IMPLICATIONS OF ARTIFICIAL DISC DESIGN ON THE INTERSEGMENTAL BIOMECHANICS OF THE LUMBAR SPINE

Chen, W M[1]; Ahn, Y H[1]; Lee, K Y[2]; Park, C K[3]; Lee, S J[1, 4]

1Department of Biomedical Engineering, Inje University, Gimhae, Korea
[2]Department of Mechanical Engineering, Sejong University, Seoul, Korea
[3]Department of Neurosurgery, Kangnam St.Mary's Hospital, the Catholic University of Korea, Seoul, Korea;
[4]Paik Institute for Clinical Research, Inje University, Busan, Korea
sjl@bme.inje.ac.kr, Tel: +82-55-326-5747, Fax: +82-55-327-3292

INTRODUCTION:

Design of total disc replacement (TDR) prosthesis plays an important role in the long-term clinical performance of these implants. Prodisc-L (Spine Solutions, Inc. Synthes, Paoli, PA, USA), a semi-constrained TDR system, has a ball-and-socket based design; whereas SB Charité III (DePuy Spine, Inc, Raynham, MA, USA) has a theoretically unconstrained articulation which allows the mobile core to slide freely in the A-P direction between two metal endplates during spinal motion. The biomechanical efficacies of these two TDR designs on lumbar spine kinematics and loading transfer have not been fully elucidated. In this study, a finite element (FE) analysis was performed to evaluate the range of motion (ROM) changes and facet load transfer of the lumbar spine following TDR with semi-constrained (Prodisc-L) and unconstrained (Charité III) disc prostheses.

METHODS:

A validated, three-dimensional, intact osteoligamentous lumbar segments L2-L4 FE model was created as the baseline case. Seven major groups of ligaments were represented by non-linear cable elements. The facet joint articulations were modeled by contact gap elements. The intact model was altered to accommodate the TDR prostheses. Both Prodisc-L and Charité III were designated to be implanted by anterior approach into the L3-L4 disc space (Figure 1). The anterior longitudinal ligament, superior, inferior endplates were removed, while preserving about 30~32% of the lateral annulus.

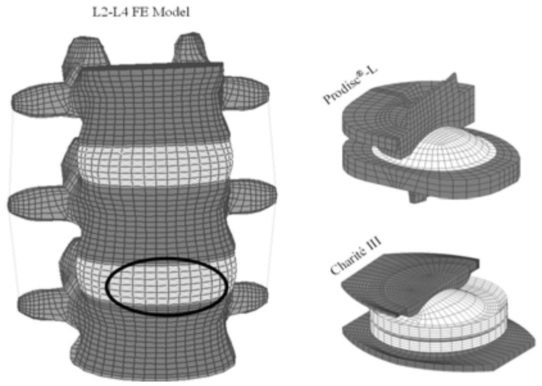

Figure 1. The intact lumbar FE model (L2-L4) was modified to accommodate the Prodisc-L and Charité III at L3-L4 level.

Since our model was aiming to simulate the biomechanical behavior after healing, the bone-implant interface behavior was accomplished via “tie” contact condition, which enables the ADR endplates and vertebrae to be bonded together permanently by full constraint. The mobile feature of the TDR implants were simulated by surface based “finite sliding” contact in ABAQUS, which allows arbitrary large sliding and rotations between two surfaces.

A coefficient of friction 0.04 between the CoCrMo Alloy and UHMWPE was chosen [1]. Both the intact model and surgical model were subject to 400N compressive pre-load and 10Nm of flexion/extension moments at the superior endplate L2, while the inferior endplate of L4 was fully constrained.

RESULTS:

Following TDR with Prodisc-L, flexion motion at both implanted level (L3-L4) and its adjacent level (L2-L3) remained unchanged, while during extension ROM of the implanted level had a 91.4% increase and showed a decrease of 6.8% at the adjacent level. For TDR with Charité III, the ROM at implanted level increased by 30% in flexion and 123.7% in extension. The facet contact force at the same implanted level for two types of artificial discs were increased, and that of the Prodisc-L were less than that of the Charité model (Figure 2).

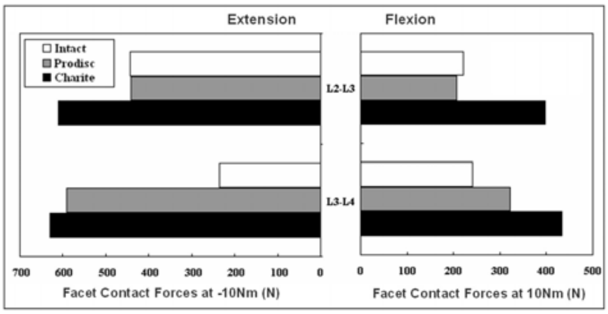

Figure 2. The predicted facet contact force during lumbar flexion/extension motion.

CONCLUSION:

Under current loading control, both semi-constrained (Prodisc-L) and unconstrained (Charité III) disc prostheses exhibited larger ROM in the sagittal plane than intact spine, although the ROM remained within the physiological motion range found in the literature [2]. Charité III showed more mobility than Prodisc-L, especially for extension motion. Moreover, the “unconstrained” feature of the Charité III may also be blamed for the more stressed facet joint at the implanted level during flexion/extension motion due to its lacking of supporting intervertebral shear, which may increase the risk for facet joint degeneration.

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References:
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