A Finite Element Study of L5-S1 Spinal Biomechanics
Comparing Different Surgical Therapies.

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Objective:
Surgical therapies in the L5-S1 disc space vary in terms of their biomechanical effects. Many finite element models have been developed to help understand the biomechanics of the normal and treated lumbar spine, however few represent the L5-S1 segment due to its complex geometry.

This study evaluates the effect of various surgical therapies on the biomechanics of the L5-S1 spinal segment utilizing a finite element model.

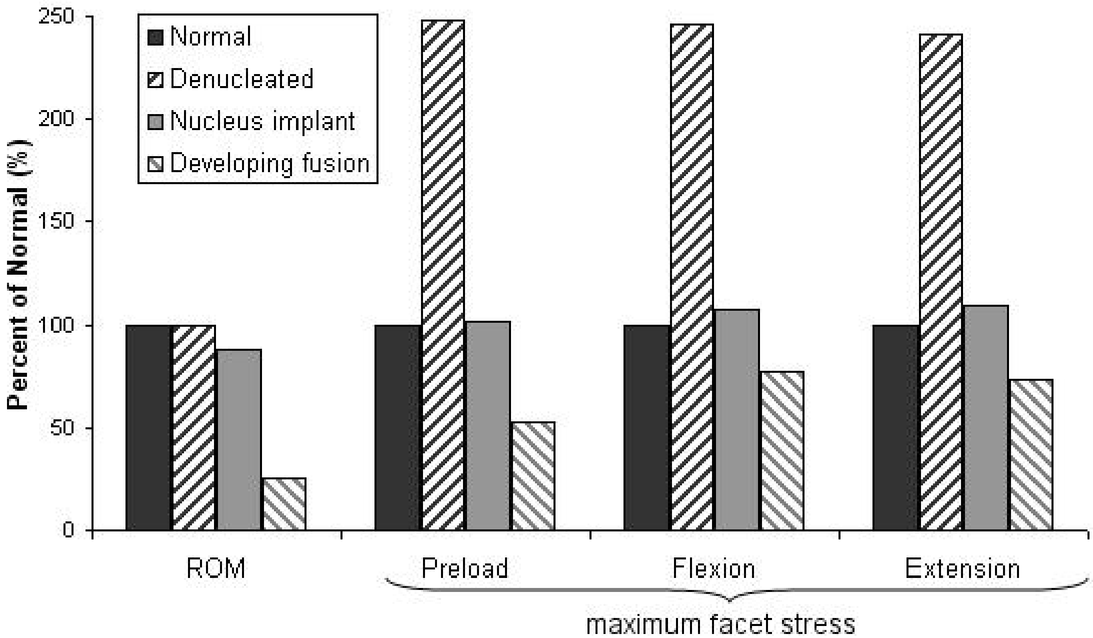
Methods:
A 3D nonlinear finite element model of the L5-S1 motion segment was developed. Tissue properties were sourced from the literature. In order to accommodate the nonuniform geometry and lordosis of the L5-S1 disc, fibers were modeled as reinforcement layers (rebars) in surface elements for three annular layers. Careful attention was paid to facet geometry to correctly model its role in segmental biomechanics. The model was validated against *in vitro* data (L5-S1 range of motion (ROM), center of rotation, facet motion) [Beaubien, SAS, 2007], and published values (intradiscal pressure, axial compressive stiffness, fiber mechanics) [Shirazi-Adl, Spine, 1984].

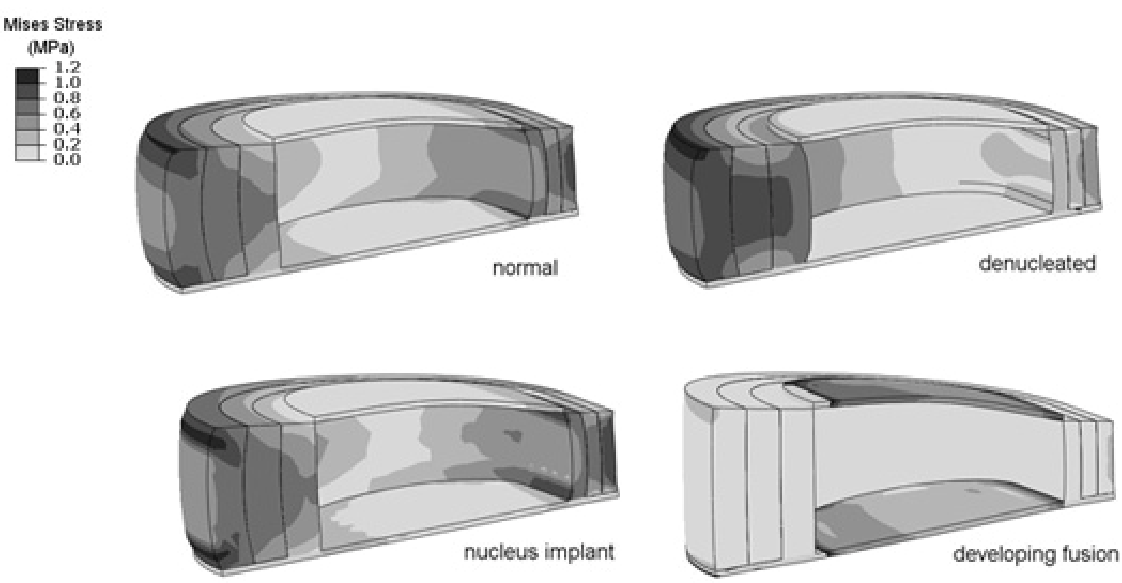
Surgical therapies were simulated by varying the nucleus space contents as follows: normal segment (fluid-filled), denucleated (empty), nucleus implant (*in situ* formed silicone), and developing fusion (simulated cortical bone). All segments were subjected to ±7.5 Nm flexion/extension with a 400N preload. Segmental ROM, facet contact stress, and stress distributions in disc tissues were analyzed.

Results:
Segmental ROM did not change with denucleation compared to normal, slightly decreased with the nucleus implant (13%) and dramatically dropped with the developing fusion (75%). The changes in the maximum facet stresses compared to the normal segment are: 145% increase with denucleation, 32% decrease with developing fusion and 6% increase with the nucleus implant (Fig.1).

The stress distribution in the annulus and endplates indicates that after denucleation, inward annulus bulging provides the main support to the applied loading, creating high stresses in the annulus layers. With a developing fusion, segment stresses are concentrated on the underlying endplate. Nucleus implant placement restores the normal stresses in the annulus and the endplate (Fig.2).

Conclusions:
In this finite element study, denucleation altered the L5-S1 disc mechanics and more than doubled facet stress compared to the normal disc. A simulated developing fusion resulted in a dramatic reduction in loading of the facet joints, high stresses on the endplates and minimal annulus stresses. The study also predicted that an *in situ* formed nucleus implant restores normal stresses in the facet joints and disc tissues.


250
200
150
100
50
0
Percent of Normal (%)
Normal
Denucleated
Nucleus implant
Developing fusion
ROM
Preload
Flexion
Extension
maximum facet stress


Mises Stress
(MPa)
1.2
1.0
0.8
0.6
0.4
0.2
0.0
normal
denucleated
nucleus implant
developing fusion