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Stress Measurement at Knee for Different Limb Alignment by Experimental and FEA

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Abstract**:** ***Need of Stress Measurement at knee for different limb alignment by Experimental and FEA is essential for the surgeon's must understand concept limb alignment. Precise knee alignment in the limb is important for proper implant function.***

Keywords**:** ***TKR (Total Knee Replacement), FEA- Finite Element Analysis, Computed tomography (CT)***

I. INTRODUCTION

Fulvia Taddei et.al [1] have understand problem regarding heterogeneous properties of human bone and complicated shape for modelling by using MRI/CT. They discussed on errors with the preparation of the finite-element models.

Ramos et.al. [2] have find out and compared result by using hexahedral and tetrahedral mesh femur bone. Expressions of theoretical stresses and strains were derived for the simplified model of the human femur bone. Analysis of the geometry of the proximal human femur bone, a CAD model was used and analysis was done with Hyperworks finite element analysis software. Analysis was done by using hexahedral element. Von Mises stresses was used for stress analysis of human femur bone.

A. Different Limb positions:

Mechanical axis (FMA) is a joining straight line drawn from the human femoral bone head to the middle of intercondylar portion and tibial mechanical axis (TBA) is a joining straight line drawn from tibial plateau to center of ankle. It must passes through the center of intercondylar of the human knee.

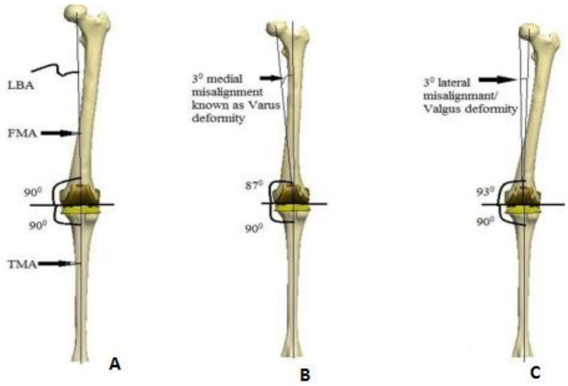

Figure 1 A.Alignment of normal limb B. Varus Deformity. (C) Valgus Deformity.

II. EXPERIMENT METHODOLOGY

a) By using Experimental Method

Work methodology flow cart is shown as below.

Design and development of mechanical set up for finding of load distribution in various alignment positions.

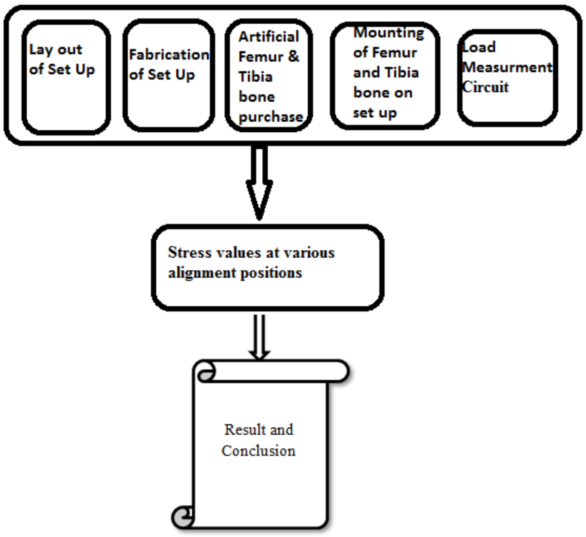

Figure 2. Human Limb Alignment Analysis Set Up

2. 1 Mechanical System Setup

The fabrication of setup for stress measurement in total knee replacement considering various alignment positions in coronal plane for the range of 0 to ± 3°. The set up will obtain the various alignment positions by variation of angle by 1^o.

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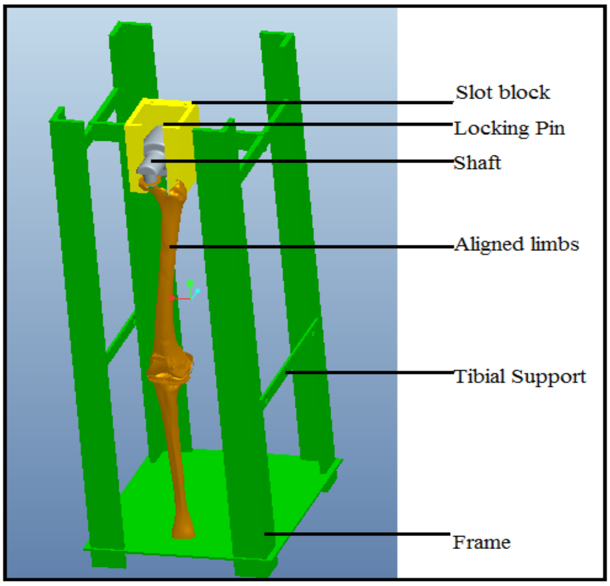

Fig. 3 Model for Experiment Analysis

Fig. 5 Actual Model for Experiment Analysis

2.2 Components of Experimental setup

1. Flex sensor

Fig. 4 The sensor has an output for A/D conversion is zero V is no force and 4.2V is for 100.

2.3 8-bit Microcontroller with 4K Bytes

Atmel AT89S51 is a powerful microcontroller is used.

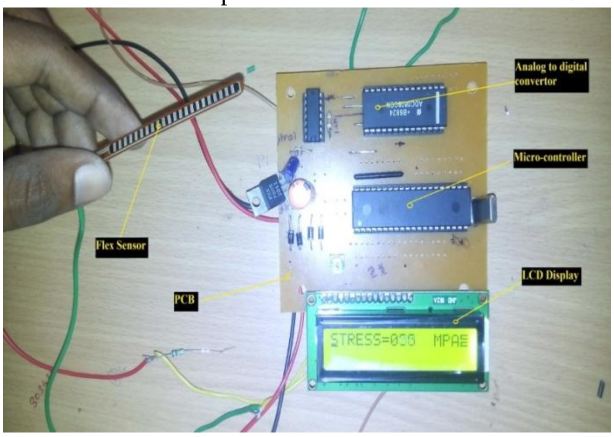

Fig. 6 Sensor and Printed Circuit Board

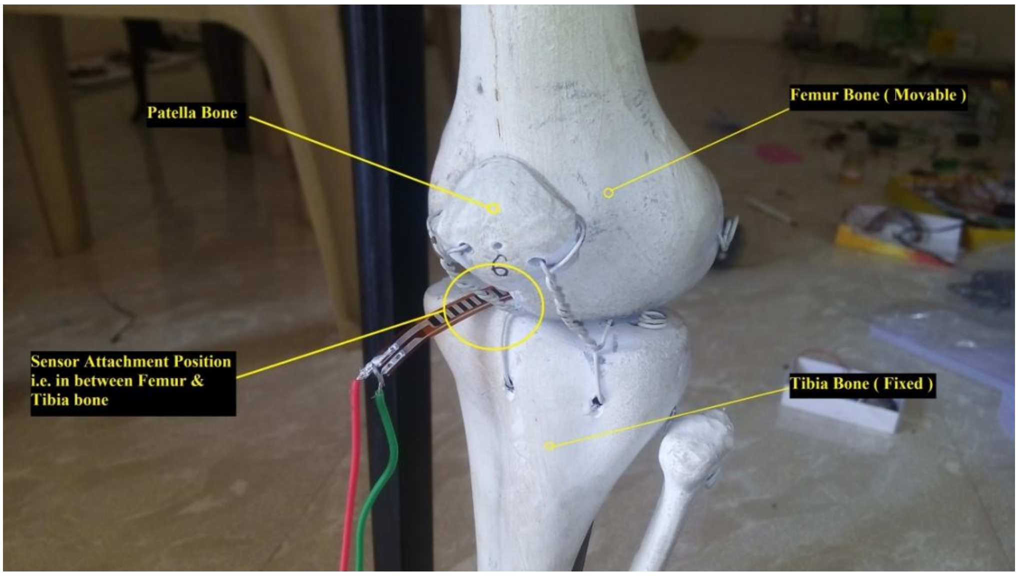

Fig. 7 Sensor attachment position

III. EXPERIMENT RESULTS

3.1 Stress calculation

Load applied on head 2kg.

Table 1. Stress distribution and change in stress values at knee due to different alignment by using Experimental method.

Alignment Variation in Deg.	Stress (MPa)	% change with Neutral value
3° Varus	0.71849	0.63167
2° Varus	0.71452	0.07563
1° Varus	0.71263	0.18908
Neutral	**0.71398**	**0**
1° Valgus	0.71518	0.16807
2° Valgus	0.71638	0.33614
3° Valgus	0.71962	0.78994

IV. FEA ANALYSIS OF LIMB ALIGNMENT

4.1 Methodology

Setp1: Modelling of Femur and Tibia

Computed tomography (CT) is used for modelling of femur bone and tibia bone.

Steps used for modelling.

1) **Scanning of artificial bone:** Cloud Data obtained after scanning.
2) **Surface preparation:** The cloud points can be grouped in patches by using dedicated software (IMAlign).
3) **Cloud segmentation:** Data classified in to two groups 1) cylindrical data 2) dome shape, conical shape and the transition shape
4) **Curve fitting and analysis**: B spline curve is used to fitted to set of cloud points.
5) **Surface fitting:** A lofted surface is generated over the sets of curves. Binding all these lofted surface we get required model.

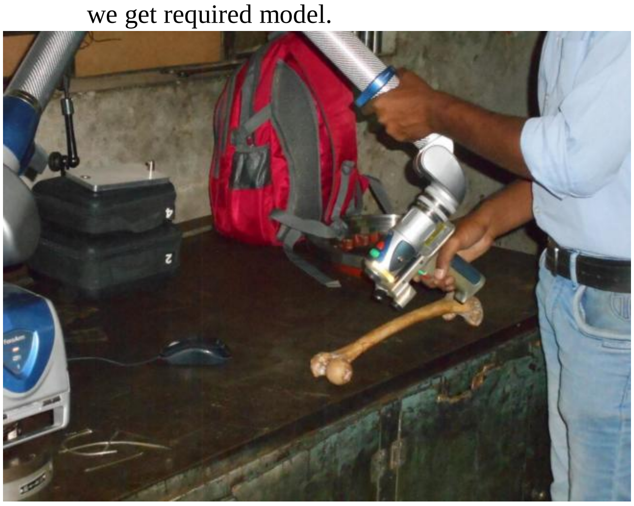

Fig. 8 Industrial Laser 3-D Scanner (Faro Made)

Fig.9 CATIA model of femur bone

4.2 Analysis is done by using analysis software.

1) Free meshing is done for femur and tibia bone. Bone shape is irregular so we go for free meshing.

2) **Load Applied**: Load applied on head of femur bone is 100kg.

3) Fixed support is applied at bottom of the tibia bone.

V. FEA RESULTS

1. For zero degree angle:

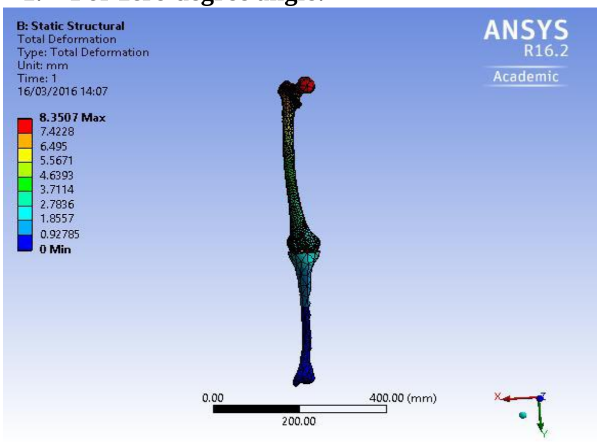

Fig: 10 Total deformation

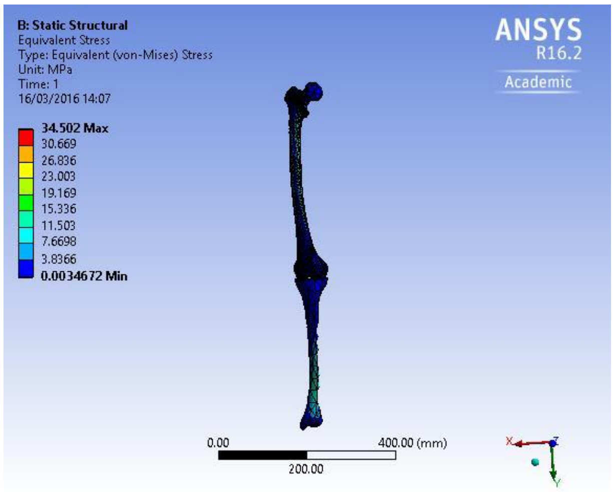

Fig: 11 Equivalent stresses

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2. VAROUS ANGLE:

a) For one degree angle:

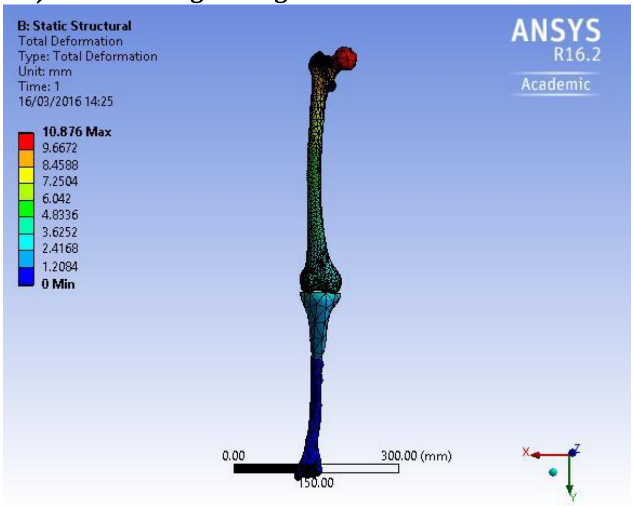

Fig: 12 Total deformation

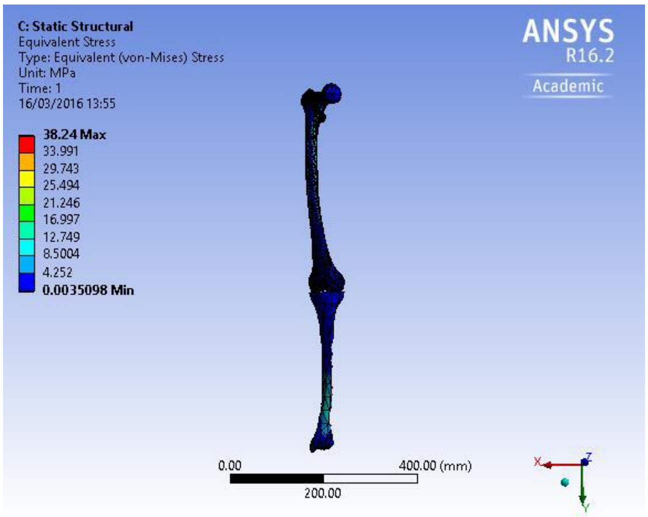

Fig: 13 Equivalent stresses

b) **For two degree angle:**

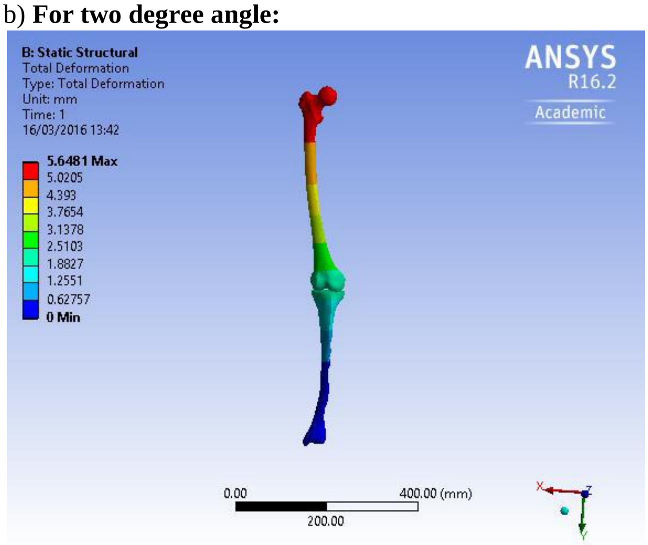

Fig: 14 Total deformation

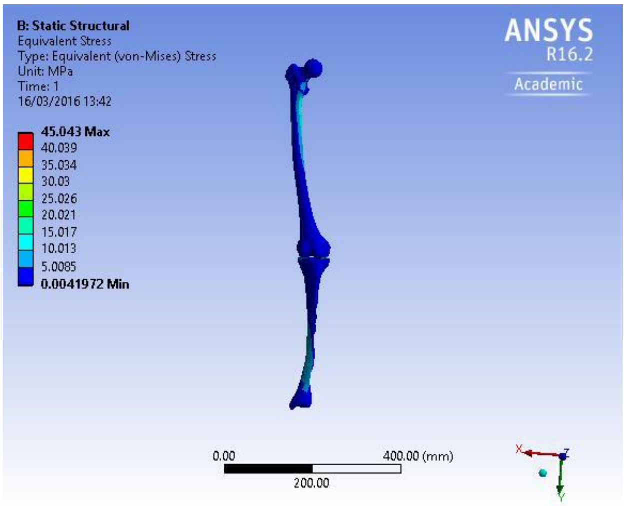

Fig. 15 Equivalent stresses

c) **For three degree angle:**

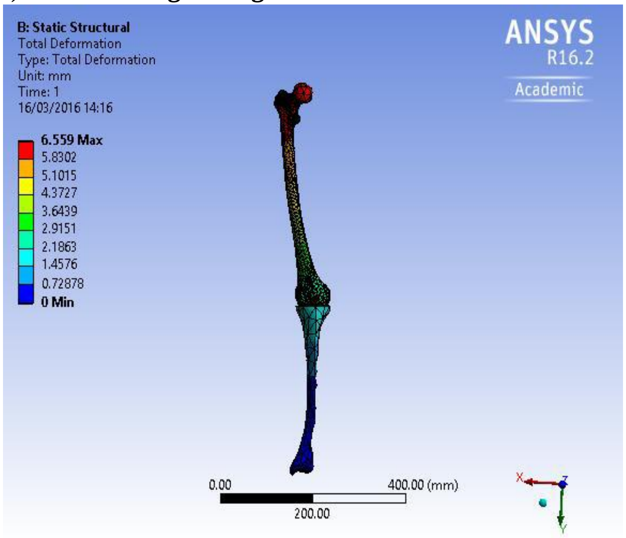

Fig.16 Total deformation

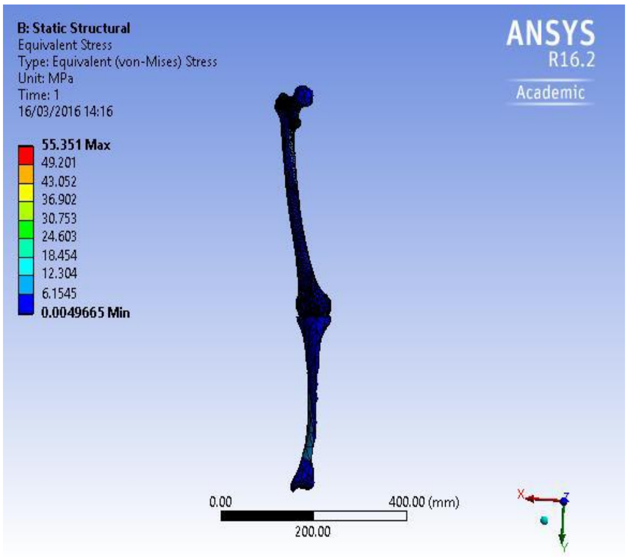

Fig:17 Equivalent stresses

3. VALGUOS ANGLE:

a) For angle one degree:

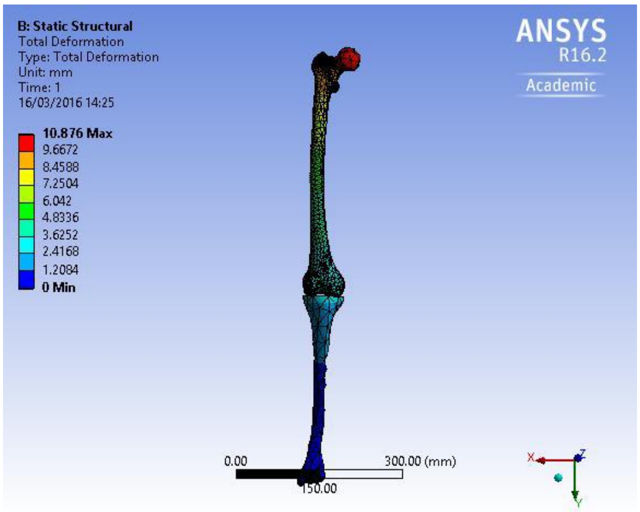

Fig:18 Total deformation

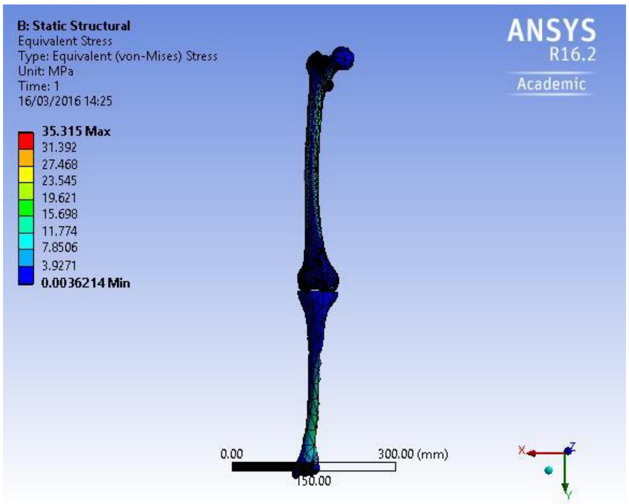

Fig.19 Equivalent stresses

For two degree angle:

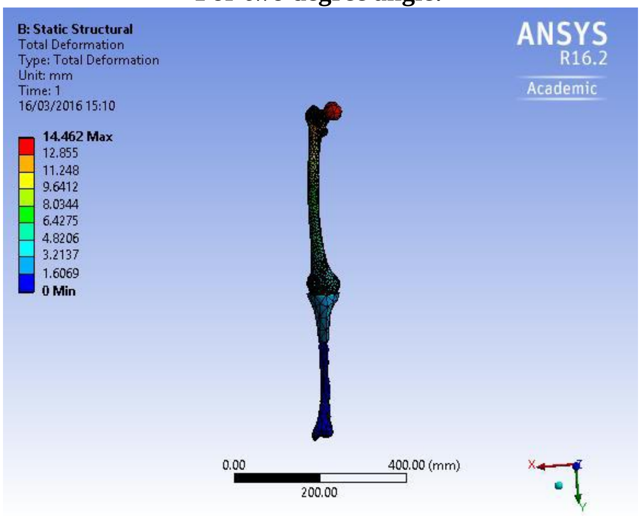

Fig.20 Total deformation

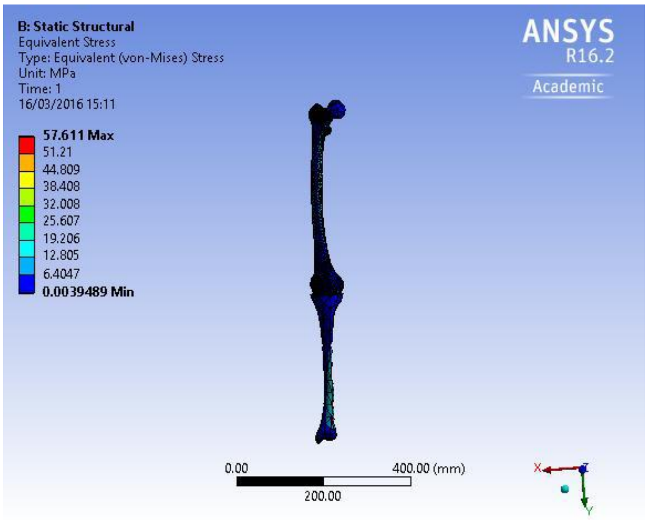

Fig 21 Equivalent stresses

c) For three degree angle:

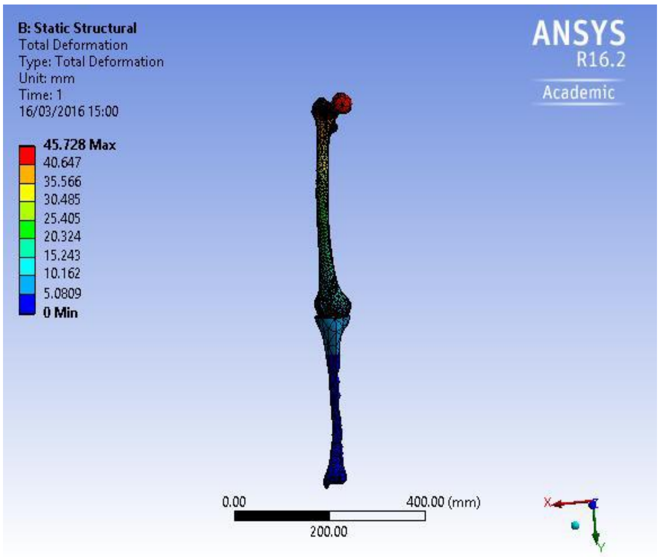

Fig: 22 Total deformation

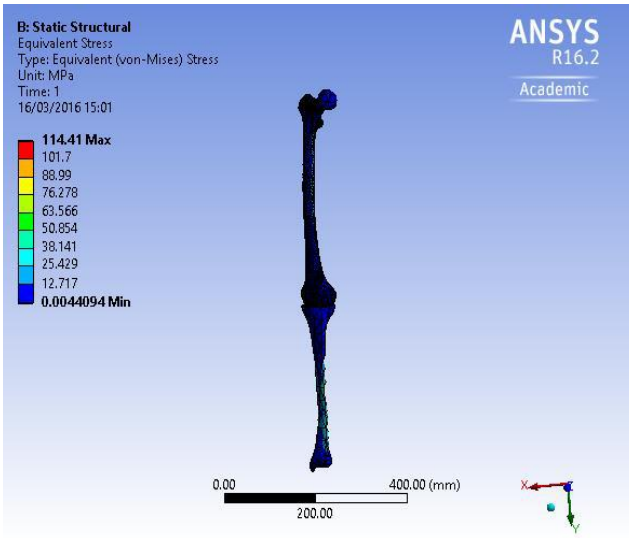

Fig: 23 Equivalent stresses

Table 1. Stress distribution and change in stress values due to different alignment by using FEA

Angle in degree	Equivalent stress MPa	Total Deformation mm
-3	114.41	45.728
-2	57.611	14.462
-1	35.315	10.807
0	34.502	8.3507
1	38.24	5.5036
2	45.043	5.6481
3	55.35	6.55

VI. CONCLUSION

1) By using FEA and Experimental method normal stress varies at knee, in different alignment positions.

2) FEA and Experimental method give indication that angle must within ± 2°. The rise in normal stress at knee not much with in± 2°. After ± 2° there is drastic change in the stress values.

3) It is observed that, the stress analysis technique using ANSYS is the best method for stress evaluation of the Real Proximal Human leg Bone.

4) The femur is subject to maximum deformation. Neck is the critical portion of human femur bone.

5) Von moises stresses are increased with increase in the flexion angle so alignment is most important for life of the knee replacement.

6) Deformation is maximum at the femur head and maximum stress on the tibia bone.

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