BIOMECHANICAL EFFECTS OF THE POSTERIOR LUMBER RECONSTRUCTIONS ON THE ADJACENT MOTION SEGMENT

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Introduction: Lumber posterolateral fusion (PLF) using a pedicle screw system in the treatment of spinal instability has been widely used to correct deformities, maintain the physiological alignment and restore stability. To overcome the limitations of PLF in maintaining lumbar lordosis, posterior lumbar interbody fusion (PLIF) has been developed. However, adding PLIF to the conventional PLF (PLIF/PLF) may carry a risk of promoting degenerative changes of the adjacent unfused motion segments because of the increased stiffness of the fused segments. Few studies to date have compared the effects of PLF and PLIF/PLF on the adjacent segments. Therefore, the indication of adding a cage is even now controversial clinically.

It is widely known that some surgical treatments for the adjacent segment problems following posterior fusions do not carry good results. It remains a problem to be solved whether local malalignment at the fused segments following lumbar spinal fusion promotes the incidence of early degenerative changes in the adjacent segments. There has been lack of biomechanical study comparing the effects of residual kyphosis after PLF and physiological alignment restored by PLIF on the adjacent segments. The purpose of the present study was to compare the biomechanical effects of three different posterior reconstructions (in situ PLF, kyphotic PLF, and in situ PLIF/PLF) on the adjacent motion segment and to discuss indication for PLF and PLIF.

Methods: Specimens preparation: Ten fresh cadavers were investigated. Each specimen was embedded in polyester resin superior to L2 and inferior to SI and mounted on the fixed jigs. Flexion-extension tests were performed with a custom three-dimensional coordinate system that could apply pure moments to the specimens. Loads were applied sequentially and the maximum applied moment was ±6 Nm. Two-level fusion was simulated at L5-S1 and L4-L5 as defined as an upper adjacent segment and an intervertebral segment. Levels were sequentially and the maximum applied moment was ±6 Nm. Two-level fusion was simulated at L5-L6-S1 and L4-L5 was defined as an upper adjacent segment and an intervertebral segment. Levels were sequentially loaded, and the maximum applied moment was ±6 Nm. Two-level flexion-extension tests were performed with a custom three-dimensional coordinate system that could apply pure moments to the specimens. Loads were applied sequentially and the maximum applied moment was ±6 Nm. Two-level fusion was simulated at L5-S1 and L4-L5 as defined as an upper adjacent segment and an intervertebral segment. Levels were sequentially loaded, and the maximum applied moment was ±6 Nm. Two-level fusion was simulated at L5-L6-S1 and L4-L5 as defined as an upper adjacent segment and an intervertebral segment. Levels were sequentially loaded, and the maximum applied moment was ±6 Nm. Two-level fusion was simulated at L5-L6-S1 and L4-L5 as defined as an upper adjacent segment and an intervertebral segment.

Experimental stages: After the intact state had been tested, spinal destabilization was performed. Transsection of supraespinous and interspinous ligaments following bilateral partial facetectomy and diskectomy were performed at L5-L6 and L6-S1. After the diskectomy, three types of spinal reconstruction were then randomly conducted using pedicle screw system and interbody fusion cages in the following manner based on the surgical procedures performed in the clinical setting:

1. L5-L6-S1 in situ pedicle screw fixation (in situ PLF);
2. L5-L6-S1 kyphotic pedicle screw fixation (kyphotic PLF); and
3. L5-L6-S1 in situ PLF with interbody fusion cages (in situ PLIF/PLF)

The PLF was simulated by pedicle screw fixation, and the PLIF by interbody fusion cages. For the fixation, titanium pedicle screws were inserted bilaterally at L5, L6, and S1 parallel to the endplate. For the in situ PLF, straight titanium rods were used. For the kyphotic PLF, kyphotically pre-bent (30 degrees) rods were applied. For the in situ PLIF/PLF, two carbon fiber rectangular cages were inserted into each disc bilaterally and straight titanium rods were used. Using the biaxial servohydrolic materials test machine, an axial compression force (125 N) was applied to the specimen when tightening the rod-screw junctions.

For all reconstruction groups, this pre-load value was chosen referring the previous report. The biomechanical testing was repeated after each reconstruction and permitted each specimen to serve as its own control, ensuring data normalization.

Statistical analysis: Statistical significance was determined using a repeated measures analysis of variance (ANOVA) and a post hoc multiple comparison with a Fisher’s PLSD test at 95% confidence.

Results: Construct stiffness of operative segments (L5-S1). All reconstruction models exhibited statistically higher construct stiffness than the intact condition. Construct stiffness of the in situ PLIF/PLF was significantly higher compared to both in situ PLF and kyphotic PLF, however, statistical significance was not detected between two PLFs.

Intradiscal pressure (Flexion loading) All reconstruction models presented significantly higher intradiscal pressure at the cranial adjacent segment than the intact condition. Similar to the results for construct stiffness, adjacent intradiscal pressure of the in situ PLIF/PLF model was significantly higher than those of the in situ PLF and kyphotic PLF models, and no statistical difference was observed between the latter two models. (Extension loading) A significant increase in the intradiscal pressure under extension loading was found in the kyphotic PLF and in situ PLIF/PLF models compared with the intact condition. Intradiscal pressure were higher with kyphotic PLF than with in situ PLF and were even higher in the in situ PLIF/PLF group, however, it did not reach statistical significance.

Discussion: The effects of operative segments and parameters of biomechanical effects on the unfused adjacent segment and indirectly evaluated the load transmission through the anterior and posterior columns. The intradiscal pressure was significantly higher in the in situ PLIF/PLF group than in the in situ PLF group under flexion loading. However, under extension loading, there was no significant difference between the two reconstructions. These results may arise from the effect that the cages mainly increased flexural stiffness of the instrumented segments.

Effect of kyphotic deformity: It is widely known that spinal malalignment after spinal instrumentation may accelerate degenerative changes at adjacent motion segments. In the present study, residual local kyphosis following PLF was simulated utilizing kyphotically pre-bent rods. As well, correction of local kyphosis by PLIF was simulated using straight rods and interbody cages. Then, biomechanical effects of kyphotic PLF and in situ PLIF/PLF on the adjacent segment were compared. During flexion-extension loading, construct stiffness of the in situ PLF/PLF was significantly higher compared to both in situ and kyphotic PLF groups, however, statistical significance was not detected between two PLF groups. These findings indicate that the stiffness at the instrumented segments was significantly increased by the intervertebral cages. Under flexion loading, neither intradiscal pressure nor lamina strain demonstrated statistical difference between in situ PLF and kyphotic PLF. However, the in situ PLIF/PLF group had statistically higher intradiscal pressure at the adjacent segment than the kyphosis group. Furthermore, the in situ PLIF/PLF group had the highest tensile lamina strain under flexion among three groups. These findings indicate that PLIF/PLF increases both anterior and posterior column load at the adjacent segment due to higher flexural stiffness of the segments.

Conclusion: Additional PLIF may lead to higher adjacent level load transmission through both anterior and posterior columns due to increased construct stiffness, even if local kyphosis is corrected by performing PLIF. Hence, correction of spinal malalignment by spinal instrumentation may not decrease the load on the adjacent mobile segments.