INTRODUCTION

Posterior dynamic stabilization systems (PDS) has been proposed as an alternative solution for treatment of degenerative disc disease. PDS systems are designed to restore the kinematics of destabilized segment to its intact state. The objective of this study was to investigate the biomechanical effect of a novel PDS system on lumbar spine. A cadaveric experiment followed by a Finite Element (FE) modeling approach were used for this purpose.

MATERIALS AND METHODS

The dynamic stabilization system included a set of dynamic rod and dynamic screws. The diameters of each coil was so that there was no gap between each layer. To perform the cadaver testing, six fresh-frozen human lumbar spine specimens were used. The specimens were screened and the CT images were obtained to ensure that the specimens are healthy and free of any abnormality. Each specimen was cleaned and was potted an either ends prior to mounting on the testing machine, Figure 1. A set of LEDs, attached to a rigid plate, was affixed to each vertebrae to track the spatial motion at each level. Rods and screws were attached to the upper rigid block at the cranial end of the specimen for applying the physiological bending moment. Each specimen was tested as intact and instrumented state. The instrumentation was performed at L4-L5 level and included two surgical cases: Dynamic Screw and Dynamic Rod (DSDR) and Rigid Screw and Rigid Rod (RSRD). The screws and rods were made of stainless steel. For the surgical cases, a discectomy was performed at the index level prior to instrumentation.

Both intact and instrumented cases were subjected to a pure bending moment which was applied in increments of 1.5, 3.0, 4.5, 7.0 and 10 Nm (maximum) to simulate physiological flexion (Flex), extension (Ext), lateral bending (LB), and axial rotation (AR). The OptoTrak camera system was used to capture the instantaneous spatial coordinate of each LED and use these coordinates to compute the relative kinematics of each motion segment. A statistical analysis was performed on the obtained kinematic data using two-tailed paired Student's t-tests to determine whether significant changes in motion occurred after implantation. Repeated measures analysis of variance (ANOVA) followed by the Neuman-Keul's test was used to detect statistically differences between treatment intervention. A 95% confidence interval was assessed. P-values less than 0.05 were considered a significantly different.

A finite element (FE) evaluation was followed by cadaver experiment using a nonlinear and 3D model of L1-S1 segment, Figure 1. This model consists all main physiological features of the actual spine including bone, intervertebral disc and ligament group [1]. The FE model was validated with cadaveric data through simulation of same surgical scenarios the discectomy followed by instrumentation at L4-L5 same as in vitro. A 3D model of each instrumented construct was obtained, meshed and placed at L4-L5 of the FE model to simulate each surgical intervention. The rod ends were fixed into screw heads in each construct and screw shafts were affixed to pedicle hole at each level. A frictionless contact formulation was defined between coils of the left and right dynamic rods in the dynamic stabilized model. The kinematic results obtained from the FE cases were compared with those of in vitro experiment for validation of the model, then the FE model was used to predict the
important biomechanical feature i.e. peak stresses in the screws.

Figure 1: Lumbar spine instrumented at L4-L5: Cadaver spine (left), FE spine (right).

RESULTS

Post dynamic stabilization, the ROM was observed for all motion directions, Flex, Ext, LB and AR (Figure 2). At the treated segment, L4-L5, a statistically significant reduction in motion was observed for RSRR fixation in flexion (p<0.024), extension (P<0.020) and bending (P<0.024) (33%Flex, 56%Ext, 44%LB and 55%AR). After implantation, DSDR restored motion close to intact in all loading directions (P>0.05) (7.4° Flex, 5.4° Ext, 4.4°LB, 4.9°AR).

Figure 2: The FE data of range of motion compared with experimental data for intact vs. instrumented cases.

The FE model has ROM predictions for DSDR and RSRR within the range of experiment. In the FE model, the DSDR had motions with values of 6.9°, 5.7°, 5.3° and 5.9° in flexion, extension, left bending and rotation respectively. FE analysis predicted that the peak stress at the screw tail in DSDR case was 35, 26, 49 and 21MPa in Flex, Ext, LB and LR in respectively (Figure 3). In DSDR model these values were 108, 89, 110 and 128MPa respectively (Figure 3).

Figure 3: Peak stress in the pedicle screw in rigid and dynamic systems.

DISCUSSION

Both in vitro and FE simulations showed that all systems were able to stabilize the treated segment where DSDR restored the kinematics to intact. The data showed that the rigid system provides more constrained on the treated level. Dynamic system allowed near normal kinematic at the treated level which is resulted with less load distribution on the screw than rigid systems. The novel dynamic instrumentation avoids adjacent disc hypermobility. Rigid systems might cause screw failure due to high stress on the screw tails. However novel dynamic rod prevented high stress on the pedicle screws by preserving the normal spinal motion. These results may suggest that the novel dynamic instrumentation may be used for back pain treatment. Clinical investigation still remains for DSDR system in order to verify the system functionality.

REFERENCES