MECHANICAL EVALUATION OF LUMBER SPINAL FUSION WITH UNILATERAL PEDICLE SCREW SYSTEM

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SUMMARY
Lumbar fusion combined with unilateral pedicle screw fixation has received favorable clinical reports. However, there are very few reports about the biomechanical properties of this system. The purpose of this study was to compare the biomechanics of a unilateral pedicle screw system with a bilateral system. A fresh lumbar vertebral column from a human cadaver was used. A total of 4 models, that is an intact model, a damaged model, a unilateral model and a bilateral model, were prepared by the sequential damage and spinal instrumentation of the specimen. A Bending test in a total of 8 directions was performed to clarify the range of motion for each model using a 6-axis material tester that we have developed. The results suggest that the unilateral PS system causes dispersion in rigidity depending on the direction of bending, and that rigidity is particularly weak in the diagonal direction to that of PS insertion. On the other hand, the bilateral PS system can achieve excellent fixation in all directions.

INTRODUCTION
The pedicle screw and rod system (PS system) is the spinal instrumentation expected to achieve the most stable fixation results for patients with lumbar degenerative disease such as lumbar spinal canal stenosis with spondylolisthesis and segmental spinal instability. The PS system is effective in correcting lumbar alignment and improving bone fusion rate. However, due to the excessive rigidity of the system, this instrumentation is also suspected to cause decreased mineral content in the fixed area and degeneration of adjacent segments. To reduce this rigidity, Kabins et al. [1] performed lumbar fusion using a unilateral PS system and reported favorable results. Lumbar fusion with a unilateral PS system has subsequently been reported to reduce both operative duration and intraoperative bleeding, with the procedure achieving clinical results comparable to those of lumbar fusion with a bilateral PS system [2]. Recently, this unilateral PS system has been more frequently employed in combination with transforaminal lumbar interbody fusion (TLIF) rather than in posterolateral fusion and posterior lumbar interbody fusion (PLIF) [3,4].

As described above, favorable results have been reported for lumbar fusion with a unilateral PS system. However, little data are available on the biomechanical properties of the system. Therefore, this study used a bending test of the lumbar functional spinal unit (FSU) from a human cadaver to compare the biomechanics of the unilateral and bilateral PS systems.

METHODS
A fresh lumbar vertebral column from a human cadaver was extracted after pathological autopsy at the university hospital after obtaining consent from the family. The protocols were approved by the university's ethics committee. First, muscle and fat were removed from the specimen and the FSU (L3/4) was cut out. Both ends of the specimen were fixed using dental resin. Damage and spinal instrumentation were sequentially administered to the specimen. A total of 4 models were prepared (Figure 1). These included: an intact model (Model A) without any damage; a damaged model (Model B) prepared by drilling a hole 5 mm in diameter at 3 sites (front, center, back) in the intervertebral disc and total resection of the left facet joint; a unilateral PS model (Model C) prepared by PS fixation on the left side in addition to the condition generated in Model B; a bilateral PS model (Model D) prepared by PS fixation on the right side in addition to the condition generated in Model C.

![Figure 1: Experimental models of lumbar FSU.](image-url)
A 6-axis material tester [5], which we have developed, was employed as the biomechanical measurement device (Figure 2). A bending test was performed to clarify the biomechanical properties of the models. In the bending test, torque was applied at -3 Nm to 3 Nm at an angular velocity of 0.05 degree/second in 8 directions. These included oblique front right, oblique front left, oblique back right and oblique back left in addition to the usual directions of flexion, extension, right-side bending and left-side bending, under conditions of 3 degrees of freedom. Range of motion (ROM) was defined as the rotational angle in the torque–rotational angle curve obtained from the bending test under maximum torque (±3 Nm), and data obtained on the third attempt were employed as the experimental results.

![Figure 2: 6-axis material tester that we have developed.](image)

**Figure 2**: 6-axis material tester that we have developed.

**Figure 3**: ROMs obtained from bending test in 8 directions in all models.

**RESULTS AND DISCUSSION**

Figure 3 shows the ROMs obtained from the bending test in 8 directions in all models. In the figure, the ROMs were plotted on the respective axes and these plots were connected by lines for each model. As found from the results, the ROM increased in all directions in Model B (damaged model) compared with Model A (intact model). The ROM decreased in all directions in Model C (unilateral PS fixation model) compared to Model B, but demonstrated considerable differences depending on the bending direction. The ROM decreased considerably in all directions in Model D (bilateral PS model) compared with Model A and Model B.

In our study, the results of a bending test demonstrated the excellent fixation achieved by the bilateral PS system in all bending directions. Conversely, in the unilateral PS system, the ROM decreased in the direction of PS insertion (oblique anterior right and oblique posterior left directions), but barely decreased in the diagonal direction to that of PS insertion (oblique anterior left and oblique posterior right directions). These results suggest that the unilateral PS system causes dispersion in rigidity depending on the direction of bending, and that rigidity is particularly weak in the diagonal direction to that of PS insertion.

According to the present results, ROM of a unilateral PS system in flexion–extension and right-sided and left-sided bending was 1.5 to 2 times higher than that of the bilateral PS system. Our results thus indicated that fixation was less rigid in a unilateral PS system compared to a bilateral PS system, as reported by Slucky et al. [6] and Harris et al. [7]. We tested bending in diagonal directions in addition to flexion–extension and right-sided and left-sided bending. The results indicated that fixation by a unilateral PS system was very weak in the diagonal direction to that of PS insertion, and that this system offered uneven fixation that demonstrated dispersion in rigidity depending on the direction of bending.

**CONCLUSIONS**

In conclusion, biomechanical investigation of lumbar vertebrae from human cadavers suggests that a unilateral PS system offers uneven fixation that demonstrates dispersion in rigidity depending on the bending direction. The bilateral PS system can achieve excellent fixation in all directions.

**REFERENCES**