Finite element modeling of the full lumbar spine with an intervertebral disc nucleus replacement device

Jessica S. Coogan1, W. Loren Francis2, David C. LoPresti3, Travis D. Eliason1, Todd L. Bredbenner, James D. Lutz, Nadi S. Hibri, Daniel P. Nicolella1

1Southwest Research Institute, San Antonio, TX, 2Spine Stabilization Technologies, San Antonio, TX, 3NovaSpine Pain Institute, Sun City, AZ

Introduction

• Nuclear replacement technologies are a minimally invasive treatment for degenerative disc disease.
• Nuclear replacement may better restore the natural biomechanics of the spine compared to alternative treatments.
• Finite element (FE) modeling can be used to determine the biomechanics associated with nuclear replacement devices.
• A novel nucleus replacement device was developed consisting of a conforming silicone implant with two chambers.
• FE modeling compared the biomechanics associated with the novel device, a solid silicone device, and a normal disc.
• A model of the full lumbar spine was used to investigate the effect of device placement in one level on adjacent levels.

The objective of this work was to develop a FE model of the full lumbar spine that incorporates nucleus replacement devices and determine the resulting biomechanics.

Materials and Methods

• A 3D FE Model of the T12-L5 lumbar vertebrae was constructed from CT data.
• Vertebrae bodies were semi-automatically segmented from the imaging data and meshed.
• Intervertebral discs constructed by space-filling area between vertebral endplates.
• Tension only springs were added to model ligaments.

• Normal disc properties and ligament properties were derived from literature references [1-4] and given in Table 1.

<table>
<thead>
<tr>
<th>Structure</th>
<th>Property</th>
<th>Value(s)</th>
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<tbody>
<tr>
<td>Nucleus</td>
<td>Bulk Modulus (MPa) [1]</td>
<td>1.7</td>
</tr>
<tr>
<td></td>
<td>Yield Modulus (MPa) [2]</td>
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<td></td>
<td>Poisson’s Ratio [2]</td>
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<tr>
<td>Amnulus</td>
<td>Coefficient (G)</td>
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<tr>
<td></td>
<td>Characteristic times (s)</td>
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<td>Viscelastic Coefficients [3]</td>
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<tr>
<td></td>
<td>0.090</td>
<td>0.031 s</td>
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<tr>
<td></td>
<td>0.085</td>
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</tbody>
</table>

Results

• Under compressive loading, the novel device resulted in slightly more axial displacement, and the solid device resulted in less axial displacement compared to baseline (normal disc).
• The displacement of adjacent levels remained unchanged with the introduction of the devices.

Discussion

• We have developed a finite element model of the full lumbar spine that incorporates a novel nucleus replacement device.
• The full spine biomechanics were determined with a nucleus replacement device placed in a single level.
• Placement of the device did not have adjacent level effects on axial displacement under compression loading or annulus stress under rotation loading.
• The solid device resulted in less axial displacement, more endplate stress, and less annulus stress compared with the novel device and the normal disc.

References


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