# BIOMECHANICS OF THE PRODISC ARTIFICIAL DISC USING FINITE ELEMENT ANALYSIS

Yabo Guan, Frank A. Pintar, Narayan Yoganandan, Jiangyue Zhang, Dennis J. Maiman

Department of Neurosurgery, Medical College of Wisconsin
VA Medical Center, Milwaukee, Wisconsin

## INTRODUCTION

Surgical treatments for degenerative disc disease can be grouped into two categories: fusion (arthrodesis) and total disc replacement (arthroplasty). Because fusion limits motion of the fused segments, it is believed that fusion may induce or accelerate degenerative change at adjacent levels. As an alternative to interbody fusion, an artificial disc serves to replace the degenerated disc and restore the functional biomechanical properties of the motion segment. The objective of this study is to develop an experimentally validated three dimensional nonlinear finite element (FE) model of lumbosacral spine to provide useful information for artificial disc designers and examine the effects of surgical treatment on the structure for clinicians.

## METHODS

An intact 3D L4-S1 lumbosacral spine nonlinear FE model was used. The 3D geometrical details for FE model were obtained from computed tomography (CT) images of a human cadaver. CT data were imported into Mimics and geometrical surfaces of the lumbosacral spine were generated. The exported IGES files from the Mimics software were inputted to TrueGrid to create a hexahedral finite element mesh. The model included intervertebral discs, vertebral bodies, ligaments, and facet joints. The model was validated against the experimental data in flexion and extension, left and right lateral loadings[2]. Then the model was modified to implant a Prodisc artificial disc into L5-S1 level (Figure 1). The disc consists of two cobalt-chrome alloy end plates that are plasma sprayed with titanium and have two vertical keels for fixation in the vertebral bodies and a polyethylene inlay. The material properties used for the disc are shown in Table 1. The elements representing the L5-S1 disc and anterior longitudinal ligament were removed at L5-S1 level. Posterior longitudinal ligament remained unchanged. The contact between the plate and vertebral body was simulated using a tie constraint. A surface-based contact was used to simulate the sliding between upper metallic plate and polyethylene inlay. The coefficient of friction between plate and inlay was assigned as 0.05. All nodes on the inferior surface of S1 were constrained in all degrees-of-freedom. A pure moment up to 4.0 Nm was applied through a coupling element which is coupled with all nodes on the superior surface most of the entire L4 vertebra. Flexion and extension loading conditions were used. The intersegmental sagittal rotations under flexion and extension bending moments were obtained. The contact pressure on the interface between cobalt-chrome endplate and polyethylene inlay were obtained.

## RESULTS

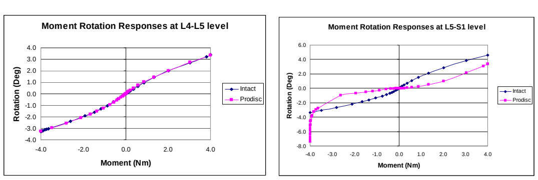
The rotation-moment response curves for both intact (no surgery) and Prodisc model at unimplanted level (L4-L5) are shown in Figure 2(a). The intersegmental rotations under flexion were $3.3^0$ and $3.4^0$ for intact and Prodisc, respectively. Under extension, these values became the same at $3.2^0$. The rotation-moment response curves at implanted level (L5-S1) are shown in Figure 2(b). The intersegmental rotations under flexion were 4.50 (intact) and 3.40 (Prodisc), respectively. Under extension, these values became $3.3^0$ (intact) and $7.3^0$ (Prodisc). The history of contact pressure occurred on the surface of inlay was shown in Figure 3.

## DISCUSSION / CONCLUSIONS

The rotation-moment response curves imply that the implantation of Prodisc does not affect the motions at adjacent level under both flexion and extension. At implanted level, the rotation decreased by 24% under flexion and increased by 120% under extension. High value of rotation predicted under extension was mainly caused by the complete annulotomy and can be explained as following. When the anterior longitudinal ligament was removed, there is no motion restraint under extension except for the contact constraint between superior plate and inlay. Other FE studies have shown that reconstruction of anterior longitudinal ligament may restore the biomechanical function[1,3]. Preserving the posterior portion of annulus or the lateral annulus may improve stability. Secondly, without the compressive preload, after certain amount of pure moment, the superior plate no longer contacted the inlay. This can be demonstrated by the abrupt motion change under extension shown in Figure 2(b). The history of contact pressure on inlay also indicated that superior plate detached from the inlay after 2.0 Nm moment was applied. Although the body weight can produce compressive loading to alleviate this scenario, the predication from computer model may suggest that excessive extension should be avoided for patients implanted with artificial disc.

Under flexion, the contact pressure increased constantly with the increase of moment and reached the largest at the moment of 3.0 Nm. The contact was occurred at the anterior region of polyethylene inlay (Figure 4). Contact pressure is much lower during extension due to the mechanism mentioned above. These results indicated that anterior region of inlay may be the most likely worn.

**Figure 1:** L4-S1 FE model with Prodisc implanted at L5-S1.




(a) (b)

**Figure 2:** Moment-rotation responses at (a) L4-L5 level and (b) L5-S1 level.

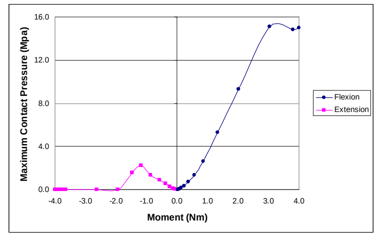



**Figure 3**: History of contact pressure on the inlay.

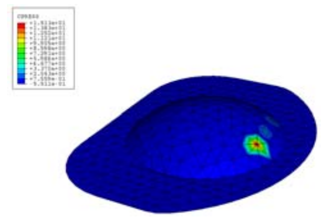


**Figure 4:** Contact pressure contour under flexion when highest value reached.

**Table 1.** Material properties used for Prodisc.

| | Young Modulus (Mpa) | Poisson's Ratio |
|---|---|---|
| cobalt-chrome alloy plate | 220,000 | 0.32 |
| polyethylene inlay | 1,000 | 0.49 |

## REFERENCES


1. Dooris AP, Goel VK, Grosland NM, et al. Load-sharing between anterior and posterior elements in a lumbar motion segment implanted with an artificial disc. Spine 2001;26:E122-9.
2. Guan Y, Yoganandan N, Zhang J, et al. Validation of a clinical finite element model of the human lumbosacral spine. Med Biol Eng Comput 2006;44:633-41.
3. Rohlmann A, Zander T, Bergmann G. Effect of total disc replacement with ProDisc on intersegmental rotation of the lumbar spine. Spine 2005;30:738-43.


## ACKNOWLEDGEMENTS


The study was supported in part by a grant from Synthes Spine, L.P.