial for implantation.

2. LITERATURE REVIEW

R. M. Deshmukh, S. S. Kulkarni, Different types of materials are used as biomaterials in implantation of femur bone plate like polymers, ceramics, composites, metals etc. in present paper a review of various biomaterials used for bone plate was discussed. A brief discussion about biocompatibility, advantages and properties of titanium alloys, stainless steel, cobalt chromium, polymers etc. was shown. It is found that titanium is most common biomaterial used for bone plate as it is having high strength as compared to other biomaterials but it has also some disadvantages like incompatibility, corrosion, anode-cathode reaction, magnetism effect, increase in bone porosity, decrease in bone mass and delay in fracture healing etc. Conclusions are made

that biomaterials with low stiffness is mostly recommended for long bone fractures [1].

Muhammad Shahzad Masood, Atique Ahmad, Finite element analysis principles is used for analysis of human femur bone. Using 3D animated Blender 2.63a software polygonal model of femur bone was made. This polygons mesh model was imported into ANSYS software for further analysis by converting it into cad model with the help of Pro/ENGINEER [2].

Sandeep Das, Saroj Kumar Sarangi, Finite Element analysis of simple bone plate of different biomaterial was carried out to examine the biomechanical feasibility. A bone plate was modeled in Solidworks CAD software and using CT scan was performed on femur bone with horizontal and oblique crack and this was saved in DICOM format then to get 3D model of femur bone, it was imported into Mimics software. Across the fracture line on the femur bone the bone plate was fixed using screws. The assembly was imported into ANSYS software for further analysis. By applying torsional as well as compressive loadings along with various stages, the stress distribution near to femur fracture bone was obtained. Also results are found out by using different biomaterials like titanium, cobalt chrome and stainless steel for bone plate. From results it concluded that titanium generates higher stresses as compared to other two materials and provides better stability to fracture fixation [3].

K. S. Zakiuddin, I.A.Khan, Roshni A. Hinge, from this paper It observed that human body experiences various types of forces during their daily living activities. Also in uncertain cases like twist, accidents, while heavy loads carrying etc. and it increases the chances of human femur bone fracture. In present paper analysis of femur bone as carried out based upon the structure, material properties, load resistance and chance of failure of human femur. Vibrational analysis was done using Elmer software and ANSYS software was used for finite element analysis. This analysis was helpful for the problems and issues faced by the orthopedic surgeons during hip implant [4].

Sandeep Kumar Parashar, Jai Kumar Sharma, This paper presents the state of art review on finite element modeling application in the four areas of bone biomechanics, i.e. analysis of stress and strain, determination of mechanical properties, fracture fixation design (implants)S and fracture load prediction. The aim of this review is to provide a comprehensive detail about the development in the area of application of FEM in bone biomechanics during the last decades. It will help the researchers and the clinicians alike for the better treatment of patients and future development of new fixation designs [5].

Nithin Kumar KC, Tushar Tandon, In this study, The finite element analysis of femur bone was carried to find out stresses generated at hip contact region during normal activities like walking, running, jumping, standing. Author has considered different load acting on femur bone during activities like standing, walking, running and jumping. Human femur bone behaviour was found out by applying different loading conditions. Femur bone model was created in Solid Edge V19 CAD modeling software and analysis was carried out using ANSYS 14.0 software. This analysis is helpful to find out stress generated in fractured bone and also useful to predict which type of artificial material is necessary to rejoin the fractured bone [6].

P.S.R. Senthil Maharaj, R. Maheswaran, Fracture of femur bone is one of the common problems found nowadays. Fractured femur bone can be joined/ repaired by using bone plates. But as this bone plated is fitted into human body major precaution should have to take while selection bone plates material. In this study, author has suggested best suitable material for bone plate by doing analysis of bone plates which are made from different materials such as stainless steel, Alumina, Titanium, Nylon and PMMA. Femur bone, bone plate model was created in Solidworks CAD modeling Software and further imported into ANSYS software for doing analysis. Investigation was carried out by considering 75Kg weight male during normal position and stress distribution, fatigue failure and total deformation of femur bone found out. More deformation of bone was on head side while on lower side less deformation occurs. Total equivalent stress obtained for Titanium is less as compared with other. Titanium is best suited material for bone plate [7].

Dr A Thimmana Gouda, Jagadish S P, mechanical properties of SS316L which is used for orthopedic implantation was found out. The test was conducted on electronic UTM machine. It is necessary to know mechanical properties such as tensile, compressive and bending strength of SS316L to check whether this is having as good strength as natural femur bone. Properties required during selection of biomaterial for orthopedic implantation. Finally, results obtained by carrying out test using electronic UTM machine was matches with femur bone prosthesis [8].

D. Amalraju, Dr. A. K. Shaik, Dawood, failure of femur bone is most common among all bone failures. Fracture of femur can be repaired using orthopedic implantation. In current paper, analysis was done to find out stresses developed by applying static loading conditions at Femur Distal Locking Plate Implant of Ti-6Al-4V and S.S-316L material. Analysis was carried out for different loads. Stresses and deformation obtained for different loads was very low. It was observed that loads do not have effect on failure of implant. Based on the results obtained concludes as Ti-6Al-4V material have very low density material, it is biocompatible and having excellent mechanical properties. It is comfortable for human being. One can move his leg without much effort. It can be kept in human body for long time whereas stainless cannot be suitable for human body as chances of failure of stainless steel implant is more due to cyclic loading conditions. Titanium coated stainless steel implant is also preferred for implantation [9].

Arpan Gupta, Kwong Ming Tse, in present paper finite element simulation was carried out to study vibration analysis of femur bone. Abaqus simulation software was used to perform simulation and from this natural frequency and mode shape was obtained for first twenty vibration modes by considering fixed-fixed boundary conditions. Due to External excitation on the human body results may vary. If excitation

frequency coincides with natural frequency then it may lead to fracture of femur bone [10].

Mohd. Shahjad A. Sheikh Prof. A. P. Ganorkar, intramedullary nailing is generally used method for treating femoral shaft fractures. A specially designed nailing is inserted into the marrow canal of the femur. This nail can be inserted at the hip or the knee of canal through a small incision. Mostly titanium material is used for this nail which is costly. Therefore surgery of fractured bone is also costly. In this paper, analysis was carried out to suggest best alternative material at low cost. For this, 3D scanner was used to model femur bone and using Solidwork CAD software intramedullary nailing was modeled. Analysis was carried out in Ansys software. Results showed that higher deformation occurs at the head of femur and lowest occur at the lower end. Maximum equivalent stress 67733 Pa and Minimum principle stress is 99.98 Pa. Maximum principle stress is generated at the middle section of the femur. The equivalent (Von Misses) stress 67733 Pa occurs. Static load was applied on the models. The deformation of bone-nailing system in compressive for apply titanium material. Through this static loading condition and material comparison analysis we have found out the Titanium Implant mechanical properties is better than other material. But also stainless steel material has good stability. Since Ti-6Al-4V material cost more, Titanium cost over the Stainless Steel can be used as an alternative for Re-Engineered Indian femur implant nailing [11].

3. CONCLUSIONS

The current study elaborates detailed study of different types of biomaterials used in orthopedic implantation. Numerous investigations has been done on the human femur bone like properties of human femur bone, biomaterials with their properties by considering biocompatibility with human femur bone, methods to replace fractured femur bone, by applying different static load on femur bone. In this paper a short description of finite element analysis carried out for titanium alloy, stainless steel, alumina, nylon and PMMA biomaterials to check and compare their feasibility with natural human femur bone. Femur bone modeling can be done using CT scan, Mimic software and for analysis of femur bone one can use Ansys, abaqus software.

Most of the researchers suggested that Titanium is the best suitable material for human implantation. It is having good mechanical properties. It is more costly than stainless steel. but Stainless steel cannot withstand more longer in human in body to cyclic loading conditions. Also detailed study of evaluation of mechanical properties of titanium and stainless steel alloy using electronic UTM machine was described.

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BIOGRAPHIES

Miss. Aparna. G. Kadam has completed Masters of engineering in Design engineering from Savitribai phule Pune university. Presently, She is working as assistant professor in department of mechanical engineering at Fabtech Technical Campus, College of Engineeing, Sangola. She has published two papers in International journals. Her research includes Finite element methods, Vibrations, Product design and development.

Miss. Smita A. Abhang is PG schlor in design engineering at NBN Sinhgad School of Engineering, Ambegaon from savitribai Phule, Pune University. Her research includes finite element method, vibrations, operation research etc.