BIOMECHANICAL ANALYSIS OF THE CERVICAL DISCECTOMY AND FUSION USING A THREE SEGMENT MODEL

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INTRODUCTION: Anterior discectomy and fusion (ACDF) is the main surgical procedure for the patients with cervical disc diseases and spondylosis. The Smith-Robinson technique has been a common procedure of the ACDF since 1950. However, the biomechanical effect of the stability of the segment which has undergone fusion as well as the change in flexibility in the adjacent segments have not been well defined in the literature. The present study attempts to quantify percentage changes in flexibility in the fusion segment (C5-C6) and the adjacent segments (C4-C5 and C6-C7) under moment loadings using three segments (C4-C7) finite element model. It is hypothesized that (1) change in stiffness in the fused segment would be much greater than the stiffness changes in adjacent segments and (2) the overall change in stiffness over the three segments due to fusion in the mid segment is small as compared to the change in fused segment stiffness.

MATERIAL & METHOD: Finite element modeling was used for this study. The Smith-Robinson procedure with fusion was modeled for the experiment. A three dimensional non-linear finite element model of an intact C4-C7 cervical spine segment was developed using CT scans of 38-year-old female normal subject. The CT slices were digitized using CAD programs to construct three-dimensional model of the vertebrae, uncinate processes and the intervening discs. The model included fiber reinforced annular fibers represented by cable elements whose cross-sectional area decreased along radial direction from outer portion of annulus. The nucleus was modeled by fluid elements. Ligaments were modeled using non-linear “no compression” uni-axial elements (cable elements). Insertion points of various ligaments were determined from the CT scans. Facet joints assumed inclined at an angle of 45 degrees to transverse plane were modeled by three-dimensional moving contact surface elements. To simulate cartilage layers at the facet joints, three-dimensional elements with cartilage properties were attached to facet contact surfaces. Initially the facet contact surfaces were assumed to be in contact (gap=0.02 mm) with each other. Material properties for the current model were taken from the literature. The analyses were conducted using large displacements small strains theory since it is known that the cervical spine undergoes large displacements due to applied loads. For all the load cases, nodes in the inferior surface of C7 were assigned zero displacements in all directions. Moment load was generated by applying equal and opposite forces at the anterior most and posterior most nodes on the superior surface of C4 vertebra. The ACDF model (the Smith-Robinson procedure) was generated from the intact model by replacing the annulus and the disc of C5-C6 segment by fitting tight graft between the superior and inferior vertebra of C56. A graft of mean cross-sectional area equal to 75% of end plate area was used. The elastic property of the graft was taken as 3500Mpa to simulate iliac crest bone. The predicted responses due to moment loads
(0.6 Nm) along with a pre-load (40N) as a result of the model variations due to the Smith-Robinson procedure was studied to provide all the three displacements and rotations of C4 with respect to C5, C5 with respect to C6, C6 with respect to C7 and C4 with respect to C7 vertebrae.

**RESULT:** The present study showed that the anterior disectomy and fusion produced large decrease in motion as compared to intact segment at the fused segment level for all moment loads. An ACDF produced a reduction in flexion motion (Figure) of 68%, a 52% reduction in extension motion, a maximum of 91% reduction in lateral bending motion, and a 77% reduction in its principal motion under torsion. The adjacent disc motions increased in response to all the four-moment loads. Lateral bending produced an increase in motion of 25% at C6/C7 level and 18% at C4/C5 level. A 10% increase in motion was seen at C4/C5 level under torsion and at C6/C7 level under extension. All other increases at adjacent levels were less than 5%.

An overall (motion of C4 with respect to C7) increase in motion of less than or equal to 5% was observed under extension and lateral bending moment loads. Flexion and torsion moment loads produced a decrease in overall motion of 10% to 15% due to fusion at C5-C6 level.

**CONCLUSION:** The present study showed that the ACDF produced a stable segment at the fused level while increasing the flexibility of the adjacent segments nominally. The fused segment was more stable under torsion and lateral bending moment loads as compared to flexion/extension bending loading modes. The interbody graft effectively reduced the motion of all the three motion segments taken together under all the four-moment loadings. From the biomechanical point of view, the interbody fusion is more reliable for reconstructing the stability of the cervical spine after anterior decompression.