Evaluation of a biochemical/biophysical intervertebral disc model

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Introduction
FE models have become an important tool to study load distribution in the healthy and degenerated disc (Fig 1). However, in most models, degeneration is simulated phenomenologically, but not according to matrix composition. We have developed a novel 3D disc model that accounts for pre-stressing of collagen fibers due to physical principles of osmosis and is based on experimentally quantified material properties from human tissue that are dependent on matrix biochemical composition [1].

Objective
In this study, the 3D disc model is corroborated with experimental data of whole discs from literature.

Material & Methods
The disc model resembled one forth of a full disc [1]. The model distinguished between an elastic non-fibrillar solid matrix, a 3D viscoelastic collagen structure and an osmotically pressurized fluid [1,2]. The bulging and creep behavior of the 3D disc model was confronted with experiments of whole discs from the literature (radial bulging, height change and intradiscal pressure) [3,4].

During corroboration 4 adaptations to the model were explored. The fibrillar matrix was extended to incorporate smaller secondary fibril structures, e.g. minor collagen, elastin, etc. The shear stiffness (Gm) was also varied.

Results
Table 1. Results of disc deformation in comparison to Heuer et al. [4]

<table>
<thead>
<tr>
<th>Disc deformation</th>
<th>Model adaptation 3</th>
<th>Heuer et al.[4]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Height change</td>
<td>-0.87mm</td>
<td>- (1.00 - 1.35mm)</td>
</tr>
<tr>
<td>Radial bulging ON → 500N</td>
<td>0.61mm</td>
<td>(0.46 – 1..34mm)</td>
</tr>
<tr>
<td>Creep 500N over 900s</td>
<td>0.1mm</td>
<td>0.1mm</td>
</tr>
</tbody>
</table>

Discussion
Radial bulge, axial creep deformation (Table 1) and intradiscal pressure (Fig 3.) were in good agreement with the experiments from the literature, provided that the simplified fiber structure was extended with a more complex secondary fiber structure. This reduced the deformability of the 3D model and a slightly increased shear stiffness (1.5x) ensured convergence of the highly non-linear simulations.

Conclusion
The evaluated 3D disc model may now be used to explore the biomechanical implications of disc degeneration on its function and integrity as well as to explore therapeutic mechanisms for repair and regeneration.

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References: