The biomechanical effect of adding a Dynamic Stabilization device to the degenerated lumbar spine: A Finite Element based study

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Introduction: Disc degeneration is one of the main causes of low back pain. Chronic patients may require surgery and the procedures vary from conservative treatment, dynamic systems to fusion with or without devices. Dynamic systems are used under the hypothesis that it will lessen the disc load at the treated level thereby relieving pain and limiting further degeneration, while minimizing the negative effects on the adjacent levels. Several design concepts ranging from springs to articulating type devices have been proposed. In this study finite element (FE) method was used to analyze the effect of a male-female type sling design concept – DSMM, a pedicle screw-based dynamic motion system, on the biomechanics of the lumbar spine, Fig 1.

Materials and Methods: A three dimensional, ligamentous, experimentally validated L3-S1 Finite Element (FE) model [1] was used to simulate the Dynamic fixation system. At first step, the L4-L5 disc height was reduced by 14% of its original height, the material property of the nucleus was modified (gel to fibrous structure) and 15% tears were created inside the annulus at the same level to simulate the disc degeneration. The associated ligamentous laxity was due to decrease in disc height and a 50% bilateral medial facetectomy was simulated at L4-L5 level. A pair of cobalt-chrome DSMM devices was used to stabilize the degenerative segment. The DSMM devices were attached to the pedicles using pedicle screws. The pedicle screws have adjustable heads and can be manipulated to set the IAR of the device in the proper anterior/posterior, medio-lateral and cephalad-caudal position. A compressive follower load of 400 N plus a bending moment of 10 Nm were applied to implanted, injured and intact models to simulate physiological extension, flexion, lateral bending and axial rotation. Motion and intradiscal pressure (IDP) across the segments were computed for all the cases.

Results: The motion and IDP values at the adjacent level (L3-L4) were similar to the intact and implanted model (Fig 2&3). In flexion, the motion at L4-L5 increased in injured model while in the implanted model, the motion was similar to the intact. However in extension, lateral bending and axial rotation, the motion at the implanted level decreased. The intradiscal pressure (IDP) increased significantly at the operative level in the injured model. The addition of the implant to the injured model significantly decreased the intradiscal pressure at operative level (L4-L5).

Discussion: In this study, we observed that addition of non-fusion based Posterior Dynamic Stabilizer is helpful in re-stabilizing the degenerative segment by controlling motion and reducing intradiscal pressures while avoiding excessive motion at the adjacent segment usually observed in the fusion-based treatments, especially in flexion mode. The decrease in IDP at the implanted level suggests that the device can unload the treated disc to an extent, affording an environment for its regeneration. The decrease in motion in other loading modes is due to presence of urethane bumpers which restrict compression and control the range of motion between male and female sliding components. This suggests that the bumpers play an important role and thus should be appropriately designed. Likewise, the effect of different settings of the device such as misalignment and anterior/posterior shifting of the device IAR on kinematics of the implanted segment can be investigated using the FEA. These parametric studies will help fine tune to the design setting stage for the other biomechanical studies.

References: (1) Goel et al. 2006 Spine.

Acknowledgements: Work support in part by a grant from Innovative Spinal Technologies Inc, Mansfield, MA.