CLINICAL ARTICLE

Whether Anterolateral Single Rod Can Maintain the Surgical Outcomes Following Oblique Lumbar Interbody Fusion for Double-Segment Disc Disease

Long Zhao, MD, Tianhang Xie, MD, Xiandi Wang, MD, Zhiqiang Yang, MD, Xingxiao Pu, MD, Jiancheng Zeng, PhD, MD

Department of Orthopedics and Orthopedic Research Institute, West China Hospital, Sichuan University, Chengdu, China

Objective: To evaluate the outcomes of oblique lumbar interbody fusion (OLIF) combined with anterolateral single-rod screw fixation (AF) in treating two-segment lumbar degenerative disc disease (LDDD) and to determine whether AF can maintain the surgical results.

Methods: A retrospective analysis was performed on patients who underwent OLIF combined with AF (OLIF-AF) for LDDD at the L3-5 levels between October 2017 and May 2018. A total of 84 patients, including 44 males and 40 females, with a mean age of 62.8 ± 6.8 years, who completed the 12-month follow-up were eventually enrolled. Clinical outcomes, including the Oswestry Disability Index (ODI), visual analog scale (VAS) score for the low back and leg, and radiographic parameters, including the cross-sectional area (CSA) of the spinal canal, disc height (DH), foraminal height (FH), degree of upper vertebral slippage (DUVS), segmental lumbar lordosis (SL), fusion rate, and lumbar lordosis (LL), were recorded before surgery and 1 and 12 months after surgery. Surgical-related complications, including cage subsidence (CS), were also evaluated. The local radiographic parameters were compared between L3-4 and L4-5. The clinical results and all radiographic parameters were compared between patients with and without CS.

Results: Significant improvements were observed in radiographic parameters 1 day postoperatively ($p < 0.05$). Local radiological parameters in L4-5 had a significant decrease at 12 months postoperatively ($p < 0.05$), while they were well-maintained at L3-4 throughout the follow-up period ($p > 0.05$). CS was observed in 26 segments (15.5%). Endplate injury was observed in four segments (2.4%). There was no significant difference in the fusion rate between the segments with and without CS ($p = 0.355$). The clinical results improved significantly after surgery ($p < 0.05$), and no significant difference was observed between the groups with and without CS ($p > 0.05$).

Conclusions: Anterolateral fixation combined with OLIF provides sufficient stability to sustain most radiological improvements in treating double-segment LDDD. Subsidence was the most common complication, which was prone to occur in L4-5 compared to L3-4, but did not impede the fusion process or diminish the surgical results.

Key words: Anterolateral single-rod screw fixation; Cage subsidence; Double segmental lumbar disorder; Minimally invasive; Oblique lumbar interbody fusion

Introduction

Over the past few years, the lumbar interbody fusion (LIF) technique has continued to evolve, with the aim of reducing operative complications and improving surgical achievements. As an indirect decompression technique, extreme lateral interbody fusion (LLIF) has been increasingly performed, with the advantages of minimal invasiveness, less blood loss, and shorter operative times than the conventional

Address for correspondence Jiancheng Zeng, PhD, MD, Department of Orthopaedics, West China Hospital, Sichuan University, 37# Wuhou Guoxue road, Chengdu 610041, China Tel: +86-028-85422570; Fax: +86-028-85423438; Email: tomzeng5@126.com;
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LIF technique via the posterior (PLIF) or transforaminal (TLIF) approach. However, the LLIF technique was reported to be associated with the risk of injuring the lumbar plexus due to its direct lateral approach that passes through the psoas major muscle.[1] In an attempt to decrease the complications related to a transpsoas approach, oblique lateral lumbar interbody fusion (OLIF) was introduced in 2012 by Silvestre *et al.*[2] The minimally invasive OLIF procedure provides psoas-preserving access to the index lumbar disc *via* an anterior oblique retroperitoneal approach between the aorta and major psoas muscle. A large sample study pointed out that the risks of sensory nerve injury and psoas weakness were significantly reduced following OLIF compared with LLIF, which was mainly due to the adoption of a more optimized surgical approach.[3] By virtue of the advantage of its surgical approach, a large amount of bone graft material can be implanted by inserting a relatively large cage, and at the same time, a larger and more consummate prepared endplate can be provided as a bone graft bed, eventually enabling achievement of a higher rate of intervertebral fusion following OLIF compared to other traditional LIF techniques.[4]

Supplemental fixation is routinely employed to maximize the stability of spine-instrumentation construction to promote intervertebral fusion.[5] Traditionally, posterior bilateral pedicle screw fixation (PF) was considered to provide the most sufficient biomechanical support and the maximum restriction for intervertebral movement at the index construction, thus having been widely recommended previously, especially for cases requiring surgical instrumentation for two or more levels.[5] However, the invasion of posterior spinal elements for pedicle fixation, the increased surgical duration, anesthesia-related accidents, and the risk of cage migration due to intraoperative repositioning should not be neglected.[6] Therefore, a convenient instrumentation choice should be taken into consideration. An anterolateral single-rod screw fixation (AF) system could be assembled through the same incision following cage implantation, which was believed to shorten the surgical duration and mitigate the aforementioned complications caused by repositioning.

AF has been biomechanically proven to significantly reduce the range of motion of the operated spinal segment in all directions after single level thoracolumbar surgery, with no significant difference in restrictions on lateral bending compared to PF,[7] and thus increasingly being used as an alternative to posterior fixation in treating single-segment degenerative lumbar disc disease (LDDD). In this context, Guo *et al.*[8] compared the surgical results of OLIF combined with AF (OLIF-AF) and PF (OLIF-PF) in treating single-segment LDDD. The author found that there were comparable results in terms of clinical symptom relief and radiological achievements between the two techniques. And what's more, there were advantages of shortening operation time and anesthesia time, reducing blood loss and fluoroscopy time following OLIF-AF compared to OLIF-PF. Similarly, a previous study also showed that AF well maintains postoperative radiographic achievements after OLIF for single-segment instrumentation.[9]

Two-segment LDDD is a common setting of degenerative spinal disease, with a rate of 11.6% in a large population survey.[10] Patients with two-segment LDDD tend to be older.[10] With the merits of being minimally invasive and requiring shorter duration of surgery and anesthesia, OLIF-AF seems to be a better choice for patients with two-segment LDDD. However, to the best of our knowledge, there have been few reports on the use of OLIF-AF for the treatment of two-segment LDDD. The purpose of this study was to investigate the feasibility and effectiveness of the OLIF-AF technique for two-segment LDDD by retrospectively analyzing the clinical outcomes, radiological achievements, and complications of patients who underwent OLIF-AF for LDDD at L3-5 in our institution to evaluate the unique advantages of anterolateral fixation combined with OLIF technology and promote the indication extension and technique improvement of OLIF-AF surgery.

Methods

Inclusion and Exclusion Criteria

The inclusion criteria were as follows: (i) patients with chronic lumbago-leg pain who were unresponsive to conservative treatment for at least 3 months; (ii) OLIF-AF was performed for two-segment LDDD at L3-5; and (iii) patients who had a follow-up of more than 12 months. We excluded patients who were diagnosed with severe stenosis (Schizas grade C or D) or stenosis caused by extruded herniated discs, calcified discs or bony spur formation and who were diagnosed with isthmic spondylolisthesis or severe degenerative spondylolisthesis (Meyerding grade II-IV). Patients who underwent additional endoscopic discectomy were also excluded.

This study was performed retrospectively on 84 patients, including 44 males and 40 females, with a mean age of 62.8 ± 6.8 years, who underwent pure OLIF-AF at L3-5 between October 2017 and May 2018, and was approved by the ethics committees of West China Hospital (no. 2020-554). The requirement for informed consent was waived because of the study's retrospective nature.

Surgical Procedure

Patients were placed in the right decubitus position. The external oblique, internal oblique, and transverse abdominal muscles were separated bluntly. Subsequently, discectomy was performed at L4-5, and then an appropriate PEEK cage (height: 8–14 mm, length: 45–55 mm, width: 18 mm, lordosis: 6°) loaded with CPC rhBMP-2 was inserted into the disc space. Then, these steps were performed again at L3-4. Finally, three Solera screws were inserted parallelly into the L3, L4, and L5 vertebrae and then connected by a single rod with an appropriate length.

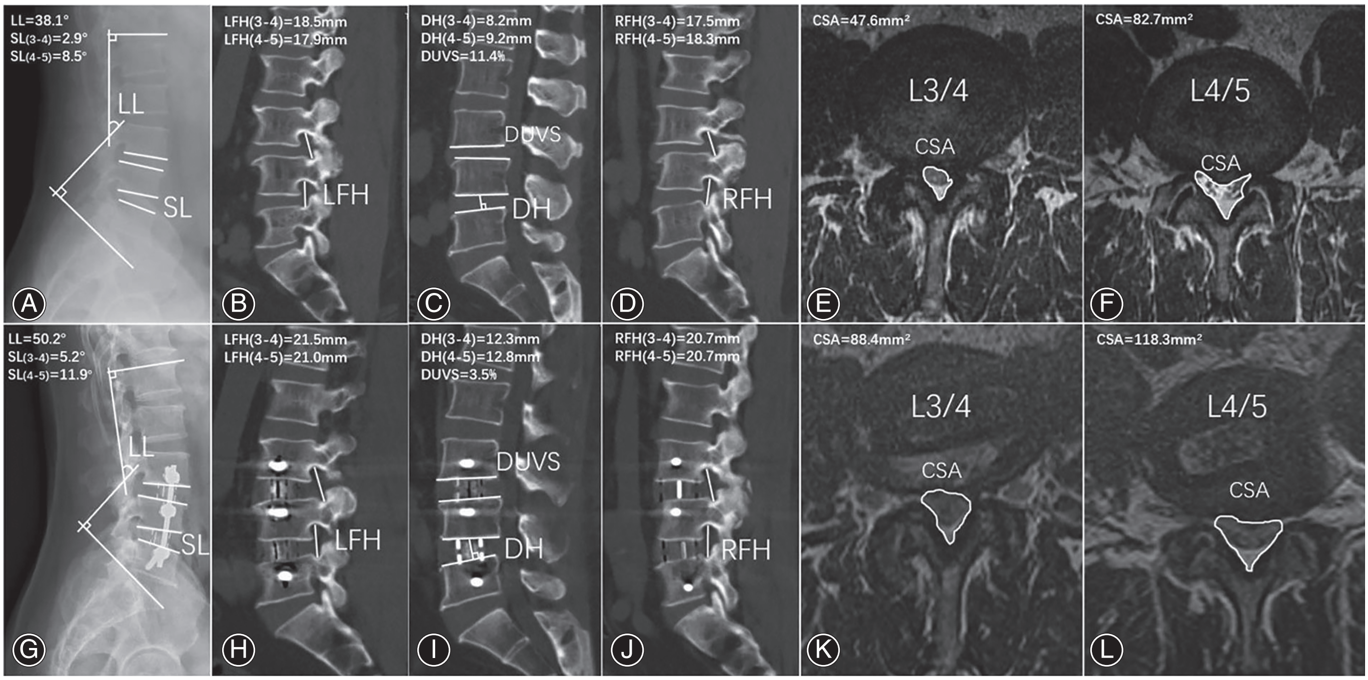

Fig. 1 Measurement illustration. LL and SL (A) were measured using Cobb's measurment on the standing lateral X-ray. LFH (B), DH and DUVS (C), RFH (D) were measured on 3D-CT. CSA was measured as the enclosed area of spinal canal on axial MRI (E,F). All radiological parameters significantly improved from preoperative (A–F) to 1 day postoperative (G–L), and no significant difference in the improvement between two levels was observed except for SL (A,G)

Radiographic and Clinical Evaluation
Serial radiographs were measured preoperatively and 1 day and 12 months postoperatively. Clinical results were recorded before and 1 and 12 months after surgery.

Cross-Sectional Area (CSA). The CSA of the spinal canal was used to evaluate the decompression of the intraspinal structure. It was measured at the operative level using T2-weighted MRI. A single axial slice through the center of the operative disc was used as the comparative measure location in axial views for measurement of the CSA. The outline of the thecal sac in the selected axial view was traced manually, and the area enclosed (mm^2) was measured.[11]

Disc Height (DH) and Foraminal Height (FH). DH and FH were used to evaluate the restoration of the decreased intervertebral disc and neural foramen space.[9] These parameters are usually measured using 3D-CT. DH was defined as the vertical distance between the midpoint of the upper endplate and the lower endplate on the midsagittal plane. FH was measured as the maximum distance between the inferior margin of the upper pedicle and the superior margin of the lower pedicle.

Degree of Upper Vertebral Slippage (DUVS). The DUVS was one of the parameters reflecting the the vertebral malalignment in the sagittal plane. It was defined as the ratio of the length of slippage of the upper vertebrae to the length of the upper endplate of the lower vertebrae on 3D-CT.

Lumbar Lordosis (LL) and Segmental Lordosis (SL). LL and SL are usually used to evaluate the alignment of the spinal column in the sagittal plane and are believed to be associated with long-term postoperative outcomes. These were measured using standing lateral X-ray. LL was defined as the angle between the vertical line of the upper endplate of L1 and S1, and SL was measured as the angle between the lower and upper endplates of the operated level (Figure 1).

Cage Subsidence (CS). CS manifests as cages sinking into vertebrae through adjacent endplates prior to complete fusion and is regarded as a complication. It was measured as the amount of DH reduction after surgery on 3D-CT and classified into four grades. Grade 0, 0%–24%; Grade I, 25%–49%; Grade II, 50%–74%; and Grade III, 75%–100%. Grades 0 and I were considered as low-grade subsidence, while Grades II and III were considered as high-grade subsidence.[12]

Visual Analog Scale (VAS) Score and the Oswestry Disability Index (ODI). The VAS was designed to assess the pain of the lower back and leg. The score ranges from 0 (no pain) to 10 points (most pain). The ODI is currently the most widely used scale for evaluating postoperative functional recovery

TABLE 1 Comparison of clinical result before and after surgery (n = 84)

Parameter	Pre-	1 month post-	12 months post-
VAS-back	7.6 ± 0.5	2.8 ± 0.4 (*,10.06)	1.8 ± 0.6 (**,4.20)
VAS-leg	6.4 ± 0.7	2.3 ± 0.5 (*,8.21)	1.3 ± 0.4 (**,3.37)
ODI	43.6 ± 7.2	20.0 ± 4.2 (*,12.62)	10.8 ± 2.9 (**,8.46)

Note: Data presented as mean ± standard deviation. Numbers in parentheses represent t values; Abbreviations: Pre-, preoperative; post-, postoperative; * $p < 0.05$, compared to the pre-; ** $p < 0.05$, compared to the 1 month post-.

TABLE 2 Comparison between patients with (group A, n = 18) and without subsidence (group B, n = 66)

Parameter	Group	Pre-	1 month post-	12 months post-
VAS-back	A	7.5 ± 0.4 *	3.1 ± 0.5 (**,4.10)	1.8 ± 0.7 *
	B	7.6 ± 0.5	2.6 ± 0.3	1.8 ± 0.6
VAS-leg	A	6.5 ± 0.7 *	2.6 ± 0.5 (**,3.50)	1.4 ± 0.3 *
	B	6.4 ± 0.7	2.1 ± 0.4	1.2 ± 0.4
ODI	A	42.9 ± 9.1 *	22.9 ± 3.5 (**,6.48)	11.2 ± 3.2 *
	B	43.8 ± 6.5	19.0 ± 3.9	10.6 ± 2.8

Note: Data presented as mean ± standard deviation. Numbers in parentheses represent t values; Abbreviations: Pre-, preoperative; post-, postoperative; * $p > 0.05$ compared to group B; ** $p < 0.05$ compared to group B.

after lumbar surgery. The score ranges from 0 (no disability) to 100 points (most disability).

Fusion was defined as the presence of bridging trabecular bone. Endplate injury was recorded in the case of discontinuities of cortical bone in the endplate on CT view.

Statistical Analysis

SPSS 22.0 (IBM Corp., Armonk, New York, USA) was used for the statistical analysis. All measurements are presented as the means ± standard deviations. The variance of continuous numerical variables was compared statistically using one-way repeated measures analysis of variance, and the variance of categorical variables was compared statistically using the chi-square test. $P < 0.05$ was considered statistically significant.

Results

Follow-up

All patients were followed up in the outpatient department or by telephone with a standard questionnaire survey. The mean follow-up time was 15.0 ± 1.8 months (range from 12 to 18 months) (Table 1). The content of follow-up included the clinical results (ODI, VAS score), radiological changes (CSA, DH, FH, DUVS, SL, LL), and complications.

General Results

A total of 84 patients, including 40 males and 44 females, with an average age of 62.8 ± 6.8 years, were included. The average disease history and body mass index (BMI) were 4.5 ± 0.6 years and 21.9 ± 2.7, respectively. The mean surgical duration, bleeding volume, and hospitalization were 172.6 ± 8.9 min (range: 159–192 min), 67.8 ± 10.5 ml (range: 50–89 ml), and 5.7 ± 0.7 days (range: 5–7 days), respectively.

Clinical Improvement and Functional Evaluation

The VAS scores for lower back and leg pain improved from 7.6 ± 0.5 and 6.4 ± 0.7 preoperatively to 2.8 ± 0.4 ($p < 0.001$, $t = 10.06$) and 2.3 ± 0.5 ($p < 0.001$, $t = 8.21$) at 1 month postoperatively and to 1.8 ± 0.6 ($p < 0.01$, $t = 4.20$) and 1.3 ± 0.4 ($p < 0.01$, $t = 3.37$) at 12 months postoperatively, respectively. The ODI decreased from 43.6 ± 7.2 preoperatively to 20.0 ± 4.2 ($p < 0.001$, $t = 12.62$) at 1 month postoperatively and to 10.8 ± 2.9 ($p < 0.01$, $t = 8.46$) at 12 months postoperatively (Table 1). The VAS scores of the lower back ($P < 0.01$, t = 4.10) and leg ($p < 0.01$, t = 3.50) and the ODI ($p < 0.01$, $t = 6.48$) were significantly lower in patients without CS than in those with CS at 1 month postoperatively, but there was no significant difference at 12 months postoperatively between the two groups ($p > 0.05$) (Table 2).

Radiography Improvement

The DH and the right and left FH at L3-4 ($p < 0.001$, $t = 17.10$, 5.66, 6.17) and L4-5 ($p < 0.001$, $t = 16.19$, 5.12, 6.21) significantly increased at 1 day postoperatively, and the improvement was comparable between the two levels ($p > 0.05$). Only slight loss in these parameters was observed at L3-4 at 12 months postoperatively ($p > 0.05$). In contrast,

TABLE 3 Comparison of the variation in radiological parameter between L3-4 and L4-5 ($n = 84$)

Parameter	Level	Pre-	1 day post-	Improvement	12 months post-	Loss
DH (mm)	L3-4	9.7 ± 1.1	13.6 ± 1.0 $^{(*,17.10)}$	3.9 ± 0.3	13.1 ± 1.4 $^{(*,12.86)}$	0.4 ± 1.0$^{(***,2.75)}$
	L4-5	9.7 ± 1.1	13.7 ± 1.1 $^{(*,16.19)}$	3.9 ± 0.2	12.6 ± 2.3 $^{(*,7.18)}$ $^{(**,2.54)}$	1.0 ± 1.6
RFH (mm)	L3-4	16.7 ± 3.0	20.3 ± 2.8 $^{(*,5.66)}$	3.6 ± 0.4	19.0 ± 3.3 $^{(*,3.08)}$	1.3 ± 1.2$^{(***,2.32)}$
	L4-5	17.1 ± 3.1	20.6 ± 3.1 $^{(*,5.12)}$	3.5 ± 0.4	18.7 ± 3.8 $^{(*,2.01)}$ $^{(**,2.50)}$	2.0 ± 1.9
LFH (mm)	L3-4	16.3 ± 2.5	19.7 ± 2.5 $^{(*,6.17)}$	3.5 ± 0.2	18.8 ± 2.7 $^{(*,4.36)}$	1.0 ± 1.0 $^{(***,4.60)}$
	L4-5	16.4 ± 2.6	19.9 ± 2.6 $^{(*,6.21)}$	3.5 ± 0.2	18.3 ± 3.0 $^{(*,3.15)}$ $^{(**,2.57)}$	1.6 ± 1.5
CSA (mm^2)	L3-4	69.6 ± 16.7	106.4 ± 12.2 $^{(*,11.50)}$	36.8 ± 9.2	102.2 ± 10.4 $^{(*,10.78)}$	4.2 ± 1.5
	L4-5	82.0 ± 19.2	122.9 ± 11.9 $^{(*,11.81)}$	41.0 ± 14.2	118.1 ± 11.9 $^{(*,10.44)}$	4.8 ± 1.7
DUVS (%)	L3-4	10.9 ± 3.7	3.4 ± 2.1 $^{(*,6.28)}$	7.4 ± 2.2	4.0 ± 2.4 $^{(*,5.60)}$	0.6 ± 0.4
$n =$	$n = 26$					
44 seg	L4-5	8.7 ± 3.9	2.5 ± 2.5 $^{(*,3.97)}$	6.1 ± 1.7	3.7 ± 3.5 $^{(*,2.86)}$	1.2 ± 1.2
	$n = 18$					
SL (°)	L3-4	5.3 ± 2.5	8.7 ± 2.7 $^{(*,5.99)}$	3.4 ± 0.5 $^{(***,3.24)}$	7.7 ± 2.6 $^{(*,4.27)}$	1.1 ± 0.3$^{(***,2.93)}$
	L4-5	6.8 ± 2.6	10.8 ± 2.4 $^{(*,7.22)}$	4.0 ± 0.7	9.7 ± 2.4 $^{(*,5.20)}$ $^{(**,2.09)}$	1.2 ± 0.2
LL (°)		27.8 ± 6.5	38.9 ± 6.1 $^{(*,8.05)}$	–	36.1 ± 6.1 $^{(*,6.03)}$	–

Note: Data presented as mean ± standard deviation. Numbers in parentheses represent t values; Abbreviations: Pre-, preoperative; post-, postoperative; * $p < 0.05$, compared to pre-; ** $p < 0.05$, compared to 1 day post-; *** $p < 0.05$, compared to L4-5.

significant loss was observed at L4-5 during the follow-up ($p < 0.05$, $t = 2.54, 2.50, 2.57$).

Compared with the preoperative values, the CAS of L3-4 and L4-5 significantly increased at 1 day postoperatively ($p < 0.001$, $t = 11.50, 11.81$) and only slightly decreased during the 12-month follow-up ($p > 0.05$). No significant difference in the changes was observed between the two levels ($p > 0.05$). Similar trends were observed in the DUVS.

The LL significantly improved at 1 day after surgery ($p < 0.05$, $t = 8.05$) and was well-maintained during the 12-month follow-up ($p > 0.05$). The SL at L3-4 ($p < 0.05$, $t = 5.99$) and L4-5 ($p < 0.05$, $t = 7.22$) significantly increased 1 day after surgery, and the improvement was significantly higher at L4-5 compared to that at L3-4 ($p < 0.05$, $t = 3.24$). At the 12-month follow-up, a slight loss was observed at L3-4 compared with 1 day postoperatively ($p > 0.05$), while a significant loss was detected at L4-5 ($p < 0.05$, $t = 2.09$).

Implant Evaluation

CS was detected in a total of 26 segments (18 patients), with an incidence of 15.5% (21.4%). Grade 0 CS was noted in 18 segments (L3-4: 4 segments, L4-5: 14 segments). Grade I CS was detected in eight segments (L3-4: 2 segments, L4-5: 6 segments). Grade II or III subsidence was not observed. A significant difference was observed in the incidence of CS between the L3-4 and L4-5 levels (7.1% *VS* 23.8%, $P = 0.003$, t = 8.19). There was no significant difference in the incidence of fusion between segments with CS (84.6%, 22/26) and without CS (88.7%, 126/142) (P = 0.482), and between L3-4 level (90.5%, 76/84) and L4-5 (85.7%, 72/84) ($P = 0.355$). The radiographic outcomes of all cases are shown in Tables 3 and 4. Typical radiographic images are shown in Figures 2 and 3.

TABLE 4 Comparison of subsidence and fusion between L3-4 and L4-5 ($n = 84$)

Parameters	Level	Rate (%)	p
Subsidence	L3-4	7.1(6/84)	0.003 $^{(8.19)}$
	L4-5	23.8 (20/84)	
Fusion	L3-4	90.5 (76/84)	0.355
	L4-5	85.7 (72/84)	

Note: Data presented as mean ± standard deviation; The number in the upper right corner of p represents the X^2 value.

Complications

No major vessel injuries or nerve root injuries occurred during the operations. Two patients had levoscoliosis at the index intervertebral level, which made cage entry difficult even after adjustment of the operating table, and were identified as intraoperative endplate injuries. A total of four patients (four segments) incurred endplate injury intraoperatively. They were asked to remain in bed for 4–6 weeks before being able to leave their bed under the protection of a lumbar brace, and CS was eventually identified in two of them. In the evaluation at 12 months postoperatively, cage subsidence was observed in 18 patients (26 segments). Only one patient who with CS at both the L3-4 and L4-5 levels had a second operation to relieve recurrent symptoms.

Discussion

Radiological Outcomes of OLIF-AF for Two-Segment LDDD

Two-segment LDDD tends to be associated with more severe spinal stenosis and greater sagittal malalignment with a lack

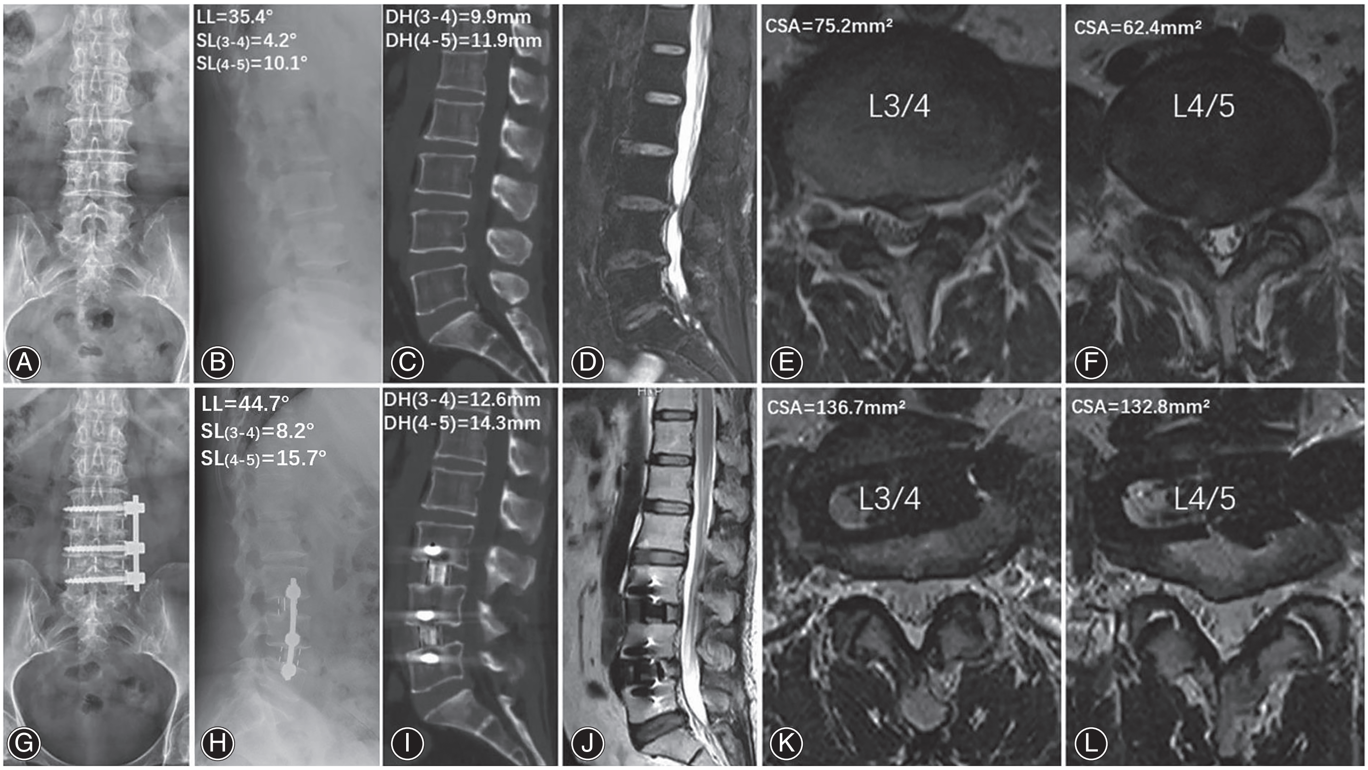

Fig. 2 LL, SL, and DH had significant improvement from preoperative (A–D) to 12 months postoperative (G–J). Significant expansion in spinal canal was observed at 12 months postoperative (J–L) compared to preoperative (D–F). Successful fusion and no subsidence were observed at 12 months postoperatively (I)

of LL due to the loss of DH,[13] suggesting that adequately enlarging the spinal canal and correcting sagittal malalignment should be the surgical management objectives. With these objectives, we chose to implant a large cage with a lordotic angle of 6° using the OLIF approach and observed 45.3% enlargement in CAS and 11.1° improvement in LL on average. When comparing the results between L3-4 and L4-5, there were no significant differences in the improvement of local radiological parameters except for a significantly greater improvement in lordosis at L4-5 than L3-4, which was believed to be related to the fact that the anterior margin of the psoas major muscle is more anterior at L4-5 than L3-4, resulting in cage placement more anterior at the L4-5 level to further promote lordosis.[14]

Better Clinical Outcomes of OLIF-AF for Double-Segment LDDD

To obviate the need for repositioning in the traditional OLIF procedure, Blizzard *et al.*[6] reported implanting posterior screws percutaneously with the patient in a lateral decubitus position. However, the rate of revision surgery due to pedicle breach was increased. In our study, we implanted the implants through a lateral abdominal incision with patients taking the lateral position, and the surgical duration and bleeding volume were 172.6 ± 8.9 min and 67.8 ± 10.5 ml, respectively, which were significantly lower than the values of 217.4 ± 92.1 min and 240.6 ± 153.8 ml reported by Can Zhang *et al.*[15] using OLIF with posterior fixation to treat LDDD. A relatively shortened surgical duration and less bleeding were noted, and no anterolateral instrumentation-related complications were observed in our study, indicating that anterolateral instrumentation not only saved time by obviating intraoperative repositioning but also avoided interference with spinal posterior elements.

Good Maintenance of OLIF-AF Outcomes

Notably, postoperative loss of spinal lordosis causes greater residual low back pain[16]; therefore, whether single-rod screw fixation provides sufficient additional stability to maintain radiographic achievements must be discussed. Fogel *et al.*[5] compared the biomechanical stability of anterolateral plate-screw fixation to that of bilateral posterior pedicle screw fixation at a single-level discectomy and concluded that the former could significantly reduce the range of motion of the operated level in all directions and with no significant difference in lateral bending between the two. Lowe *et al.*[17] compared the biomechanical stability of single- and double-rod screw fixation in the thoracolumbar region and found that single-rod screw fixation combined with intervertebral support could provide sufficient stability for a person of average

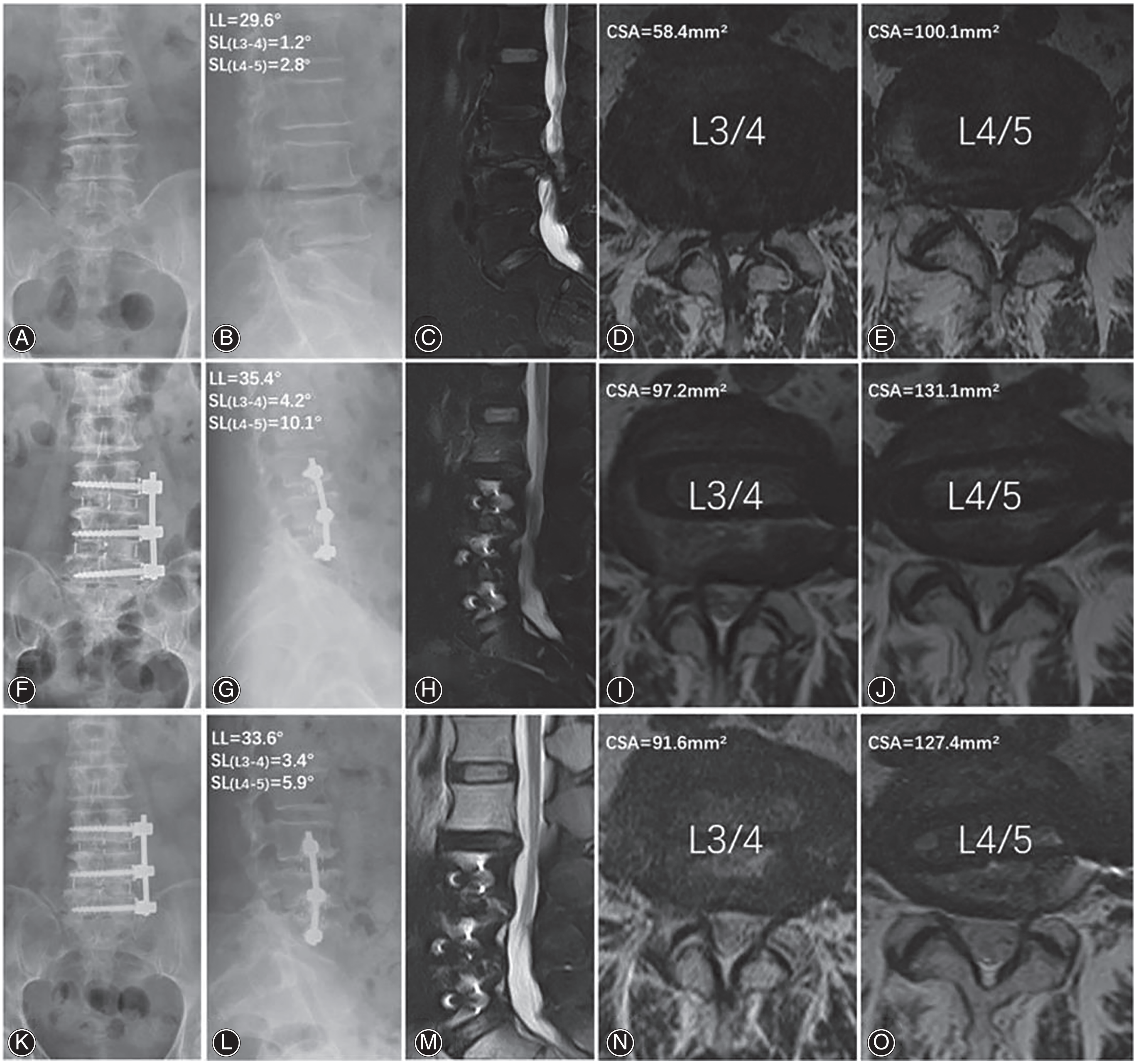

Fig. 3 LL and SL siginfiacntly improved from preoperative (A,B) to 1 day postoperative (F,G), and was well-maintained until 12 months postoperative (K,L) except for SL at L4-5 level. Stenosed pinal canal (C–E) was significantly decompressed at 1 day postoperative (H–J) and only had slight rebound at 12 months postoperative (M–O). No obviuosly screw loosening was observed during the follow-up (F,G,K,L)

size and normal bone quality. A previous clinical study drew similar conclusions after single-level discectomy.[8–9] In terms of the application in two-level discectomy, we found that local radiological parameters were well-maintained at L3-4 and only significantly decreased at SL, DH, and FH at L4-5 during the follow-up. Meanwhile, all parameters showed significant improvement compared to those before surgery. Therefore, we thought anterolateral single-rod screw fixation is reliable in treating two-segment LDDD.

Complications of OLIF-AF

The reported complication rates of traditional OLIF are approximately 11.2%–32.2%.[14–15,18] Theoretically, OLIF-AF does not cause additional complications compared to traditional OLIF. In our study, the overall complication rate was 21.4%. The incidence of endplate injuries was 4.8% (4/84 segments), which was believed to be related to poor bone condition[19] or lumbar scoliosis. Therefore, anti-osteoporosis and appropriate patient positioning are helpful to avoid endplate injury. CS was the most common complication in the current study and was observed in 26 segments (15.5%) in 18 patients (21.4%), including Grade 0 in 18 segments, Grade I in eight segments, and Grade II or III in no segments. For the 18 patients with CS, the mean bone mineral density (BMD) and BMI were -2.5 ± 0.3 and 26.1 ± 1.1, respectively; moreover, four segments were accompanied by endplate injuries. Therefore, we speculated that avoiding bony endplate injury, treating osteoporosis, and controlling body weight may be beneficial to prevent CS.[20] Interestingly, we found that the incidence of CS at L4-5 was significantly higher than that at L3-4 (7.1% *vs* 23.8%, $p = 0.003$), which may be attributed to the fact that the L4 vertebra has higher endplate compression strength than the L5 vertebra,[21] and also explains the greater loss of DH, FH, and SL at L4-5 than at L3-4 (Figure 3). This phenomenon of differential CS requires us to focus more on L4-5, and we hypothesized that the load tolerance of the L5 endplate may be enhanced by tricortical screw insertion or even with bone cement-reinforced screws to prevent CS.[22]

CS represents the progression of cage sinking prior to complete incorporation of the fusion mass; in this process, microinstability of the operated level will gradually develop, which may affect the fusion process.[23] Several articles have discussed the impact of CS on fusion and final clinical outcomes, but the conclusion remains controversial.[17,24,25] Choi *et al.*[24] reported that CS did not result in lower fusion rates, while Satake *et al.*[19] reported that CS caused a lower fusion rate but did not affect clinical outcomes. Jiya *et al.*[25] reported that a higher rate of CS is most likely related to poor clinical outcomes. In our study, we did not detect a significant difference in the incidence of fusion between the patients with low-grade CS and no CS. In terms of clinical outcomes, although patients with low-grade CS exhibited statistically poorer clinical results than those without CS 1 month postoperatively, no significant difference was observed between the two groups 12 months postoperatively; thus, we primarily concluded that low-grade CS does not impede the fusion process or compromise clinical outcomes.

Limitations

The present study had some limitations. This retrospective study lacks a direct comparison with OLIF combined with pedicle screw fixation or stand-alone or conventional fusion surgery such as TLIF, which undermines the presentation of the trait of anterolateral fixation and should be studied in the future. In addition, our findings were based on a small sample with short follow-up. In the future, a longer follow-up investigation will be conducted for a larger cohort.

Conclusion

OLIF is an effective procedure for achieving indirect decompression and sagittal alignment repair in the treatment of two-segment LDDD at L3-5. AF construction could provide sufficient stability to sustain most achievements. Low-grade CS is the most common complication, which is likely to occur at L4-5 compared with L3-4 but does not impede the fusion process or compromise clinical outcomes.

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Author Contributions

Long Zhao: conceptualization, writing manuscript. Tianhang Xie: methodology. Xiandi Wang: data curation. Zhiqiang Yang: statistics. Xingxiao Pu: software. Jiancheng Zeng: supervision, validation.

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