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Using Lordotic Cages at the L5–S1 Level Does Not Guarantee the Improvement of Sagittal Alignment in Patients Who Underwent Posterior Lumbar Interbody Fusion

Jae Hwan Cho, Chang Ju Hwang, Dong-Ho Lee, Choon Sung Lee

Department of Orthopaedic Surgery, Asan Medical Center, University of Ulsan College of Medicine, Seoul, Korea

Study Design: Retrospective comparative study.

Purpose: This study aimed to investigate the effects of the lordotic angle of cages on sagittal alignment in patients who underwent 1- or 2-level posterior lumbar interbody fusion (PLIF), including the L5–S1 level.

Overview of Literature: Few studies have addressed the effects of the lordotic angle of cages on regional and global sagittal balance in patients undergoing PLIF at the L5–S1 level.

Methods: Sixty-one patients who underwent 1- or 2-level PLIF, including the L5–S1 level, were divided into two groups based on the lordotic angle of cages (4° and 8° in 41 and 20 patients, respectively). Clinical and radiological parameters were compared. Correlation analyzes were performed to reveal the effect of flexibility and position of cages on the regional sagittal parameters.

Results: Pre- and postoperative clinical and radiological parameters were not different between the two groups. Although clinical outcomes improved postoperatively, sagittal parameters did not improve postoperatively in both groups. Patients who underwent 1-level PLIF at the L5–S1 level with the use of 8° cages showed no postoperative improvement (segmental angle: 16.1°–15.9°, p=0.140; lumbar lordosis: 44.8°–47.8°, p=0.740) of regional sagittal parameters. The degree of anterior location of cages showed a positive correlation with the postoperative restoration of the segmental angle (p=0.012 and p=0.050 at 1 and 2 years postoperatively, respectively).

Conclusions: Clinical and radiological outcomes based on the lordotic angle of cages were not different. Even with the use of 8° cages and regardless of the more anterior position of cages, sagittal alignment did not improve in cases involving the L5–S1 level. PLIF at the L5–S1 level should be used with caution because improvement in sagittal alignment did not occur.

Keywords: Posterior lumbar interbody fusion; Cage; Sagittal balance; Lordosis; Radiological outcome

Introduction

Sagittal alignment and its association with functional outcomes have been the focus of recent research [1,2]. Because regional sagittal imbalance is correlated with poor clinical outcomes in degenerative lumbar diseases, this

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Corresponding author: Jae Hwan Cho
Department of Orthopaedic Surgery, Asan Medical Center, University of Ulsan College of Medicine, 88 Olympic-ro 43-gil, Songpa-gu, Seoul 05505, Korea
Tel: +82-2-3010-3549, Fax: +82-2-3010-8555, E-mail: spinecjh@gmail.com

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concept is applicable and important for general spine surgeons and specialized deformity surgeons [3,4]. Knowledge of sagittal alignment is highly significant, even when performing degenerative lumbar spine surgeries, because several spinal deformities also arise from simple lumbar fusion surgeries, including iatrogenic flatback [5].

Among various types of lumbar surgeries, posterior lumbar interbody fusion (PLIF) is a well-proven procedure to perform in patients who require stabilization following wide decompression for spinal stenosis or spondylolisthesis [6,7]. PLIF has several advantages in maintaining sagittal balance compared with posterolateral fusion [8]. Intervertebral height elevation and cage insertion are believed to be the main reasons for the superiority of PLIF, followed by compression between pedicle screws posteriorly. For this reason, research has focused on the effect of cage morphometry on postoperative sagittal parameters [9,10]. Although several studies have addressed the effects of the lordotic angle of cages on regional and global sagittal balance in patients who underwent PLIF, these studies did not compare the effect of lordotic cages focusing on the L5–S1 level [10]. In fact, the characteristics of the L5–S1 disk space are completely different from those of the L4–5 or L3–4 disc space regarding the high nonunion rate and greater segmental angle (SA). Therefore, a lordotic cage may be mandatory to keep the lordotic angle at the L5–S1 level. Therefore, we hypothesized that lordotic cages have different effects at the L5–S1 PLIF. This study aimed to determine the effects of the lordotic angle of cages on sagittal alignment in patients who underwent L5–S1 PLIF.

Materials and Methods

1. Patients and operative methods

A total of 298 consecutive patients who underwent 1 or 2-level PLIF for spinal stenosis or spondylolisthesis from March 2014 to December 2018 in Asan Medical Center (Seoul) were included in this study. Of the 298 patients, only 61 who underwent L5–S1 fusion (L5–S1 or L4–5–S1) were finally enrolled. All surgeries were performed by a single surgeon (J.H.C.) and were followed up for more than 2 years. We used a Jackson spine table with supporting cushions in the chest and bilateral pelvic area to avoid pressure on the abdomen, which could lead to lumbar lordosis (LL). The operative procedure was performed in the following manner: open midline approach, pedicle screw insertion, disk space distraction with temporary rod fixation, total laminectomy with complete total facetectomy, disk material removal with serial dilation, endplate curettage with ring curette, polyetheretherketone cage insertion with bone graft material (local bone fragments with demineralized bone matrix or bone morphogenetic protein-2), and rod fixation by maximal compression between screws to maximize segmental lordosis. We typically attempted to insert cages bilaterally. Four-degree lordotic cages were routinely used between 2014 and 2016. Since 2017, 8° lordotic cages were used. Based on the lordotic angle of the cages, patients were divided into two groups (4° and 8° in 41 and 20 patients, respectively).

2. Study variables

Demographic and surgery-related data were obtained by electronic chart reviews. Visual Analog Scale, Oswestry Disability Index (ODI), and EuroQol-5 Dimension questionnaire (EQ-5D) were used to evaluate clinical outcomes. Radiological parameters were obtained from whole-spine standing lateral radiographs pre- and postoperatively. The SA and LL were measured as regional sagittal parameters. The SA was defined as a Cobbs angle between the uppermost and lowermost endplates of the involved vertebra (i.e., L4 and L5 if L4–5 fusion, respectively). The C7–S1 sagittal vertical axis (SVA) and pelvic incidence (PI)–LL (PI–LL) were measured as global sagittal parameters. The flexibility of the involved segment was measured by the difference of SA in flexion and extension lateral radiographs (i.e., the value divided by two if 2-level fusion). The position of cages was measured by subtracting the distance between the posterior margin of the cage and the posterior end of the disk space from the distance between the anterior margin of the cage and the anterior end of the disk space. A positive value indicates that the cages are anteriorly located in the disk space. The measurement methods are briefly illustrated in Fig. 1. All patients were followed up at 1, 3, 6, and 12 months postoperatively and annually thereafter. This study was approved by the Institutional Review Board of Asan Medical Center (IRB no., 2020-1306), which waived the requirement for informed consent due to the retrospective nature of the study.

3. Statistical analyzes

Demographic data, surgery-related data, clinical out-

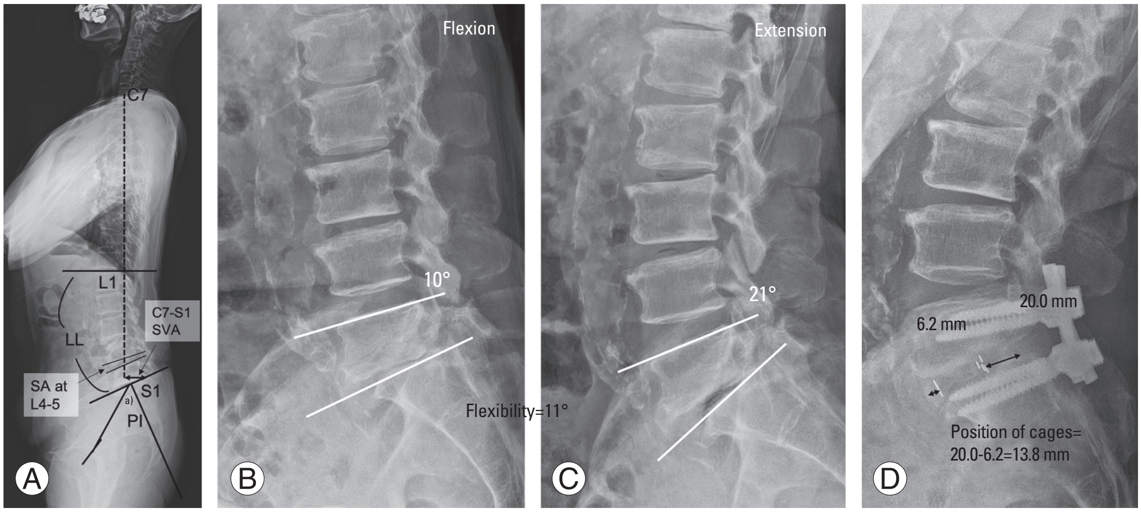

Fig. 1. (A, B) Radiological measurements. **(A)** Segmental angle (SA), lumbar lordosis (LL), pelvic incidence (PI)[a], and sagittal vertical axis (SVA). **(B–D)** Flexibility of segments and position of cages.

Table 1. Demographic data and preoperative radiological parameters

Characteristic	4° Cages (N=41)	8° Cages (N=20)	*p*-value
Age (yr)	63.5±9.4	63.5±8.4	0.988
Sex			
Male	11	3	0.302
Female	30	17	
Height (cm)	156.6±8.9	155.7±6.0	0.689
Weight (kg)	61.5±12.1	60.2±9.3	0.693
Body mass index (kg/m^2)	25.0±4.0	24.9±3.9	0.954
Bone mineral density (T score)	-1.2±1.2	-1.3±1.2	0.804
Operation level			
1	23 (56.1)	13 (65.0)	0.507
2	18 (43.9)	7 (35.0)	
Follow-up period (mo)	28.3±10.2	23.8±8.4	0.341
Flexibility (°)	7.8±3.6	10.3±6.0	0.070
Position of cages (mm)[a]	2.5±4.1	2.7±7.1	0.932
Segmental angle (°)	18.5±7.7	20.1±7.0	0.466
LL (°)	41.6±13.3	43.4±9.9	0.621
C7–S1 SVA (mm)	24.1±46.3	19.2±34.2	0.687
PI (°)	52.9±9.8	52.3±11.0	0.838
PI–LL (°)	11.3±13.0	8.9±8.8	0.485

Values are presented as number of cases (%) for categorical variables and mean±standard deviation for continuous variables.
LL, lumbar lordosis; SVA, sagittal vertical axis; PI, pelvic incidence; PI–LL, PI–LL mismatch.
[a]Positive means anteriorly located cages in the disc space.

comes, and radiological outcomes were compared between the groups using Student *t*-test or chi-square test. Correlation analyzes were performed to reveal the effect of flexibility or position of cages on the SA or LL. Statistical analyzes were performed using the IBM SPSS software ver. 21.0 (IBM Corp., Armonk, NY, USA). All *p*-values <0.05 were considered statistically significant.

Results

The patients had a mean age of 63.5 years old. Demographic data showed no differences between the two groups (Table 1). Moreover, no differences in preoperative radiological parameters were detected between the two groups.

1. Comparisons of clinical and radiological outcomes between the 4° and 8° cage groups

SA (20.2°–19.3°, p=0.259), LL (42.7°–43.3°, p=0.705), C7–S1 SVA (28.3–30.5 mm, p=0.795), and PI–LL (10.2°–9.6°, p=0.725) did not change postoperatively. No differences in the radiological parameters between the two groups at every follow-up period were noted (Table 2). Furthermore, clinical outcomes showed marked improvement postoperatively. Back and leg pain VAS scores decreased from 5.4 to 3.0 (p=0.004) and from 5.3 to 3.8 (p=0.099), respectively. Moreover, ODI scores decreased from 56.0 to 28.6 postoperatively (p<0.001). However, no differences in VAS, ODI, and each domain of EQ-5D were found between the two groups (Table 3).

Table 2. Comparisons of radiological parameters by the lordotic angle of cages

Variable	Period	4° Cages (n=41)	8° Cages (n=20)	*p*-value
SA (°)	Preop	18.5±7.7	20.1±7.0	0.466
	PO 6 mo	18.4±8.0	20.0±6.9	0.581
	PO 1 yr	18.7±6.5	21.1±5.6	0.263
	PO 2 yr	17.4±7.4	20.7±6.2	0.139
LL (°)	Preop	41.6±13.3	43.4±9.9	0.621
	PO 6 mo	45.7±10.5	41.5±9.0	0.242
	PO 1 yr	44.6±10.1	43.8±7.8	0.802
	PO 2 yr	42.9±13.3	45.2±9.0	0.545
C7–S1 SVA (mm)	Preop	24.1±46.3	19.2±34.2	0.687
	PO 6 mo	28.6±30.9	31.9±27.7	0.756
	PO 1 yr	13.0±28.3	18.8±22.0	0.516
	PO 2 yr	23.8±33.20	9.4±25.5	0.340
PI–LL (°)	Preop	11.3±13.0	8.9±8.8	0.485
	PO 6 mo	7.5±14.6	11.1±7.2	0.376
	PO 1 yr	5.8±15.6	9.6±8.7	0.415
	PO 2 yr	8.4±20.8	-1.4±9.3	0.279

Values are presented as mean±standard deviation.
SA, segmental angle; Preop, preoperative; PO, postoperative; LL, lumbar lordosis; SVA, sagittal vertical axis; PI–LL, pelvic incidence-LL mismatch.

Table 4. Effect of lordotic angle of cages in 1-level L5–S1 fusion cases

Variable	4° Cages (N=27)	8° Cages (N=13)	*p*-value[a)]
Flexibility (°)	8.3±4.0	11.7±7.0	0.142
Position of cages (mm)	3.2±4.4	4.8±7.3	0.411
SA_preop (°)	16.1±6.0	16.1±4.7	0.994
SA_PO 6 mo (°)	16.4±8.4	15.3±3.7	0.706
SA_PO 1 yr (°)	16.8±5.7	16.9±3.3	0.973
SA_PO 2 yr (°)	15.3±6.7	15.9±3.6	0.811
LL_preop (°)	42.0±13.6	44.8±11.2	0.548
LL_PO 6 mo (°)	48.4±9.7	41.8±10.5	0.164
LL_PO 1 yr (°)	46.3±10.2	45.3±8.5	0.812
LL_PO 2 yr (°)	45.8±12.6	47.8±10.5	0.703

Values are presented as mean±standard deviation.
SA, segmental angle; Preop, preoperative; PO, postoperative; LL, lumbar lordosis.
[a)]Each *p*-value represents the comparison between 4° cages and 8° cages.

Table 3. Comparisons of functional outcomes by the lordotic angle of cages

Variable	Period	4° Cages (N=41)	8° Cages (N=20)	*p*-value
VAS (back)	Preop	5.3±2.6	5.9±1.7	0.491
	PO 1 yr	2.7±2.7	4.6±2.6	0.057
	PO 2 yr	4.0±3.3	4.7±2.5	0.450
VAS (leg)	Preop	5.8±2.8	4.7±3.0	0.328
	PO 1 yr	2.3±2.8	3.3±2.8	0.374
	PO 2 yr	3.1±3.3	3.7±3.2	0.566
ODI	Preop	54.0±16.9	62.0±17.4	0.165
	PO 1 yr	31.3±17.8	29.4±14.1	0.753
	PO 2 yr	32.7±21.1	34.6±17.4	0.750
EQ-5D (mobility)	Preop	3.2±0.9	3.7±1.1	0.092
	PO 1 yr	2.2±1.0	1.8±1.0	0.221
	PO 2 yr	2.2±1.0	2.1±1.1	0.693
EQ-5D (self)	Preop	2.4±1.0	2.7±1.4	0.460
	PO 1 yr	1.8±0.9	2.0±0.9	0.458
	PO 2 yr	1.8±1.0	2.2±0.8	0.190
EQ-5D (general)	Preop	3.0±1.0	3.5±1.4	0.243
	PO 1 yr	2.0±1.1	2.1±0.8	0.715
	PO 2 yr	2.3±1.1	2.3±0.8	0.970
EQ-5D (pain)	Preop	3.4±1.1	3.6±0.9	0.435
	PO 1 yr	2.4±1.0	2.6±0.9	0.667
	PO 2 yr	2.6±1.0	2.9±1.0	0.291
EQ-5D (depression)	Preop	2.7±1.4	2.7±1.4	0.868
	PO 1 yr	1.9±1.0	1.9±1.1	0.875
	PO 2 yr	1.8±1.0	2.3±1.3	0.096

Values are presented as mean±standard deviation.
VAS, Visual Analog Scale; Preop, preoperative; PO, postoperative; ODI, Oswestry Disability Index; EQ-5D, EuroQol-5 Dimension questionnaire.

2. Comparisons of regional sagittal parameters in 1 or 2-level PLIF, including the L5–S1 level

Patients who underwent PLIF at the L5–S1 level with 4° cages showed no postoperative improvement in regional sagittal parameters. SA changed from 16.1° to 15.3° (p=0.357), and LL changed from 42.0° to 45.8° (p=0.132) at postoperative 2 years. This result was also confirmed even with the use of 8° cages. SA changed from 16.1° to 15.9° (p=0.140), and LL changed from 44.8° to 47.8° (p=0.740) postoperatively. Additionally, no differences in sagittal parameters between 4° and 8° cages in 1-level L5–S1 fusion cases (Table 4) and 2-level L4–5–S1 fusion cases were noted (Table 5).

3. Correlation between segmental flexibility, position of cages, and postoperative changes in segmental angle and lumbar lordosis

Preoperative segmental flexibility was not correlated with postoperative changes in the SA and LL. However, the

Table 5. Effect of lordotic angle of cages in 2-level L4–5–S1 fusion cases

Variable	4° Cages (N=14)	8° Cages (N=7)	*p*-value[a)]
Flexibility (°)	6.8±2.0	7.9±2.7	0.343
Position of cages (mm)	6.5±6.5	2.5±4.3	0.181
SA_preop (°)	23.3±8.8	27.0±4.3	0.321
SA_PO 6 mo (°)	22.8±5.6	27.1±3.6	0.141
SA_PO 1 yr (°)	21.8±6.8	26.0±2.9	0.175
SA_PO 2 yr (°)	21.4±7.2	26.3±2.4	0.071
LL_preop (°)	40.8±13.3	40.9±7.4	0.992
LL_PO 6 mo (°)	39.5±10.7	41.0±6.7	0.778
LL_PO 1 yr (°)	41.4±9.8	42.0±7.2	0.898
LL_PO 2 yr (°)	37.9±13.3	42.3±6.6	0.386

Values are presented as mean±standard deviation.
SA, segmental angle; Preop, preoperative; PO, postoperative; LL, lumbar lordosis.
[a)]Each *p*-value represents the comparison between 4° cages and 8° cages.

degree of anterior location of cages was positively correlated with the postoperative SA restoration (p=0.012 and p=0.050 at 1 and 2 years postoperatively, respectively). This effect was not shown in LL restoration (Table 6). A representative case is briefly illustrated in Fig. 2.

Discussion

Sagittal alignment has been widely researched and is closely related to functional outcomes [1,2]. Aggravation of regional sagittal parameters, including decreased LL or increased pelvic tilt, resulted in poor clinical outcomes, even if global sagittal parameters are well maintained [11-13]. Thus, a thorough understanding of the maintenance

Table 6. Correlation between segmental flexibility, position of cages and postoperative changes in segmental angle and lumbar lordosis

Variable	SA diff (pre–1 yr) (°)		SA diff (pre–2 yr) (°)		LL diff (pre–1 yr) (°)		LL diff (pre–2 yr) (°)	
	r	*p*-value	*r*	*p*-value	*r*	*p*-value	*r*	*p*-value
Flexibility (°)	-0.105	0.133	-0.059	0.474	-0.141	0.043	-0.067	0.414
Position of cages (mm)	0.175	0.012	0.160	0.050	-0.013	0.856	-0.096	0.239

SA, segmental angle; diff, difference; Pre, preoperative; LL, lumbar lordosis.

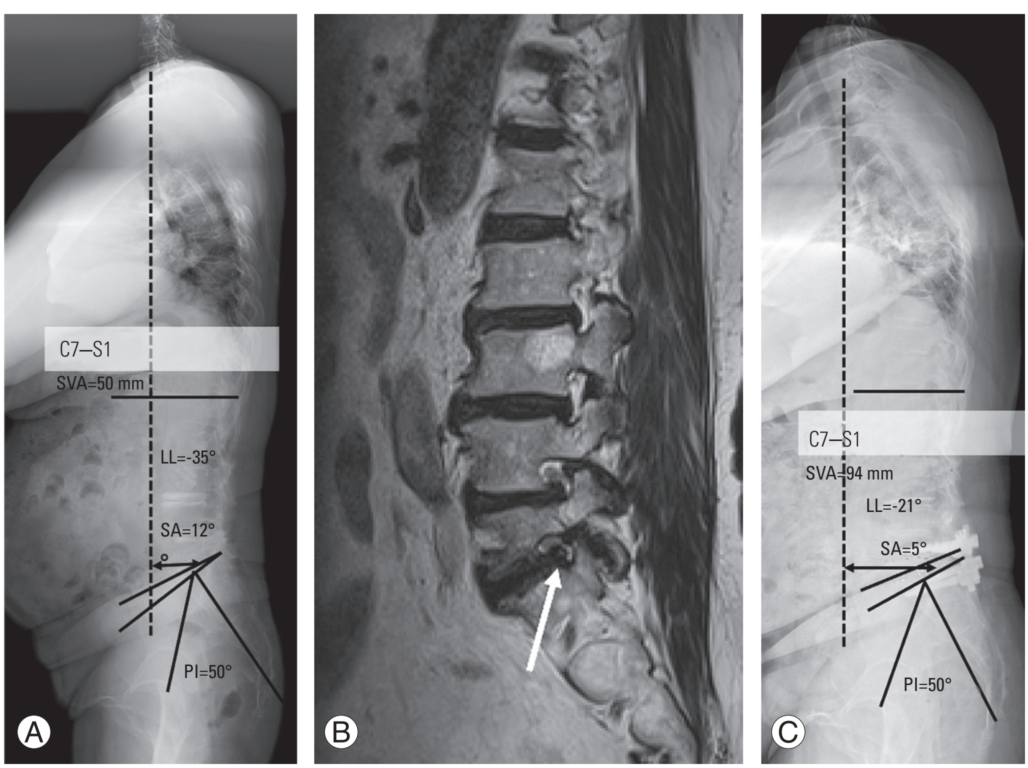

Fig. 2. A representative case showing the aggravation of sagittal balance following posterior lumbar interbody fusion at L5–S1 level with 8° lordotic cages. **(A)** A 68-year-old female patient with left leg sciatica and intermittent claudication showed regional sagittal imbalance preoperatively. **(B)** Magnetic resonance imaging showed left foraminal stenosis at L5–S1 level (arrow). **(C)** Regional sagittal parameters did not improve in the 2-year postoperative radiograph, despite the use of 8° cages. SVA, sagittal vertical axis; LL, lumbar lordosis; SA, segmental angle; PI, pelvic incidence.

of sagittal alignment is significant for lumbar fusion surgeries.

Recently, the regional sagittal alignment between L4 and S1 has become a meaningful parameter to predict mechanical complications following deformity correction [14,15]. Sagittal realignment at the lower lumbar level should be stressed in degenerative lumbar surgeries to avoid sagittal imbalance and minimize adjacent segment disease. Although anterior or oblique lumbar interbody fusion techniques could restore LL better, PLIF and TLIF are the most frequently used procedures if direct decompression is required. To improve regional sagittal balance, such as the SA or LL, lordotic cages have been used [16]. Although several studies compared the clinical and radiological outcomes, most studies did not demonstrate any differences based on the lordotic angle of the cages or cage morphometry [9,11]. However, those studies did not focus on the L5–S1 level.

In our study, we did not find improvement in sagittal parameters following L5–S1 PLIF despite using 8° cages. Furthermore, we did not observe differences between the 4° and 8° cage groups. The reason for this finding is unclear. An intact anterior longitudinal ligament could prevent successful lordotic changes [17,18]. Severe degenerative changes causing disk height loss may also inhibit enough distraction to use lordotic cages [19]. For this reason, posterior insertion of higher-degree cages, such as 12°, will be challenging. The level of degenerative lumbar disease is also difficult. The physiologic lordosis of the L5–S1 level is greater than that of the L3–4 or L4–5 level [20]. Owing to more frequent surgeries at the L5–S1 level, the probability of failure to restore ideal lordosis may increase by using PLIF.

The abovementioned results suggest that PLIF at the L5–S1 level is insufficient to restore ideal lordosis in patients with a degenerative lumbar spine. However, another study proposed SA restoration at the L5–S1 level by using the “insert and rotate maneuver” [21]. This technique was suggested to obtain the optimum cage position for lordosis. In fact, it was reported that the anterior position of cages is significant to restore segmental lordosis [21], which is a concurrent finding in our study (Table 6). Furthermore, LL and SVA restoration was reported by using hyper-lordotic cages (15°) [22]. Therefore, to reveal the effects of lordotic cages on lordosis restoration at the L5–S1 level, comparisons of different insertion techniques or higher lordotic angles of cages are required.

The lack of LL following lumbar degenerative surgeries indicates a high probability of iatrogenic flatback deformity, as well as adjacent segment degeneration, in the future [23-25]. In our study, although it was easy to insert the cages more anteriorly at the L5–S1 level, it did not guarantee sufficient restoration of segmental lordosis at the L5–S1 level. Therefore, surgeons should pay attention to the sagittal restoration when they perform PLIF, particularly at the L5–S1 level.

The reasons for the failure to restore ideal lordosis at the L5–S1 level using PLIF can be explained by anatomical characteristics. First, the physiological lordotic angle of the L5–S1 level is the largest among all disk levels [20]. Second, disk degeneration followed by disk height collapse at the L5–S1 level is a frequent mechanism of neural foraminal stenosis; the disk collapse makes the insertion of cages with enough height more difficult [26,27]. Third, the inherent rigidity of the sacrum could prevent free manipulation of the L5–S1 disk space.

Based on the current study, the authors started researching the risk of aggravation of sagittal alignment more carefully before operating at the L5–S1 level. If there is preoperative sagittal malalignment or the ideal angle of lordosis is greater (such as in patients with high PI), we considered other options to avoid postoperative iatrogenic sagittal malalignment. Although lack of access due to frequent vascular anatomic barriers is a challenge, oblique lumbar interbody fusion is an alternative approach [28,29].

This retrospective study had some limitations. First, the number of patients was not equally distributed. A smaller number of patients underwent PLIF at the L5–S1 level with 8° cages, making it difficult to reach the statistical power required to detect significant differences. Second, this study included heterogeneous diseases, including central spinal stenosis, degenerative spondylolisthesis, isthmic spondylolisthesis, and neural foraminal stenosis. The heterogeneity could cause selection bias regardless of the statistical analyzes. Third, comparison with anterior or lateral approaches, including ALIF or OLIF, which are well-known types of lordotic surgeries, could have been better; however, we did not have enough cases for the comparison.

Regardless of the abovementioned limitations, this study is meaningful in that surgeons should pay attention to the sagittal alignment even when performing simple lumbar fusion surgeries at the L5–S1 level. Regional sagittal imbalance at the L5–S1 level could be related to the development of adult spinal deformities in the future.

Conclusions

No differences in clinical and radiological outcomes based on the lordotic angle of the cages in PLIF, including the L5–S1 level, were noted. Despite the use of 8° cages and regardless of the more anterior position of cages, sagittal alignment did not change postoperatively in cases involving the L5–S1 level. Therefore, since the improvement in sagittal alignment did not occur, caution should be used during PLIF at the L5–S1 level.

Conflict of Interest

No potential conflict of interest relevant to this article was reported.

ORCID

Jae Hwan Cho: https://orcid.org/0000-0002-1178-9778

Author Contributions

Conceptualization: JHC; data curation: JHC, CJH; formal analysis: JHC; funding acquisition: DHL, CSL; methodology: JHC, CJH; project administration: DHL, CSL; visualization: CJH, DHL; Writing-original draft: CJH; writing-review & editing: CJH, DHL, CSL; and final approval of the manuscript: all authors.

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