Retrospective Review

Open Lumbar Microdiscectomy and Posterolateral Endoscopic Lumbar Discectomy for Antero- and Retrospondylolisthesis

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Background: Posterolateral endoscopic lumbar discectomy (PLELD) or percutaneous endoscopic lumbar discectomy has been reported to be effective as treatment for herniated lumbar disc in degenerative spondylolisthesis. Few studies have investigated the outcomes of open lumbar microdiscectomy (OLM) and PLELD for antero- and retrospondylolisthesis with mild slippage and instability.

Objectives: We aimed to evaluate the outcomes of OLM and PLELD for antero- and retrospondylolisthesis with mild slippage and instability.

Study Design: This study used a retrospective design.

Setting: Research was conducted in a hospital and outpatient surgical center.

Methods: This study enrolled 84 patients aged 20 to 60 years with low-grade degenerative spondylolisthesis who underwent OLM or PLELD for antero- or retrospondylolisthesis at our hospital between March 2007 and August 2014 and who were followed up for at least 3 years. Telephone survey and chart review, with a particular focus on pre- and postoperative radiographic parameters, were conducted. Additionally, patients were invited to undergo reexamination to update their clinical and radiological data.

Results: Telephone surveys and clinical/imaging evaluation were conducted on the OLM and PLELD groups at a mean of 71.44 and 74.69 months, respectively. Out of 43 patients who underwent OLM, 34 responded to the telephone survey, 17 of whom then underwent reexamination. Among 41 patients who underwent PLELD, 32 responded to the telephone survey, 19 of whom then underwent reexamination. Based on telephone surveys and patient charts, reoperation at the same vertebral level was confirmed in 8 patients (23.5%) who underwent OLM and one patient (4.4%) who underwent PLELD, with a significantly higher rate of reoperation in the OLM group ($P = .028$). Vertebral disc height decreased more after OLM than after PLELD. Compared to PLELD, OLM was associated with significantly worse rates of iatrogenic endplate damage, endplate defect scores, and alterations in subchondral bone signal intensity. However, the final clinical outcomes did not differ between OLM and PLELD.

Limitations: The limitations of this study include its relatively small sample size and the possibility of bias owing to nonrandomized patient selection.

Conclusions: In patients with spondylolisthesis who have a herniated lumbar disc as mild slippage with instability, PLELD may be a good treatment option to reduce recurrence rates and mitigate disc degeneration.

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Key words: Anterospondylolisthesis, disc degeneration, endplate, herniated lumbar disc, open lumbar discectomy, percutaneous endoscopic lumbar discectomy, posterolateral endoscopic lumbar discectomy, retrospondylolisthesis, slippage

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Degenerative spondylolisthesis and herniated lumbar disc (HLD) are common degenerative diseases that cause low back pain and sciatica. Patients with degenerative spondylolisthesis often have spinal stenosis, for which fusion surgery has been the gold standard treatment (1). In spondylolisthesis with mild slippage and instability, decompressive surgery is effective even without fusion surgery (2,3). However, if HLD is the main lesion and the degree of slippage and instability of spondylolisthesis is not severe, surgeons may wonder whether fusion or decompressive surgery is more appropriate. Furthermore, posterolateral endoscopic lumbar discectomy (PLELD) or percutaneous endoscopic lumbar discectomy has been reported to be effective as treatment for HLD in degenerative spondylolisthesis (4-6). We investigated the outcomes of open lumbar microdiscectomy (OLM) and PLELD for antero- and retrospondylolisthesis with mild slippage and instability.

Methods

Study Design

The protocol of this study was approved by our hospital's ethics review committee. All procedures were conducted in accordance with the provisions of the Declaration of Helsinki. All patients provided written informed consent for the collection, storage, and analysis of their data for research purposes.

We enrolled patients with spondylolisthesis who underwent OLM or PLELD for HLD at our hospital between March 2007 and August 2014 and who were followed up for at least 3 years. We conducted a telephone survey and chart review, particularly focusing on pre- and postoperative radiographic parameters. Additionally, patients were invited to undergo reexamination to update their clinical and radiological data.

The inclusion criteria were age of 20 to 60 years and characteristic symptoms of low back pain and sciatica. Both fragmentectomy and discectomy were conducted. OLM and PLELD were performed by 2 experts. OLM or PLELD was indicated for antero- or retrospondylolisthesis in patients with > 4-mm instability on simple flexion-extension radiographs but ≤ 25% slippage of the vertebral bodies. The exclusion criteria were as follows: history of previous lumbar operation; follow-up period < 36 months; inadequate imaging records for accurate measurement of radiologic parameters; spondylolisthesis with pars defect; and fragmentectomy or laminectomy alone.

All patients meeting the inclusion criteria (n = 84) were contacted by telephone to ascertain their reoperation status and to invite them to undergo reexamination of clinical symptoms and radiographic parameters. Recurrence was defined as reoperation at the same level with or without the recurrence of previous symptoms. We reviewed the records of all survey responders to determine pre- and postoperative radiographic parameters. Patients presenting for reexamination underwent T2-weighted magnetic resonance imaging (MRI) and L-spine radiography.

We contacted 43 patients who underwent OLM; out of 34 patients who responded to the telephone survey, 17 presented for reexamination. We contacted 41 patients who underwent PLELD; out of 32 patients who responded to the telephone survey, 19 presented for reexamination (Fig. 1).

Surgical Techniques

OLM was performed as usual, using general anesthesia, with the patient in a prone position. After fluoroscopic confirmation of the disc level, a one-inch midline skin incision was made directly over the disc. Then the paraspinal muscle and soft tissues were retracted, and partial hemilaminectomy of the upper lamina was performed with a high-speed drill. After removal of the ligamentum flavum, the nerve root was gently retracted and the herniated fragment was removed with pituitary forceps, using an operating microscope.

PLELD was performed under local anesthesia with the patient awake and in a prone position. Fluoroscopic identification of the disc level was performed with the aid of a needle placed at the skin surface. After an 18-gauge spinal needle was inserted into the disc space, an intraoperative discogram was obtained to identify the pathologic lesion in the lumbar disc. A thin guidewire then replaced the spinal needle and a small stab incision was made. The herniated fragment was removed by forceps, and the posterior annulus and disc tissues were vaporized by a Holmium-YAG laser or shrunken by a bipolar radiofrequency through the working channel under endoscopic visualization. Finally, complete decompression was confirmed intraoperatively through the endoscopic view (7). Discectomy was performed as much as possible when performing OLM and PLELD.

Clinical Assessment

Telephone Survey

Clinical evaluation included gender, age, body mass index, bone mineral density, smoking, alcohol con-

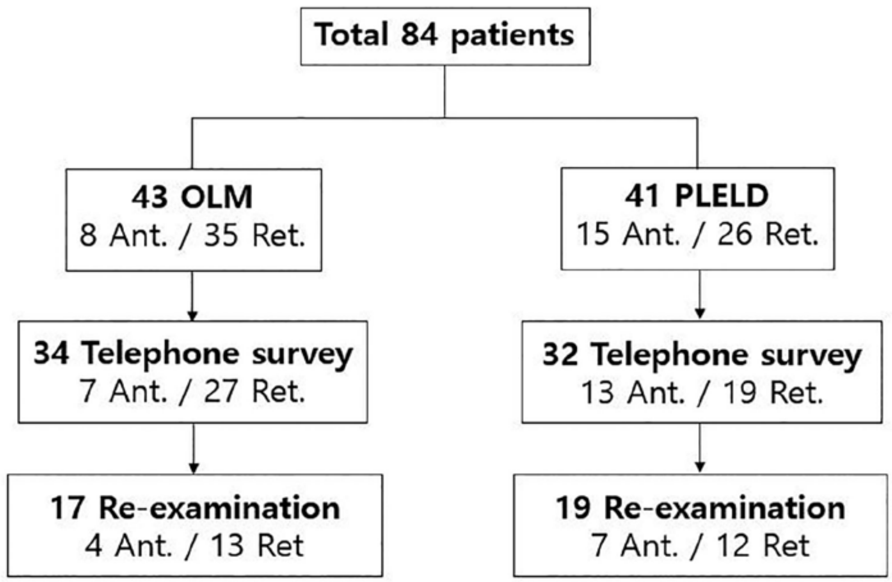

Fig. 1. *Flow chart of patient inclusion and stratification. Ant., antero; OLM, open lumbar microdiscectomy; PLELD, posterolateral endoscopic lumbar discectomy; Ret., retro; SL, spondylolisthesis.*

sumption, hypertension, diabetes mellitus, operation time, preoperative and postoperative Visual Analog Scale (VAS) of the patient's back and legs, Odom's criteria, and postoperative complications. Odom's criteria and postoperative VAS scores were recorded whenever the patient had an outpatient appointment. On the telephone, the patient was asked whether the previous operation site had been reoperated on. Recurrence was defined as reoperation of the same site but not recurrence of previous symptoms.

Reexamination

Patients who participated in the telephone survey were advised to visit the hospital again for reexamination. During the visit, we checked the back and leg VAS. In addition, we evaluated the incidence and severity of back pain within the preceding 12 months.

Radiologic Assessment

All patients underwent preoperative plain radiography, computed tomography, and MRI studies. On postoperative day one, the patients underwent T2-weighted MRI and L-spine radiography. Antero- and retrospondylolisthesis were evaluated on L-spine radiographs. Spondylolisthesis was defined as > 4-mm translation (8). The following radiologic factors were evaluated: slip grade (9), slip length, lateral slippage, lumbar lordotic angle, local lumbar angle at the treated level, disc height, facet angle and facet depth (10), presence of a vacuum or fluid correction of the facet capsule, craw spurs, traction spurs, vacuum disc at the index level, and disc migration (11) (Fig. 2).

Disc degeneration was assessed according to the Pfirrmann grading system (12), endplate defect score (13), and presence of Modic changes (14). Postoperative MRI was used to assess if there was iatrogenic endplate damage. Iatrogenic endplate damage was assessed on MRI and defined as damage to the central endplate rather than to the epiphyseal rim. Pre- and postoperative data were compared. Preoperative and final follow-up data were compared for patients with final follow-up data. MRI scans from the final follow-up could not be used to classify Modic changes because only T2 images were obtained. Therefore, we measured changes in subchondral bone signal intensity.

All radiographic parameters were measured with a picture archiving and communication system tool by 3 neurosurgeons.

Statistical Analysis

SPSS Version 22.0 (IBM Corporation, Armonk, NY) was used for analysis. Data were expressed as mean ± standard deviation, frequency (percentage), or frequency alone. Continuous variables were compared

Fig. 2. *Imaging findings at 53 months after posterolateral endoscopic lumbar discectomy. Anterior slippage and instability did not progress. (A, B) Disc height is preserved, and disc degeneration did not significantly progress (C, D, E) (white and white dotted arrows). FU, follow-up; Post-OP, postoperative; Pre-OP, preoperative.*

between groups using the Student t test or Mann-Whitney test, whereas categorical variables were compared using the Pearson chi-square test or Fisher exact test. The paired t test or Wilcoxon signed rank test was used for intragroup comparisons. A *P* value below .05 was considered to indicate statistical significance.

Results

Clinical Outcomes of Telephone Survey Respondents

The mean follow-up duration was 71.44 ± 18.8 and 74.81 ± 33.28 months in the OLM and PLELD groups, respectively. Recurrence was confirmed in 8 patients (23.5%) who underwent OLM and one patient (4.4%) who underwent PLELD, with a significantly higher recurrence rate in the OLM group (*P* = .028). Operative time was significantly faster in the PLELD group (*P* < .001). The preoperative VAS score for back pain was significantly worse in the PLELD group (*P* = .002). There was no significant difference in other clinical data (Table 1).

Clinical Outcomes of Reexamined Patients

Among the telephone survey respondents, 17 (50%) presented for reexamination 67.41 ± 11.23 months after OLM, whereas 19 (59.3%) presented for reexamination 64.42 ± 24.65 months after PLELD. These included 5 patients (62.5%) with recurrence in the OLM group and one patient (100%) in the PLELD group. In 2 patients, recurrence was confirmed based on information from hospital charts and telephone survey; another patient reported to have undergone fusion surgery, but we did not have access to these medical charts.

The preoperative VAS score for back pain was significantly worse in the PLELD group (*P* = .002). The incidence of back pain within the preceding 12 months was 58.8% (10 of 17) in the OLM group and 68.4% (13 of 19) in the PLELD group. Fifteen patients (88.3%) in the OLM group and 11 patients (57.9%) in the PLELD group reported little or no pain. Two patients (11.8%) in the OLM group and 5 patients (26.3%) in the PLELD group reported occasional pain, whereas no patient in the OLM group and 3 patients (15.8%) in the PLELD group reported pain often or always. Overall, there was no significant difference in pain (*P* = .193) or other clinical data between the groups (Table 1).

Radiographic Outcomes of Telephone Survey Respondents

Antero- and retrospondylolisthesis were detected in 7 and 27 patients who underwent OLM and 13 and 19 patients who underwent PLELD, respectively (*P* = .077). Preoperative slip length was 5.10 ± 0.81 in the OLM group and 5.19 ± 1.09 in the PLELD group. There was no statistically significant difference between the 2 groups (*P* = .691). Migration of the herniated disc was statistically significant in the OLM group (*P* < .001). Preoperative disc degeneration, endplate defect scores, and Modic changes did not differ significantly between the 2 groups. The rate of iatrogenic endplate damage was significantly higher in the OLM group than in the PLELD group (6 vs 0 patients; *P* = .025) (Table 2).

Table 1. *Demographic, surgical, and clinical data of patients*

	Telephone Survey			Reexamination (Final Follow-up)		
Characteristics	**OLM**	**PLELD**	***P* Value**	**OLM**	**PLELD**	***P* Value**
Number of Cases	34	32		17	19	
Male Gender	22	16	.227	11	9	.296
Female Gender	12	16		6	10	
Age, yrs	54.18 ± 9.87	53.29 ± 7.55	.688	46.47 ± 9.79	41.94 ± 10.52	.330
FU Interval, mos	71.44 ± 18.8	74.81 ± 33.28	.611	67.41 ± 11.23	64.42 ± 24.65	.649
Recurrence	8 (23.5)	1 (4.4)	.028*	5 (29.4)	1 (5.3)	.081
Ant. SL	2	0		1	0	
Ret. SL	6	1		4	1	
BMI, kg/m²	24.74 ± 2.85	23.98 ± 3.0	.293	24.49 ± 2.68	24.61 ± 3.15	.594
Smoking, Yes/No	13/21	10/22	.721	11/6	14/5	.679
Alcohol Consumption, Yes/No	16/18	18/14	.623	7/10	8/11	.999
HTN, Yes/No	6/28	6/26	.908	4/13	3/16	.684
DM, Yes/No	6/28	3/29	.477	3/14	2/17	.650
OP Duration, min	102.50 ± 31.82	69.36 ± 20.19	< .001*	109.11 ± 29.22	69.21 ± 23.11	< .001*
Affected Level			.350			.881
L2/L3	0 (0)	2 (6.3)		0	0	
L3/L4	9 (26.5)	6 (18.8)		5 (29.4)	4 (21.1)	
L4/L5	19 (55.9)	21 (65.6)		10 (58.8)	13 (68.4)	
L5/S1	6 (17.6)	3 (9.4)		2 (11.8)	2 (10.5)	
Complications, Yes/No	0/34	0/32		0/17		
Preop. VAS Score						
Back	4.32 ± 2.28	6.28 ± 2.52	.002*	4.29 ± 2.69	6.53 ± 2.25	.010*
Leg	8.32 ± 1.49	8.06 ± 1.87	.531	5.53 ± 1.12	7.74 ± 1.85	.135
Postop. VAS Score						
Back	2.26 ± 1.68	2.47 ± 1.27	.581	3.15 ± 2.35	2.84 ± 1.17	.610
Leg	2.88 ± 2.18	2.43 ± 1.34	.326	2.75 ± 2.47	2.37 ± 1.64	.575
VAS Score at Final FU						
Back				2.53 ± 2.24	3.42 ± 1.47	.162
Leg				2.88 ± 2.64	3.05 ± 2.20	.834
Patient Success per Odom's Criteria			.304			.121
Excellent	5 (14.7)	7 (21.9)		5 (29.4)	6 (31.6)	
Good	25 (73.5)	25 (78.1)		8 (47.1)	13 (68.4)	
Satisfactory	3 (8.8)	0 (0)		3 (17.6)	0 (0)	
Poor	1 (2.9)	0 (0)		1 (5.9)	0 (0)	

Patients were stratified according to the surgical approach. Data are presented as mean ± standard deviation, frequency (percentage), or frequency/frequency.
Abbreviations: Ant., antero; BMI, body mass index; DM, diabetes mellitus; FU, follow-up; HTN, hypertension; OLM, open lumbar microdiscectomy; OP, operation; PLELD, posterolateral endoscopic lumbar discectomy; Postop., postoperative; Preop., preoperative; Ret., retro; SL, spondylolisthesis; VAS, Visual Analog Scale
*Significant difference between the 2 groups ($P < .05$).

Radiographic Outcomes of Reexamined Patients

Antero- and retrospondylolisthesis were detected in 4 and 13 patients who underwent OLM and 7 and 12 patients who underwent PLELD, respectively (*P* = .077). Preoperatively, one patient in the PLELD group had Meyerding grade II, whereas the other patients had grade I. Slip length was 5.24 ± 0.96 and 5.36 ± 1.07 mm preoperatively in the OLM and PLELD groups, respectively (*P* = .699), in comparison with 5.24 ± 1.71 and 5.31 ± 3.63 mm postoperatively (*P* = .944). The change in slip length (pre- vs postoperatively) was 0.01 ± 1.38 and 0.05 ± 3.10 mm in the OLM and PLELD groups, respectively (*P* = .938). While disc height was similar between the 2 groups preoperatively (*P* = .680), postoperative disc heights were significantly smaller in the OLM group than in the PLELD group (*P* = .012) (Table 2).

Table 2. *Radiologic data of patients 1*

	Telephone Survey			Reexamination (Final Follow-up)		
Characteristic	**OLM**	**PLELD**	***P* Value**	**OLM**	**PLELD**	***P* Value**
Ant. SL/Ret. SL	7/27	13/19	.077	4/13	7/12	.837
Preop. Slip Grade						
I	34 (100)	32 (100)		17 (100)	18 (94.7)	.999
II	0 (0)	0 (0)		0 (0)	1 (5.3)	
Preop. Slip Length, mm	5.10 ± 0.81	5.19 ± 1.09	.691	5.24 ± 0.96	5.36 ± 1.07	.699
Postop. Slip Length, mm				5.24 ± 1.71	5.31 ± 3.63	.944
Slip Length Change, mm				0.01 ± 1.38	0.05 ± 3.10	.938
Lateral Slippage, mm	0.99 ± 1.00	0.67 ± 1.12	.227 .071	1.45 ± 2.09	1.23 ± 1.57	.707 .328
Segmental Angle, °	7.97 ± 5.90	4.67 ± 8.25		7.17 ± 6.74	4.37 ± 9.71	
Preop. LL, °	37.96 ± 15.95	34.09 ± 24.31	.444	34.18 ± 18.47	33.51 ± 25.79	.594
Postop. LL, °				41.05 ± 13.53	41.35 ± 15.82	.956
Preop. Disc Height, mm	7.38 ± 1.93	7.35 ± 1.76	.938	7.30 ± 1.81	7.56 ± 1.97	.680
Postop. Disc Height, mm				3.21 ± 1.97	5.27 ± 2.59	.012*
Facet Angle, °	85.71 ± 15.81	82.90 ± 18.84	.513	90.01 ± 14.29	84.60 ± 17.26	.316
Facet Depth Dimension, mm	3.40 ± 0.93	3.37 ± 0.71	.891	3.24 ± 0.83	2.77 ± 1.18	.184
Preop. Facet Depth, mm	15.64 ± 2.19			15.74 ± 2.41		
Postop. Facet Depth, mm	12.33 ± 2.48			12.57 ± 3.00		
Facet Depth Change, mm	3.31 ± 1.83			3.18 ± 2.44		
Facet Arthropathy, Yes/No	1/33	5/27	.100	0/17	3/16	.231
Traction Spur, Yes/No	1/33	2/30	.608	3/14	1/18	.326
Craw Spur, Yes/No	7/27	3/29	.306	5/12	1/18	.801
Preop. Vacuum Disc at Index Level, Yes/No	1/33	3/29	.348	1/16	2/17	.999
Disc Location			.879			.855
Central	27 (79.4)	24 (75.0)		11 (64.7)	13 (68.4)	
Subarticular	7 (20.6)	7 (21.9)		6 (35.3)	5 (26.3)	
Foraminal	0 (0)	1 (3.1)		0 (0)	1 (5.3)	
Migration			< .001*			< .001*
No	2 (5.9)	23 (71.9)		1 (5.7)	13 (68.4)	
Low	16 (47.1)	8 (25.0)		7 (41.2)	5 (26.3)	
High	16 (47.1)	1 (3.1)		9 (52.9)	1 (5.3)	

Patients were stratified according to the surgical approach. Data are presented as mean ± standard deviation, frequency (percentage), or frequency/frequency.
Abbreviations: Ant., antero; FU, follow-up; LL, lumbar lordosis; OLM, open lumbar microdiscectomy; OP, operation; PLELD, posterolateral endoscopic lumbar discectomy; Postop., postoperative; Preop., preoperative; Ret., retro; SL, spondylolisthesis.
*Significant difference between the 2 groups (*P* < .05).

Preoperative disc degeneration grade was similar between the 2 groups (*P* = .296), although both groups experienced worsening of disc degeneration. In both groups, the disc degeneration grade was worse preoperatively than preoperatively (*P* = .570). Similarly, the endplate score did not significantly differ between the 2 groups preoperatively (*P* = .144) and worsened in both groups following surgery, but exhibited significantly poorer postoperative values in the OLM group (*P* = .003). The rate of iatrogenic endplate damage was significantly higher in the OLM group than in the PLELD group (5 vs 0 patients) (*P* = .047). Preoperative Modic changes did not significantly differ between the 2 groups (*P* = .158). However, the endplate and subchondral bone signal intensities changed in 15 patients (88.2%) who underwent OLM and 8 (42.1%) who underwent PLELD (*P* = .012) (Table 3).

Table 3. *Radiologic data of patients 2*.

Parameter	Telephone Survey			Reexamination (Final Follow-up)		
	OLM	PLELD	*P* Value	OLM	PLELD	*P* Value
Preop. DD Grade			.908			.296
1	0 (0)	0 (0)		0 (0)	0 (0)	
2	0 (0)	0 (0)		0 (0)	0 (0)	
3	6 (17.6)	6 (18.8)		6 (35.3)	10 (52.6)	
4	28 (82.4)	26 (81.3)		11 (67.7)	9 (47.4)	
5	0 (0)	0 (0)		0 (0)	0 (0)	
Postop. DD Grade						.570
1				0 (0)	0 (0)	
2				0 (0)	0 (0)	
3				1 (5.9)	1 (5.3)	
4				6 (35.3)	10 (52.6)	
5				10 (58.8)	7 (36.8)	
Preop. EP Defect Score			.138			.144
1	1 (2.9)	4 (12.5)		0 (0)	0 (0)	
2	8 (23.8)	5 (15.6)		1 (5.9)	0 (0)	
3	15 (44.1)	7 (21.9)		4 (23.5)	11 (57.9)	
4	9 (26.5)	13 (40.6)		10 (58.8)	6 (31.6)	
5	1 (2.9)	3 (9.4)		2 (11.8)	2 (10.5)	
6	0 (0)	0 (0)		0 (0)	0 (0)	
Postop. EP Defect Score						.003*
1				0 (0)	0 (0)	
2				0 (0)	0 (0)	
3				1 (5.9)	7 (38.9)	
4				5 (29.4)	3 (16.7)	
5				1 (5.9)	6 (33.3)	
6				10 (58.8)	2 (11.1)	
Postop. EP Injury, Yes/No	6/28	0/32	.025*	5/12	0/19	.047*
Preop. MC Grade			.167			.158
0	26 (76.5)	29 (26.7)		8 (47.1)	10 (55.6)	
1	4 (11.8)	0 (1.9)		2 (11.8)	4 (22.2)	
2	4 (11.8)	3 (3.4)		6 (35.3)	1 (5.6)	
3	0 (0)	0 (0)		1 (5.9)	4 (16.7)	
Evolution of MC, Yes/No				15/2	8/10	.012*

Patients were stratified according to the surgical approach. Data are presented as frequency (percentage) or frequency/frequency. Abbreviations: DD, disc degeneration; EP, endplate; FU, follow-up; MC, Modic changes; OLM, open lumbar microdiscectomy; PLELD, posterolateral endoscopic lumbar discectomy; Postop., postoperative; Preop., preoperative. *Significant difference between the 2 groups (*P* < .05).

In the OLM group, 5 out of 8 patients with recurrence underwent revision OLM, 2 underwent PLELD, and one underwent revision OLM 48 months postoperatively but experienced another relapse 6 months after revision OLM and underwent fusion surgery in another hospital. Of these 8 patients, 5 underwent surgery at our hospital, and 7 recurrences were confirmed on MRI. In one patient who underwent fusion surgery, recurrence was confirmed based on the telephone survey alone. Only one patient had recurrence after PLELD, which was resolved with fusion surgery at our hospital 108 months after the initial PLELD (Table 4).

Discussion

Fusion surgery is a good treatment option for spondylolisthesis with severe translation and instability. However, fusion surgery carries the risk of instrument failure, muscle atrophy, failed back syndrome, and adjacent segment disease (15,16). Moreover, if HLD is the main lesion and the slippage and instability are not severe, OLM and PLELD may be better treatment options than fusion. However, when OLM is performed in these cases, the nucleus pulposus might be subtotally removed, annular injury might be wider, the facet might be partially removed, and the muscle and ligament might be injured. This raises concerns that spondylolisthesis may progress further and instability may occur. PLELD better preserves the peripheral tissue and bone structure and has a faster recovery time than OLM (17). However, as with OLM, when performing discectomy, there is a concern about the progression of spondylolisthesis and instability.

Among telephone survey respondents, the recurrence rate was significantly higher in the OLM group than in the PLELD group (23.5% vs 4.4%; *P* = .028). Reported recurrence rates after discectomy range from 7% to 26% (18). The cause of the high recurrence rate after OLM in this study may be multifactorial. First, post-OLM microinstability may cause recurrence (19,20). The supraspinous and interspinous ligament is the largest contributor to flexion resistance in the lumbar spine, followed by the intervertebral disc and ligamentum flavum. In the facet joint complexes, the intervertebral disc is the largest contributor to extension resistance in the lumbar spine (10,21). When OLM is performed, the nucleus pulposus, facet joint, and ligamentum flavum are partially removed, and the supraspinous and interspinous ligaments may be damaged. Therefore, microstability may be compromised at the index level, leading to increased axial loading and thus a higher risk of recurrence.

Microinstability can be detected based on the postoperative changes in disc height. Among patients presenting for reexamination, decreased disc height was significantly more pronounced for OLM than for PLELD (*P* = .012), perhaps because discectomy is more extensive for OLM than for PLELD. Mochida et al (22) reported that the postoperative decrease in disc height is proportionally exacerbated by nucleus pulposus removal. The nucleus pulposus acts as a hydraulic cushion distributing stress evenly between the vertebrae. If the nucleus pulposus is degenerated or removed, high stress is concentrated at the annulus fibrosus, leading to a decrease in disc height (23,24). This further concen-

Table 4. *Overview of patients with recurrent herniated lumbar disc.*

	Case No.	Gender	Age	OP Level	Ant. SL/Ret. SL	Recurrence Interval, mos	Treatment
OLM	1	Male	30	L 4/5	Ret. SL	12	Revision OLM
	2	Female	54	L 4/5	Ret. SL	3	Revision OLM
	3	Female	53	L 4/5	Ant. SL	24	Revision OLM
	4	Male	42	L 5/S1	Ret. SL	12	Revision OLM
	5	Male	43	L 4/5	Ant. SL	6	PLELD
	6	Male	53	L 4/5	Ret. SL	48 54	Revision OLM Fusion
	7	Male	53	L 4/5	Ret. SL	48	PLELD
	8	Male	53	L 4/5	Ret. SL	3	Revision OLM
PLELD	1	Female	52	L 3/4	Ret. SL	108	Fusion

Patients were stratified according to the surgical approach.
Abbreviations: Ant., antero; OLM, open lumbar microdiscectomy; OP, operation; PLELD, posterolateral endoscopic lumbar discectomy; Ret., retro; SL, spondylolisthesis.

trates stress at the annulus fibrosus and then the posterior column (facet joints) (25,26). If part of the facet, ligamentum flavum, and the lamina are removed, the loadbearing and kinematic characteristics of the spine may change, resulting in hypermobility, which would promote recurrent intervertebral disc herniation and accelerated bone degeneration (19,20).

If an endplate defect progresses or develops postoperatively, deep disc degeneration may occur, contributing to recurrence (27). We found that, although the preoperative endplate defect score was similar between the groups and worsened after either type of surgery, the postoperative score was significantly worse in the OLM group (*P* = .003). This may be related to the fact that OLM has a greater effect on disc height and axial loading. Specifically, if axial loading increases at the same time that disc height decreases, existing endplate defects are expected to expand, and new defects may develop (28). As disc height becomes critically small, the upper and lower vertebral bodies may collide, further exacerbating endplate damage. In addition, OLM-related endplate damage may contribute to the decreased endplate defect score postoperatively. The incidence of post-OLM endplate changes ranges from 6% to 18% (29,30). Among the respondents of our telephone survey, examination of pre- and postoperative MRI scans revealed that the incidence of new endplate defects in the central endplate area was significantly higher in the OLM group than in the PLELD group. The most probable cause lies in the discectomy technique. Unlike PLELD, OLM does not facilitate visualization of the inside of the disc during discectomy. Because the surgical instruments used for OLM are relatively large and can enter the disc at various angles, the risk of iatrogenic endplate damage is higher for OLM than for PLELD (Fig. 3).

Endplate defects can promote disc herniation (27). If the continuity of the endplate is disrupted due to iatrogenic damage, the endplate may gradually fall off the vertebral body, leading to reherniation of the disc containing the remaining nucleus pulposus (28).

Endplate defects cause Modic changes, which are also reportedly involved in disc herniation (31,32). In our study, the changes in subchondral bone signal intensity were significantly more pronounced in the OLM group than in the PLELD group. Changes in subchondral bone signal intensity may occur due to Modic changes caused by degeneration as a result of endplate defects. Moreover, if the disc height is extremely small, the vertebrae may come in contact and cause endplate erosion, which manifests as a signal change similar to that characteristic of osteoarthritis (33). Taken together, these findings indicate that recurrence is caused by microinstability and progression of degeneration due to endplate defects.

Interestingly, there was almost no change in slip length after surgery, with some patients actually having decreased slip length and instability. When PLELD is performed, it is presumed that spondylolisthesis does not progress because the disc height is preserved for a long period of time and damage to structures affecting stability is small. However, the disc height is greatly reduced, and disc degeneration progresses more in the OLM group than in the PLELD group (Figs. 2 and 3). In some patients, bony osteophytes formed a bone bridge. Disc height reduced substantially, and disc degeneration progressed in both groups. As the degeneration proceeded and disc height decreased gradually, arthritic changes in the apophyseal joints, ossification between the vertebrae, and osteophytes around the margins of the vertebral bodies may have developed, which might have decreased the movement of the spine at the index level (34). We thus propose that continuous progression of degeneration at the index level eventually causes limitation of spine movement (Figs. 3 and 4).

Clinical findings suggest that changes in subchondral bone signal intensity are not directly related to back pain. There was no statistical correlation between the 2 groups. Because of the long time that had elapsed since surgery, it was thought that the disc degeneration was not an inflammatory response phase but an end-stage phase, so there was no significant difference in clinical symptoms. However, the incidence and intensity of back pain in the preceding year tended to be higher in the PLELD group. This may be related to the fact that the preoperative VAS score for back pain was higher in the PLELD group.

PLELD has been reported to be effective as treatment for HLD in patients with degenerative spondylolisthesis (4-6). However, to the best of our knowledge, this study is the first to compare and analyze clinical and radiologic outcomes with a long-term follow-up of OLM and PLELD in patients with low-grade degenerative spondylolisthesis. It is also significant that patients with retrospondylolisthesis and anterospondylolisthesis were included in the study.

One limitation of this study is that the number of patients participating in the study was small. Moreover, we could not measure the recurrence rate in all patients who underwent OLM and PLELD at our hospital. There may have been a bias in determining whether to perform OLM or PLELD in patients with HLD. The operative method was determined according to the preference of the patient and the operator. However, patients with HLD with high migration typically underwent OLM. Further, our study did not include patients of all ages, as we were attempting to exclude the effect of aging on the degree of back muscle atrophy and spondylosis. Finally, the endplate defect score may have been worse in the OLM group owing to the natural course of degeneration. Long-term follow-up studies involving more patients will be necessary.

Conclusions

For patients with HLD as the main lesion and mild slippage and instability, PLELD and OLM can be good treatment options. The PLELD group had a lower recurrence rate than the OLM group. There was no difference between the 2 groups with respect to the final clinical outcome. Postoperatively, the OLM group showed a greater decrease in disc height, more iatrogenic endplate damage, worse endplate defect score, more changes in subchondral bone signal intensity, and more recurrence than the PLELD group. Considering recurrence and degeneration, PLELD may be a good treatment option for patients with HLD who have antero- and retrospondylolisthesis with a mild degree of slippage and instability.

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