A model of early degenerated disc

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Introduction

Our fiber reinforced osmoporviscoelastic (FR-OPVE) micromechanical cartilaginous tissue model based on constituent content and their material properties could capture the normal mechanical behavior of both nucleus pulposus and annulus fibrosus tissues of a normal intervertebral disc (IVD) (Fig 1) [1].

Aim: Investigate if orientation of the collagen network in an early degenerated disc can be assumed to be similar to healthy discs in order to model their tissue mechanical behavior using a multi-scale model of the disc.

Approach

Tissue from human Pfirrmann grade III discs (Fig 2) were previously mechanically tested (tensile and confined compression) and their constituent contents biochemically determined (table 1) [2]. Assuming no change in collagen fiber orientation to that of a healthy disc (grade 1), the constituent material properties will be calculated by fitting the FR-OPVE tissue model to the mechanical test results. Goodness-of-fit to the experimental data as well as reasonable constituent material properties will be evaluated.

Fig 2. Lumbar intervertebral discs sectioned in the mid-sagittal plane, (A) Grade 1 disc; (B) Grade 2 disc; (C) Grade 3, showing moderate degenerative changes; (D) Grade 4 disc, showing severe degenerative changes.

Preliminary results

In a previous study [2], by only accounting for the altered biochemical contents of grade 3 discs, no good fit could be obtained between experimental and numerical data (Fig 3). However, these results were biased by incomplete biochemical data.

Further work

• Redo the fit between experimental data and FR-OPVE model using the complete biochemical dataset, assuming similar collagen network orientation as in a healthy IVD (in progress).

• If no acceptable fit between experimental and numerical data can be obtained, orientation of the collagen network in grade III disc will be measured (MRI or microscopy). The outcome of these measurements will be integrated in the model and the fit redone.

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References:


Table 1: Biochemical content of human Pfirrmann grade III discs.

<table>
<thead>
<tr>
<th></th>
<th>Water [% WW]</th>
<th>GAG [μg/mg DW]</th>
<th>FCD [mg/mL]</th>
<th>Collagen [μg/mg DW]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nucleus</td>
<td>74.99 (3.54)</td>
<td>60.61 (16.56)</td>
<td>0.28 (0.12)</td>
<td>168.49 (68.67)</td>
</tr>
<tr>
<td>Annulus</td>
<td>71.36 (3.93)</td>
<td>77.88 (15.31)</td>
<td>0.31 (0.16)</td>
<td>334.64 (76.62)</td>
</tr>
</tbody>
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Fig 3. Confined compression simulation: mean experimental stress-relaxation curves ± SD and best model solution for (a) nucleus.