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Effect of intraoperative position in single-level transforaminal lumbar interbody fusion at the L4/5 level on segmental and overall lumbar lordosis in patients with lumbar degenerative disease

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Abstract

The purpose of this study was to investigate the effect of intraoperative positions in single-level (L4–5) transforaminal lumbar interbody fusion (TLIF) on segmental and overall lumbar lordosis (LL) in patients with lumbar degenerative disease. Thirty-eight consecutive patients who had undergone single-segment (L4–5) TLIF with 0° polyetheretherketone (PEEK) cage and pedicle screw fixation were evaluated. Twenty patients underwent surgery on the four-poster type frame with hip flexion at 30° (Group I) and 18 patients were operated on a Jackson spinal table to adjust their hip flexion to 0° (Group II). Preoperative standing, intraoperative prone, and postoperative standing lateral radiographs were obtained in each patient. The overall and segmental LL were analyzed according to the position in which the patients were placed for their operation and results compared between Groups I and II. Intraoperative intervertebral segmental LL at L4–5 and L5–S1 was increased in Group II than in Group I, whereas postoperative intervertebral segmental LL at L4–5 (fused level) was increased LL. In Group I intraoperative intervertebral segmental LL at L4–5 did not achieve sufficient lordosis, whereas postoperative intervertebral segmental LL at L3–4 was increased. The overall spinal alignment was unaffected by the decreased segmental LL in the fused level owing to the compensation of the upper adjacent segments. The more the hip was extended intraoperatively, the more the segmental lordosis increased in the lower lumbar spine. Thus, selecting the appropriate surgical table and hip position are very important. Underachievement of segmental lordosis leads to the acceleration of upper adjacent segment load.

Abbreviations: DS = degenerative spondylolisthesis, FS = foraminal stenosis, LL = lumbar lordosis, PACS = Picture Archiving and Communication System, PEEK = polyetheretherketone, PI = pelvic incidence, PSs = pedicle screws, TLIF = transforaminal lumbar interbody fusion.

Keywords: lumbar degenerative disease, lumbar lordosis, operative position, segmental lordosis, surgical table, transforaminal lumbar interbody fusion

1. Introduction

Lumbar interbody fusion procedures have been widely used for the treatment of degenerative disorders, such as spondylolisthesis of the lumbar spine. It is very important to restore adequate lumbar lordosis (LL) when performing lumbar interbody fusion. Because sagittal malalignment has been identified as a factor, which is strongly correlated with low back pain and disability.[1,2]

The method for achieving postoperative LL varied, such as the use of angled cage with or without posterior column osteotomy.[3] It has been reported that different operative positions

Editor: Jianxun Ding.

This study received approval from our institution's Ethical Committee. All procedures were performed in accordance with the ethical standards of this committee, as well as with the 1964 Helsinki Declaration and its later amendments.

This study was not funded.

All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

The authors have no conflicts of interest to disclose.

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How to cite this article: Miyazaki M, Ishihara T, Abe T, Kanezaki S, Notani N, Kataoka M, Tsumura H. Effect of intraoperative position in single-level transforaminal lumbar interbody fusion at the L4/5 level on segmental and overall lumbar lordosis in patients with lumbar degenerative disease. Medicine 2019;98:39(e17316).

Received: 8 May 2019 / Received in final form: 26 July 2019 / Accepted: 12 August 2019

http://dx.doi.org/10.1097/MD.0000000000017316

have different effects on the overall and segmental LL.[4,5] Previous reports have shown that lumbar sagittal alignment was produced by different hip positions on a routinely used spinal surgical table. Depending on the degree of hip flexion, LL may or may not be maintained. It was reported that there is a significant reduction in overall and segmental LL when patients were positioned with the hip flexed at 60° to 90° during the operation.[4,5] There were many reports showing that different operative positions have different effects on the overall and segmental LL.[4–7] However, there are few studies that analyzed intraoperative and postoperative segmental and overall LL in patients who have undergone single-level lumbar interbody fusion in different operative hip positions.

The purpose of this study was to investigate the effect of intraoperative positions in single-level (L4–5) transforaminal lumbar interbody fusion (TLIF) on segmental and overall LL in patients with lumbar degenerative disease and to analyze the compensatory mechanisms of each segmental LL in overall LL postoperatively.

2. Materials and methods

2.1. Study design and patients

This study was a retrospective case review based on the database in our institution. We retrospectively reviewed 38 consecutive patients who had undergone single-segment (L4–5) TLIF with 0° polyetheretherketone (PEEK) cage and pedicle screw fixation between November 2011 and March 2017 in our hospital. The inclusion criteria were as follows: L4 single segmental degenerative spondylolisthesis (DS) or L4–5 lumbar foraminal stenosis (FS) (34 cases were DS and 4 cases were FS); mechanical low back pain and/or lower limb numbness, radiating pain, or intermittent claudication for >3 months despite conservative treatment; complete preoperative standing lateral, intraoperative prone lateral, and 1-year postoperative standing lateral radiographs; and L4–5 single-level TLIF. The exclusion criteria were as follows: patients with spondylolysis, congenital vertebral anomalies, infections, fractures, history of spinal surgery, and scoliosis >20°.

2.2. Grouping of patients

The patients were divided into 2 groups according to the positioning device (four-poster type frame [Group I] or Jackson table [Group II]). The patients in Group I, who received surgery between November 2011 and March 2015, were placed on the four-poster type frame and the hip was flexed at 30° (Fig. 1). The patients in Group II, who received treatment between April 2015 and March 2017, were positioned on the Jackson table to adjust their hip flexion to 0° (Fig. 2). The hip flexion angle is the angle formed by the longitudinal axis of the trunk and the longitudinal axis of the femur in the sagittal plane. The single criterion for deciding which positioning device was to be used was the date of the operation. Therefore, the four-poster type frame was applied to all patients who underwent TLIF during the first 41 months and the Jackson table was used for all patients during the subsequent 24 months. Table 1 lists the preoperative demographic characteristics in both groups.

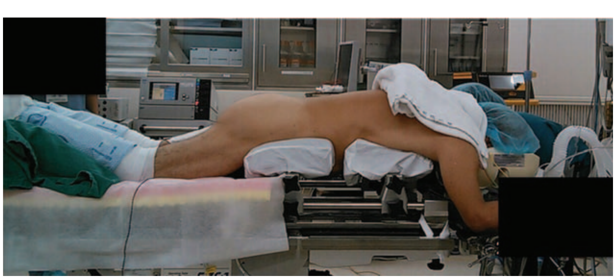

Figure 1. Four-poster type frame. A photograph showing a patient in the prone position on the four-poster type frame with hip flexion at 30°.

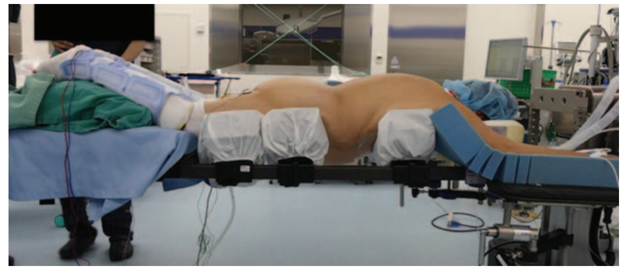

Figure 2. Jackson table. A photograph showing a patient in the prone position on the OSI Jackson table with hip flexion at 0°.

2.3. Surgical techniques

The patients were placed on the four-poster type frame or Jackson table in the prone position. A standard midline incision, 5.0 to 8.0 cm in length, was made. A subperiosteal dissection was followed to expose the transverse process and pars interarticularis at the cephalad and caudal level. Bilateral pedicle screws (PSs) were implanted after confirming the operative level with fluoroscopy. Initially with a rongeur and then with a high-speed drill, the medial aspect of the facet joints was excised and total laminectomy and unilateral facetectomies were achieved by resecting the spinous process and lamina. Once the disk space was exposed clearly, the posterior annulotomy was done and radical discectomy was performed using a combination of serial dilator and pituitary rongeurs. The disc and cartilage were removed carefully so as not to violate the subchondral bone, and at this point, an angled curette was used to remove the cartilaginous endplate from the far lateral side. A trial spacer was then used to estimate the appropriate size of the cage, and with protection of the thecal sac and root by a retractor, an interbody cage filled with graft material (cancellous autobone harvested from the resected spinous process and lamina)

Table 1

Patient demographic data.

Parameter	Group I (four-poster type frame) (n=20)	Group II (Jackson table) (n=18)
Age at surgery, y	70.8±8.7	71.7±10.4
Sex (male/female)	6/14	7/11
Operation time, min	195.2±30.8	199.2±38.6
Blood loss, mL	205.0±127.9	192.8±149.2
Degenerative spondylolisthesis (DS)	18	16
Foraminal stenosis (FS)	2	2

Values are means±standard deviation.

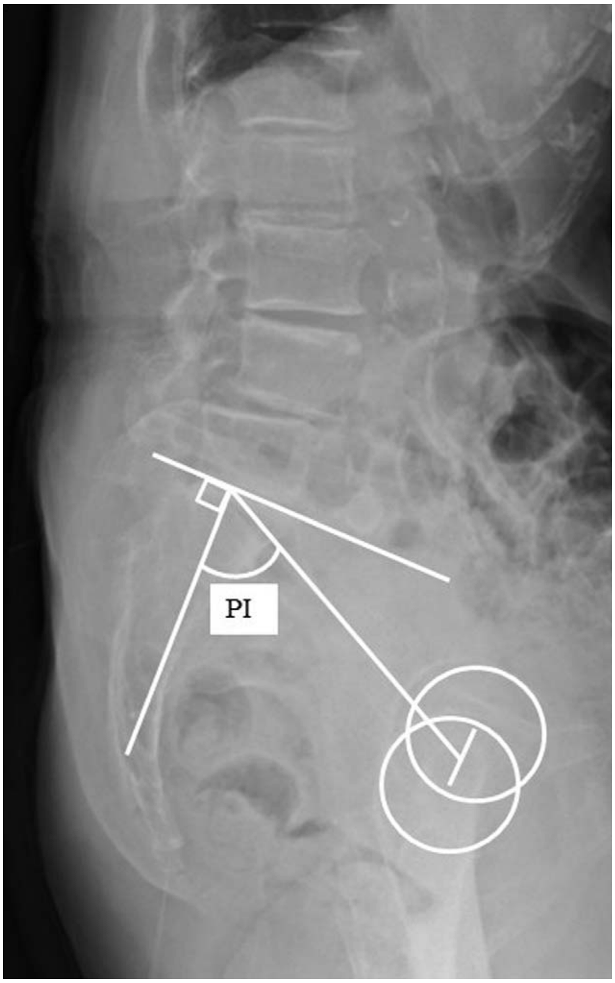

Figure 3. Pelvic incidence (PI). PI was the angle between the line perpendicular to the midpoint of the sacral endplate and the second line connecting the same sacral midpoint and the center of the femoral heads.

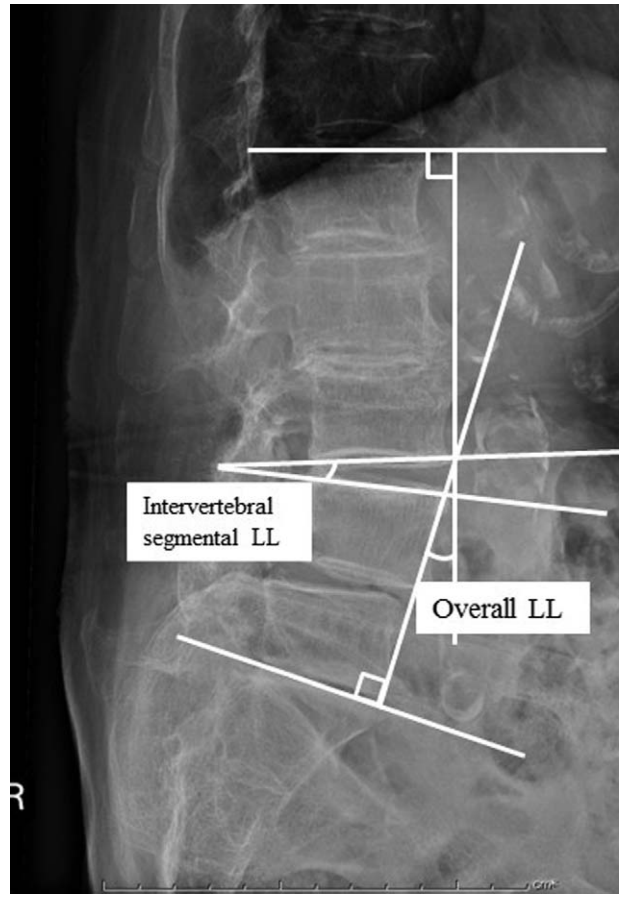

Figure 4. Overall lumbar lordosis (LL) and intervertebral segmental LL. Overall LL was the angle between the superior endplate at L1 and the superior endplate of S1. The intervertebral segmental LL was the angle between the inferior endplate of the upper vertebra and the superior endplate of the lower spine.

was inserted and additional bone chips were packed into the disc space. In patients with DS, slip reduction was performed by the slipped vertebral body lifted through PS using a combination of anatomic landmarks and fluoroscopic guidance. After slip reduction, PS fixation is performed by the conventional method with compression force.

2.4. Radiological assessment

All patients underwent preoperative standing lateral, intraoperative prone lateral, and 2-year postoperative standing lateral radiographs. The following factors were analyzed: pelvic incidence (PI), overall LL, and intervertebral segmental LL. PI was the angle between the line perpendicular to the midpoint of the sacral endplate and the second line connecting the same sacral midpoint and the center of the femoral heads (Fig. 3). Overall LL was the angle between the superior endplate at L1 and the superior endplate of S1. The intervertebral segmental LL was the angle between the inferior endplate of the upper vertebra and the superior endplate of the lower spine (L1–2, L2–3, L3–4, L4–5, L5-S1) (Fig. 4).

Measurements were performed using Picture Archiving and Communication System (PACS) software. Two independent observers (MM and TI) measured each parameter in consensus (intra- and inter-observer agreements were good to excellent for each parameter; kappa >0.70).

2.5. Statistical analysis

SPSS (version 13; SPSS, Chicago, IL) was used for statistical analyses. Data are presented as mean ± standard deviation. Between-group differences were evaluated using the Mann–Whitney *U* test. A probability value <.05 was considered to indicate statistical significance.

3. Results

A total of 38 consecutive patients (13 men and 25 women) were enrolled in this study. Group I included 20 patients (6 men and 14 women), with an average age of 70.8 ± 8.7 years (age range, 54–85 years). Group II comprised 18 patients (7 men and 11 women), with an average age of 71.7 ± 10.4 years (age range, 50–85 years) (Table 1).

3.1. PI, overall LL, and PI-LL

The radiographical parameters are summarized in Table 2. The PI was similar in both groups in the preoperative standing

Table 2

Radiographical outcomes 1.

Parameters	Group I (four-poster type frame) (n=20)	Group II (Jackson table) (n=18)	*P*-value
Pelvic incidence (PI), °	51.8±8.3	49.6±8.3	.42
Overall lumbar lordosis (LL)			
Preoperative, °	37.8±14.7	35.4±14.2	.61
Intraoperative, °	37.6±9.4	40.9±11.1	.33
Postoperative 2 years, °	41.3±13.9	38.7±14.9	.59
PI-LL			
Preoperative	14.0±15.6	14.1±14.3	.97
Intraoperative	14.2±9.2	8.7±12.8	.14
Postoperative 2 years	10.5±13.2	10.8±15.8	.94

Preoperative values are measured by standing lateral radiographs.
Intraoperative values are measured by prone lateral graphs.
Postoperative 2 years values are measured by standing lateral radiographs.
Values are means±standard deviation.

Table 3

Radiographical outcomes 2.

Intervertebral segmental LL	Group I (four-poster type frame) (n=20)	Group II (Jackson table) (n=18)	*P*-value
L1–2			
Preoperative, °	4.5±2.9	4.5±2.5	.19
Intraoperative, °	3.3±2.3	4.0±1.7	.34
Postoperative 2 years, °	4.4±2.6	4.2±2.6	.07
L2–3			
Preoperative, °	5.1±4.2	4.3±2.9	.52
Intraoperative, °	5.5±2.6	5.2±3.9	.79
Postoperative 2 years, °	5.9±3.6	4.0±3.3	.10
L3–4			
Preoperative, °	8.4±3.1	7.7±4.0	.56
Intraoperative, °	7.8±3.2	6.3±3.8	.19
Postoperative 2 years, °	10.8±4.0	7.9±4.4	.04*
L4–5 (fusion level)			
Preoperative, °	3.7±4.5	3.0±4.9	.64
Intraoperative, °	4.8±2.2	6.9±3.7	.03*
Postoperative 2 years, °	5.7±2.3	7.9±3.3	.03*
L5-S1			
Preoperative, °	5.8±5.3	5.1±3.8	.64
Intraoperative, °	5.9±3.1	8.0±3.5	.04*
Postoperative 2 years, °	4.3±3.2	4.8±3.6	.63

Preoperative values are measured by standing lateral radiographs.
Intraoperative values are measured by prone lateral graphs.
Postoperative 2 years values are measured by standing lateral radiographs.
Values are means±standard deviation.
* $P<.05$.

lateral radiographs (51.8°±8.3° for Group I and 49.6°±8.3° for Group II, $P=.42$). Preoperatively, the overall LL was 37.8°±14.7° for Group I and 35.4°±14.2° for Group II, which was changed to 37.6°±9.4° and 40.9°±11.1° intraoperatively and 41.3°±13.9° and 38.7°±14.9° at 2-year follow-up, respectively (not significant). Preoperatively, the PI-LL was 14.0±15.6 for Group I and 14.1±14.3 for Group II, which was changed to 14.2±9.2 and 8.7±12.8 intraoperatively and 10.5±13.2 and 10.8±15.8 at 2-year follow-up, respectively (not significant). No statistical difference was observed in overall LL and PI-LL preoperatively, postoperatively, and at the postoperative 2-year follow-up between the study groups (Table 2).

3.2. Intervertebral segmental LL (L1–2, L2–3, L3–4, L4–5, L5-S1)

Intervertebral segmental LL at L1–2 was 4.5°±2.9° for Group I and 4.5°±2.5° for Group II preoperatively, which was changed to 3.3°±2.3° and 4.0°±1.7° intraoperatively and 4.4°±2.6° and 4.2°±2.6° at the postoperative 2-year follow-up, respectively (not significant). Intervertebral segmental LL at L2–3 was 5.1°±4.2° for Group I and 4.3±2.9° for Group II preoperatively, which changed to 5.5°±2.6° and 5.2°±3.9° intraoperatively and 5.9°±3.6° and 4.0°±3.3° at the postoperative 2-year follow-up, respectively (not significant). Intervertebral segmental LL at L3–4 was 8.4°±3.1° for Group I and 7.7°±4.0° for Group II preoperatively, which was changed to 7.8°±3.2° and 6.3°±3.8° intraoperatively, respectively (not significant). At the postoperative 2-year follow-up, intervertebral segmental LL at L3–4 was 10.8°±4.0° for Group I and 7.9°±4.4° for Group II, which showed significant differences ($P=.04$). Intervertebral segmental LL at L4–5 (fusion level) was 3.7°±4.5° for Group I, and 3.0°±4.9° for Group II preoperatively, which was changed to 4.8°±2.2° and 6.9°±3.7° intraoperatively, respectively, showing significant differences ($P=.03$) and 5.7°±2.3° and 7.9°±3.3° at the postoperative 2-year follow-up, respectively, showing significant differences ($P=.03$). Intervertebral segmental LL at L5-S1 was 5.8°±5.3° for Group I and 5.1°±3.8° for Group II preoperatively, which was changed to 5.9°±3.1° and 8.0°±3.5° intraoperatively, showing significant differences ($P=.04$) and 4.3°±3.2° and 4.8°±3.6° at the postoperative 2-year follow-up, respectively (not significant), (Table 3).

The intraoperative intervertebral segmental LL at L4–5 and L5-S1 was greater in Group II than in Group I, and postoperative intervertebral segmental LL L4–5 (fusion level) achieved increased LL. In Group I, intraoperative intervertebral segmental LL at L4–5 did not achieve sufficient segmental LL, and postoperative intervertebral segmental LL at L3–4 was increased as a compensatory mechanism.

3.3. Surgical revisions and complications

There were no implant breakages or vascular and neurologic complications at the final follow-up, and all patients demonstrated bone fusion at 2 years postoperatively.

3.4. Case presentation

3.4.1. Case 1: Group (four-poster type frame). Overall LL was 49° and intervertebral segmental LL at L3–4, L4–5, and L5-S1 was 6°, 2°, and 3°, respectively, preoperatively (Fig. 5A). Overall LL was changed to 53° and intervertebral segmental LL at L3–4, L4–5, and L5-S1 was changed to 7°, 4°, and 5°, respectively, intraoperatively (Fig. 5B). Postoperative radiographs obtained at 2 years after surgery showed that overall LL was changed to 52° and intervertebral segmental LL at L3–4, L4–5, and L5-S1 changed to 12°, 4°, and 3°, respectively (Fig. 5C).

3.4.2. Case 2: Group II (Jackson table). Overall LL was 46° and intervertebral segmental LL at L3–4, L4–5, and L5-S1 was 11°, 7°, and 5°, respectively, preoperatively (Fig. 6A). Overall LL was changed to 49° and intervertebral segmental LL at L3–4,

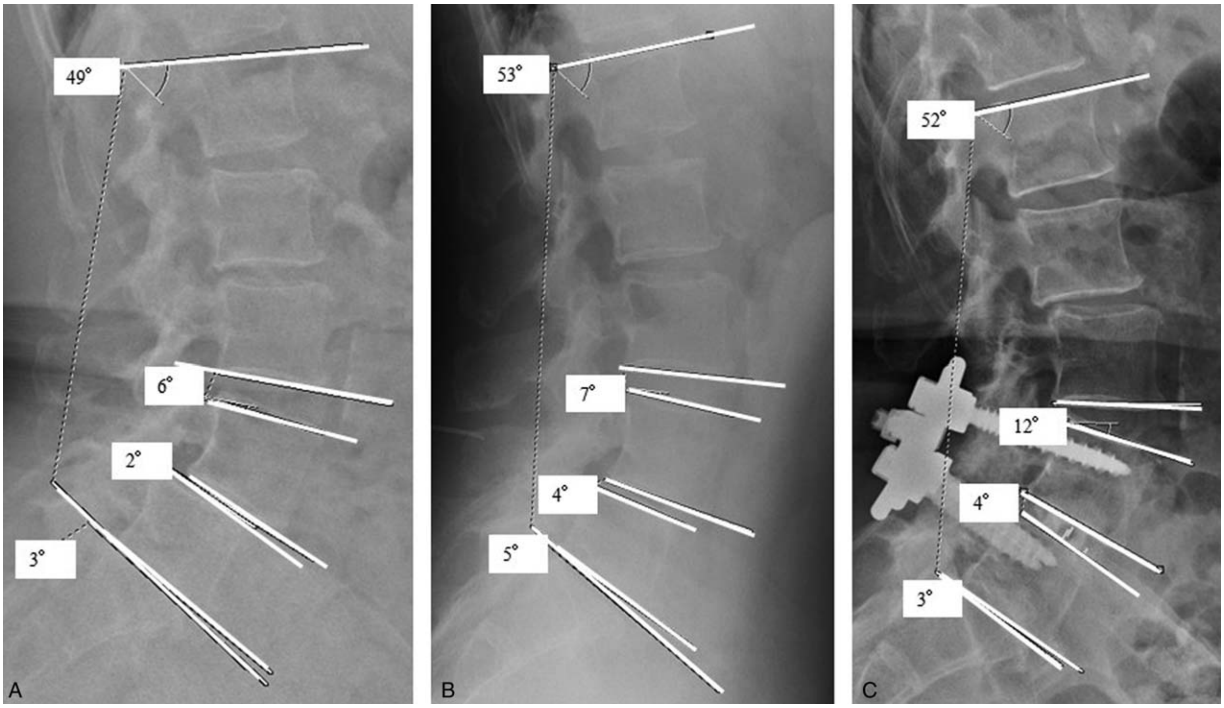

Figure 5. The change of overall lumbar lordosis (LL) and intervertebral segmental LL in Group I (four-poster type frame). A: Overall LL was 49° and intervertebral segmental LL at L3–4, L4–5, and L5-S1 was 6°, 2°, and 3°, respectively, preoperatively. B: Overall LL was changed to 53° and intervertebral segmental LL at L3–4, L4–5, and L5-S1 was changed to 7°, 4°, and 5°, respectively, intraoperatively. C: Postoperative radiographs obtained at 2 years postoperatively showed that overall LL was changed to 52° and intervertebral segmental LL at L3–4, L4–5, and L5-S1 was changed to 12°, 4°, and 3°, respectively, postoperatively.

L4–5, and L5-S1 was changed to 11°, 10°, and 8°, respectively, intraoperatively (Fig. 6B). Postoperative radiographs obtained at 2 years after surgery showed that overall LL was changed to 50° and intervertebral segmental LL at L3–4, L4–5, and L5-S1 was changed to 11°, 11°, and 5°, respectively (Fig. 6C).

4. Discussion

In the present study, the hip flexion of the patients who were operated on the four-poster type frame was 30° (Group I), and the hip flexion of those who were operated on the Jackson spinal table was adjusted 0° (Group II). The overall LL of the

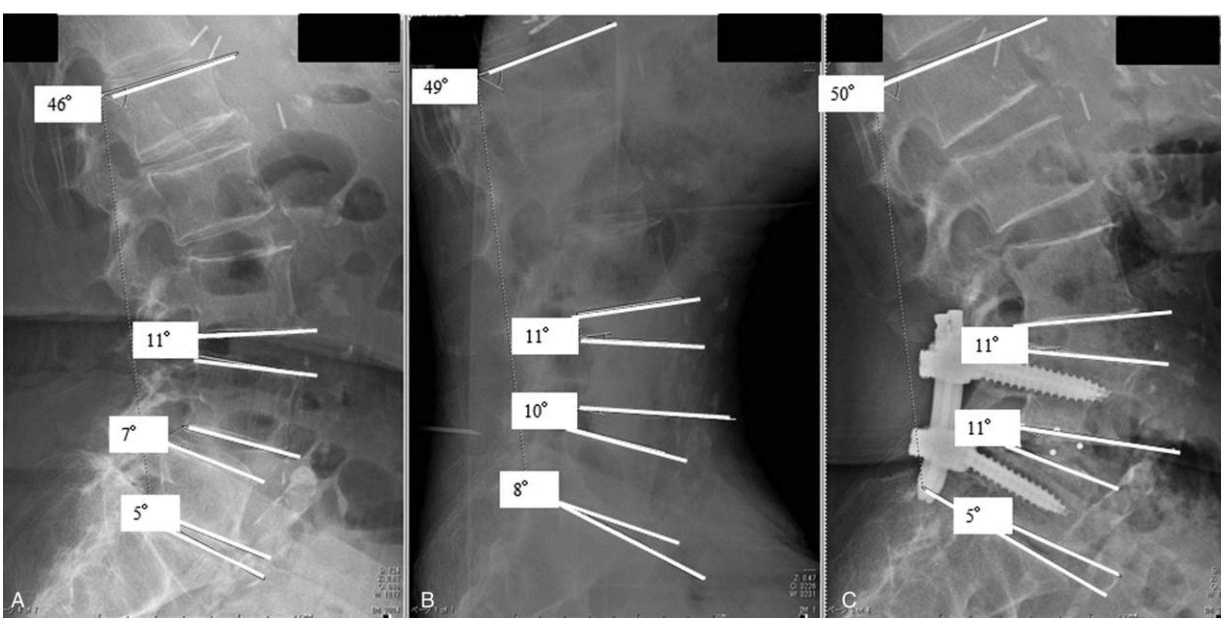

Figure 6. The change of overall lumbar lordosis (LL) and intervertebral segmental LL in Group II (Jackson table). A: Overall LL was 46° and intervertebral segmental LL at L3–4, L4–5, and L5-S1 was 11°, 7°, and 5°, respectively, preoperatively. B: Overall LL was changed to 49° and intervertebral segmental LL at L3–4, L4–5, and L5-S1 was changed to 11°, 10°, and 8°, respectively, intraoperatively. C: Postoperative radiographs obtained at 2 years postoperatively showed that overall LL was changed to 50° and intervertebral segmental LL at L3–4, L4–5, and L5-S1 was changed to 11°, 11° and that at L5-S1 to 5°, respectively.

intraoperative prone position was not changed in both groups. However, the segmental lordosis at L4–5 and L5-S1 of the intraoperative prone position was significantly larger in Group II than in Group I. Therefore, the more the hip was extended, the more the segmental lordosis increased in the lower lumbar spine. The segmental lordosis at L4–5 at 2 years postoperatively was also significantly larger in Group II than in Group I. On the other hand, the segmental lordosis at L5-S1 at 2 years postoperatively was not changed in both groups, and the segmental lordosis at L3–4 at 2 years postoperatively was significantly larger in Group I than in Group II. Interestingly, although the segmental lordosis of the fused level (L4–5) did not achieve sufficient amount in Group I at 2 years postoperatively, the overall LL at 2 years postoperatively was not decreased compared with the preoperative lordosis. These results show that the overall spinal alignment was unaffected by the decrease in segmental LL in the fused level due to the compensation of the upper adjacent segments.

Loss of lordosis after lumbar spine fusion can lead to chronic low back pain, positive sagittal balance with forward inclination of the trunk, and adjacent segment degeneration.[1] Preservation of the physiological sagittal alignment is essential in spinal reconstructive surgery,[8] and intensive knowledge of LL restoration is very important.

Segmental lumbar hypolordosis from degenerative spondylolisthesis is a common trigger for the development of sagittal imbalance. Especially at the level of L4–5 and L5-S1 where the two-thirds of LL is formed,[9] restoration of local and regional lordosis at that level is critical for preserving and improving sagittal balance.[10] Although the TLIF technique provides anterior column support and posterolateral stabilization, and it seems to be an ideal procedure for lumbar degenerative spondylolisthesis,[11,12] with regard to the restoration of segmental hypolordosis, conflicting results have been reported.[10] In contrast, various authors demonstrated that a significant amount of segmental lordosis could be achieved.[11,13,14]

There are many reports on the factors related to LL restoration following lumbar interbody fusion.[13–17] One of the most important factors was the selection of surgical table and hip and knee position. Stephens et al[4] have compared operative tables used commonly for spinal procedures to determine which positions reproduce "normal" LL. Ten volunteers without any history of lumbar surgery or symptomatology underwent lateral radiograph in the standing position and in 3 different kinds of operative position: prone position on the Jackson table, knee flexed at 15°, knee-chest position with hips flexed at 90° on the Andrews table, and intermediate position with hips flexed at 60°. The mean LL angle from L1 to sacrum was 51.7° in the standing position, 52° in the prone position on the Jackson table, 17° in the knee-chest position, and 27.3° with the hips flexed at 60°. The decrease in lordosis was statistically significant in the knee-chest position and the intermediate position compared with the standing position and the prone position on the Jackson table. Peterson et al[7] also reported that the "90–90" position on the Hastings frame was associated with significant reduction of total and segmental lordosis in the middle and lower lumbar spine. Thus, the intraoperative total LL and segmental lordosis decreased with increasing intraoperative hip flexion angle.[18,19]

The biomechanical effect of postoperative hypolordosis in lumbar fusion on instrumented and adjacent spinal segments has been described by Umehara et al.[20] Postoperative lumbar hypolordosis accelerate adjacent segment deterioration by loading the motion segment. The loss of lordosis in the instrumented segments not only affects the adjacent segments, but also increases the load on the posterior spinal implant. The tension in the anterior soft tissue structures decreases, increasing the implant load needed to balance the extension moment. To maintain good balance in the presence of a loss of lordosis, the posterior shear force on the proximal segments increases. This increases the extension moment on the lumbar spine and leads to an increased loading of the posterior implant. The loading of the posterior column in the segment above the instrumentation increases and may contribute to the degenerative changes at the junctional level reported as long-term consequences of lumbar fusion.

There are several limitations to the present study that should be mentioned. The present study had a retrospective design and the follow-up period was 2 years, which was relatively short. The global sagittal alignment and thoracolumbar, lower extremities alignment parameters were also not evaluated. Long-term radiographic evaluation of adjacent segments and comparison between operative correction and clinical outcome could indicate a further insight into the natural history of post-fusion lumbar spine. Further studies are needed to elucidate these issues.

5. Conclusion

The results of the present study indicate that the more the hip was extended intraoperatively, the more the segmental lordosis increased in the lower lumbar spine. Using the OSI Jackson spinal table with hip flexion at 0°, the segmental lordosis of the fused level was increased. On the other hand, using the four-poster type frame with hip flexion at 30°, the segmental lordosis of the fused level was not sufficient enough, resulting in the compensation of the upper adjacent segment to maintain overall lordosis. In this point, selecting the appropriate surgical table and hip position are very important. Underachievement of segmental lordosis leads to acceleration of the upper adjacent segment load.

Author contributions

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