

## A FINITE ELEMENT EVALUATION OF TWO-LEVEL DISC REPLACEMENT IN THE LUMBAR SPINE

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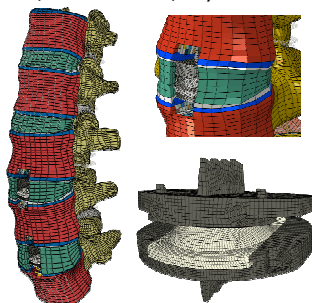
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### Introduction

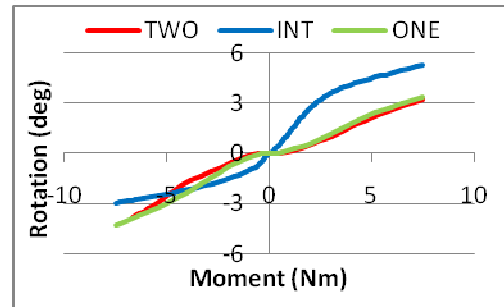
Total disc replacement (TDR) has become an appealing alternative to spinal fusion for treating spinal degeneration and discogenic pain. In theory, TDR holds the potential to restore intact state kinematics and biomechanics of spinal motion segments. Recently, TDR has been utilized on multiple lumbar levels to treat multi-level spinal pathology. However, the biomechanical consequences of multi-level TDR implantation have not been elucidated. The objective of this study was to assess the biomechanical changes, if any, as a result of single and two level disc replacement in the lumbar spine.

### Methods

A previously developed nonlinear finite element (FE) model of the human lumbar spine was utilized. The annulus fibrosus was modeled as a nonlinear anisotropic continuum, with variable fiber orientations and mesh refinement was verified for the mechanical predictions for individual soft and osseous tissues. The range of motion (ROM), facet force transmission (FFT), intradiscal pressure and bony strain predictions were validated by comparison to experimental data. The prosthetic device geometry (ProDisc-L, Synthes Inc, West Chester, PA) was based on CAD data and meshed using 8-noded hexagonal elements (Figure 1). The implantation was simulated by a complete nucleotomy, removal of the inner annular layers, and removal of the anterior region of the annulus fibrosus. The endplates of the ProDisc-L were tied to the inferior and superior endplates of the vertebral bodies at the treated level. Three conditions were simulated: intact (INT), single level treatment at L3/L4 level (ONE) and two level treatment at L3/L5 (TWO). All models were tested under 7.5Nm of pure-moment loading in three principal directions (flexion/extension, lateral bending and axial rotation) and solved with ABAQUS Standard (ver. 6.8, Simulia, Providence, RI)



**Figure 1:** The FE model with two treated levels (left) and the ProDisc-L mesh



**Figure 2:** ROM predictions for L3L4 in flexion(+) and extension(-).

### Results

Both treatment cases resulted in increased ROM and FFT in extension at the operated levels. On the other hand, ONE resulted in the reduction in ROM and facet forces in all directions except for extension at the inferior level (Table 1). The impact of treatment on the inferior level was observed to be greater than that on the superior level for all loading scenarios with the ONE condition. The nonlinearity of the motion pattern at the treated levels was reduced (Figure 2).

	ROM(deg)			FFT(N)		
	INT	ONE	TWO	INT	ONE	TWO
<b>L1L2</b>	2.72	2.75	2.76	51	53	54
<b>L2L3</b>	2.83	2.35	2.36	86	52	53
<b>L3L4</b>	2.27	2.5	2.41	112	128	126
<b>L4L5</b>	3.6	2.71	3.93	93	65	119

**Table 1:** ROM and FFT predictions under axial rotation in all levels.

### Discussion

The biggest effect of treatment on the spinal segments was observed to be the increased FFT and ROM at the operated levels in extension. On the other hand, two level disc replacement was not observed to have a big impact on the biomechanical behavior as opposed to single level treatment. There was no substantial change in the total flexion/extension ROM magnitude consistent with previous findings (Panjabi et al., Spine, 2007), however a shift in the moment rotation curve and reduction in the nonlinearity was observed (Figure 2). Furthermore, the relatively large changes in FFT as opposed to ROM indicate that internal biomechanical parameters (such as FFT) should be quantified, in addition to kinematics, in order to accurately assess the clinically relevant changes induced by TDR.