COMPARISON OF TITANIUM, 316 LSTAINLESS STEEL, MAGNESIUM CEMENTLESS HIP IMPLANTS MECHANICAL CHARACTERISTICS IN VITRO USING FINITE ELEMENT ANALYSIS

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ABSTRACT

Hip prosthesis was used for the patients who has the hip fracture and unable to recover naturally. This study aims to analyses the three different material used in hip prosthesis by finite element analysis. All model is cement less hip stem which were used to analyses simulating two of the most common physiological activities. The design of a hip prosthesis involves parameters which include neck size and lateral shape with the same size of ball diameters. In this research the forces on ball was analyzed. The results showed that the different materials affected the stress distribution on the ball of the hip prosthesis when inserted in the femoral bone. The Young's modulus of 316LSS is very compared the bone ,but the material parameters are good , but when there is variation in Young's modulus will to clinical complications To conclude, hip prosthesis should have a material equivalent to the human bone for the appropriate stress distribution. Therefore, the new materials of hip prosthesis must take these conditions in to consideration for good clinical result and the decrease in the implant damage.

Keywords: Hip prosthesis, Finite element analysis.

INTRODUCTION

Total hip replacement is a healing process of hip fracture and osteoarthritis in the hip joint. The hip prosthesis is designed and manufactured in various shapes and sizes to fit various body sizes and types. Thus, there are many models of total hip prostheses on the market. New models keep coming with improvements in long term functionality of the prosthesis. In the past, design and analysis of bone-implant hip prosthesis relied on expert's knowledge, experience and ability, trying to avoid any unrecoverable damage on the bones of patients. Due to the difficulty of performing implant tests in vivo, mathematical models have been developed to carry out the structural analysis of implants before applying on a patient. Thus, bone-implant hip prosthesis could be designed and studied with computer simulations. In this research 17 different parameters were analyzed. The finite element method (FEM) is an advanced simulation technique that has been used in orthopedic biomechanics since 1972 (Brekelmans, 1972). It is an important tool used in the design and analysis of total joint replacements and other orthopedic devices. Finite element analysis offers a non-destructive approach for bone-implant hip prosthesis. . In this research 17 different parameters were analyzed, to be studied in computer environment before the prosthesis is actually inserted. This simulation streamlines the design and prevents any permanent damage caused by miss-implementation (Kayabasi, 2006). This study is aimed to analyze three different material of hip prosthesis by finite element analysis. This analysis is to attempt to analyze the prosthesis by using the mechanical parameters to test the effect of load on femoral head with the same size of ball diameters with different prosthetic materials when inserted in the femoral bone.

Materials and Methods

Finite element models: A three-dimensional model of the femoral bone was created by computed tomography (CT) scan data based on the average geometry Indian femoral (Mahaisavariya, 2002). All models of hip prosthesis made by using ANSYSWorkBench10 software. Hip prostheses and femoral bone were analyzed by finite element method software ANSYSWorkBench10. The femur-implant model had a total of 37,168 nodes and 147,299 elements.

A finite element analysis (FEA) was performed. Three different materials were chosen 1. 316LStainless Steel 2. Magnesium Alloy 3. Titanium Alloy. In this analysis, ball diameter and neck length were fixed. The following parameters were analysed 1.Directional Deformation, 2. Elastic Strain Intensity, 3.Equivalent Elastic Strain, 4.Equivalent Stress, 5.Maximum Elastic Strain, 6.Maximum Principle Stress, 7.Maximum Principle Elastic strain, 8.Maximum Shear Elastic Strain, 9.Maximum shear stress,10.Middle Principle Elastic Strain,11. Normal Elastic Strain, 12.Normal Stress, 13.Shear Elastic Strain, 14. Shear Elastic Strain, 15. Shear Stress, 16.Stress Intensity, 17. Structural Error, 18.Total Deformation.

Material properties: Material properties of the cortical bone, cancellous bone,(Perez, 2008) and hip prosthesis were assumed to be homogeneous, isotropic, and linear elastic as shown in table. 1.

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Table.1.Material properties of bones and prostheses.

Material	Elastic modulus (MPa)	Poisson Ratio
Cortical bone	14,000	0.4
Cancellous bone	600	0.2
Titanium	110,000	0.3

Boundary conditions: Loading and boundary conditions described by Heller *et al.* (Heller, 2005) applied to the proximal femur depended on the load carrying activities of the hip prosthesis as shown in Fig1.

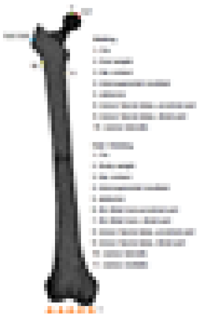
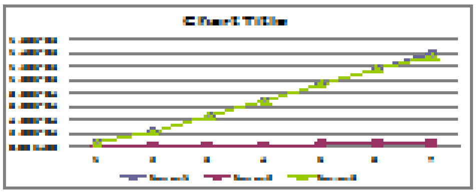
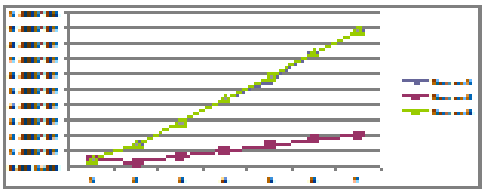


Fig.1 Show loading condition which applies to the femoral bone

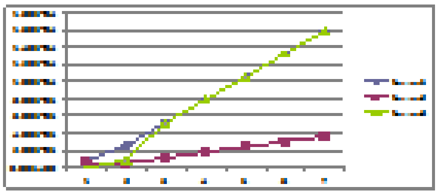
RESULTS



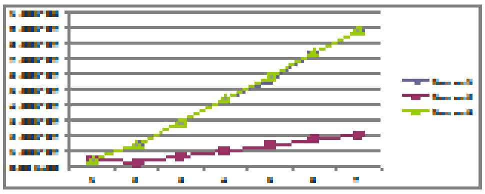
Directional deformation



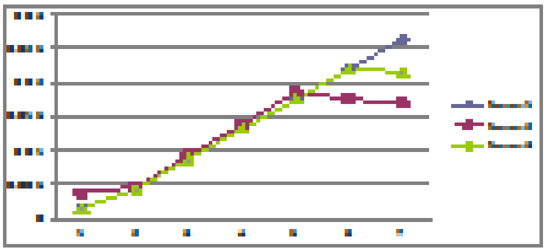
Elastic strain intensity



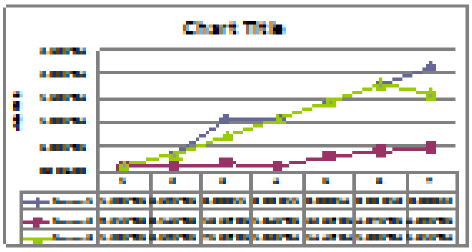
Equivalent strain intensity



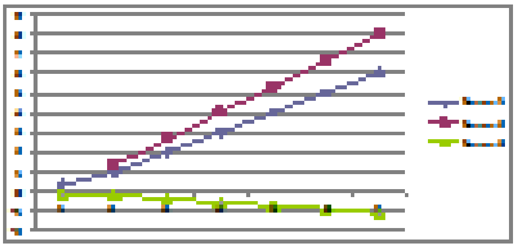
Elastic strain intensity



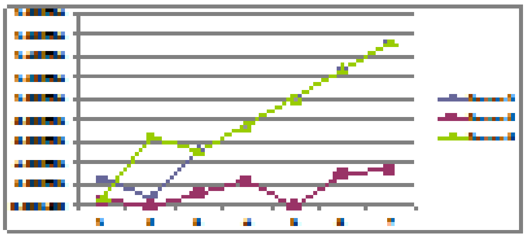
Equivalent stress



Maximum shear elastic strain



Maximum Principal stress



Maximum Principle elastic strain

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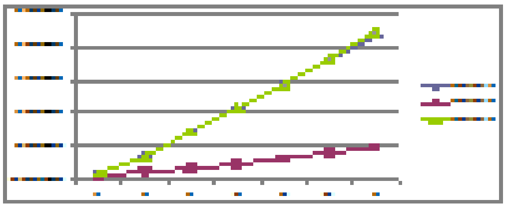
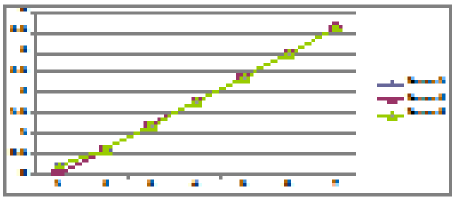
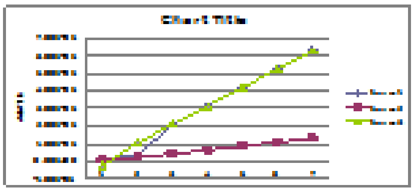


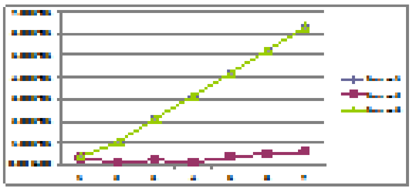
Maximum shear elastic strain



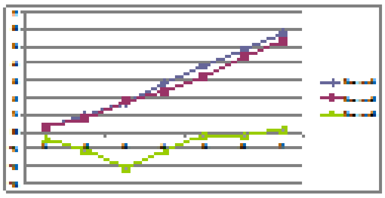
Maximum shear stress



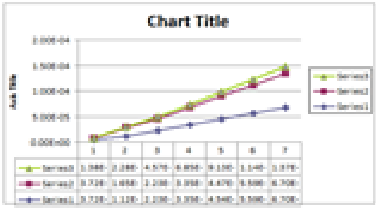
Middle principle elastic strain



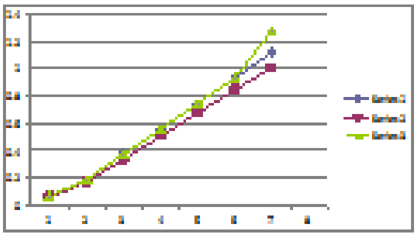
Normal Elastic Strain



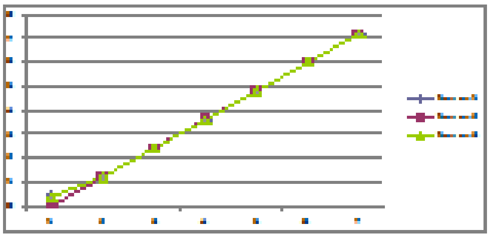
Normal Stress



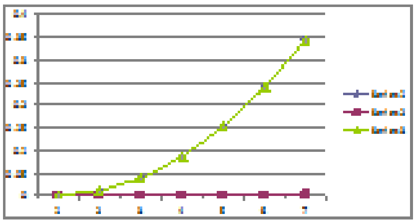
Shear Elastic Strain



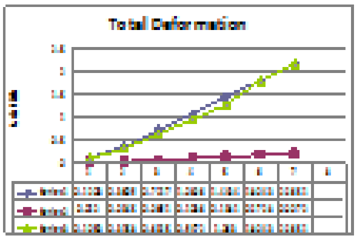
Shear stress



Stress Intensity



Structural Error



Total Deformation

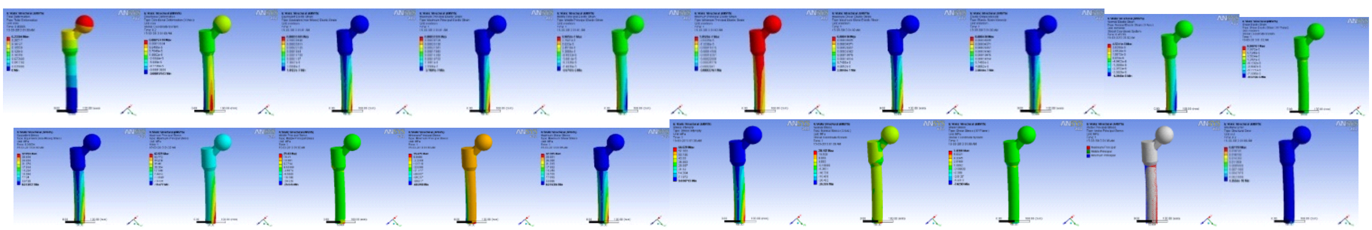


Figure2a: Stainless steel Hip Implant 1800N

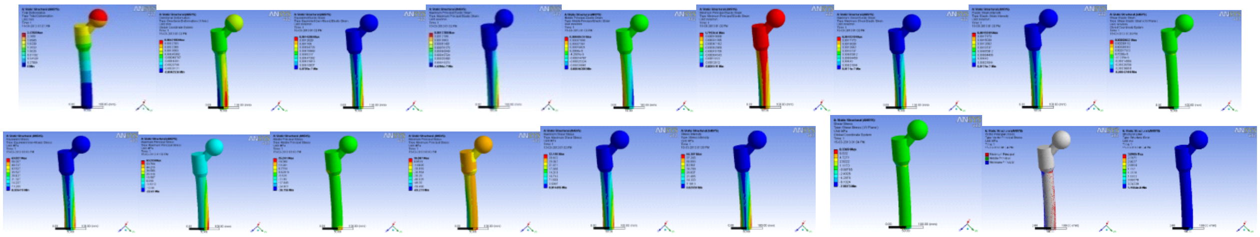


Figure 2b: Magnesium Hip Implants 1800N

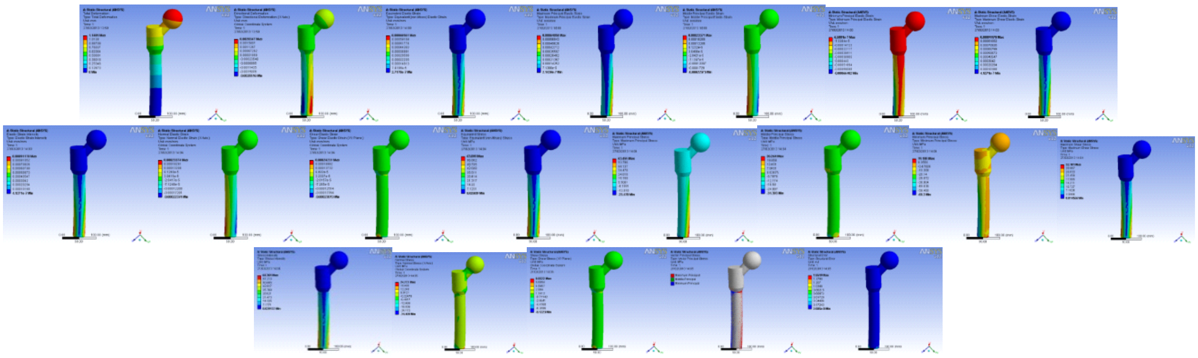


Figure 2c: Hip Implant Titanium 1800N

Table.2.Characteristics curves of mechanical behavior of hip prosthesis for different materials and loads

Parameters	Magnesium	Titanium	316LSS
1.Directional Deformation	Very high	Very high	Very less
2. Elastic Strain Intensity	Very high	Very high	Some deviation
3.Equivalent Elastic Strain	Very high	Very high	Some deviation
4.Equivalent Stress	Similar	Similar	Similar
5.Maximum Elastic Strain	Very high	Very high	Very small deviation
6.Maximum Principle Stress	Less	Negative	More
7.Maximum Principle Elastic strain	More	More	Some deviation
8.Maximum Shear Elastic Strain	More	More	Some deviation
9.Maximum shear stress	similar	similar	Similar
10.Middle Principle Elastic Strain	Similar	Similar	Some deviation
11. Normal Elastic Strain	Similar	Similar	Small deviation
12.Normal Stress	more	small	More
13.Shear Elastic Strain	less	more	more
14. Shear Stress,	similar	similar	similar
15.Stress Intensity	similar	similar	similar
16. Structural Error	high change	high change	No change
17.Total Deformation	Very high	Very high	Small deformation

The load on the hip prosthesis was applied between 100N to 1800N using the finite element software effect of this load on 17 different parameters were analysed, the graphs were drawn as shown in graph1. The Finite Element Analysis results of 1800N is shown in figure 2a, b, c. The table 2 shows the summary of the effect of parameters on the three different hip implant materials, Magnesium, Titanium, 316LSS.

DISCUSSION

1. Directional Deformation in the stainless steel hip implant shows very less directional deformation whereas both the magnesium and titanium shows very high deformation, very large deformation will have adverse effect on the bone.

2. Elastic Strain Intensity is very high for both magnesium and titanium, the human bone cannot take very high intensity, the implant should take the intensity, these materials are better than 316L stainless steel 3.Equivalent Elastic Strain, the strain on the human bone is the form of microstrains the hip implant should not show very large strains.

4. Equivalent Stress all the implant materials shows similar deformation when loaded.
5. Maximum Elastic Strain very small strains are needed on the implants when loaded so stainless steel well suited as implant.
6. Maximum Principle Stress is negative in the case of titanium, it can bounce back when unloaded, it have severe problem on the implants.
7. Maximum Principle Elastic strain 316LSS is well suited than the magnesium and Titanium 8.Maximum Shear Elastic Strain effect on the hip implant will try to shear the bone, which will have adverse effect on the bone 9. Maximum shear stress is similar for all the three implant materials.
10. Middle Principle Elastic Strain 316L stainless steel shows very less compared to magnesium and titanium.
11. Normal Elastic Strain 316L stainless steel shows very less compared to magnesium and titanium
12. Normal Stress titanium takes more stress when compared with magnesium and 316LSS 13.Shear Elastic Strain for magnesium is less when compared with 316LSS and Titanium.
14. Shear Stress all the three materials are similar
15. Stress Intensity is similar all three materials.
16. Structural Error, 316LSS is rigid, it does not show very error in the structure.
17. Total Deformation, the Young's modulus of 316LSS is very high so the Structural deformation is very less compared to the magnesium and Titanium.

CONCLUSION

To conclude, hip prosthesis should have a material equivalent to the human bone for the appropriate stress distribution. Therefore, the new materials of hip prosthesis must take these conditions in to consideration for good clinical result and the decrease in the implant damage.

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