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COMPARATIVE ANALYSIS OF STRESS AND STRAIN DISTRIBUTION IN ARTIFICIAL KNEE IMPLANT AND HUMAN KNEE JOINT

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ABSTRACT

Knee joint is a hinge joint which posses six degrees of freedom and withstand entire load of the human body. In Recent statistics Knee replacement surgery has been increased for the major issues like Bone cancer, Bone damage etc. The TKP involves the replacement of damaged or defected knee joint and replaced with artificial implant. In general artificial implant is made up of bio-compatible materials such as Titanium alloys which are restricted in their motion (2-3 Degrees) when compared to human knee joint. In this work it is discussed about the comparative study of stress and strain distribution of artificial knee implant with human knee joint. The CT scan image of human knee joint has taken for this work and converted in to 3D model using MIMICS software and analysed at various loading conditions such as 300, 500, 700 and 900N.

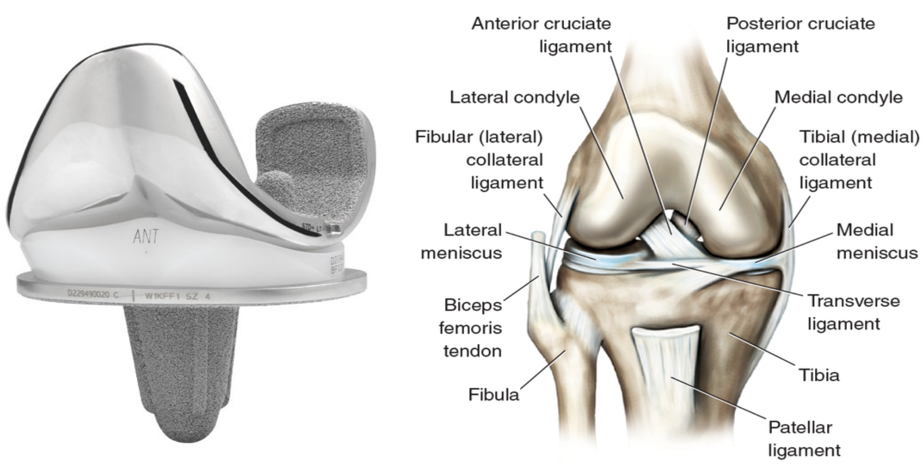
Keywords: artificial knee implant, bone cancer, bio-compatible, titanium alloys, MIMICS.

Nomenclature

HK Human knee
AK Artificial knee
F Femur
T Tibia
TKP Total knee replacement

INTRODUCTION

The knee is a complex joint that moves straight backward as well as twists slightly from side to side. The knee is the meeting point of the femur in the upper leg and the tibia in the lower leg. The fibula, the other bone in the lower leg, is connected to the joint but is not directly affected by the hinge joint action. Another bone, the patella or kneecap, is at the centre of the knee. Natural-Knee (NK) knee replacement system Figure-1(a) was conceived by Dr. Aaron A. Hofmann in 1985 working with the talented engineers Joe Skraba and Jim Dales. The design principles of this system were based on restoration of anatomy and alignment of the knee joint as in Figure-1 (b). Bone resection, followed by an equal amount of prosthetic replacement, provides the knee with near normal varus-valgus and rotational. [1]



(a) (b)

Figure-1. (a) Artificial knee model (b) anatomy of human knee joint.

Stability throughout full range of motion. If the replacement becomes loose, breaks or gets infected another operation is necessary; this is called a revision knee replacement. The replacement will last longer in lighter people and in older people who put less demand on the materials.

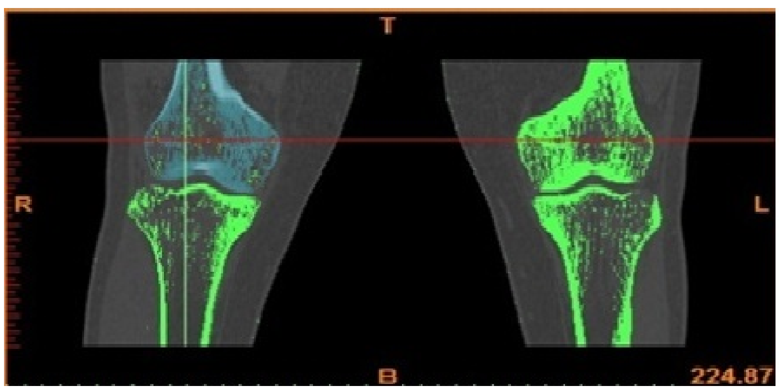
EXPERIMENTAL WORK

The CT scan of human knee joint has been converted in to 3D Model using the MIMICS Tool with basic dimensions for the knee joint.

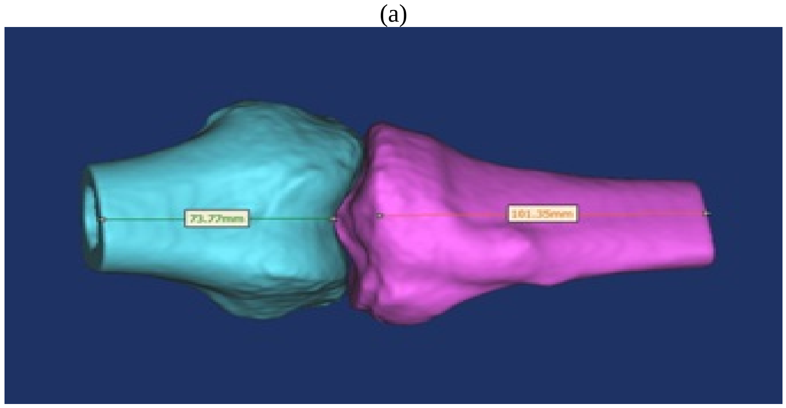
Table-1. Stress and Strain values for tibial and femoral component.

S.No.	**Load** (N)	**Part**	**Stress** (AK) **N/mm²**	**Strain** (AK) **N/mm²**	**Stress** (HK) **N/mm²**	**Strain** (HK) **N/mm²**
1	300	F	0.00398	0.03804	0.00351	0.00351
3	500	F	0.00468	0.00468	0.04476	0.00476
5	700	F	0.00747	0.00747	0.00371	0.00371
7	900	F	0.01231	0.01239	0.02769	0.02709
2	300	T	0.00441	0.00441	0.00263	0.00263
4	500	T	0.00063	0.00063	0.00374	0.00374
6	700	T	0.00883	0.00883	0.00163	0.00163
8	900	T	0.00132	0.00132	0.00138	0.00138

This helps to evaluate the stress and strain relationship by applying various loading conditions. The knee joint 3D model has been compared with the developed artificial prosthesis model with loads such as 300, 500, 700 and 900 N on both tibial and femoral components. The Table-1 shows the stress and strain values of femoral and tibial joint for different loads.



(a)



(b)

Figure-2. (a) CT Scan image of human knee joint (b) 3D model from MIMICS.

The figure shows stress distribution of femoral and tibial component for AK joint which showing for the 300 N. In Figure-2 (a) it is showing about the MIMICS screen which is uploaded with the CT scan of human knee joint. In Figure-2 (b) it is showing 3D model developed using the MIMICS software which showing the dimensions in it.

RESULTS AND DISCUSSIONS

The Figure-3 showing the stress and strain distribution of femoral joint of HK joint at load of 300 N.

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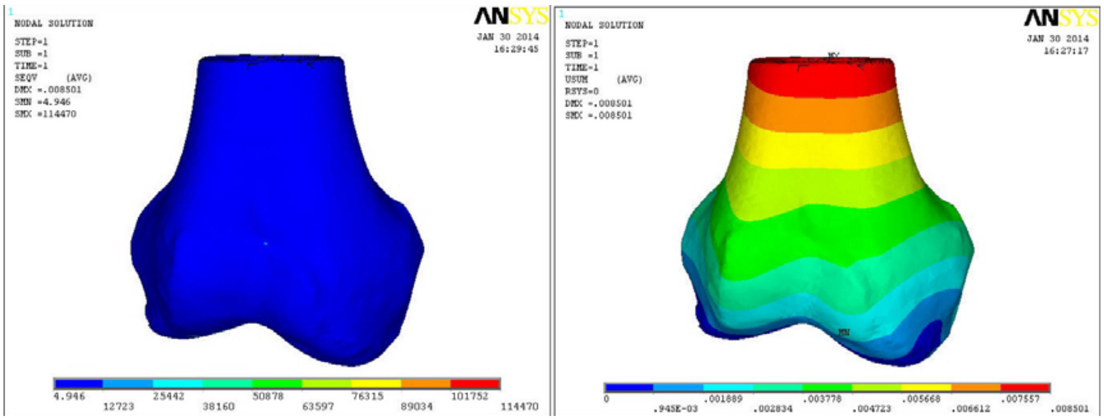
The Graph has been plotted between the stresses, strain and the applied load for the HK joint and AK joint for femoral component shown in Figure-4 It is showing that stress graph of AK Joint has limited before 0.02 N/mm^2 when compared to HK joint which is moving ups and downs in the graph scale. Similarly the Strain graph of AK joint is maximum at the load of 300 N and when at the stage of 900 N it is reduced to the minimum value.



(b)

Figure-3. (a) Strain distribution of femur (HK) (b) Stress distribution of femur (HK).

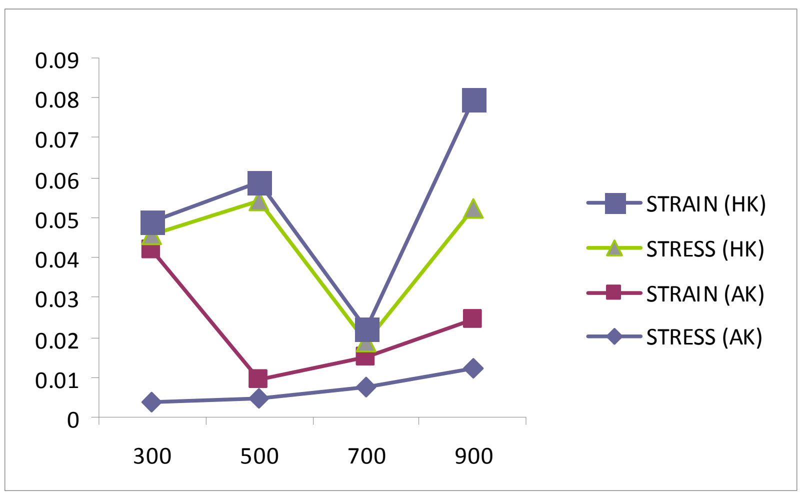
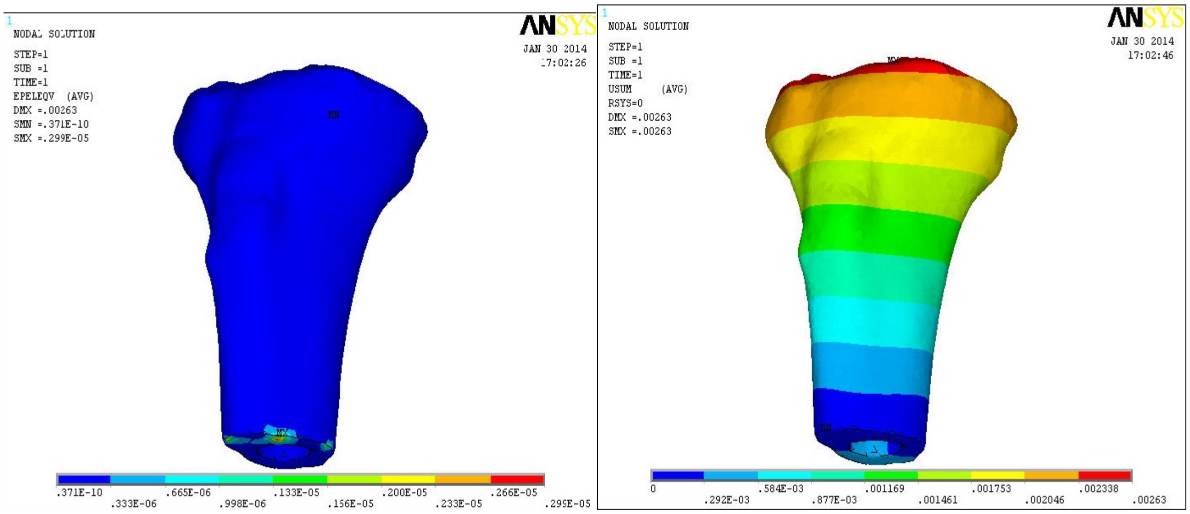


Figure-4. Stress and strain graph for HK Vs AK for femoral component.

The Figure-5 showing the stress and strain distribution of tibial joint of HK joint at load of 300 N. Similar Graph has been plotted between the stresses, strain and the applied load for the HK joint and AK joint for the tibial component shown in Figure-6 It is showing that stress graph of AK Joint has slight increase at the load of 300 N and becomes zero at load of 500 N and achieved peak again at 700 N. Where as in strain graph of AK joint is similar to the stress graph in case response with applied load. The graph becomes zero at the load of 500 N and suddenly archives the peak in the load of 700 N.



(a) (b)

Figure-5. (a) Strain distribution of Tibia (HK) (b) Stress distribution of Tibia.

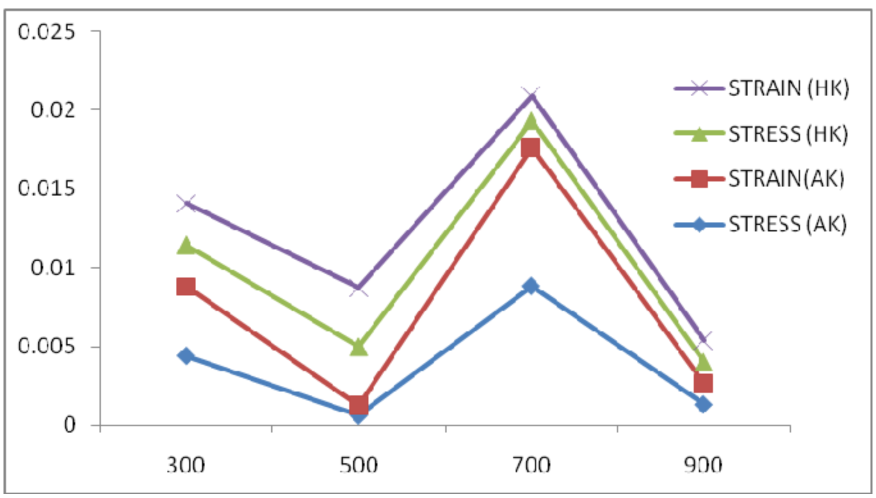


Figure-6. Stress and strain graph for HK Vs AK for Tibial Component.

CONCLUSIONS

From the above discussions it is showing that Stress and Strain graph of HK joint and AK joint is drawn between the applied load with stress and strain for Tibia and Femoral component of Knee joint. In both the case AK and HK joints of tibial and femoral joints posses minimum values at load of 500 N load for AK joint and Maximum values for HK joint. Also at load of 300 N for Femoral component both Stress of HK and Strain of AK has same value. With this results it is concluded that compare to HK values of stress and strain the AK joint has comparatively less values and suitable to with stand maximum load.

ACKNOWLEDGEMENT

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