COMPARISON OF THE LOAD SHARING CHARACTERISTICS BETWEEN SEMI-RIGID AND RIGID PEDICLE SCREW SYSTEMS

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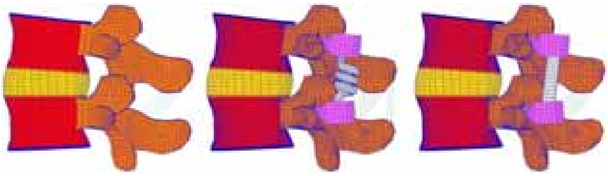
Introduction

Semi-rigid fixation systems of the lumbar spine have gained increasing scrutiny. Hypothetically, the use of 'compliant' metal alloys such as nitinol (Ni-Ti) or flexible rod design may be able to achieve fusion without stress shielding and to maintain or restore the load sharing characteristics to the level of the intact spine with little negative effect on the adjacent segments [1]. In this study, we created a finite element (FE) model of the lumbar spine from L3-L4 vertebral body to investigate changes in load sharing characteristics of semi-rigid fixation system.

Materials and Methods

A validated 3D nonlinear FE model of the intact lumbar spine (L3-L4) was developed. The fusion model was then modified from the intact model to simulate two kinds of pedicle screw systems (Figure 1): a semi-rigid fixation system (nitinol rods with a 3-coiled turn manner, Φ=4.0 mm) and a conventional rigid fixation system (Ti6Al4V, Φ=6.0 mm). Since our models were aiming to simulate the biomechanical behavior after healing, the bone-implant interface behavior was accomplished via "tie" contact condition, which enables the screw threads and vertebrae to be boned together permanently by full constraint [2].



(A) (B) (C)

Figure 1: FE models of (A) Intact L3-4 motion segment (B) Stabilized motion segment with semi-rigid fixation; and (C) Stabilized motion segment with rigid fixation.

To simulate the load on the lumbar spine in a quiet standing posture, the axial compressive load (400 N) was applied as a uniform pressure at the superior endplate of the L3 vertebral body and the inferior endplate of L4 vertebral body was totally constrained. Subsequently, the FE models were used to predict the changes in load sharing characteristics. Axial force across the facet joints was the axial component of the facet contact force predicted from the gap elements. Axial force transmitted through the implants was computed from the reaction forces in case of the total discectomy model under same deformation under an assumption that the "residual" forces are carried by the anterior column.

Results

The intact model showed that 12% of compressive load was shared by the facet joints. When the compressive load was applied on the implanted models, the predicted axial compressive load transmitted through the semi-rigid system and rigid system was 141.8 N and 266.8 N, respectively. Axial force across the semi-rigid and rigid system with facet joints predicted to take over 41% and 71% of the applied compression load, respectively.

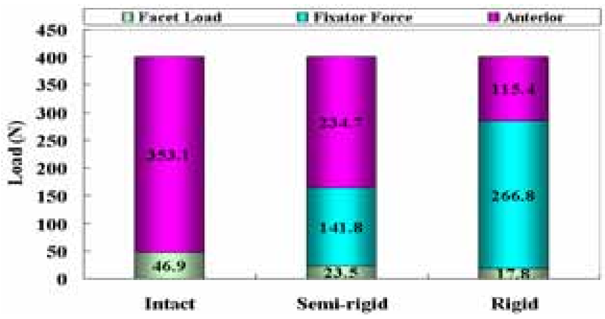


Figure 2: Predicted axial forces across the facet joint, fixator and anterior column of each models.

Discussion

In this study, a computational approach was used to evaluate the load sharing characteristics of two types of pedicle screw system. Previous studies have shown that rigid implants increase the risk of stress shielding, with a decrease in bone mineral density of the stabilized segment [3, 4]. Our results confirmed the hypothesis on the semi-rigid type by showing the substantial reduction in stress-shielding characteristics. Higher axial load was noted across the anterior structure with the semi-rigid fixation system, which could slow the degeneration process of bony structures.

Acknowledgement

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