INTRODUCTION:

It is known that pedicle screw fixation with rigid rod may cause abnormal stress concentration at the posterior part of the spine. This may lead to stress-shielding at the index level and excessive motion at the adjacent level that may further cause disc degeneration [1]. To address these issues, the systems with smaller diameter of the rod were introduced along with many other changes [2]. Also recently, additional insertion of interbody fusion devices (i.e., cages) is performed to redistribute the load to the anterior part of the spine and to further increase the stability of the spine. [3]. However, the biomechanical efficacies of the rod diameter reduction and the additional interbody fusion still remain unknown.

In this study, we used a finite element (FE) model of the lumbar spine to investigate changes in load sharing characteristics at the fused level and ROM at the adjacent level with respect to changes in diameter of rods and insertion of cage with the pedicle screw fixation.

METHODS:

A validated 3-D nonlinear FE model of the intact lumbar spine (L2-5) was used [4]. The post-operative models were made by modifying the intact model to simulate the implantation of the pedicle screw system at L4-5 with three different rod diameters (Ti6Al4V, E=114GPa, ν=0.3; φ=6mm, 4.5mm, 3mm). Further, posterior lumbar interbody fusion (PLIF) cages (n=2, Ti6Al4V, Bio-Square Cage, Biospine Inc., Korea) were inserted in each cases. A total of 6 post-op FE models (3 without cage, W/O; 3 with cage, W/C) were studied. For PLIF cage insertion, laminectomy at L3-5 level and local discectomy at L4-5 were simulated by removing relevant anatomic parts [5]. And the bone-implant interface was accomplished via ‘tie’ contact condition to assume complete postoperative bony union. The axial compressive displacement load of 400N was applied at L4-5 level as a uniform pressure at the superior endplate of the L4 vertebral body and the inferior endplate of L5 vertebral body was fixed by all direction. To simulate the in situ stabilization, compressive follower pre-load 400N was imparted as a uniform pressure at the superior endplate of the L2. And the flexion 8Nm/extension 6Nm pure moments were applied [6]. The inferior endplate of S1 vertebral body was constrained by all direction. For each post-operative case, load sharing between the anterior (the intervertebral disc) and the posterior (the facet joint and the rod of the pedicle screw) was assessed. Ranges of motion in the sagittal plane at the fused (L4-5) and the adjacent (L3-4) levels were normalized to those of the intact pre-operative spine. ABAQUS/Standard V6.8 (Simulia Corp., Providence, RI, USA) was used.

RESULTS:

As shown in Fig. 1, reduction of rod diameter resulted in overall relief of highly concentrated load at the posterior part of the spine from 34% to 25%. Insertion of cages (i.e., W/C cases) further contributed to lessening of the posterior load by half as compared to respective pedicle-screw-fixation-only (i.e., W/O) cases in all rod sizes. ROM results (Fig. 2) showed that the segmental motion at the fused level remained relatively unchanged at less than 40% of the pre-op level regardless of reduction of rod diameters or insertion of cages. This suggests that the stability of the fused spine was not compromised with use of small diameter of the rod, nor further augmented by insertion of PLIF cages. At the adjacent level, pedicle screw fixation contributed rise in motion by 20% as compared to the before surgery and the additional cage insertion resulted in extra 40% increase. It appears that additional fusion with cages resulted in unwanted increase in adjacent segmental motions.

DISCUSSION:

Our results demonstrated that pedicle screw fixation indeed provide stability at the fused level by limiting the motion and caused excessive segmental motion at the adjacent level regardless of changes in rod diameter. Use of smaller diameter rod was found to encourage more favorable load distribution. Additional implantation of PLIF cages did further reduced the posterior concentration of the load, more uniform load-sharing and closer to the pre-operative level. However, it was found to be unnecessary in terms of limiting the motion at the fused level. Rather, it caused significant increase in motion at the adjacent level which may initiate degeneration of the intervertebral disc and bony structure.

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