Evaluation of the location of intervertebral cages during oblique lateral interbody fusion surgery to achieve sagittal correction

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Abstract:

Introduction: Oblique lateral interbody fusion (OLIF) can achieve recovery of lumbar lordosis (LL) in minimally invasive manner. The current study aimed to evaluate the location of lateral intervertebral cages during OLIF in terms of LL correction.

Methods: The subjects were patients who underwent OLIF for lumbar degenerative diseases, including lumbar spinal stenosis, spondylolisthesis, and discogenic low back pain. Their clinical outcome was evaluated using visual analogue scale on lower back pain (LBP), leg pain and numbness. The following parameters were retrospectively evaluated on plain radiographic images and computed tomography scans before and at 1 year after OLIF: the intervertebral height, vertebral translation, and sagittal angle. The cage position was defined by equally dividing the caudal endplate into five zones (I to V), and its association with segmental lordosis restoration was analyzed. Subjects were also evaluated for a postoperative endplate injury.

Results: Eighty patients (121 fused levels) with lumbar degeneration who underwent OLIF were included. There were no significant specific distribution in preoperative disc pathology such as disc angle, height, and translation. After OLIF, sagittal alignment was improved with an average correction angle of 3.8° at the instrumented segments in a level-independent fashion. All cases showed significant improvement in clinical outcomes, and had improvement in the radiological parameters ($P<0.05$). A detailed analysis of the cage position showed that the most significant sagittal correction and the most postoperative endplate injuries occurred in the farthest anterior zone (I). Cages with a 12-mm height were associated with more endplate injuries compared with shorter cages (8 or 10 mm).

Conclusions: OLIF improves sagittal alignment with an average correction angle of 3.8° at the instrumented segments. We suggest that the optimal cage position for better lordosis correction and the fewest endplate injuries is zone II with a cage height of up to 10 mm.

Keywords:

oblique lateral interbody fusion (OLIF), lumbar lordosis, lateral intervertebral cage, endplate injury, sagittal correction

Spine Surg Relat Res 2017; 1(4): 197-202
dx.doi.org/10.22603/ssrr.1.2017-0001

Introduction

Sufficient lumbar lordosis (LL) is considered necessary to maintain activities of daily living (ADL) by achieving adequate global sagittal spinal alignment[1]. Some lumbar degenerative spine pathologies such as spondylolisthesis cause sagittal imbalance, which can result in patient dissatisfaction due to chronic pain and an ADL disorder[2]. Other types of sagittal imbalance such as a flat-back deformity and kyphotic change have also been associated with occasional

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Received: January 7, 2017, Accepted: March 17, 2017

failure in restoring LL[3,4]. Thus, the restoration of LL in such cases is one of the main objectives of lumbar spinal surgery.

Regarding the restoration of LL, lumbar corrective fusion surgeries, including multiple intervertebral transforaminal/posterior lumbar interbody fusion or posterolateral fusion, have been performed, and interbody fusion surgery has been reported to be superior to posterior fusion alone for acquiring higher fusion rates[5]. Sometimes more invasive corrective osteotomy surgeries such as pedicle subtraction osteotomy[6] or vertebral column resection[7,8] are performed to achieve more dramatic LL correction, but these procedures are invasive and associated with massive hemorrhaging after osteotomy and epidural bleeding[9-11].

Surgical procedures associated with effective sagittal alignment correction other than posterior surgery include anterior lumbar interbody fusion and lumbar lateral interbody fusion (LLIF), which enables surgeons to approach the anterior spine with the least amount of exposure and perform anterior column interbody fusion by using cages designed for oblique or lateral placement. These procedures are attracting more attention since they are less invasive. Two popular and common LLIF procedures are oblique lateral interbody fusion (OLIF) and extreme lateral interbody fusion (XLIF), which each require specially designed instruments[12-15]. OLIF, especially, enables surgeons to easily and less invasively access the vacant oblique corridor in front of the psoas muscles without causing any splitting, which occurs with XLIF[16,17]. The lateral interbody fusion cage for OLIF has a lordotic angle of 6°. However, it is unclear how much LL will actually be achieved with the use of the cage.

Therefore, the current study aimed to evaluate whether placing lateral intervertebral cages anteriorly during OLIF surgery are effective for correcting LL in patients with a lumbar spinal disorder.

Materials and Methods

Subjects

The subjects were patients with a pathological lumbar degenerative disease and spondylolisthesis clinically diagnosed by radiography, magnetic resonance imaging, myelography, or computed tomography (CT). A diagnosis of spondylolisthesis and the indication for OLIF surgery were determined on the basis of the following criteria: (1) a more than 5% anterior slip of the vertebra in a neutral position; or (2) a more than 5-mm dynamic translation in a flexion position on functional radiographic evaluation. Patients with decreased bone mineral density (T-score<-2.0) were excluded.

Surgical technique

OLIF surgery was performed according to the standard procedure described previously[18]. Briefly, patients were placed in the lateral decubitus position on their right side, and the target intervertebral disc space was identified under fluoroscopic guidance. A 4-cm skin incision was made 6 to 10 cm anterior to the midportion of the target disc. The surgical team approached the retroperitoneal space via blunt dissection, and the peritoneum was moved anteriorly to expose the oblique lateral window (about 1 to 2 cm of the annulus fibrosus immediately in front of the psoas muscle). Subsequently, discectomy was performed, and a 6° lordotic polyether ether ketone cage (OLIF25 Clydesdale Spinal System; Medtronic Sofamor Danek, Minneapolis, MN, USA), ranging in height from 8 to 14 mm, was inserted. After anterior fusion, patients were placed in the prone position to undergo *in situ* posterior fusion without compression with pedicle screws via an open or percutaneous procedure depending on the pathology.

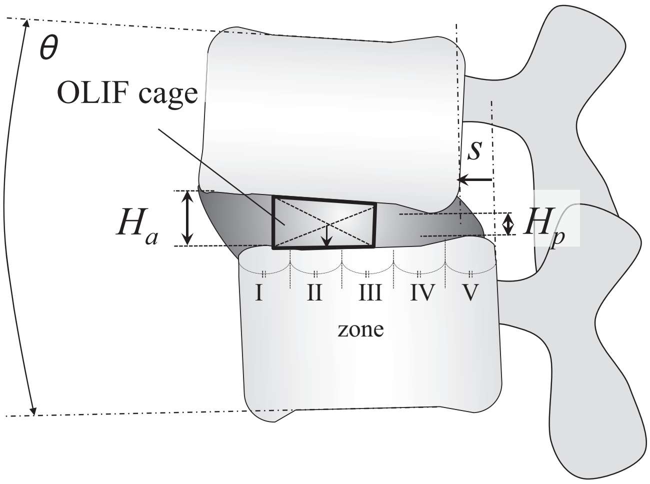

Figure 1. Scheme illustrating the radiological parameters of the fused segment (sagittal plane).
Ha, anterior disc height; Hp, posterior disc height; S, distance of anterior slip (mm); θ, segmental lordosis of the fused level (°). The average disc height, H, was calculated as the average of Ha and Hp.

Radiologic evaluation

Plain radiographic images and CT scans were evaluated before and 1 year after OLIF surgery. Fig. 1 shows the following radiological parameters that were evaluated: the segmental lordotic angle at the fused level, translational length of the upper vertebra, and disc height before and after the surgery.

The cage position was defined where the center of the cage falls on the caudal endplate, which was equally divided into five zones (I-V). Fig. 2A-D shows representative images of zones I and IV.

We also assessed patients for an endplate injury, including cage subsidence, which was defined as discontinuity of the endplate contour affected by the cages after the surgery.

Three experienced spine surgeons performed these radiologic evaluations in a blind manner.

Clinical evaluation

We evaluated the change in low back pain, leg pain, and leg numbness before and 1 months after surgery using a visual analogue scale (VAS) score (0, no pain or numbness; 10,

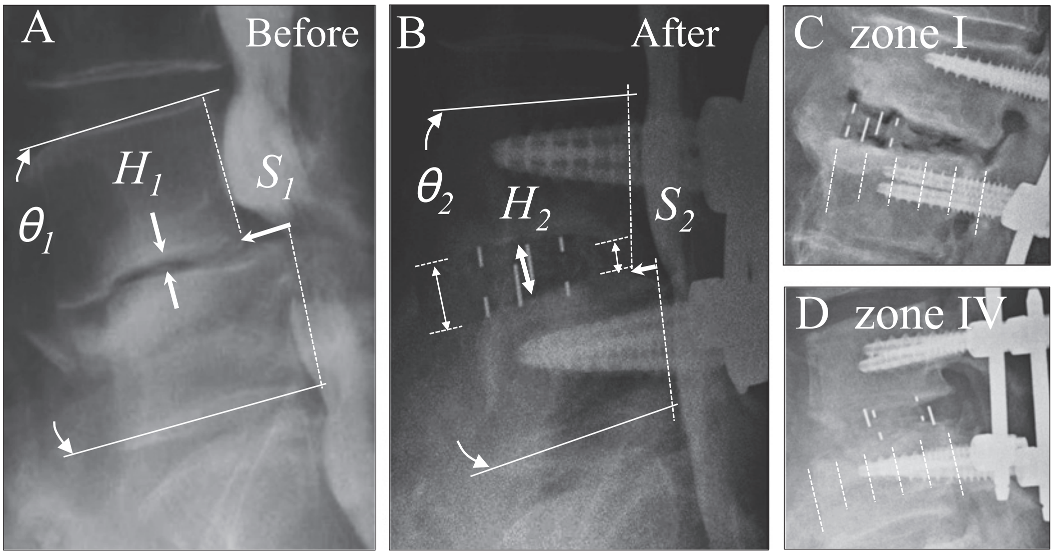

Figure 2. Representative images.
A, B) Myelograms before ($_1$) and after ($_2$) OLIF surgery. Sufficient correction in the alignment was observed, and the spinal canal was enlarged by indirect decompression. C) Zone I. D) Zone IV.

Table 1. Demographic Characteristics.

No. of patients (male/female)		80 (39/41)
Age (years, mean±SD)		64.9±15.1 (35-80)
Diagnosis		
Lumbar spinal stenosis		36
Spondylolisthesis		16
Discogenic low back pain		15
Kyphoscoliosis		15
Fused level	Total	121
	L1/2	9
	L2/3	16
	L3/4	34
	L4/5	62

SD: standard deviation; T, thoracic; L, lumbar.

Table 2. Distribution of the Cages in Oblique Lateral Interbody Fusion Surgery.

Zone	No. of cases	Average cage height (mm; mean±SD)
I	12 (9.9%)	10.8±1.33
II	38 (31.4%)	9.9±1.313
III	55 (45.5%)	10.1±1.58
IV	16 (13.2%)	9.9±1.36
V	0 (0%)	

SD: standard deviation.

worst pain or numbness). Additionally, cases in which lower back and lower extremity symptoms had worsened compared to preoperative levels were defined as having deterioration of neurological symptoms.

Statistical analysis

The statistical significance of each parameter was evaluated before and after the surgery by using the Mann-Whitney U test. P values less than 0.05 were considered statistically significant.

Results

Table 1 shows the patients' demographic characteristics. Eighty-two cases with 121 fused levels underwent OLIF surgery from April 2013 to September 2015 and were included in the analysis.

Table 2 shows the distribution of the OLIF cages. Twelve cages were located in zone I (9.9%), 38 in zone II (31.4%), 55 in zone III (45.5%), and 16 in zone IV (13.2%). No cages were located in zone V. The average cage heights were 10.8±1.33 mm in zone I, 9.9±1.313 mm in zone II, 10.1±1.58 mm in zone III, and 9.9±1.36 mm in zone IV. There were no significant differences in the distribution of the average cage height among the zones. Preoperative parameters on disc pathology such as disc height, translation, and angle showed no significant distribution among the groups (Fig. 3).

Fig. 4 presents data for the radiological parameters before and after OLIF surgery. The intervertebral height (Fig. 4A), vertebral translation (Fig. 4B), and sagittal intervertebral angle (Fig. 4C) were significantly improved after the surgery in all cases.

There were no significance differences among the fused levels, and the average correction angle was 3.8^o (Fig. 5A). However, the more anterior the cages were located, the more sagittal lordosis was achieved, and this was significant (7.6^o for zone I, 5.1^o for zone II, 3.7^o for zone III, and 2.7^o for zone IV) (Fig. 5B).

The incidence rate of an endplate injury was 33.1% (40/121 cases). Endplate injury occurred the most in zone I (50.0%), whereas the fewest endplate injuries occurred in

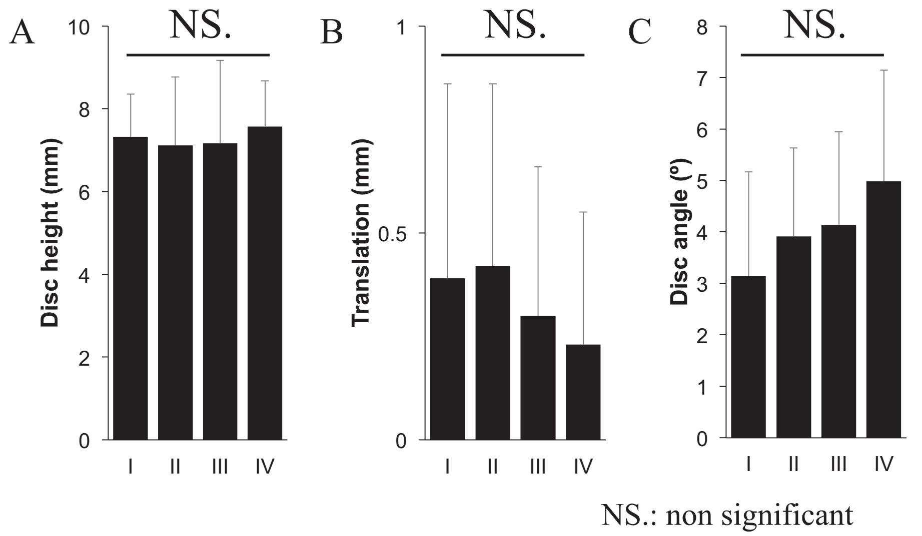

Figure 3. Preoperative parameters regarding intervertebral disc pathology.
Preoperative parameters on disc pathology such as (A) disc height, (B) translation, and (C) angle showed no significant distribution among the groups.

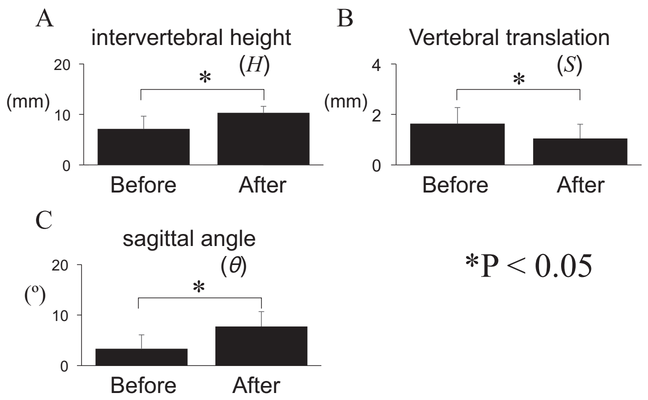

Figure 4. Perioperative radiological parameters.
Each parameter showed significant improvement in terms of the intervertebral height (H), vertebral translation (S), and sagittal angle (θ). *P<0.05.

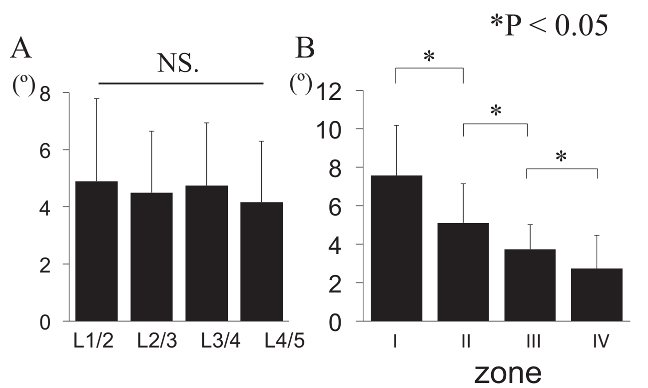

Figure 5. Average correction angle.
A) There were no significances in the correction angle among the fused levels. N.S., no significance. B) The more anterior the cages were located, the more sagittal lordosis was achieved, and this was significant. *P<0.05; L, lumbar.

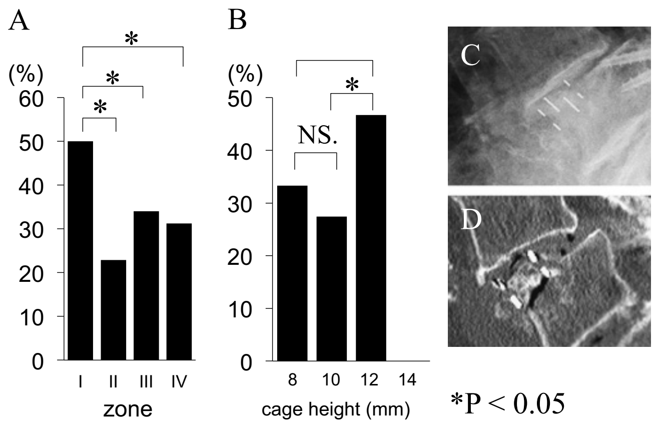

Figure 6. Incidence of endplate injuries.
A) Zone I was significantly associated with the most injuries. Zone II was associated with the fewest injuries. B) A 12-mm cage height was significantly associated with the most injuries. *P<0.05. C, D) Vertebral collapse shown on radiography and computed tomography, respectively.

zone II (21.1%) (Fig. 6A). In terms of the cage height, 12-mm high cages significantly caused more endplate damage than shorter cages (46.7% vs. 33.3% [8 mm] and 27.4% [10 mm]) (Fig. 6B). Fig. 6C and 6D show representative images of vertebral collapse in a case with a cage in zone I. When we checked the postoperative CT scan, the fusion rate with continuous bony fusion with both or either side of endplate amounted to 97.5% (118 levels out of 121).

All of the patients showed significant postoperative reliefs in lower back pain, leg pain, and numbness (Table 3).

Discussion

The current study demonstrated that OLIF surgery improved sagittal alignment with an average correction angle

Table 3. Clinical Outcome Using Visual Analogue Scale.

	Before surgery	1 year after surgery
Low back pain	6.5±1.9	2.4±1.3*
Leg pain	8.4±2.1	1.9±0.9*
Leg numbness	7.4±2.5	4.1±1.3*

*: p<0.05

of 3.8° at the instrumented segments in 80 lumbar degenerative patients in a level-independent fashion. All cases achieved successful improvement in the intervertebral height, vertebral translation, and sagittal angle. A detailed analysis of the intervertebral OLIF cage position showed that the most anterior zone (I) was associated with the most significant sagittal correction, but it was also associated with the most endplate injuries. Zone II was associated with the fewest endplate injuries. A cage height of 12 mm was significantly associated with the most endplate injuries. A 14-mm cage was only used in one case that did not have an endplate injury. There were no significance differences between the 8-mm and 10-mm cages. The lower back pain and leg pain were significantly improved.

The fact that the overall parameters improved after the surgery support that efficient intervertebral fusion and correction can be achieved with OLIF surgery by using a lateral intervertebral cage followed by ligamentotaxis, which has favorable mid-term results[12,13,15,18)]. It has been reported that LLIF can correct a deformity with larger lateral interbody cages. Kepler et al. evaluated lordosis acquisition in terms of the cage installation position by using a transpsoas XLIF cage with 10° of lordosis, and they reported significant lordosis correction with a mean increase of 3.7° at the fused levels[19)], which is similar to the correction angle found in the current study. This similarity indicates that the cage lordosis angle itself does not directly affect postoperative lordosis correction. Moreover, the current study showed that the cage position at zone I was significantly associated with the largest correction angle of 7.6°, followed by 5.1° at zone II. This finding indicates that the more anterior the cage position, the more lordosis will be achieved. The amount of lordosis achieved can also depend on the approach to the spine, e.g., an oblique anteroposterior trajectory via the vacant oblique corridor in front of the psoas muscle[20)] in OLIF or a direct lateral to lateral-anterior trajectory in XLIF[21)]. These differences can also lead to an anterior longitudinal ligament (ALL) tear or injury, as XLIF can cause this complication when the cage is placed anteriorly because of its trajectory. Technically the OLIF trajectory proceeds from anterior to posterior with less chance to injure ALL compared with the XLIF procedure, in which ALL can be damaged if the trajectory proceeds to anterior portion as well as its use of box cutter.

However, resection of the ALL and anterior annulus fibrosus may result in more lordosis, which can cause spine instability and failure of ligamentotaxis. The OLIF approach rarely injures the ALL due to its oblique anteroposterior trajectory. The surgeons should avoid possible segmental artery injuries which run close to or intersect the intervertebral disc by evaluating preoperative image[22)].

The current study also indicated that an anteriorly placed OLIF cage at zone I was associated with the most postoperative endplate injuries. A previous cadaveric study on this topic proved that endplate strength is strong at the posterior and marginal sites[23)]. On the basis of this previous study, the endplate would be strongest at zone V and weakest at zone III, followed by zones I, II, and IV. The following reasons explain the discrepancy between the cadaveric study and the current study. First, the existence of the posterior facet joint is an issue, as it causes large moment with the longest lever arm, and it works as a fulcrum. Second, the existence of the ALL can cause overload to the endplate due to tension when it is overdistracted. Third, the current study indicated that a taller OLIF cage can cause a postoperative endplate injury due to overdistraction. Our study's results indicate that surgeons should insert an OLIF cage with a height of up to 10 mm in zone II to gain the most lordosis correction and fewest endplate injuries. Possible involvement of endplate injury and subsidence during OLIF surgery have been reported in the previous study[24)].

The current study has some limitations. First, this was a retrospective study, so a future prospective study with a more detailed evaluation should be considered to determine the best strategy for lordosis correction. Second, the current study did not involve global sagittal alignment, including the pelvis, which is important when considering alignment correction. For instance, global spinal alignment such as lumbar lordosis from the L1-S level and the sacral slope should be evaluated in a future study. Third, the current study included the two pathologies of intraoperative endplate injury and postoperative cage subsidence together, as is based on the 1-year postoperative CT scan image. These mixed-up pathologies can affect the incidence of the endplate injury. These pathologies can can influence the rate of correction loss at the fused intervertebral space by different mechanism, which can result in the relatively small correction angle of 3.8° considering the lordotic angle of the cage (6°). On the other hand, the current study provides the comprehensive data regarding the concept on the lordotic correction using OLIF cage according to its location. Based on the current data, we should investigate and develop the corrective strategy more in detail.

In conclusion, the OLIF procedure improved sagittal alignment with an average correction angle of 3.8° at the instrumented segments in 80 lumbar degenerative patients in a level-independent fashion. Further analysis indicated that the more anterior the cage position, the more lordosis was achieved. However, anteriorly positioned and taller cages in zone I were associated with a postoperative endplate injury. The current study's findings suggest that surgeons should insert an OLIF cage with a height of no more than 10 mm in zone II to achieve the most lordosis correction and fewest endplate injuries.

Conflicts of Interest: The authors declare no conflicts of interest.

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