

---

## ORIGINAL RESEARCH

# Comparison of mechanical motion profiles following instrumented fusion and non-instrumented fusion at the L4-5 segment

---

Ho-Joong Kim MD<sup>1</sup>  
Seong-Hwan Moon MD<sup>1</sup>  
Heoung-Jae Chun PhD<sup>2</sup>  
Kyoung-Tak Kang MS<sup>2</sup>  
Hak-Sun Kim MD<sup>1</sup>  
Eun-Su Moon MD<sup>1</sup>  
Jin-Oh Park MD<sup>1</sup>  
Byung-Yoon Hwang MD<sup>1</sup>  
Hwan-Mo Lee MD<sup>1</sup>

<sup>1</sup> Department of Orthopaedic Surgery and <sup>2</sup> Department of Mechanical Engineering, Yonsei University, Seoul, Korea

*Manuscript submitted 14th May, 2008*  
*Manuscript accepted 29th December, 2008*

*Clin Invest Med* 2009; 32 (1): E64-E69.

---

### Abstract

**Purpose:** To investigate the difference in motion profiles between instrumented and non-instrumented fusion of the lumbar spine.

**Method:** *In vivo* retrospective radiological analysis of dynamic (flexion-extension) lateral plain films was performed in different lumbar spine fusion types. Twenty-eight patients underwent lumbar fusion surgery at the L4/5 level. Fourteen patients underwent anterior fusion surgery without implantation, and the others underwent posterior instrumented fusion. Segmental angular motion was measured at the fused and adjacent levels using dynamic plain lateral film 2 years after operation.

**Results:** The anterior uninstrumented fusion group showed mean 2.0° of segmental angular motion at the fused level compared with mean of 0.8° in the posterior instrumented fusion group ( $P < 0.05$ ). In contrast, at the proximal adjacent level, decreased angular motion (mean 7.7°) was noted in the anterior uninstrumented fusion group compared with mean 11.6° in the posterior instrumented fusion group ( $P < 0.05$ ).

**Conclusion:** This study suggests that differing stiffness of fusion segments could cause different mechanical motion profiles at adjacent segments.

Since spine fusion surgery was first introduced by Albee for the treatment of Pott's disease,<sup>1</sup> and by Hibbs, who performed spinal fusion as a treatment for spinal deformity,<sup>2</sup> it has been used for the treatment of various spinal diseases. Reported rates of success with fusion range from 65% to 93%.<sup>3-5</sup> Clinical outcomes of fusion usually depend on the fusion state. However, a complete, solid fusion does not guarantee satisfactory results, and many problems such as infection, instrument failure, nonunion remain.

Adjacent segment degeneration (ASD) is one of the serious complications following spinal fusion surgery.<sup>6-8</sup> Since ASD was first reported about 50 yr ago,<sup>9,10</sup> it has recently become more widespread with the increase of spinal fusions. Although many biomechanical studies have shown that the fusion process could impose considerable stress and increased motion at the adjacent segment,<sup>11-13</sup> there have also been conflicting results.<sup>14</sup> Several studies have argued that progression of existing degenerative changes is the main cause of ASD<sup>15,16</sup> or that disc degeneration could

be determined by individual characteristics.<sup>17</sup> These divergent views of ASD may be due to differing patient populations and methodologies. Even though fusion affects motion and stress of the adjacent segment, the following questions remain: how much does the fusion process contribute to ASD and to what extent does each type of fusion (anterior, posterior, and circumferential) impact ASD?

The stiffness of fused segments or fusion mass has been proposed as one of the risk factors for ASD.<sup>7,13</sup> However, there has been no *in vivo* study to support this hypothesis. It has been suggested that the fusion method would cause different mechanical motion profiles because instrument fixation using pedicle screws and rods is stiffer than bone or fusion mass. The different fused segment motion may result in different effects on the motion of adjacent segments.

To investigate the difference in motion profiles between instrumented and non-instrumented fusion, in the present study, each segmental range of motion was measured at the fused segment and both proximal and distal adjacent segments in dynamic lateral plain films.

### Patients and methods

Twenty-eight adult patients underwent spinal fusion surgery at the L4/5 level for degenerative disc disease, spondylolisthesis. Only patients who satisfied the following conditions were included in this study.

- i. Patients had only single segment pathology in the lumbar spine. Two years after operation, there was also no evidence for further degenerative

changes in adjacent segments at plain radiographs.

- ii. Patients had a definite fusion mass identified in plain film, and ambiguous cases were excluded.
- iii. Patients had motion of  $\leq 5^\circ$  at the fusion segment, no matter whether a fusion mass was present. Patients were excluded if measurement of segmental range of motion was difficult in dynamic lateral film. Patients had no back pain or tenderness in the lumbar spine.
- iv. Lumbar lordosis was noted and was maintained 2 yr after operation.

Age and sex-matched patients were selected in both groups. Anterior or posterior spinal fusion was performed on each of the 14 patients. In the anterior fusion group, all cases underwent interbody fusion, and there was no additive instrumentation. In the posterior fusion group, all cases involved instrumented posterolateral fusion. Fusion was accomplished using autologous iliac chip bone graft. Care was taken not to damage the facet joint above the fusion segments, and the posterior ligament complex (supraspinous and interspinous ligaments) was also preserved above the fusion level. Upon radiological examination of dynamic plain film, there were no definite degenerative changes such as disc space narrowing or bony spurs at adjacent segments in any patients. In preoperative standing lateral films, mean lumbar lordosis (L1–5) was  $22.2^\circ$  ( $11^\circ$ – $29^\circ$ ),  $17.8^\circ$  ( $10^\circ$ – $32^\circ$ ) in the anterior non-instrumented fusion and posterior instrumented fusion groups, respectively (P:NS). In this study, the mean age was 43.4 yr and 45.0 yr in the anterior fu-

TABLE 1. Demographic data of patients.

	Anterior fusion group (n = 14) (without instrumentation)	Posterior fusion group (n = 14) (Instrumented)	P
Age (yr) [Mean(range)]	43.4 (22 – 57)	45.0 (21 – 57)	NS
Sex (M:F)	8:6	8 : 6	NS
Diagnosis (No. of cases)	Degenerative disc disease: 10 Spondylolisthesis: 4	Degenerative disc disease: 9 Spondylolisthesis: 5	

P:NS: M:male, F:female

TABLE 2. Intraobserver error and interobserver error calculations using Pearson's correlation coefficient.

	Intra-observer Error		Inter-observer Error	
	<i>P</i>	<i>r</i> <sup>2</sup>	<i>P</i>	<i>r</i> <sup>2</sup>
Proximal adjacent level	<0.001	0.84	0.003	0.77
Fusion level	<0.001	0.72	<0.001	0.78
Distal adjacent level	0.002	0.81	<0.001	0.84

sion and posterior fusion groups, respectively. The male:female ratio for the two groups was 8:6 (P:NS).

#### Measurement of segmental range of motion

Dynamic (flexion-extension) lateral plain films were obtained in the standing position both before and at 2 yr after operation. To gain radiographs in the most natural flexion-extension state, patients were asked to pose in full flexion and full extension. One independent observer (observer 1) measured the range of motion at three segments, including the fusion level, the proximal adjacent segment, and the distal adjacent segment, using the method described by Frobin *et al.*<sup>18</sup> Observers were blinded to the study's purpose. Using the method described by Frobin *et al.*,<sup>18</sup> the intervening angle between the upper segment midplane and the lower segment midplane was measured, and this midplane angle was regarded as the segmental angle. The angular motion of each segment (segmental range of motion) was calculated as the difference between segmental angles in flexion and extension. Angle measurements were performed on a PACS (picture archiving communication system) workstation using dedicated computer-assisted measurement software (Centricity, GE, Milwaukee, WI). Midplane lines were

drawn by mouse click, and the intervening midplane angle was measured automatically.

#### Validation of measurements

Intraobserver (observer 1) error calculations were made between 2 sets of measurements of 20 randomly-selected radiographs from all patients several months apart. In order to assess the inter-observer error, a second independent (observer 2) preformed measurements of the same randomly selected radiographs.

#### Statistical analysis

All data were analyzed using the SPSS 12.0.1 statistic package (SPSS, Inc., Chicago, IL). Mann-Whitney tests were used to compare the mean angular motion of each segment between two groups before and at 2 yr after operation, and significant values were calculated. For comparison of the preoperative range of motion with postoperative angular motion at each segment, Wilcoxon signed ranks test was used. Pearson correlations were also used to measure Intraobserver and Interobserver error. A value of *P* < 0.05 was accepted as clinically significant.

TABLE 3. Comparison segmental range of motion between two groups.

	Uninstrumented anterior fusion group	Instrumented posterior fusion group	<i>P</i>	
Range of motion <sup>o</sup>	Preoperative L3/4	6.9 [3.2], 2.0–10.5	6.9 [2.8], 5.9–11.5	0.887
	Proximal adjacent segment (L3/4)	7.7 [4.5], 4.0–14.2	11.6 [3.1], 7.3–16.3	0.044
	<i>P</i>	0.310	0.005	
	Fused segment (L4/5)	2.0 [1.4], 0.1–4.6	0.8 [0.6], 0.1–2.6	0.015
	Preoperative L5/S1	9.7 [6.4], 5.1–17.1	9.2 [6.1], 3.5–20.3	0.955
	Distal adjacent segment (L5/S1)	10.3 [5.6], 6.4–16.9	12.0 [4.5], 3.8–19.3	0.48
	<i>P</i>	0.463	0.139	

(Mean [SD], range)

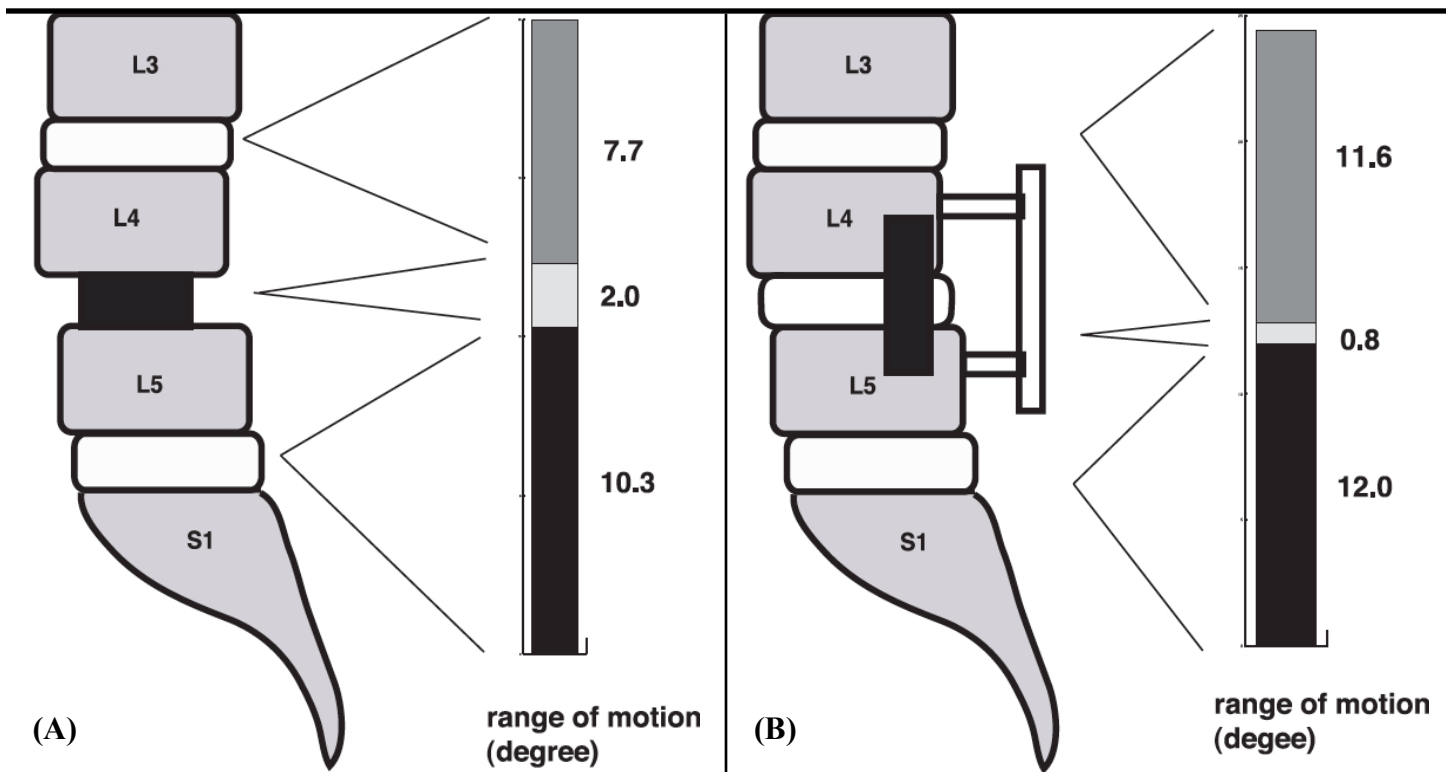


FIGURE 1. Schematic drawing of lumbar fusion surgeries, and segmental range of motion (mean) at each segment. (A) anterior uninstrumented fusion, (B) posterior instrumented fusion

## Results

### Validation of measurement

Intra-observer and inter-observer error demonstrated good observer agreement (Table 2).

### Range of motion between two groups

There was no difference in angular motion at each segment between the two groups (Table 3). In the anterior non-instrumented fusion group, preoperative mean angular motion of L3-4, L5-S1 (range) was 6.9 (2.0-10.5) and 9.7 (5.1-17.1), respectively. Mean segmental motion (range) of the instrumented posterior fusion group was 6.9 (5.9-11.5) at L3-4 and 9.2 (3.5-20.3) at L5-S1 in the preoperative state.

In the instrumented posterior fusion group, the mean angular motion (range) was 0.8° (0.1-2.6) at the fused segment compared with 2.0° (0.1-4.6) in the non-instrumented anterior fusion group ( $P=0.015$ ).

There was no difference at the distal adjacent segment (L5/S1). The mean angular motion (range) of proximal adjacent segment was 7.7° (4.0-14.2) in the anterior non-instrumented fusion group compared with 11.6° (7.3-16.3) in the posterior instrumented fusion ( $P=0.044$ ) (Figure 1A, 1B).

In comparing the preoperative and postoperative angular motion at each segment, only the L3-L4 segment in the instrumented posterior fusion exhibited an increase in angular motion ( $P=0.005$ ) (Table 3).

## Discussion

The results of the current study were consistent with our hypothesis.

Although small, there were different degrees of motion between elastic bony fusion masses and stiff instruments, resulting in different degrees of motion at adjacent segments. This finding means that the stiffness of the fusion mass affects the mechanical motion

profile at the adjacent segment. In fact, some motion in the fusion segment has been reported by several studies.<sup>19-21</sup> Although there has been disagreement about the extent of residual motion of fused segment,<sup>19</sup> many spine surgeons consider  $< 5$  degrees of segmental motion to be the definition of fusion.<sup>19,20</sup> Bono *et al.*,<sup>21</sup> using finite element analysis, reported that residual sagittal motion in lumbar fusion could be influenced by the type, location, and completeness of the fusion. Incidences of implantation failure after solid fusion may also reflect this idea that a fusion mass is more flexible than inserted rods or screws.<sup>22</sup>

At the proximal adjacent segment, flexion/extension motion was larger in the instrumented posterior fusion group than in the non-instrumented anterior fusion group. In contrast, distal adjacent segments showed no difference in the amount of motion between the two groups. These results could be explained by an early biomechanical studies that reported that fusion produced a cephalad shift of the centre of rotation, and only adjacent segments above the instrumentation became more mobile.<sup>11,23</sup>

The stiffness of the fusion segment has been proposed as a possible risk factor of ASD,<sup>7,13</sup> although there was a conflicting study.<sup>24</sup> This is the first *in vivo* study to elucidate the importance of the stiffness of fusion segments, and the results agree with those of previous biomechanical studies.<sup>7,13</sup> Therefore, we suggest there would be different mechanical loads at adjacent segments following differing fusion methods because a bony fusion mass is less stiff than implanted instruments. In keeping with these results, Penta and Wai *et al* used only anterior spinal fusion without instrumentation and failed to demonstrate increased degeneration above the fusion segment.<sup>15,16</sup>

The present study showed that the average angular motion of the proximal adjacent segment (L3-4) was  $7.7^\circ$  in non-instrumented anterior fusion. This is smaller than a previous report in which Hayes *et al*<sup>25</sup> reported the average angular motion at each lumbar segment in asymptomatic individuals, and the average angular motion was  $10^\circ$  in the L3-4 segment. How-

ever, subjects in that study were asymptomatic without a history of back pain, leg pain, or back surgery, while patients in our study had experienced back pain and undergone surgery. Moreover, preoperatively there was no difference in the each segmental motion between the two groups.

Nevertheless, the present study has several limitations. First, the authors selected complete fusion cases using plain x-ray, flexion-extension dynamic plain film, and physical examination. It is possible that false positive cases may have been included. In order to overcome this limitation, we excluded patients with an ambiguous fusion mass or motion  $> 5^\circ$  at fused segments. Second, we measured segmental angular motion through dynamic film, although this has been reported to be a less accurate method.<sup>26</sup> To reduce this methodological limitation, we utilized the precision measurement method Frobin *et al.*<sup>18</sup> Third, only a small number of patients were enrolled in each group. However, age and sex-matched patients were selected and we minimized other confounding factors.

Undoubtedly, the stiffness of fusion segments can affect the mechanical kinematics at adjacent segments. Concerns over this have led to the development of alternative surgical treatments, including ligament stabilization procedures and lumbar disc arthroplasty. However, these new techniques should be evaluated by long-term results and cost-effectiveness. Moreover, considering the results of the present study, we believe that removal of instruments (pedicle screws and rods) after complete fusion might be an option to prevent ASD. This also requires verified by biomechanical studies before clinical application.

### Acknowledgments

This study was supported by grants from the AOSpine research fund and by grant No. R01-2006-000-10933-0 from the Basic Research Program of the Korea Science & Engineering Foundation and by the Brain Korea 21 Project for Medical Science, Yonsei University.

## References

1. Albee FH. Transplantation of a portion of the tibia into the spine for Pott's disease. *JAMA* 1911;57:885.
2. Hibbs RA. An operation for progressive spinal deformities. *NY Med J* 1911;93:1013.
3. Jackson RK, Boston DA, Edge AJ. Lateral mass fusion. A prospective study of a consecutive series with long-term follow-up. *Spine* 1985;10:828-32.
4. Kiviluoto O, Santavirta S, Salenius P, et al. Posterolateral spine fusion. A 1-4 year follow-up of 80 consecutive patients. *Acta Orthop Scand* 1985;56:152-4.
5. O'Beirne J, O'Neill D, Gallagher J, et al. Spinal fusion for back pain: A clinical and radiological review. *J Spinal Disord* 1992;5:32-8.
6. Lee CK. Accelerated degeneration of the segment adjacent to a lumbar fusion. *Spine* 1988;13:375-7.
7. Park P, Garton HJ, Gala VC, et al. Adjacent segment disease after lumbar or lumbosacral fusion: review of literature. *Spine* 2004;29:1983-44.
8. Chen WJ, Lai PL, Niu CC, et al. Surgical treatment of adjacent instability after lumbar spine fusion. *Spine* 2001;26:519-24.
9. Anderson CE. Spondyloschisis following spine fusion. *J Bone Joint Surg Am* 1956;38:1142-6.
10. Unander-Scharin L. A case of spondylolisthesis lumbalis aquisita. *Acta Orthop Scand* 1950;19:536-44.
11. Lee CK, Langrana NA. Lumbosacral spinal fusion: a biomechanical study. *Spine* 1984;9:574-81.
12. Yang SW, Langrana NA, Lee CK. Biomechanics of lumbosacral spinal fusion in combined compression-torsion loads. *Spine* 1986;11:937-41.
13. Shono Y, Kaneda K, Abumi K, et al. Stability of posterior spinal instrumentation and its effects on adjacent motion segments in the lumbosacral spine. *Spine* 1998;23:1550-8.
14. Rohlmann A, Neller S, Bergmann G, et al. Effect of an internal fixator and bone graft on intersegmental spinal motion and intradiscal pressure in the adjacent regions. *Eur Spine J* 2001;10:301-8.
15. Penta M, Sandhu A, Fraser RD. Magnetic resonance imaging assessment of disc degeneration 10 years after anterior lumbar interbody fusion. *Spine* 1995;20:743-7.
16. Wai E, Santos E, Morcom R, et al. Magnetic resonance imaging 20 years after anterior lumbar interbody fusion. *Spine* 2006;31:1952-6.
17. Pellisé F, Hernández A, Vidal X, et al. Radiologic assessment of all unfused lumbar segments 7.5 years after instrumented posterior spinal fusion. *Spine* 2007;32:574-9.
18. Frobin W, Brinchmann P, Leivseth G, et al. Precision measurement of segmental motion from flexion-extension radiographs of the lumbar spine. *Clin Biomech (Bristol, Avon)* 1996;11:457-65.
19. McAfee PC, Boden SD, Brantigan JW, et al. Symposium: a critical discrepancy-a criteria of successful arthrodesis following interbody spinal fusions. *Spine* 2001;26:329-34.
20. Frymoyer JW, Hanley EN, Jr, Howe J, et al. A comparison of radiographic findings in fusion and nonfusion patients ten or more years following lumbar disc surgery. *Spine* 1979;4:435-40.
21. Bono CM, Khandha A, Vadapalli S, et al. Residual sagittal motion after lumbar fusion: A finite element analysis with implications on radiographic flexion-extension criteria. *Spine* 2007;32:417-22.
22. Wetzel FT, Brustein M, Phillips FM, et al. Hardware failure in an unconstrained lumbar pedicle screw system. A 2-year follow-up study. *Spine* 1999;24:1138-43.
23. Bastian L, Lange U, Knopp C, et al. Evaluation of the mobility of adjacent segments after posterior thoracolumbar fixation: A biomechanical study. *Eur Spine J* 2001;10:295-300.
24. Wiltse LL, Radecki SE, Biel HM, et al. Comparative study of the incidence and severity of degenerative change in the transition zones after instrumented versus noninstrumented fusions of the lumbar spine. *J Spinal Disord* 1999;12:27-33.
25. Hayes MA, Howard TC, Gruel CR, et al. Roentgenographic evaluation of lumbar spine flexion-extension in asymptomatic individuals. *Spine* 1989; 14:327-31.
26. Wall MS, Oppenheim WL. Measurement error of spondylolisthesis as a function of radiographic beam angle. *J Pediatr Orthop* 1995;15:193-8.

Correspondence to:

Hwan-Mo Lee, MD  
 Department of Orthopaedic Surgery,  
 Yonsei University College of Medicine,  
 # 134 Shinchondong, Seodaemun-gu, Seoul, Korea.  
 E-mail : hwanlee@yuhs.ac