Retrospective Case Series

Clinical Outcomes of Percutaneous Endoscopic Lumbar Discectomy for the Treatment of Grade I and Grade II Degenerative Lumbar Spondylolisthesis: A Retrospective Study With a Minimum Five-Year Follow-up

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Background: Degenerative lumbar spondylolisthesis (DLS) occurs mainly in geriatric patients. Some authors have reported satisfactory short-term outcomes following percutaneous endoscopic lumbar discectomy (PELD) for DLS; however, the long-term clinical outcomes remain unknown. In addition, it remains unclear whether PELD causes further progression of spondylolisthesis over a long period of time.

Objectives: To evaluate long-term clinical outcomes in patients who underwent PELD and to study the degree of slippage in DLS over a long period following minimally invasive surgery.

Study Design: Retrospective case series.

Setting: The study was conducted at the Beijing Chaoyang Hospital, Capital Medical University, China.

Methods: The study included 24 patients with DLS who complained of radicular pain and lower back pain who underwent PELD and were followed up for at least 5 years (mean duration of 6.1 years). Visual analog scale (VAS) scores, Oswestry disability index (ODI) scores, and the modified MacNab criteria were used to evaluate clinical outcomes. Preoperative imaging findings, including the percent slippage of spondylolisthesis (SR), disc height (DH), segmental lordosis angle (SL), and lumbar lordosis angle (LL), were compared with those obtained at follow-up.

Results: All operations were successfully completed; the mean operative incision length, intraoperative blood loss, and operation duration were 8.7 ± 0.6 mm, 11.3 ± 4.5 mL, and 121.8 ± 32.3 min, respectively. The mean VAS-back score, VAS-leg score, and ODI score were 6.5 ± 0.9, 6.0 ± 1.1, and 55.4 ± 4.4 points before surgery, respectively, and decreased to 2.6 ± 0.8, 2.2 ± 0.5, and 27.3 ± 5.3 points, respectively, at 3 months after surgery and 2.5 ± 0.9, 2.0 ± 0.5, and 21.1 ± 4.4 points, respectively, at the latest follow-up. The imaging variables related to DH were lower at the final follow-up before surgery; however, no significant differences in SR, SL, and LL were found. The proportion of excellent and good results following MacNab evaluation was 87.5%. Symptomatic re-herniation occurred in one patient, and cerebrospinal fluid leakage (CSFL) was found in another patient.

Limitations: A small number of patients were included who were all treated by one surgeon.

Conclusions: PELD maintained satisfactory clinical outcomes for the treatment of grade I and grade II DLS after a minimum 5-year follow-up; the operation did not cause further progression of spondylolisthesis. However, further large-scale multicenter studies are necessary.

Key words: Spondylolisthesis, percutaneous endoscopic lumbar discectomy, minimally invasive, clinical outcome, geriatric patients, spine, lumbar instability, comorbidities

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Degenerative lumbar spondylolisthesis (DLS) is the slipping of an upper vertebra past its normal alignment to its superior vertebra because of degenerative wear of the facet joint, which normally helps keep the 2 vertebrae aligned (1). The incidence of DLS has been reported to be 4%-8% across all ages and has been found to be greater in elderly patients (1-2). This pathologic disorder leads to narrowing of the spinal canal and foramina. Patients often present with symptoms and signs consistent with radiculopathy and neurogenic claudication. The open approach for decompression with instrumented fusion has been considered the gold standard procedure for the treatment of DLS because of the resultant extensive decompression of the nerve roots and cauda equina (3). However, DLS mainly occurs in elderly patients who often suffer from complex diseases, and the major surgical dilemma is how to reduce the perioperative risk under general anesthesia.

In recent years, with the advent of minimally invasive spine surgical technology, percutaneous endoscopic lumbar discectomy (PELD) has been widely used in clinical practice, and its indications have been extended from purely including disc herniation to the removal of various types of lumbar disc herniation and prolapse, as well as in the expansion of the spinal canal and foramina (4). PELD has the advantages of causing less trauma and bleeding and having a faster recovery than those of traditional decompression. Importantly, PELD can be used to treat patients with DLS under local anesthesia and to preserve the patient's posterior ligament complex (5). Some authors have reported satisfactory short-term outcomes following PELD for DLS. We aimed to: 1) evaluate long-term clinical outcomes in patients who underwent PELD, and 2) study whether PELD causes further progression of lumbar spondylolisthesis over a long period of time.

Our study focused on a case series of patients with grade I and grade II DLS who had persistent radiculopathy despite conservative treatment. PELD was performed under local anesthesia, with removal of the ventral superior articular process, slipped disc, and part of the superior endplate. A retrospective study with a minimum 5-year follow-up was conducted.

Methods

Patient Selection

Twenty-four consecutive patients underwent PELD for single-level DLS in our department between July 2014 and May 2016. The inclusion criteria were as follows: 1) a diagnosis of predominant grade I or grade II DLS based on physical examination results, clinical symptoms, and imaging studies; and 2) failure after at least 3 months of conservative treatment. The exclusion criteria were as follows: 1) the percent slippage of spondylolisthesis was over 50% or segmental instability (disc angle change > 10° or change in translation > 3 mm from standing or supine radiographs to dynamic radiographs) (6); 2) clinical symptoms and signs inconsistent with imaging findings; 3) pathological conditions such as spinal infection or tumor; and 4) history of lumbar surgery. The surgical procedures for all patients were performed by an experienced surgeon.

Surgical Procedures

In the PELD procedure, patients were placed in the prone position on a radiolucent table, and a posterior midline paraspinal incision was made at the definitively affected intervertebral level under regional anesthesia. The patient could communicate with the surgeon during the entire operation, which prevented intraoperative nerve root damage. The surgical procedure consisted of 3 steps. 1) Foraminoplasty: The guidewire was inserted into the superior articular process (SAP) of the targeted segment through a puncture needle, and the surgical approach was progressively expanded to 8 mm with a hollow tapered cannula. The ligamentum flavum and ventral elements of the SAP were removed. A tubular retractor with an outer diameter of 7.9 mm was then placed; when necessary, burrs were used to enlarge the foramen further. 2) Discectomy: The herniated disc was completely resected using a rongeur and could be removed with an endoscope if there was a large amount of disc tissue. 3) Resection of the superior endplate: Endoscopic forceps, endoscopic bone knife, or a high-speed drill was used to remove the superior endplate of the inferior vertebral body. Finally, adequate irrigation and hemostasis were performed, and the surgical wounds were sutured in anatomical order.

Outcome Assessment

Clinical assessments were conducted preoperatively and at 3 months, 12 months, 24 months, and the last postoperative follow-up. The degree of pain was assessed using the visual analog scale (VAS) from 0 to 10 for the back (VAS-back) and legs (VAS-leg). The Oswestry disability index (ODI) was used for functional assessment. Percent slippage of spondylolisthesis (SR), disc height (DH), segmental lordosis angle (SL), and lumbar lordosis angle (LL) were measured to assess the progression of lumbar spondylolisthesis (Fig. 1). In addition, surgical outcomes at the last follow-up were defined as excellent, good, fair, and poor according to the modified MacNab criteria.

Statistical Analysis

All statistical analyses were performed using SPSS version 23.0 (IBM Corporation, Armonk, NY). One-way analysis of variance (ANOVA) was performed for data involving multiple factors, such as VAS-leg, VAS-back, and ODI (%) before surgery, at 3 months, 12 months, and 24 months, and at the last follow-up after surgery. Paired-sample t tests were performed for comparisons between the preoperative and last follow-up imaging findings, including SR, DH, SL, and LL. Statistical significance was set at $P < 0.05$.

Results

Patient's Demographic Characteristics

A total of 24 prospective consecutive patients who underwent PELD between July 2014 and May 2016 were included in this study, including 13 women and 11 men (Table 1). The average age was 74.4 years (range, 60-84 years). There were 2 cases at the L3–4 level, 16 cases at the L4–5 level, and 6 cases at the L5–S1 level. The average duration of symptoms was 6.4 years (range, 0.5-40 years). The average percent slippage of spondylolisthesis was 15.9% (range, 9.1%–22.2%), including 21 cases of Grade I (87.5%) and 3 cases of Grade II (12.5%). Twenty-three (95.8%) patients had at least one comorbidity, and 6 patients (25.0%) had at least 3 comorbidities. The most common comorbidity was cardiovascular disease (62.5%), followed by endocrinological disease (45.8%).

Clinical Outcomes

All operations were successfully completed. The mean operative incision length was 8.7 mm (range, 8-10 mm), the mean intraoperative blood loss was 11.3 mL (range, 5-20 mL), and the mean operation duration was 121.8 min (range, 65-200 min). The average first ambulation time and hospital stay were 20.3 h (range, 12-29 h) and 7.6 days (range, 5-12 days), respectively.

All patients experienced significant relief of low back pain and leg pain, and ODI scores at 3, 12, and 24 months postoperatively and at the last follow-up examination were significantly improved ($P < 0.01$). The mean preoperative VAS leg pain, VAS back pain, and ODI score were 6.5 ± 0.9, 6.0 ± 1.1, and 55.4 ± 4.4, respectively; all mean scores improved postoperatively to 2.5 ± 0.9, 2.0 ± 0.5, and 21.1 ± 4.4 at the final follow-up evaluation, respectively (Table 2). All patients were evaluated for overall success based on the modified MacNab criteria. On evaluation at the final follow-up, 9 patients were categorized as excellent (37.5%), 12 as good (50.0%), 2 as fair (8.3%), and 1 as poor (4.2%). In total, 87.5% of the patients were rated as excellent or good. Representative cases are presented in Figures 2 and 3, respectively.

The preoperative and final follow-up imaging findings are compared in Table 3. The preoperative average SR was 15.9 ± 6.0%. The average SR at the final follow-up evaluation was 17.0 ± 7.5%, which was not significantly different ($P = 0.235$). The DH had decreased from 8.3 ± 1.1 mm preoperatively to 7.9 ± 0.2 mm at the last follow-up evaluation ($P = 0.021$). The mean height of disc loss after this surgical procedure was 0.4 mm during follow-up. The preoperative average SL and LL were 8.1 ± 2.4° and 36.1 ± 4.3°, respectively. The average SL and LL at the final follow-up evaluation were 7.9 ± 2.3° and 37.2 ± 4.5°, respectively, which were not significantly different (SL: $P = 0.382$, LL: $P = 0.203$).

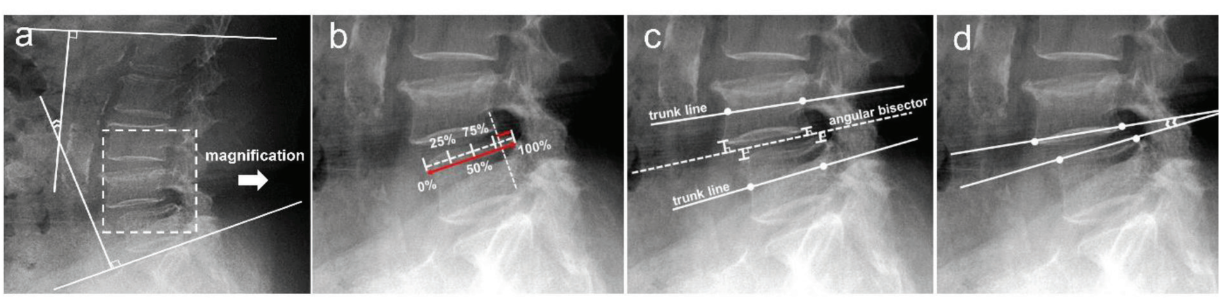

Fig. 1. *Measurement of X-ray parameters. A, lumbar lordosis angle (LL). B, the percent slippage of spondylolisthesis (SR). C, disc height (DH). D, segmental lordosis angle (SL).*

Table 1. *Summary of demographic data.*

Patient	Gender, Age (y)	Side	Level	Duration (y)	Slippage (%)	Comorbidities	OIL (mm)	IBI (mL)	OD (min)	FAT (h)	LHS (days)	Follow-up (months)	MacNab evaluation	Complication
1	M,83	Right	L4-L5	1	15.8	C B	9	5	130	18	7	65	Good	—
2	F,76	Left	L4-L5	1.5	11.4	C E P	8	10	130	24	8	72	Good	—
3	M,78	Right	L3-L4	0.5	26.6	C E	8	15	85	12	7	82	Excellent	—
4	M,78	Right	L4-L5	20	17.6	C E	9	10	65	17	6	73	Good	—
5	F,73	Left	L4-L5	1	11.6	C E	8	15	115	22	7	70	Good	—
6	M,69	Left	L4-L5	10	12.8	P H U	9	20	130	22	5	68	Good	—
7	M,74	Right	L4-L5	8	23.6	C	9	15	135	18	7	78	Excellent	—
8	F,77	Right	L4-L5	20	9.3	C B	9	5	105	17	8	75	Fair	Reherniation
9	M,76	Right	L4-L5	2	14.4	C	10	5	115	20	7	80	Excellent	—
10	F,63	Left	L3-L4	10	26.4	C	8	10	140	21	9	81	Good	—
11	F,79	Left	L4-L5	10	12.4	C E P G	9	5	200	22	11	76	Good	—
12	M,81	Right	L4-L5	5	9.7	N	8	10	190	18	9	73	Fair	—
13	F,79	Right	L4-L5	1	13.1	C B E U G	9	5	100	16	12	67	Poor	—
14	M,82	Right	L3-L4	1	10.6	C B	9	10	105	19	6	62	Excellent	—
15	F,75	Left	L5-S1	5	9.2	B	8	15	90	18	6	68	Good	—
16	F,78	Left	L5-S1	40	10.5	C E H	9	10	150	21	7	71	Good	—
17	M,60	Left	L4-L5	5	13.3	C	8	15	165	23	9	73	Excellent	—
18	F,63	Right	L4-L5	3	19.4	E H	9	15	95	22	7	79	Good	—
19	M,84	Left	L3-L4	0.5	17.1	C B E H	9	10	120	19	8	82	Excellent	—
20	F,83	Left	L4-L5	0.5	23.5	E H	9	10	80	20	9	73	Excellent	—
21	F,74	Right	L4-L5	0.5	28.2	C B	8	15	110	21	5	67	Excellent	—
22	F,72	Left	L4-L5	5	21.3	B	9	20	130	19	8	63	Excellent	—
23	M,61	Left	L3-L4	3	9.7	B E	8	10	105	29	6	78	Good	—
24	F,67	Right	L3-L4	1	15.2	—	9	10	135	28	9	75	Good	CSFL

Abbreviations: OIL, operative incision length; IBI, intraoperative blood loss; OD, operation duration; FAT, first ambulation time; LHS, length of hospital stay; C, cardiovascular; B, cerebrovascular; E, endocrinologic; P, pulmonary; H, hepatobiliary; U, urologic; G, gastroenterology; N, neurology; CSFL, cerebrospinal fluid leakage.

Table 2. *VAS pain scores and ODI score.*

	Pre-Op	3M Post-Op	12M Post-Op	24M Post-Op	Latest Follow-up	*P* Value
VAS leg pain	6.5 ± 0.9	2.6 ± 0.8	2.5 ± 0.8	2.6 ± 0.4	2.5 ± 0.9	< 0.001*
VAS back pain	6.0 ± 1.1	2.2 ± 0.5	2.3 ± 0.6	2.2 ± 0.5	2.0 ± 0.5	< 0.001*
ODI (%)	55.4 ± 4.4	27.3 ± 5.2	25.4 ± 4.7	22.7 ± 3.8	21.1 ± 4.4	< 0.001*

* indicates a significant difference

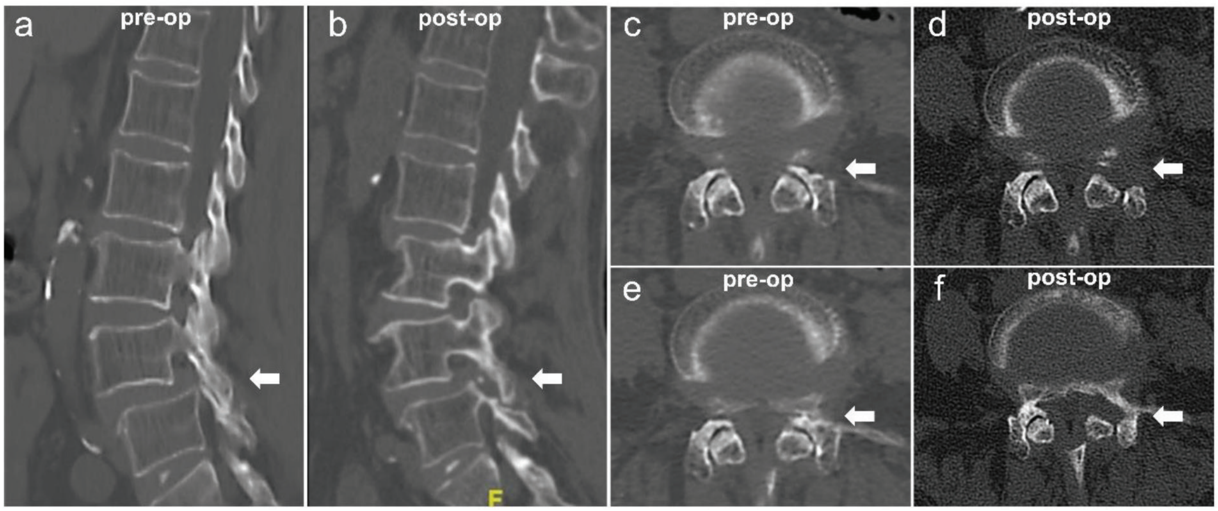

Fig. 2. *Percutaneous endoscopic lumbar discectomy performed on a 72-year-old woman diagnosed with degenerative lumbar spondylolisthesis. A, preoperative sagittal computed tomography. B, postoperative sagittal computed tomography. C and E, preoperative axial computed tomography. D and F, postoperative axial computed tomography.*

Fig. 3. *Percutaneous endoscopic lumbar discectomy performed on a 72-year-old woman diagnosed with degenerative lumbar spondylolisthesis. A, preoperative lateral X-ray of the lumbar spine. B, postoperative lateral X-ray of the lumbar spine showed that there was no progression of lumbar spondylolisthesis 5 years after surgery. A, preoperative midsagittal MRI of the lumbar spine. B, postoperative midsagittal MRI of the lumbar spine showed that there was no recurrent disc herniation 5 years after surgery. MRI = magnetic resonance imaging.*

Table 3. *Radiographic parameters*.

Parameters	Pre-Op	Latest Follow-up	*P* Value
SR (%)	15.9 ± 6.0	17.0 ± 7.5	0.235
DH (mm)	8.3 ± 1.1	7.9 ± 0.9	0.021*
SL (°)	8.1 ± 2.4	7.9 ± 2.3	0.382
LL (°)	36.1 ± 4.3	37.2 ± 4.5	0.203

SR, slippage; DH, disc height; SL, segmental lordosis angle; LL, lumbar.
lordosis angle. * indicates a significant difference

Recurrences and Complications

One patient experienced recurrence at 3 months postoperatively, resulting in a recurrence rate of 4.2%. This patient had low back pain and radiating leg pain, with a single-level lumbar disc herniation at L4–L5 verified using magnetic resonance imaging and computed tomography. The patient underwent a second open approach for decompression with instrumented fusion surgery. One patient experienced cerebrospinal fluid leakage, and the symptoms were relieved after conservative treatment. There were no occurrences of thrombophlebitis, infection, vascular injury, or cauda equina syndrome.

Discussion

DLS is a common condition in elderly patients with radicular pain, mechanical back pain, and intermittent claudication. An open approach for decompression with instrumented fusion that requires general anesthesia tends to have a higher perioperative risk for the elderly, especially those with multiple medical comorbidities. PELD is an ultra-minimally invasive surgical technique that can be performed under local anesthesia. Our research focused on the long-term outcomes of PELD for the treatment of DLS and found that it was able to maintain satisfactory clinical outcomes after a minimum 5-year follow-up, and the operation did not cause further progression of lumbar spondylolisthesis.

Some authors have reported satisfactory short-term outcomes following PELD for DLS. Xin-Feng et al (7) reported good or excellent outcomes in 81.3% of 26 patients with low-grade DLS (Meyerding grades I and II) and found that there was no statistically significant difference between the percent slip of spondylolisthesis before surgery and one year after surgery. Xiao-Kang et al (3) developed PELD for geriatric patients with central spinal stenosis and DLS and found that 93.3% of patients reported high rates of satisfaction after 12 months of follow-up. Dong-Ju et al (8) compared the clinical results of open lumbar microdiscectomy (OLM) and PELD for antero- and retrospondylolisthesis and found that recurrence was confirmed in eight patients (23.5%) who underwent OLM and only one patient (4.4%) who underwent PELD, with a significantly higher recurrence rate in the OLM group (P = 0.028) after at least 3 years of follow-up. However, in our study, we evaluated clinical outcomes and radiographic changes over a minimum 5-year follow-up in a retrospective study of PELD performed to treat DLS with a relatively long follow-up time.

In the present study, the proportion of excellent and good results following MacNab evaluation was 87.5% at the final follow-up examination. The average relief rates of the VAS-back, VAS-leg, and ODI scores at the final postoperative follow-up were 64.6%, 61.6%, and 69.4%, respectively. Jasper et al (1) reported that the average pain relief 1 year postoperatively was 71.9%, which is higher than our reported rate of 61.6%. We believe that there are 2 main reasons for this difference. First, the patients enrolled in our study were older, and geriatric patients tend to have more complex degeneration often associated with facet joint hyperplasia and cohesion, osteophyte formation, and disc space narrowing, which may affect the effect of decompression. Second, our study involved a longer follow-up; patients may develop new degenerative diseases in the lower back after a follow-up of at least 5 years, which may lead to a decrease in patient satisfaction. In addition, compared to open surgery, our study showed the advantages of less trauma, less bleeding, and faster recovery. However, one patient in this study experienced cerebrospinal fluid leakage. This is because the patient's dura mater adhered to the ligamentum flavum and could not be visualized clearly during surgery. Therefore, strict hemostasis and adequate irrigation should be performed to ensure a clear surgical field of vision. Importantly, the surgeon must patiently and gently separate the dura from the ligamentum flavum. The symptoms of the patient with cerebrospinal fluid leakage were relieved after conservative treatment, and no neurological sequelae were observed during the follow-up period. In addition, one patient experienced recurrence at 3 months postoperatively and underwent further treatment using an open approach for decompression with instrumented fusion surgery.

In our study, DH-related imaging variables were lower at the final follow-up than before surgery; however, no significant changes were found for SR-, SL-, and LL-related variables. The authors believe that there are 2 possible reasons for the decrease in disc height in this study. First, previous reports on the relationship between disc height changes and age found that the disc height of each segment of the lumbar spine increases with age, but after entering old age, the disc height decreases significantly (9-10). The mean age of patients included in our study was 73.1 years, and they were followed up for at least 5 years. Therefore, the decrease in disc height may be related to natural degeneration. Second, because the nucleus pulposus tissue is a jelly-like semi-liquid substance, it has a certain degree of fluidity. After a part of the nucleus pulposus tissue is removed in PELD surgery, the original integrity of the intervertebral disc is destroyed, and the volume of the intervertebral disc gradually decreases, leading to its absorption (11). This may cause the height of the disc to decrease. Although our study showed a slight decrease in disc height, no patients with lumbar instability were identified at the final follow-up. Sang Soo et al (12) also reported that the average disc height was 81.54% of the original disc height after 10 years of follow-up, but there were no cases of lumbar instability among all patients.

Our results show that lumbar slippage showed no significant progression, even after a minimum 5-year follow-up. The number of subjects in this study was small; however, we have accurate data on slippage to one-tenth of a millimeter, which improves the credibility of the paper. Moreover, some authors have also reported that lumbar slippage did not progress further after PELD during short-term follow-up (3,7-8). Nevertheless, further large-scale multicenter, long-term studies are necessary. Confusingly, an open approach for decompression without fusion can lead to further slippage and may require additional fusion therapy (13-15). However, decompression using minimally invasive PELD techniques, similarly lacking fusion, does not cause further slippage. We believe that the main reason for this is the different extent of damage to the soft tissues that maintain the stability of the spine. Paravertebral muscles, especially the multifidus muscles, are important structures for maintaining spinal stability (16), and an open approach for decompression usually removes large paravertebral muscles. However, minimally invasive treatment using the working channel to decompress the intermuscular space can avoid injury to the paravertebral muscles, reduce ischemic necrosis due to interruption of the blood supply to the multifidus muscle, preserve the physiological function of the multifidus muscle to the maximum extent possible, and maintain spinal stability.

Although minimally invasive transforaminal lumbar interbody fusion techniques (MIS-TLIF) have been used for degenerative diseases of the lumbar spine (17), spinal fusion is not indicated in all patients with spondylolisthesis, and the procedure should be selected according to the symptoms (18). Spondylolisthesis does not mean that the spine must be unstable (19-20), and it is often described to have an initial phase of instability followed by further degenerative changes that eventually stabilize the spine. Intervertebral disc space stenosis, osteophyte formation, and facet joint degeneration have been considered to be characteristic manifestations of re-stabilization on imaging, and fusion is not necessary at this time (18-19,21). Therefore, Minamide et al (20) suggested that fusion may be necessary in patients with early spondylolisthesis and dynamic instability. In our study, PELD was able to maintain satisfactory clinical outcomes following the treatment of patients with stable degenerative spondylolisthesis, and the mean ODI score improvement rate was 34.3%. Jun-long et al (22) reported percutaneous endoscopic lumbar interbody fusion for the treatment of patients with stable grade I spondylolisthesis and found that the ODI score improvement rate was 33.7% after 24 months of follow-up. Although both PELD and MIS-TLIF may achieve satisfactory clinical effects when treating stable low-grade spondylolisthesis, PELD has more advantages with respect to intraoperative blood loss, operation time, anesthesia risk, and cost (22-24).

One limitation of this study is that it included a small number of patients treated by one surgeon; future large-scale multicenter studies are necessary. Moreover, patients should be grouped systematically according to the degeneration of anatomical structures. Many subtle anatomical factors may affect the outcome of these patients, such as facet joint morphology, presence of facet joint effusion, and degree of facet joint osteoarthritis. Furthermore, we should establish a control group of healthy elderly people to compare the lumbar vertebrae-related variables after natural degeneration with those after minimally invasive surgery.

Conclusions

As the elderly population increases in number and age, spine physicians need to develop targeted treatment plans for elderly patients with DLS, especially those with multiple medical comorbidities. PELD was able to maintain satisfactory clinical outcomes for the treatment of grade I and grade II DLS, even after a minimum 5-year follow-up, and the operation did not cause further progression of lumbar spondylolisthesis. We believe that PELD may be used as an alternative therapeutic option for DLS. However, this needs to be supported by further large-scale multicenter studies.

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