Effect of Osteoporosis on the Biomechanics of the Thoracolumbar Spine: Finite Element Study.

MA.Tyndyk[1,2], V.Barron[1], PE.McHugh[1,2]

[1]National Centre for Biomedical Engineering Science, [2]Department of Mechanical and Biomedical Engineering, NUI, Galway, Ireland

INTRODUCTION: Osteoporosis is characterised by low bone mass and structural deterioration of bone tissue. This results in reduced bone strength and a high risk of fracture, especially in the aged population. Previous numerical investigations examined the biomechanical changes associated with osteoporosis but in many cases these analyses were limited to a single vertebral body or a single motion segment. [1, 2]. To date, there is still a lack of understanding of how osteoporosis impacts on the general spinal performance and the load transfer mechanism within. Therefore, the main goal of this study was to examine the effect of different bone densities on the biomechanical behaviour of an anatomically correct thoracolumbar spine. Using finite element analysis a range of spinal conditions including healthy bone (HB), osteopenic bone (OPN), moderate osteoporosis (OPR) and severe osteoporosis (SOPR) were modelled and compared.

METHODS: As shown in Fig. 1 a seven level (Th11-L5) spine model was created from a series of CT scans from a 63-year-old male cadaver and validated by the experimental methods [3].

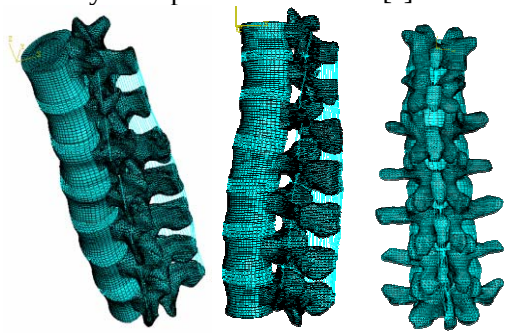

Fig. 1: 3D FE model of spine (Th11-L5).

Based upon data reported in the literature [4], different levels of bone tissue loss was simulated by changing the material properties of the cortical and trabecular bone in each segment. All models were subjected to a vertical compressive load of 750 N and a bending moment of 15 Nm to simulate flexion and extension. In this particular case the changes in the compressive stiffness and the displacement values in X, Y and Z-direction caused by the external load were examined.

RESULTS: As shown in Fig. 2, a drop in compressive stiffness was observed when osteoporosis and severe osteoporosis were simulated. By reducing the elastic properties of bone a decrease of 1, 9, and 12% was recorded for osteopenic, osteoporotic and severely osteoporotic spine, respectively.

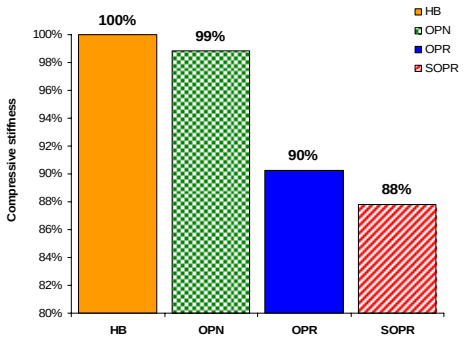

Fig. 2: Compressive stiffness calculated for all four FE models

In terms of displacement values, the behaviour of the healthy and the osteopenic spine were similar, however the displacement distribution changed significantly for the osteoporotic and severely osteoporotic spine. This suggests that the spine was less stable when the elastic properties of bone tissue were reduced, and additionally, unwanted motion occurred under a compressive load of 750 N.

DISCUSSION & CONCLUSIONS: Based on the FE model predictions, it can be seen that osteoporosis impacts significantly on the biomechanics of the thoracolumbar spine. The current FE analysis suggests that osteoporosis may lead to decreased compressive stiffness and reduced spinal stability, as a low bone density caused excessive movement between adjacent vertebrae. In the present case the "weakest link" in the spinal column was the Th12-L1 motion segment and this observation is in a good agreement with experimental data reported in the literature and clinical observations.

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