Is disc pressure and osmolarity affected by intra-extrafibrillar fluid exchange?

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INTRODUCTION: The disc is subjected to a combination of elastic, viscous and osmotic forces. Experimental results showed that osmolarity affects disc cell gene expression [1]. Correct evaluation of osmolarity requires a distinction between intra and extra fibrillar water content [2]. The purpose of this study is to determine the influence of intra-extrafibrillar fluid exchange on pressure and stress with regard to understanding disc degeneration.

METHODS: The disc model resembled one forth of a full disc [3]. The model distinguished between an elastic non-fibrillar solid matrix, a 3D viscoelastic collagen structure and osmotically pressurized fluid [3,4]. The stress in the disc was the sum of fiber stress, matrix stress and hydrostatic pressure. Composition and intrafibrillar water data were taken from experimental results of Sivan et al. [5]. The composition for the disc was as follows:

	Collagen [% of dry weight]	**Fluid** [% of wet weight]	**FCD** [mEq/ml]
Nucleus	0.9	82.5	0.3
Annulus	48	77	0.15

To study the influence of intrafibrillar water (IFW), three simulations were performed: (1) without intrafibrillar fluid, (2) with constant intra-fibrillar fluid fraction, and (3) with the intrafibrillar fluid fraction as a function of the osmotic pressure. The intrafibrillar fluid fraction as a function of the osmotic pressure for young human annuli was taken from Sivan et al. [5] (Fig. 1).

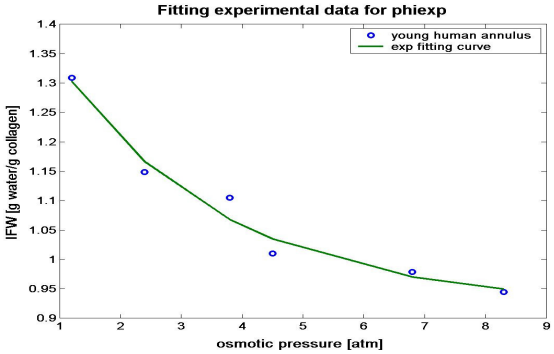

Fig.1: Exponential fitting of experimental data

For simulations with a constant intrafibrillar fluid fraction, a value of 0.5 (g/g collagen) and 0.7 (g/g collagen) were used for the nucleus and annulus, respectively.

RESULTS: The osmotic pressure in the first simulation (IWF=0) was about 0.21 MPa, for the second simulation the osmotic pressure was 0.27MPa and for the third simulation the osmotic pressure was 0.32MPa (fig.2).

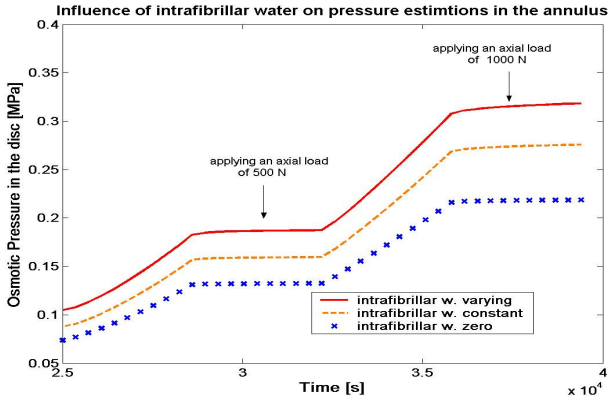

Fig.2: Osmotic pressure under different loads for anterior side of annulus

DISCUSSION & CONCLUSIONS:
No noticeable differences in pressure and stress estimation in the nucleus were seen, between constant and varying intrafibrillar water, because of the low collagen content. However, osmotic pressure, hydrostatic pressure and the total tissue stress in the annulus were clearly different (Fig. 2). Stresses, hydrostatic pressure and osmotic pressure were underestimated when the intrafibrillar water value was assumed constant and even more so when the intrafibrillar water was neglected. As the loading increased, the discrepancies increased. To conclude, the distribution of pressure and osmolarity in the disc is affected by intra-extrafibrillar water exchange.

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