Comparison of experimental and numerical stress profiles in human disc show similar stress peaks why?

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INTRODUCTION: The disc is subjected to a combination of elastic, viscous and osmotic forces. The swelling tendency of the disc tissue and the tensile stresses in the collagen structure are highly interdependent [1].
Because experimental measurements of in vivo intradiscal stresses are difficult, different finite element approaches have been made. No published 3D finite element model of the disc includes osmotic prestressing. The purpose of this study is the comparison of experimental and numerical stress and pressure profiles in the human discs, which do not show a uniform pressure profile as assumed in a healthy human disc.

METHODS: In this study the fibril-reinforced poroviscoelastic swelling model of Wilson [2] was adapted. The disc model resembles one forth of a full disc consisting of 8952 3D 8-nodes elements and is described through a biphasic swelling model. The model distinguishes between an elastic non-fibrillar solid matrix, a 3D viscoelastic collagen fiber structure and osmotically pressurized fluid. For the non-fibrillar part a compressible neo-Hookean model was used. The swelling behavior of the disc was assumed to be solely due to osmotic swelling.
The stress in the disc is the sum of fiber stress, matrix stress and hydrostatic pressure. Simulations of the effects of changes in osmotic and axial mechanical load on hydrostatic pressure, osmolarity and disc shape were performed. Model predictions were compared to experimental results obtained from human cadaveric discs tested under similar loading conditions to those applied in these simulations [3].

RESULTS: 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. The model predicted the presence of stress peaks within the peripheral annulus that corresponded both in magnitude and width to those observed experimentally (fig 1). In the same way the centre of the disc (including some of the annulus elements) showed similar mechanical behaviour to the experimental results.

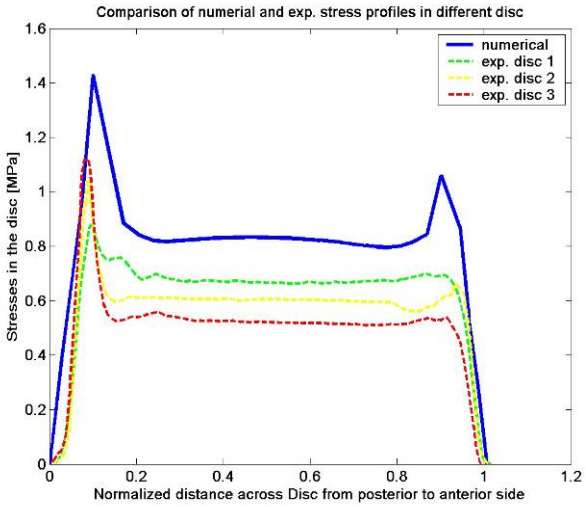

Fig. 1: *Comparison of experimental stress results with FEA predictions*

DISCUSSION & CONCLUSIONS: For the first time the intervertebral disc is modeled as a 3D osmotically pre-stressed fibril reinforced structure using finite deformation finite element analysis. The computed sum of the axial matrix stress and the hydrostatic pressure compares well with experimental results, as well as with intradiscal pressure measurements from the literature.

REFERENCES: [1] J. P. Urban and A. Maroudas (1981) *Connect Tissue Res* 9: 1-10. [2] W. Wilson, C. C. van Donkelaar, B. van Rietbergen, R. Huiskes (2005) *J Biomech* 38(6): 1195-1204. [3] D. McNally and M.A. Adams (1992) *Spine* 17(1): 66-73

ACKNOWLEDGEMENTS: This research is made possible through the support of the AOSpine and European Union (***EURODISC***, Project Number: QLRT-2001-02852).