STRESS ANALYSIS ON LUMBAR VERTEBRAE

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ABSTRACT

About 85% of the world's total population suffer from back pain which is directly or indirectly related to their daily assignments and activities. About a quarter of people reported lower back pain which is a result of vertebral compression. Intervertebral discs and L1 to L5 discs suffer most of the spine injuries very often. Modelling and analysis of lumbar discs is crucial for predicting load impact and body movements in daily life activities. To study the stress distribution of lumbar discs 3D model of L1 to L5 discs is constructed. For this analysis lumbar discs of two different personalities are studied i.e normal and obese. The results revealed that L5 witnessed lower stress and displacement as compared to that of L1. Since spine being a very complex structure, the discs are slightly simplified in their construction and idealised.

Keyword: - *Lumbar discs, Stress analysis, displacement.*

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1. INTRODUCTION

The human body is provided stability by the complex structure provided at the back known as spine. This spine enables the humans to have different motions and movements of the body while doing various daily activities. The spine consists of muscles, bones, tendons, cartilage, joints, ligaments, and other soft tissues. The spine is made of three regions which are called as cervical, thoracic and lumbar. Recently, there has been growing concern with the degeneration in the human spine. The lowest part of the spine also known as the lumbar spine bears the highest load of upper body and cause a lower back pain when lifting an excessive load or doing wrong movement activities. The lumbar spine degeneration affects normal activities and quality of life. The lower back i.e lumbar spine bears the highest load among all the three regions. The spine has majorly three important functions. First of all is that supporting the body by transferring the weights of the upper body (head and trunk) and any additional weights lifted from the body to the pelvis. Secondly, providing mobility of the trunk under sufficient physiological motions. Finally, it's protecting the spinal cord and spinal nerve roots from potential damaging forces and motions produced by both physiological movements and properties of the normal spine anatomy.

2. PROBLEM STATEMENT

There is a need to identify the relationship between load impact and physical personality applied on the lumbar spine under normal movement without effecting the lumbar spine. The hypothesis of this study is the degenerative of lumbar spine vertebra under normal activities life will affect peoples' movement. It is the relationship between the load impact while lifting objects and movement of the body during daily life that this study seeks to establish.

The objectives of this study are:

- To predict the biomechanical response of lumbar vertebra based on the stress distribution, deformation of the body and degree of motion by performing the stress analysis under various loading conditions such as flexion, extension, lateral and torsion.

- To determine the highest impact area on the interest subject during load and moment applied.

In this study, a 3D finite element model of the lumbar spine was developed based on the CT scanned images and reconstructing the surface using SOLIDWORKS software. Load and boundary conditions were applied to the model to predict the stress distribution of the spine. The model was limited to the lumbar vertebra spine section (L1 to L5) and intervertebral disc with all soft tissues were removed during the modelling process. The limitation of this study is the representation of the complex connection of the bone between vertebra itself and other soft tissues nearby. This bone was segmented on every part together with the vertebra and disc because of the different types of structures and materials. However, the most important objective was to prepare an accurate model for simulation in order to assess the effect of structural geometry on the stress distribution under several load conditions.

2.1 Modelling

We consider human lumbar vertebrae L2 – L4 with intervertebral disc further imported in SOLIDWORKS12 for categorization in five parts of lumbar vertebrae and two parts of intervertebral disc. The lumbar disc was generated using SOLIDWORKS12 software. A 3-D solid model was established that was visually same to an existent disc.

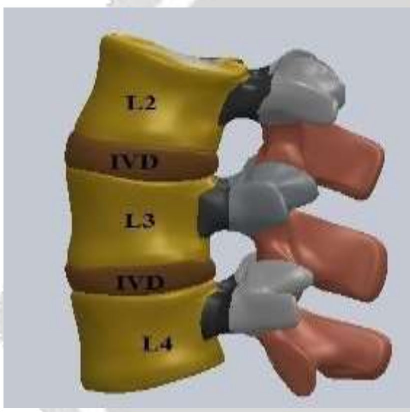

Fig-1: Human Lumbar vertebrae L2-L4 with Intervertebral Disc

Fig-2: Lumbar spine isometric view

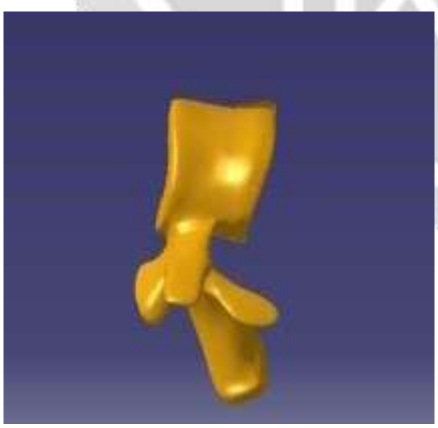

Fig-3: Lumbar spine side view

Fig-4: Lumbar spine bottom view

2.2 Solution Methodology

The 3D lumbar vertebrae were grouped as a basic 3-D solid model by using the Solid Works assemblage function and this model was imported into ANSYS for observation and analysis. It is familiar that the implant 3D model of lumbar spine is a complex body, that is, it contains of distinct infrastructures, with several elastic and geometry properties. The weight distribution and transmission among the infrastructures depend on several elements. The relationship between contacts faces of entirely models were provided as “bonded”. Three-dimensional meshes generated at different part of lumbar spine. Tetrahedral and hexahedral element generally used for simulation. Mesh details is listed in figure below.

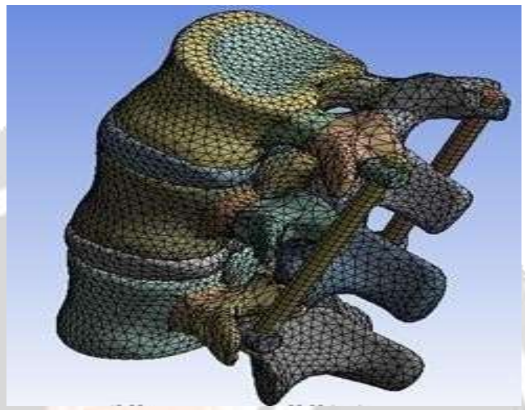

Fig-5: 3D implant model of lumbar spine with various meshing

Analysis for design using the different loads have been taken for different body weight (70 kg and 120 kg respectively) for analysis. The boundary condition is fixed at lower surface of the L4 vertebra and loads were applied on the top surface of L2 vertebrae. Analysis was performed under various loadings such as axial load, flexion, extension, lateral and torsion to determine the stress distribution and deformation on the model. In this analysis, lumbar disc with different physical personalities (normal body and obese body) have been considered. Further to this Finite element analysis (FEA) with boundary condition, i.e. fixed bottom surface of the L4 vertebrae, loads were applied on top surface of L2 vertebrae. The different loading condition has been considered for the two different body weights. Results were analyzed by providing appropriate lumbar disc size. Since the spine is a very complex structure, many of the models are simplified and idealized because of the complexity and uncertainty in the geometry, material properties and boundary conditions of these problems.

3. RESULTS & DISCUSSIONS

The distributions of maximum equivalent stress in different regions of lumbar vertebrae L2 to L4 with total deformation are obtained. After simulation all results are listed as shown below. The following figures consist of stress values obtained from ANSYS by applying various loads.

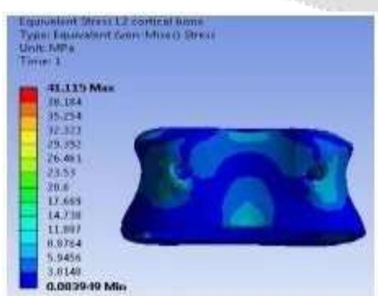

Fig-6: Equivalent stress of L5

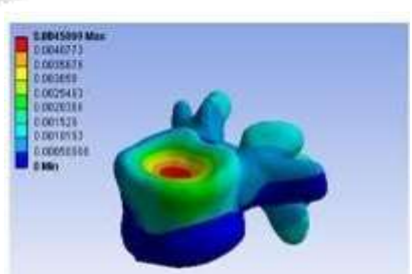

Fig-7: Total deformation of lumbar spine5 at 10 kg

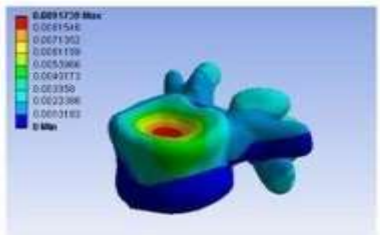

Fig-8: Total deformation of lumbar spine5 at 20 kg

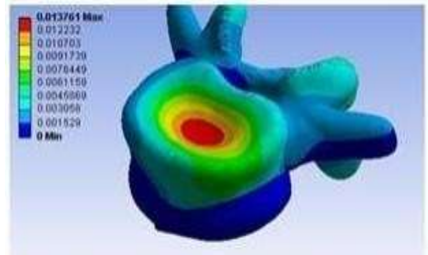

Fig-10: Total deformation of lumbar spine5 at 30 kg

Table 1: Comparison of equivalent stress and total deformation of Lumbar Spine

Lumbar	Loads(Kg)	Total deformation(mm)	Equivalent stress(MPa)
Spine 5	10	0.0045	6.94
	20	0.0091	13.88
	30	0.1376	20.826
Spine 4	10	0.0051	7.1
	20	0.102	14.18
	30	0.0153	21.33
Spine 3	10	0.0072	7.45
	20	0.122	15.76
	30	0.0178	23.52
Spine 2	10	0.0093	8.23
	20	0.0156	16.41
	30	0.0217	26.17
Spine 1	10	0.104	9.26
	20	0.0212	18.44
	30	0.0368	32.46

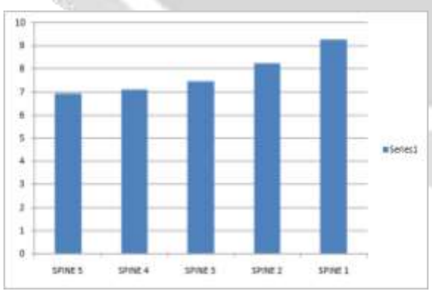

Fig-11: Comparison of total deformation at 10kg load

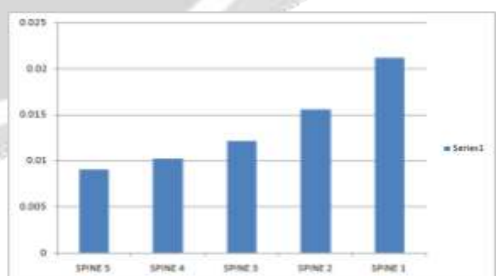

Fig-12: Comparison of equivalent stress at 10kg load

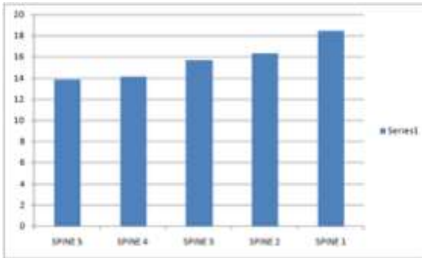

Figure 13: Comparison of total deformation at 20kg load

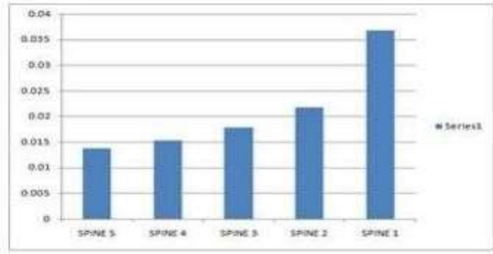

Figure 14: Comparison of equivalent stress at 20kg load

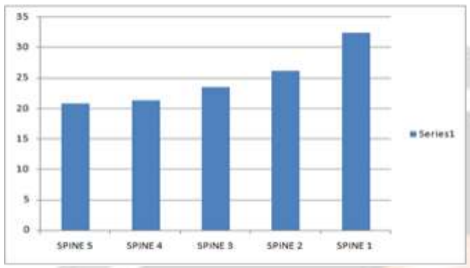

Figure 15: Comparison of total deformation at 30kg load

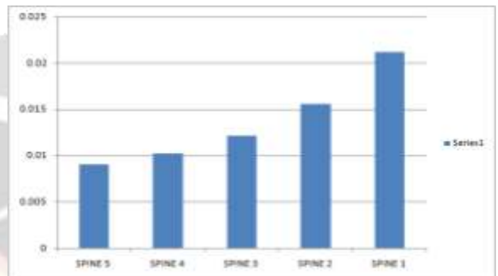

Figure 16: Comparison of equivalent stress at 30kg load

Representation of graph:

x-axis : lumbar disc number

y-axis : deformation in mm

Representation of graph:

x-axis : lumbar disc number

y-axis : equivalent stress in Mpa

4. CONCLUSIONS

Some vital biomechanical choices are often drawn from these outcomes. Most equivalent stress within the numerous regions of the body part vertebrae (cortical bone, cancellous bone, and pedicle) is affected. Our results are restricted by assumptions regarding the properties of materials and by the basic models employed in finite component analysis. These results should be thought of, then, as an earliest guide in choosing age and personality, since approaching clinical studies are needed to substantiate the results.

5. REFERENCES

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