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Factors Affecting Slip Reduction in Oblique Lumbar Interbody Fusion With Posterior Fixation for Degenerative Spondylolisthesis

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Abstract

Study Design: Retrospective case series

Objectives: Reduction of translational/angular slip is a favorable radiological result in spinal fusion for degenerative spondylolisthesis, although its clinical significance remains controversial. Few studies have investigated slip reduction and associated factors in oblique lumbar interbody fusion (OLIF) for degenerative spondylolisthesis.

Methods: This study involved a retrospective analysis of 56 operated levels of 52 consecutive patients who underwent OLIF for degenerative spondylolisthesis and had more than 1-year of regular follow-up. Translational/angular slip, anterior/posterior disc height, and spinopelvic parameters were measured preoperatively, postoperatively at 6-weeks, and at the last follow-up. Demographic, radiological, and surgical parameters were analyzed to determine factors associated with the amount of slip reduction.

Result: The mean follow-up duration was 30.4 $\pm$ 12.9 months (range, 12 to 61). The mean decrease in translational slip was 5.7 $\pm$ 2.1 mm (13.6 $\pm$ 5.5%) and the mean increase in angular slip was 7.9 $\pm$ 7.1° at the last follow-up (both $P < 0.001$). The amount of slip reduction was greater in female sex, age < 65 years, use of a 12° cage, cage position from the anterior disc margin of < 7 mm, and cases with posterior decompression (laminectomy with inferior facetectomy).

Conclusions: OLIF showed satisfactory translational/angular slip reduction in degenerative spondylolisthesis. Surgical techniques for optimal reduction include the use of a large angle cage, anterior cage placement, and resection of the inferior facet.

Keywords

degenerative spondylolisthesis, slip reduction, radiological outcome, oblique lumbar interbody fusion

Introduction

Despite controversies regarding the efficacy of lumbar fusion for low-grade degenerative spondylolisthesis, neural decompression with or without lumbar fusion is a common surgical option as a means of avoiding potential postoperative instability.[1-4] Slip reduction after lumbar fusion in spondylolisthesis is a generally favored radiological result because it may lead to indirect neural decompression and sagittal alignment restoration.[5,6] However, the clinical significance of slip reduction in degenerative spondylolisthesis has not been clearly demonstrated.[4-9]

Oblique lumbar interbody fusion (OLIF) is a recently introduced minimally invasive surgical technique that evolved from both anterior lumbar interbody fusion (ALIF) and direct lateral interbody fusion (DLIF).[10-13] OLIF has advantages over ALIF in that the larger lateral cage can achieve greater disc height restoration, indirect decompression, and angular correction.[11,14,15] Moreover, the lateral cage can be placed more securely on the peripheral dense endplate versus the central weaker portions of the endplate in ALIF.[12,16] OLIF uses

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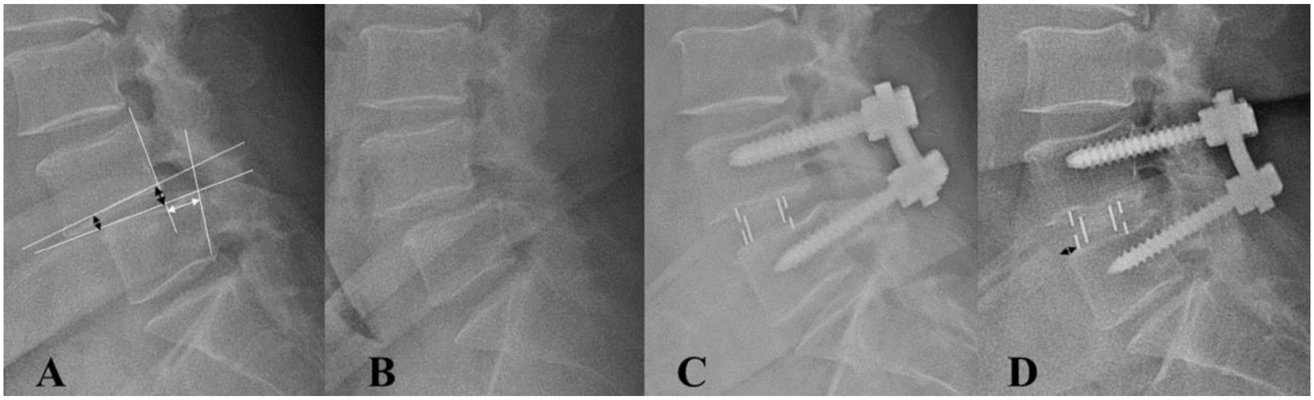

Figure 1. Radiological measurement of translational/angular slip. A, Preoperative standing lateral radiographs. The white arrow indicates translational slip and black arrows indicate anterior/posterior disc height. B, Preoperative extension radiographs. C, Postoperatively 6-weeks standing lateral radiographs. D, Last follow-up standing lateral radiographs. The black arrow indicates cage position from the anterior margin of the disc.

anterior to psoas approach in ALIF, which has advantages over DLIF in the preservation of psoas muscle and lumbar plexus.[6,14] OLIF can place the lateral cage more anteriorly than DLIF, which is advantageous in the restoration of segmental lordosis.[14,17] OLIF can avoid the vascular manipulation in ALIF, which allows many spine surgeons to perform OLIF without requiring a vascular or access surgeon.

On the other hand, slip reduction and optimal cage placement during OLIF is often technically demanding. Early studies on OLIF for degenerative spondylolisthesis showed favorable radiological and clinical outcomes.[6,18] However, few studies have evaluated the slip reduction and limiting factors in OLIF for degenerative spondylolisthesis. In the current study, we aimed to analyze the radiological outcomes and relevant factors for the slip reduction in OLIF for degenerative spondylolisthesis

Methods

Patients

Sixty-eight patients who underwent OLIF for degenerative spondylolisthesis at the L2-3 to L4-5 level, between March 2014 and May 2019, were retrospectively evaluated. Patients with a previous history of spinal surgery (n = 3), posterior column osteotomy (n = 4), more than 4 levels of fusion surgery (n = 3), incomplete data (n = 2), or lost to 1-year follow-up (n = 4) were excluded. This left 56 slip levels of 52 patients. Of these, Meyerding grade 1 was 39 levels and Meyerding grade 2 was 17 levels. Informed consent was obtained from each subject. All patients underwent preoperative routine anteroposterior/lateral/flexion/extension standing radiographs of the lumbar spine, whole-spine anteroposterior/lateral standing radiographs, computed tomography (CT), and magnetic resonance (MR) imaging. The OLIF procedures were performed by a single spine surgeon (N.C.) using the original Hynes' technique described elsewhere.[13] A lateral polyetheretherketone (PEEK) cage (Clydesdale; Medtronic Inc., Minneapolis, MN, USA) filled with autologous anterior iliac crest bone graft and demineralized bone matrix (Grafton; Medtronic Inc., Minneapolis, MN, USA) was used. Upon the completion of the anterior procedure, the patient was changed to a prone position and the supplemental posterior pedicle screw instrumentation was performed using open (n = 42) or percutaneous technique (n = 14). Slip reduction was performed by the patient positioning, anterior cage placement, use of a lordotic cage, laminectomy with inferior facetectomy, and compression of pedicle screw instrumentation. No reduction screws were used. Data on patient sex, age, body mass index (BMI), bone mineral density (BMD), smoking, operative time, estimated blood loss, and cage parameters (height, width, and lordotic angle) were obtained from medical records. The hospital's ethics committee reviewed and approved the present study (ajou-temp-20-380).

Preoperative Radiological Measurement

Preoperative radiographic parameters included translational slip (mm and %), angular slip (disc angle), and anterior/posterior disc heights on standing lateral radiograph (Figure 1A). Translational slip and angular slip were also measured on standing extension radiograph (Figure 1B). Preoperative osteoarthritic grades of the facet joints at the slip level were evaluated using preoperative CT images. The osteoarthritic grades of the facet joints were described as normal, mild (narrowing of facet joint), moderate (narrowing plus sclerosis or hypertrophy), or severe (severe osteoarthritis with narrowing, sclerosis, and osteophytes) as described by Parthria et al.[19] Sagittal vertical axis (SVA), pelvic incidence (PI), sacral slope (SS), pelvic tilt (PT), and lumbar lordosis (LL) were measured on a whole-spine standing lateral radiograph.

Follow-Up Radiological Measurement

The translational/angular slip, anterior/posterior disc height, and spinopelvic parameters were re-measured at postoperative

6 weeks and the last follow-up (Figure 1C, D). Cage position from the anterior margin of the disc was measured at the last follow-up (Figure 1D). Fusion grade was evaluated using sagittally-reconstructed CT images at the time of fusion, based on the criteria established by Bridwell et al.[20] Grade 1 (fused with remodeling and trabeculae present) and 2 (graft intact, not fully remodeled and incorporated, but no lucency present) were considered as a successful fusion. Cage subsidence was defined to be present if a cage was observed to sink into an adjacent vertebral body by > 2 mm compared with the previous radiographs.[21] All radiological measurements were performed by a single spinal surgeon (H.L.) not involved in care of the subjects using a picture archiving and communication system (PACS) (INFINITT PACS; INFINITT, Seoul, South Korea).

Statistical Analysis

Descriptive statistics are presented as frequencies (percentages) for categorical variables and as means with standard deviations for continuous variables. Changes in each radiological parameter at follow-up were compared using a paired *t*-test. The differences of translational/angular slip for each categorical variable were compared using a chi-square test or one-way analysis of variance (ANOVA) test. After correlation analysis between translational/angular slip and each continuous variable, the significantly correlated continuous variables were changed to bivariate dummy variables and subjected to chi-square testing. The statistical analysis was performed using SPSS for Windows (ver. 19.0; IBM Corp., Armonk, NY, USA). In all analyses, $P < 0.05$ was taken to indicate statistical significance.

Results

Subject Demographics

The study population consisted of 17 men and 35 women with a mean age of 64.6 ± 10.1 years (range, 37 to 83). The mean follow-up duration was 30.4 ± 12.9 months (range, 12 to 61). The mean BMI was 25.4 ± 3.8 m/kg^2 (range, 18.9 to 36.2), and the mean T score of the spine BMD was −1.2 ± 1.3 (range, −3.6 to 2.2). The number of patients with T score of less than −2.5 was 17 (32.7%). The number of current smokers was 11 (21.1%). The mean operative time for OLIF was 93.4 ± 30.7 minutes (range, 50 to 140). The mean estimated blood loss was 83.4 ± 80.7 cc (range, 10 to 200). Among the 56 slip levels, 10 (17.9%) were located at the L3-4 level, 34 (60.7%) at the L4-5 level, and 12 (21.4%) at the L5-6 (lumbarization) level. Single-level OLIF was performed in 48 patients, while 2-level OLIF was performed in the remaining 4 patients.

Preoperative Radiological Parameters

The mean preoperative translation slip was 7.5 ± 2.6 mm (18.2 ± 7.2%) on a standing lateral radiograph, which decreased to 4.8 ± 2.5 mm (11.7 ± 6.5%) on a standing extension radiograph ($P < 0.001$). The mean preoperative angular slip (disc angle) was 3.1 ± 7.5° on a standing lateral radiograph, which increased to 7.4 ± 6.8° on a standing extension radiograph ($P < 0.001$). The mean preoperative anterior and posterior disc heights were 7.9 ± 4.6 mm and 4.9 ± 2.0 mm, respectively. Preoperative osteoarthritic grades of the facet joints at the slip level were normal in 7 (12.5%) levels, mild in 16 (28.6%), moderate in 21 (37.5%), and severe in 12 (21.4%). The mean preoperative SVA, PI, SS, PT, and LL were 38.4 ± 37.8 mm, 55.2 ± 10.2°, 32.8 ± 8.8°, 21.8 ± 9.5°, and 43.1 ± 14.0°, respectively.

Surgical Parameters

Cage height was 14 mm in 11 (19.6%) cases, 12 mm in 33 (58.9%), 10 mm in 9 (16.1%), and 8 mm in 3 (5.4%). Cage width was 45 mm in 9 (16.1%) cases, 50 mm in 37 (66.1%), and 55 mm in 10 (17.9%). The cage lordotic angle was 6° in 22 (39.3%) cases and 12 in 34° (60.7%). The mean cage position from the anterior disc margin was 7.0 ± 3.3 mm. A laminectomy with inferior facetectomy was performed in 36 (64.3%) cases.

Slip Reduction and Relevant Factors

The changes in translational/angular slip, anterior/posterior disc height, and spinopelvic parameters are shown in Table 1. The mean decrease in translational slip was 5.7 ± 2.1 mm (13.6 ± 5.5%) and the mean increase in angular slip was 7.9 ± 7.1° at the last follow-up (both $P < 0.001$). Table 2 shows the factors relevant to reduction of translational and/or angular slip. Female sex, age < 65 years, cage lordotic angle, anterior cage position, and laminectomy with inferior facetectomy were relevant factors for slip reduction. Slip reduction was irrelevant to BMI, BMD, smoking, operative time, estimated blood loss, preoperative amount of translation/angular slip, anterior/posterior disc heights, osteoarthritic grades of the facet joints, spinopelvic parameters, cage height, and cage width.

Perioperative Complications

There were no cases of surgical site infection, incisional hernia, peritoneal injury, ureteral injury, spinal nerve injury, psoas/quadriceps weakness, or major vessel injury. Postoperative thigh pain (4 cases), thigh numbness (3 cases), and sympathetic symptoms on the left leg (3 cases) were observed but, disappeared by the postoperative 2-month follow-up.

Discussion

Restoration of normal alignment is a surgical goal in spinal fusion because spinal alignment related to global balance significantly influences the clinical outcomes.[22,23] Although gross spinal imbalance in low-grade degenerative spondylolisthesis is uncommon, a subtle segmental change can influence the sagittal alignment and balance.[4] Wegmann et al[5] found a modest correlation between slip reduction and clinical outcome including Core Outcome Measure Index score, Oswestry disability index, and Short form-36 physical component score in

Table 1. Radiological Outcome After OLIF.

	Preoperative			
	Lateral	Extension	Postop 6-week	Last follow-up
Translational slip (mm)	7.5 ± 2.6 (2.5 to 13.8)	**4.8 ± 2.5* (0 to 10.2)**	**1.5 ± 1.7* (0 to 6.4)**	**1.9 ± 1.7* (0 to 6.4)**
(%)	18.2 ± 7.2 (5.7 to 37.7)	**11.7 ± 6.5* (0 to 24.0)**	**3.8 ± 4.3* (0 to 16.1)**	**4.7 ± 4.3* (0 to 16.1)**
Angular slip (°)	3.1 ± 7.5 (−11.6 to 20.4)	**7.4 ± 6.8* (−6.5 to 28.8)**	**11.2 ± 4.7* (0.5 to 29.0)**	**11.1 ± 4.4* (0.7 to 19.9)**
Anterior disc height (mm)	7.9 ± 4.6 (0 to 16.7)	-	**16.3 ± 2.7* (2.7 to 22.6)**	**14.5 ± 3.1* (3.1 to 20.1)**
Posterior disc height (mm)	4.9 ± 2.0 (0 to 9.5)	-	**7.2 ± 2.1* (2.1 to 11.1)**	**6.4 ± 2.2* (2.2 to 10.8)**
Sagittal vertical axis (mm)	38.4 ± 37.8 (−29.6 to 102.4)	-	**7.9 ± 33.2*(−33.1 to 61.2)**	**13.7 ± 33.7* (−25.9 to 92.7)**
Pelvic incidence (°)	55.2 ± 10.2 (36.7 to 73.2)	-	55.2 ± 8.8 (36.5 to 74.0)	53.0 ± 10.0 (36.5 to 72.8)
Sacral slope (°)	32.8 ± 8.8 (13.7 to 54.9)	-	**36.4 ± 6.3* (18.9 to 52.4)**	**36.3 ± 7.4* (14.7 to 50.3)**
Pelvic tilt (°)	21.8 ± 9.5 (4.5 to 37.5)	-	**18.8 ± 6.7* (5.1 to 32.2)**	**16.7 ± 7.0* (8.1 to 36.9)**
Lumbar lordosis (°)	43.1 ± 14.0 (8.5 to 66.5)	-	**50.0 ± 10.5* (18.1 to 68.2)**	**50.6 ± 11.8* (19.1 to 69.4)**

Bold* are statistically significant changes from the baseline value ($P < 0.05$).
Parameters are given as the mean ± standard deviation (minimum value to maximum value).

Table 2. Factors Relevant to Slip Reduction.

	Amount of translational slip reduction (mm)	Amount of angular slip reduction (°)
Sex (M vs. F)	5.8 ± 2.4 vs. 5.6 ± 2.0	**4.1 ± 5.5 vs. 9.5 ± 7.1***
Age (< 65 yrs vs. ≥ 65 yrs)	**6.5 ± 2.2 vs. 4.8 ± 1.6***	8.9 ± 6.4 vs. 6.8 ± 7.7
Cage-lordotic angle (6° vs. 12°)	5.4 ± 1.9 vs. 5.8 ± 2.2	**5.5 ± 6.6 vs. 9.4 ± 7.1***
Cage-anterior position (< 7 mm vs. ≥ 7 mm)	**6.1 ± 2.1 vs. 5.1 ± 2.1***	**9.3 ± 8.1 vs. 5.9 ± 4.8***
Laminectomy (yes vs. no)	**6.2 ± 2.2 vs. 4.7 ± 1.6***	8.7 ± 6.2 vs. 6.6 ± 8.5

Bold* are statistically significant changes from the baseline value ($P < 0.05$).

Table 3. Slip Reductions of Lumbar Interbody Fusion in Literatures.

			Translational slip (%)		Angular slip (°)	
Author (Year)	N	Technique	Preop	Last F-U	Preop	Last F-U
Sears W (2005)	34	PLIF	20.2 ± 6.3	1.7 ± 4.9	-	-
Lian et al (2013)	73	PLIF	18.3 ± 5.8	3.1 ± 4.4	-	-
Wegmann et al (2013)	40	PLIF	34.2 ± 14.7	16.2 ± 9.0	-	-
Hayashi et al (2015)	45	PLIF	17.0 ± 4.9	9.7 ± 4.0	3.6 ± 4.7	6.9 ± 2.6
Kida et al (2014)	23	TLIF	17.7 ± 7.7	11.1 ± 6.6	4.6 ± 3.4	6.0 ± 2.9
Marchi et al (2011)	52	XLIF	15.1 ± 5.2	7.1 ± 6.0	9.7 ± 3.8	15.7 ± 7.1
Isaacs et al (2016)	29	XLIF	-	-	9.2 ± 4.5	8.5 ± 4.2
Isaacs et al (2016)	26	TLIF	-	-	8.3 ± 4.5	8.6 ± 2.2
Rao et al (2015)	27	ALIF	14.8 ± 8.0	9.4 ± 6.7	-	-
Current study	52	OLIF	18.2 ± 7.2	4.7 ± 4.3	3.1 ± 7.5	11.1 ± 4.4

degenerative spondylolisthesis. However, the clinical advantage of slip reduction in degenerative spondylolisthesis remains controversial.[4,7,8]

Whether it was intended or not, reduction of spondylolisthesis after spinal fusion is a favorable phenomenon.[4,24] The first aim of this study was to examine the reduction of translational/angular slip in OLIF for degenerative spondylolisthesis. OLIF has technical advantages of both ALIF and LLIF in the achievement of fusion, indirect decompression, deformity correction, and surgical approach.[14,25] In the current study, OLIF restored 5.7 ± 2.1 mm (13.6 ± 5.5%) of translational reduction and 7.9 ± 7.1° of angular reduction at the last follow-up. The reduction of translational/angular slip in OLIF for degenerative spondylolisthesis was comparable to those in other lumbar interbody fusion techniques (Table 3).[4,5,26-31]

Another aim of this study was to identify factors relevant to the reduction of slip in OLIF for degenerative spondylolisthesis. A reduction of slip during OLIF may occur due to postural reduction and surgical maneuver. We estimated the amount of postural reduction by measuring the amount of slip reduction on the preoperative extension radiograph. Table 1 showed that almost equal amount of postural and surgical reduction was created in translation and angular slip. Extension and distraction forces generated from postural reduction may produce a reduction load through the degenerated disc and facet joint. Additional reduction may occur by surgical maneuver including cage insertion, inferior facetectomy, and pedicle screw instrumentation.[4] Female patients showed a more angular reduction than male patients. Patients with age < 65 years showed more translational reduction. These results may come from the difference of segmental flexibility. Among surgical parameters, cage lordotic angle, anterior cage position, and laminectomy with inferior facetectomy were associated with the amount of slip reduction. The disc lordotic angle at the last follow-up was $9.4 \pm 7.1°$ in the 12° cage group, which was larger than $5.5 \pm 6.6°$ in the 6° cage group. However, the amount of translational reduction was not correlated with cage lordotic angle. Cage position from the anterior margin of the disc is known to create a larger sagittal angle in LLIF.[14,17,32] OLIF can place the lateral cage more anteriorly than DLIF because OLIF uses the anterior psoas approach. Ko et al[14] compared the anterior cage position between OLIF and DLIF. In their series, the anterior cage position was 6.7 ± 3.0 mm in OLIF and 9.1 ± 3.6 mm in DLIF ($P < 0.001$). Our results showed a similar anterior cage position of 7.0 ± 3.3 mm.

We also found that laminectomy and inferior facetectomy was a relevant factor for translational slip reduction. On the other hand, preoperative osteoarthritic grades of the facet joint did not affect the slip reduction.

Several limitations of this study warrant consideration. First, its retrospective design introduced a degree of uncertainty due to missing and erroneous data in the medical records, as well as a lack of clinical information. Moreover, the intervention techniques including direct/indirect decompression, open/percutaneous pedicle screw fixation, or the choice of cage size/angle/position were not controlled. Second, the small sample size likely affected the strength of the statistical analysis of the demographics and radiological parameters. Third, clinical outcomes dependent on slip reduction were not analyzed. Further long-term follow-up studies are warranted to determine whether such a reduction of translational/angular slip influences the clinical outcomes of OLIF for degenerative spondylolisthesis.

Conclusions

OLIF showed satisfactory slip reduction in degenerative spondylolisthesis. Surgical technique for optimal reduction included large angle cage use, anterior cage placement, and direct posterior decompression.

Authors' Note

The manuscript submitted does not contain information about medical device(s)/drug(s).

Declaration of Conflicting Interests

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