FEM Study on Impact of Osteoporosis Humerus

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***Abstract*— Cancer patients whose cancer has metastasized to bones, face uncertain bone conditions; cancer cannot be cured, with treatments only helping to reduce the pain and other symptoms of bone metastases. Close to a quarter of people with an advanced form of lung cancer has cancer metastasized to the bones. The most affected areas are the pelvic region, the spine, humerus, and femur. The study will assess biomechanical effects on bone affected with Osteoporosis on the humerus bone, and how much pressure it can withstand. The fragility of the bone may compromise the condition if it's being put under stress.**

***Keywords*— Biomechanics, Bone Fragility, Finite Element Analysis, Humerus and Osteoporotic Bone**

I. INTRODUCTION

Cancer is an aggressive disease, which, if left unchecked may metastasize to different parts as it advances, it can affect lymph nodes, tissues, organs, and bones; the process of cancer spreading to other parts is called metastases, and that cancer in itself is known as metastatic cancer or stage 4 cancer.

Patients with bone metastasis are likely to have reduced bone mass density, as opposed to those without any [2]; reduction in bone mass density may lead to osteopenia or osteoporosis, which may be accelerated by chemotherapy and hormone manipulation [3], increasing the risk of fractures.

The research delves into the impact of Osteoporosis on the Humerus bone. The humerus is the long upper bone of the arm, situated between the elbow joint and the shoulder. It is the most commonplace for bone metastasis in the upper bone region. The purpose of this work is to assess the biomechanical impact of metastatic lesions in the osteoporotic model of humerus, employing Finite Element Methods (FEM).

In this paper, we have investigated the impact of Osteoporosis on humerus bone, the tests were conducted on models of Humerus (Normal, Osteoporotic) bone using Finite Element Methods. Section II of the paper sheds light on previous work done regarding bone modeling mechanics, and discusses the challenges, limitations, and formed conclusions. In Section III, the model and the material properties (of the models – Normal, Osteoporotic) are explained. Section IV discusses the experiment, which was performed on the bone models, also discussing the effects that these experiments had on the models. In section V, comparison is made, on how the models react differently under varying circumstances. Section VI concludes the research work.

II. LITERATURE REVIEW

A. *Article 1*

The study was done to come up with a model of the thoracolumbar spine, which is based on CT scans (quantitative computed tomography) and to validate the model as well. Structural properties of bones were mapped to parametric variables, being adjusted to provide agreement in bone structure and experiment.

The findings of the study indicated that the model can be used to effectively and accurately predict the biomechanical properties of the vertebrae, ultimately being applied to identify fracture risks in potential cases facing the fractures [5].

B. *Article 2*

The research describes the biomechanical effects of damage caused due to cancer on the lumbar spine model.

The research was conducted on models on lumbar vertebra L3 and L5. The research includes analysis of the effects of metastatic anomaly and mineral density of bone on the structure of the Vertebrae. The deformity was to be studied based on radial displacement (Vertebral bulge - VB) and axial displacement (Vertebral height - VH), both of which have been found to correlate with having a rupture (burst fracture).

The research resulted in the conclusion that having a cancerous lumbar vertebra (Osteoporotic) might result in a patient having a significantly greater risk of vertebral fracture, with the risk growing along with the magnitude or size of metastasis [13].

C. *Article 3*

The research study was conducted to present a different mechanism to help forecast vertebral fractures in older men.

At present, the commonly used method to predict vertebral fracture is taking the bone mass density of an area nearing the spine or hip by dual-energy absorptiometry. The issue with the procedure is that the underlying issue may not be identified or taken into consideration by the test, issues such as the difference between cortical and trabecular (cancerous) bone, arthritis, or aortic calcification.

The research suggests a method of improving fracture risk assessment of the spine by combining CT scans (Computed Tomography) with bone mechanics using Finite element analysis to draw approximations on vertebral strength. The research concluded that the suggested mechanism as compared to areal BMD was consistently giving better fracture risk assessment [16].

D. Article 4

In the study, the researchers investigated whether Finite element models could be used to identify whether if any patients faced imminent femoral fracture, and compared the estimates with clinical evaluations by doctors.

Patients have cancerous lesions in non-fractured femur were included in the study, CT scan based models were produced for all the patients. Bones were put under stress with readings compared between non-fractured and fractured femoral bone, and; predictions compared to risk assessment as identified by experienced clinicians.

The FE models were found to be more precise in recognizing patients with higher fracture risk as compared to the prognosis of the doctor [2].

E. Article 5

A clinical study of osteoporotic vertebral strength and any issues that may arise due to daily living activities (including lifting items) using CT (computed tomography) scans. For the study strength of the second lumbar vertebrae is female patients were analyzed using CT scan based Finite element models. Three stress positions were identified and adopted for the study, including forwarding bending, erect standing, and uni-axial pressure. Predicted strengths under different bending conditions were compared and statistically analyzed.

The findings put forth the conclusion that, with osteoporotic patients, both uni-axial compression and forward bending motions should be evaluated, to measure any day to day fracture risk that the motion may pose, under normal living conditions [7].

III. MODELLING

A. Introduction

The finite element model of the humerus bone was used to perform a parametric study of its properties. At first, the boundary level for humerus bone was identified and tested such that the model mimics mechanically a humerus bone. Once the boundary values were established for the humerus bone, next step was to introduce deformity or osteoporosis, such was achieved by identifying and working with different parametric values.

B. Model Design

Bones in general are heterogeneous and irregularly shaped. Bones are asymmetrical in nature with changing textures and density running the length of a single bone. Humerus bone also follows the same pattern with a rounded head and narrow neck, is shaped cylindrical at the top and prismatic at the bottom with a shaft connecting both the ends. The model used is from a whole-body model of an adult human male.

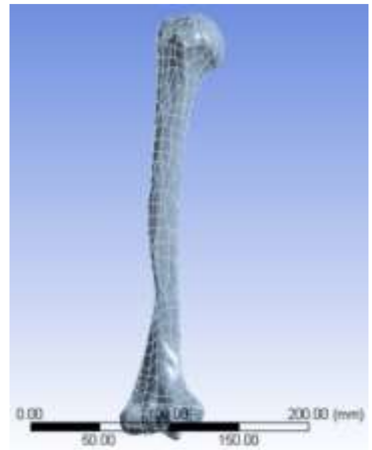

Fig. 1: Showing the humerus model

C. Material Design

The diverse nature of bone with variable materialistic properties makes for a challenging task to assign material properties to it. With the complex structure and the variable densities that the bone possesses it gets more complicated to assign different material properties running the length of the bone.

The humerus bone with varying shapes, density, and unique anatomy also follows the same pattern. For the study, we've taken the humerus model retaining the original shape and anatomy, but in material properties manner, it's been kept as a homogenous body. The density of cortical bone is applied to the model for *Normal Bone*.

The bones are categorized into two types Cortical and Trabecular bones. Cortical bone is denser in nature will less porosity, it forms at the denser outer layer of the bones, protecting the inner malleable bone structure and cavity. Around 80% of the skeletal mass is made up of the cortical bone. Cortical bone is highly resistant to bending and torsion.

The Trabecular bones are porous and as the name implies cancellous in nature (thus cancellous bone). Trabecular bones are much more malleable as compared to cortical much. Trabecular bones can be found near the joints at the ends of long bones, where the bone is not brittle and solid, but rather has holes, which are connected by thin rods and plates of bone tissue.

For the *Osteoporotic bone*, the density of the model of the bone has been reduced to mimic the porous Osteoporotic nature, although to simplify the solution the homogeneity of the structure is still kept. Density is derived from the mean density of Cortical and Trabecular bones.

IV. METHODS

A. Load and Pressure Section

The 3D finite element model was imported into FEA software. The support was kept at the Proximal End (neck) of the humerus, the neck of the humerus is the part where the joint capsule is attached. While the pressure was applied at the distal humerus

Fig. 2: Showing the Model with the Load and pressure sections identified

B. *Effects of Pressure on Normal Bone*

Static load was applied to the Humerus bone with a Pressure of 0.3MPa, which resulted in Max Total Deformity of 6.898 mm.

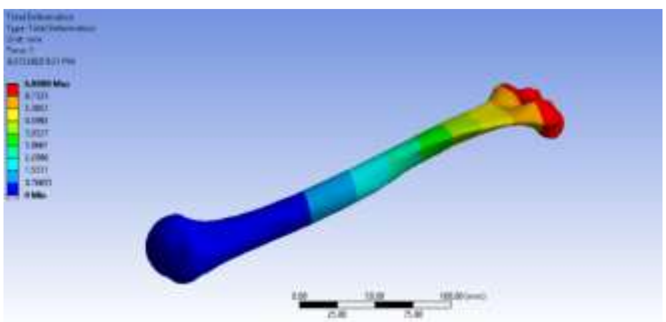

Fig. 3: Shows the Maximum total Deformity in Normal bone

C. *Effects of Pressure on Osteoporotic Bone*

Static load was applied to the Humerus bone with a Pressure of 0.3 Mpa, which resulted in Max Total Deformity of 13.798 mm.

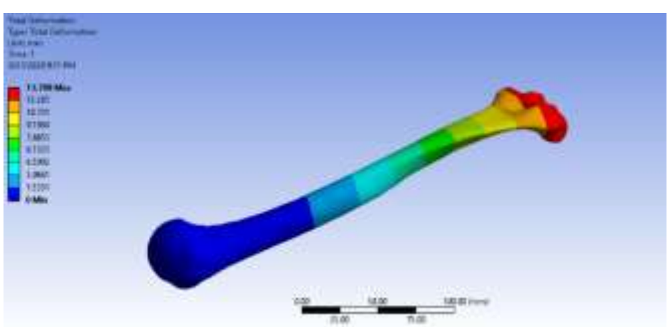

Fig. 4: shows the Maximum total Deformity in Osteoporotic bone

V. RESULTS

A. *Comparison between Normal and Osteoporotic bone*

The density of the Osteoporotic bone was set at 1652 kg/m^3, a reduction of 17.4% as compared to the normal bone which had a density of 2000 kg/m^3. While Young's modulus was reduced to 5000 MPa, as compared to 10000 MPa for a normal bone, a reduction of 50%.

Figure 5 below shows the varying level of Deformities (max) based on the application of incremental pressure. At 0.02 MPa of pressure, the difference in deformity between the bones is constricted to 0.45mm (approximately), which increases to 2.1mm (approximately), running the length of the graph to a pressure of 0.09 MPa; seeing which we can deduce that Max total deformity for normal bone was almost 50% less than that of Osteoporotic bone.

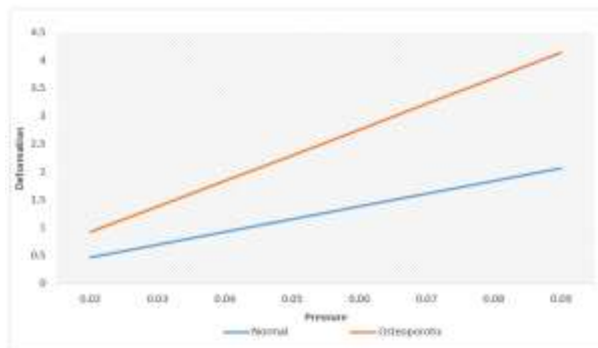

Fig. 5: Deformity between bones on varying Pressure

B. *Comparison with Literature*

The research done before relating to mechanical properties of different Osteoporotic and metastatic Femur and vertebral bone, point to the conclusion that osteoporotic bones, where, whether osteoporosis was the result of old age or metastasis resulted in the respective bone of being weak, and prone to fractures.

Most of the studies conducted were on models including vertebrae columns and Femur, with very limited literature available for humerus bone. In this study, we have delved into finding faults and draw mechanical properties of Osteoporotic humerus bone, compare the findings with normal humerus model using Finite Element Method, and have presented the results of how osteoporosis in bone results in its reduced strength.

VI. CONCLUSION

In the work, a humerus bone model was analyzed, followed by the analysis of the osteoporotic humerus bone, to find whether a metastasized bone is more fragile and prone to being deformed earlier with the application of pressure as compared to a normal humerus bone.

The same model was used to perform both the examinations, with the difference being the material properties that were applied onto the bone. Both models underwent similar testing scenarios, along with the application of the same value of pressure.

The humerus model with osteoporosis was found to be more fragile, malleable, and prone to much more damage and compared to a normal bone. The reduced density and malleability will always be leading to a higher risk of bone fracture as compared to a normal bone

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