Biomechanical Comparison of Three Types of Artificial Discs in Total Disc Replacement of Lumbar Spine

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Introduction: Even though spinal fusion has been used as one of the common surgical techniques for degenerative lumbar pathologies, high stiffness in the fusion segment could generate clinical complications in the adjacent spinal segment such as disc degeneration and facet arthrosis [1]. To avoid these limitations of fusion, recently, various kinds of artificial disc (AD) implants have been recognized to treat degenerative disc diseases as non-fusion techniques in spite of clinical controversies such as implant wear and facet arthrosis. In this study, we compared the biomechanical characteristics of three clinically available AD implants, including spinal motion at the adjacent level, contact force of the facet joint, and distribution of von-Mises stress within polyethylene core of AD, which were investigated by finite element analysis.

Materials and Methods: A three-dimensional finite element model of five spinal motion segments, from L1 to S, in intact lumbar spine was reconstructed from 1mm thick computed tomography (CT) images. The CT images were taken from a healthy human body whose height and age were 175cm and 21 years. The finite element model which consisted of six vertebrae, five intervertebral discs, and seven kinds of ligaments was developed to be symmetric across the mid-sagittal plane. Clinical data and results of previous studies were taken for material properties of the model and attachment points of ligaments [2, 3].

Three dimensional finite element models of three ADs, semi-constrained and metal on polyethylene core type (ProDisc® II, Spine Solutions Inc., USA; Type I), semi-constrained and metal on metal type (Maverick™, Medtronic Sofamor Danek Inc., USA; Type II), and un-constrained and metal on polyethylene core type (SB Charite™ III, Dupuy Spine Inc., Switzerland; Type III) were developed. Each artificial disc was inserted at L4-L5 segment of each implanted model, respectively. Upper and lower plates of ADs were attached on the L4 and L5 vertebrae. Anterior longitudinal ligaments and anterior part of intervertebral disc in L4-L5 motion segment were removed to insert ADs. Nonlinear three dimensional contact conditions were applied on facet joints in lumbar spine model and artificial discs. Bottom of sacrum was fixed on the ground and 5Nm of flexion and extension moments were applied on the superior plate of L1 with 400N of compressive load along follower load direction.

Results: In extension, all three AD models showed higher rotation ratio at the surgical levels, but lower rotations at the adjacent levels than those in the intact model (Fig. 2). There was no big difference of the intersegmental rotations among the AD models. For the comparison of the peak von-Mises stresses on the poly-ethylene core in flexion, 52.3 MPa in the semi-constrained type implant (Type I) was higher than 20.1 MPa in the un-constrained type implant (Type III) while the peak von-Mises stresses were similar, 25.3 MPa and 26.5 MPa in Type I and III, respectively in extension. The facet contact forces at the surgical level for the AD models showed 140 to 160 N in extension whereas the facet contact force in the intact model was 60 N (Fig. 3).

Discussion: From the results of this study, we could investigate the biomechanical characteristics of three different AD models. First, the relative rotation at the surgical level would be increases at the early outcome after total disk replacement. Second, the semi-constrained type AD could generate higher wear risk of the implant than un-constrained type Finally, All types of AD model have higher risk of facet joint arthrosis, and especially in the semi-constrained and metal on metal type. The results of the present study suggested that more careful care must be taken to choose optional option of total disc replacement surgery.


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