Osmotic forces are important in disc biomechanics—have they been accounted for in FE simulations?

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Introduction

The intervertebral discs are believed to be a key element of back pain and back pain disorders has a serious impact on the European economy [1]. Intervertebral discs have a primarily mechanical role in transmitting loads through the spine. They degenerate far more rapidly than other tissues [2]. The disc is thus subjected to a combination of elastic, viscous and osmotic forces [3]; previous models have typically neglected osmotic forces. The cells of the intervertebral discs are sensitive to pressure and osmotic pressure, quantification of these stresses is important.

Objectives

The EURODISC project is investigating different factors which influence disc degeneration. Eindhoven attributes to this by developing a FE-model for predicting levels of hydrostatic pressure, fluid expression, tissue strain and cellular deformation in discs subjected to physiological loading.

Methods

The validated fibril-reinforced poroviscoelastic swelling model of Wilson [4] was used for the computations. The kidney shape like mesh resembles one forth of a full disc, hence saving computation time. It was created with the preprocessor Mentat and consisted of 8952 3D 8-nodes elements. Simulations of the effects of changes in osmotic and mechanical load on hydrostatic pressure and disc shape were performed with Abaqus 6.3.

Results & Discussion

Applying a linear increasing axial load of 500N raised the hydrostatic pressure to 0.33 MPa while an axial load of 1000N increased the pressure to almost 0.7 MPa (fig.2):

![Figure 2. color plot showing the hydrostatic pressure](image)

these results compared well with the experimental ranges measured by Nachemson and Wilke [5]. Loading the disc decreased the height of the disc and resulted in an outward bulging of the outer annulus. Fiber stresses were highest on the most outward bulging on the posterior-lateral side.

Conclusion

Osmotic forces play an important role in disc biomechanics and can be calculated successfully using finite-element methods.

Future Work

For a finite element simulation the boundary conditions of the disc model should be kept clearly in mind:

- Influence of the vertebral endplate permeability (calcification) on the fluid flow from the disc

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Reference

[2] www.physiol.ox.ac.uk/EURODISC
[3] Huyghe et al., Biomech Mod Mechanobiol, 2003, 2, pp3-19,