THE EFFECT OF TRABECULAR MICRO-ARCHITECTURE ON VERTEBRA BIOMECHANICS: A FINITE ELEMENT INVESTIGATION

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INTRODUCTION

700,000 vertebral fractures occur each year in the United States alone, 85% of which are associated with osteoporosis. Although the changes in trabecular bone micro-architecture accompanying osteoporosis are well documented, the mechanisms by which these changes affect overall spine biomechanics are not well established. This study presents the development of a microstructural model of an entire lumbar vertebral body to investigate the effects of changes in trabecular bone micro-architecture on the strength and stiffness of the vertebral body.

METHODS

A finite element model of the trabecular microstructure within an entire L3 human lumbar vertebral body was created using equations given by Mizrahi[1] for the vertebral body geometry. The internal trabecular microstructure was modelled using a lattice of 3D beam elements with thickness and separation varying with age according to values given by Mosekilde[2]. Three microstructures were investigated: (i) age less than 50, (ii) age 50-75 and (iii) age over 75 years. A perturbation value of 0.3[3] introduced random microstructural variations throughout the mesh. A Young's modulus of 13GPa and a Poisson's ratio of 0.3 were applied for parent bone material. A simulated compressive load was applied to the models to displace the upper trabecular surface by 1mm in the vertical direction.

RESULTS

The model predicted large decreases in stiffness with age (age <50, K=23,030 N/mm, age 50-75 K=2,765N/mm, age 75 K=722N/mm). For an apparent compressive strain of 3.6% (1mm compression) the maximum principal tensile strain was 5.9% for age <50, 3.47% for age 50-75, and 2.87% for age 75. The minimum principal (compressive) strains were 6.5% for age <50, 4.76% for age 50-75, and 3.78% for age 75.

DISCUSSION

The FE results showed that age-related reductions in trabecular thickness and increases in trabecular spacing dramatically reduce the stiffness of the trabecular core, and vertebra body as a whole. Further, the proportion of total load carried by the trabecular core diminished from 52% in the age<50 model to a negligible amount for the age>75 model.

REFERENCES

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