Evaluation of Kinematic and Load Transmission due to Implantation of a Cervical Artificial Disc

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Disclosures:

Introduction: Anterior cervical disectomy and fusion (ACDF) has been well known as a gold standard treatment for degenerated cervical discs in spinal surgeries. However, clinical studies have reported that immobility of the fused level leads to an increase in rate of degeneration at levels adjacent to the fused site, which is a serious long-term concern with ACDF surgery. It has been hypothesized that an increase in intradiscal pressure (IDP) can block the diffusion of nutrients from the endplate to disc. Inappropriate nutrition of discs has been recognized as the major cause of disc degeneration [1]. Total disc replacement (TDR) has been introduced as an alternative surgical method to treat degenerated disc disease of cervical spine, because it can preserve motion of the implanted segment and limits changes in IDP caused by fusion. Despite the encouraging short term outcomes of TDR, there are major concerns about complications such as subsidence, dislocation, heterotopic ossification and increases in contact forces of facet joints at the treated or adjacent levels. Overloading of the facet joints may accelerate degeneration of the articular cartilage (AC). Some experimental and a few number of finite element (FE) studies have investigated the effect of TDR on biomechanics of the cervical spine. The objective of this study is to evaluate a ceramic on ceramic, mobile core, cervical artificial disc and its effects on the kinematics, and loads on the facet joints and intradiscal pressure.

Methods: A 3D FE model from C4 to C7 was developed, using 0.7 mm thick computed tomography (CT) data from a 25 years old young healthy individual. The FE model consisted of cortical, cancellous, posterior element for each vertebrae and annulus fibrosis, nucleus pulposus and cartilaginous endplate for each intervertebral disc (IVD), facet joints and five ligaments. Results of previous experimental and clinical studies were used for material properties in our model. Also, anthropometric data was used to define the geometry of soft tissues such as, cross sectional areas of annulus ground and nucleus, area and angle of fibers, length and attachment point of ligaments and facet cartilage areas. Nonlinear 3D contact algorithm was implemented on facet joints to simulate behavior of these joints [2]. Finite element model was developed in commercially available code ABAQUUS 6.10 (SIMULIA Inc. Providence, RI, USA) (Figure 1-a). The inferior surface of C7 was fully constrained and a moment up to 2 N.m. was applied to superior surface of C4. The intact FE model was validated by comparing range of motion (ROM) with previously published experimental data for the flexion-extension [3], lateral bending [4] and axial rotation [5] moments. The validated model was altered by eliminating the IVD, anterior longitudinal ligament (ALL), superior and inferior endplates to include disc prosthesis-DisocervTM mobile core artificial disc- at C5-C6 motion segment of the model.

Results: The model response in all different load cases was in good agreement with experimental results, with all motion segments being within one standard deviation of the experimental average. Arthroplasty showed an increase in ROM at C5-C6 motion segment, and a decrease in ROM at the adjacent levels (Figure1-b-e). TDR showed a decrease in ROM at segments adjacent to implanted level less than 10% in all load cases. However, at C5-C6 level ROM showed an increase of 12.5% and 22.3% at 2 N.m. and 1 N.m., respectively in flexion, and 20% and 35% at 2 N.m. and 1 N.m., respectively in extension. Also, in lateral bending mode, ROM increased 11.4% and 21% at 2 N.m. and 1 N.m., respectively. Moreover, TDR resulted in negligible changes in ROM in axial rotation mode for all of the motion segments. Evaluation of total facet contact forces for 2 N.m. moment showed that although forces in segments adjacent to implanted level changed very little, but load of facet joints in implanted level enhanced significantly. As the figure 2-a shows after TDR, in extension mode, total force increased about 47%, but in lateral bending, total force showed a 29% increase. In addition, facet joints must tolerate 55% additional load in axial rotation compared to the intact one. Assessment of IDP at 2 N.m. moment, showed that nucleus pressure does not change significantly after arthroplasty compared to intact status. Figure 2-b shows that changes in IDP are less than 10% after TDR.

Discussion: The results of this study indicate that cervical artificial disc shows higher ROM in lower moments than the natural disc. However, as the moment increases ROM gets close to the intact state. This phenomenon can be explained if the stiffness of a motion segment is taken into account. After eliminating major part of IVD and ALL at C5-C6 level, the stiffness of this motion segment mostly depends on facet joints and ligaments. Also, because the stiffness of ligaments in lower moments is in the toe region, the stiffness of implanted segment will drop significantly in small moments. Some studies have shown that an increase in facet contact force significantly depends on center of rotation and positioning of artificial discs. Motion preservation of implanted segment allows other components of the motion segment, such as facet joints and ligaments, to tolerate some part of the total load; consequently this prevents overloading of adjacent intervertebral discs compared to ACDF. Although using the
artificial disc with the goal of motion preservation can prevent the increase of IDP at adjacent levels, overloading of facet joints in implanted segment may increase the risk of degeneration in these joints.

**Significance:** Understanding the biomechanical differences of the intact and replaced disc model was the main scope of this study. Motion and load distribution among different components of spinal segments under different load configuration is an important issue in understanding the spinal system’s disorders. Alteration in intradiscal pressure and facet joint forces may lead to degeneration and also pain in the spinal system.

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Figure 2: Changes of: a) Total facet contact forces, and b) JDP

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