Changes in Center of Rotation and Load Sharing Characteristics Following Posterior Dynamic Stabilization in the Lumbar Spine

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Introduction: Recent studies have suggested that dynamic stabilization may be able to provide better surgical alternatives to the conventional fusion for the patients with chronic low back pain. They are based on the hypothesis that low back pain is caused due to abnormal changes in the pattern of loading rather than abnormal motion [1, 2]. As a result, various types of posterior dynamic stabilization (PDS) devices have been developed for the lumbar spine in recent years. They employ more 'compliant' materials or designs for the longitudinal rod than the conventional 'rigid' fusion devices. However, its biomechanical effects or clinically proven efficacies still remain unknown. For the PDS systems to provide uniform load sharing; this is important that the location of the instantaneous axis of rotation (IAR) lies close to that of the intact segment [2]. In this study, we constructed a finite element (FE) model of the lumbar spine to investigate changes in IAR of PDS devices and to compare the IAR of the intact model with rigid fixation system.

Materials and Methods: A validated 3-D nonlinear FE model of the intact lumbar spine (L3-L4) was developed (Figure 1-A). The implanted models were then modified from the intact model to simulate post-operative changes with two kinds of pedicle screw systems; a PDS system (Figure 1-B, nitinol rods with a 3-coiled turns, Φ=4.0 mm) and a conventional rigid fixation system (Figure 1-C, Ti6Al4V, Φ=6.0 mm). Ni-Ti alloy (75GPa) selected for this study has been heat treated such that it is superelastic at human body temperature and has lower elastic modulus than Ti6Al4V (114GPa). The titanium alloy pedicle screws and set screws were used for stabilizing both systems. Since our models were intended to simulate the biomechanical behavior after healing, the bone-implant interface behavior was accomplished via "tie" contact condition, which enables the screw threads and vertebræ to be bonded together permanently by full constraint [3].

Results: As shown in Figure 2, the paths of IARs were plotted on the lumbar spine. For each model, the initial location (II) of the IAR lies within the posterior part of the intervertebral. In flexion, its IAR starts out anteriorly towards the mid disc region (FI). In extension, it reverts back posteriorly (EI). The pattern of IARs (IP, FP, EP) of the PDS model remained closer to that of the intact spine. However, the initial point (IP) was translated superiorly (0.3 mm) and posteriorly (4.1 mm) as compared to those of intact model. The IARs for the rigid screw rod system lies near the posterior elements away from the intervertebral disc. The IARs (FR, ER) were seen clustered together with the initial point (IR) in both flexion and extension.