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

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Introduction
The disc is subjected to a combination of elastic, viscous and osmotic forces. In vivo measurements of intradiscal stresses are difficult. McNally et al. measured stress profiles in human disc (fig. 3) [4]. It is unclear why some exhibit stress peaks in the posterior annulus and some do not. Therefore finite element (FE) models are used to improve the knowledge of stress distribution in the disc.

Methods
The poro-mechanical FE disc model resembles one fourth of a full disc (fig. 1) [1]. The annulus stress is the sum of the matrix stress and a fiber stress. The nucleus has matrix stress only. Annulus fibers are oriented at an angle helicoidally of ±30° with the transversal plane [2]. Model predictions of matrix stress were compared to experimental results obtained through in vivo stress profilometry under similar loading conditions to those applied in the simulations.

Results
Simulating a “normal” disc with a fixed charge density (FCD) for the Nucleus of 0.3 M and annulus of 0.2M results in a uniform matrix stress profile from posterior to anterior (fig. 2). After the reduction (half) of the FCD in both nucleus and annulus the stress profiles are not uniform anymore. Stresses in the nucleus decrease. Axial annulus stresses exhibit peaks on anterior and posterior side. The stress peaks increase with a decrease of the FCD under the same loading conditions.

Discussion & Conclusion
Both experimental data and numerical simulations exhibit a sharp peak of axial stress in the posterior annulus and lower peaks in the anterior annulus. The occurrence of the peaks in the numerical simulation depends on level of FCD in the disc. Decreasing the FCD shows clearly the development of stress peaks in the annulus. A uniform stiffness is seen in the nucleus region, but not in the annulus anymore. The hydrostatic pressure, due to the FCD is not high enough to evenly distribute the load over the whole disc. The posterior stress peaks may explain why hernia develops particularly in the posterior annulus [5]. We recommend to verify the relationship between nucleus fixed charge density and the occurrence of annulus stress peaks experimentally.

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Reference