


## CLINICAL ARTICLE

# A Comparison Between Retaining and Resecting the Posterior Longitudinal Ligament in Percutaneous Endoscopic Transforaminal Discectomy for Disc Herniation: A Retrospective Cohort Study

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**Objective:** To compare the efficacy and safety of retaining the posterior longitudinal ligament (PLL) with resecting the PLL in inside-out percutaneous endoscopic transforaminal discectomy (PETD) surgery for lumbar disc herniation (LDH).

**Method:** A total of 135 patients with symptomatic LDH who were treated by inside-out PETD surgery from January 2015 to January 2017 were included in this retrospective analysis. There were 38 males and 30 females in the PLL resection group (mean age = 52.40 ± 8.73 years) and 35 males and 32 females in the PLL retention group (mean age = 53.50 ± 9.24 years). The visual analogue scale (VAS) score, Oswestry disability index (ODI), and modified Mac-Nab criteria were used to evaluate clinical outcomes. Operation time, blood loss, recurrence of LDH, and complications were recorded. Three months after surgery, magnetic resonance imaging was performed to confirm that nerve root compression was relieved.

**Results:** The VAS and ODI scores improved significantly immediately after surgery, at 1 month after surgery, at 3 months after surgery, and at last follow-up compared with those before surgery ( $P < 0.01$ ). The scores also improved significantly between immediately after surgery and 1 month after surgery in the two groups ( $P < 0.001$ ). Multivariate analysis indicated that age  $\geq 50$  years (odds ratio (OR) = 6.33, 95% confidence interval (CI): 1.64–21.98,  $P = 0.014$ ), pain duration  $\geq 6$  months (OR = 4.68, 95% CI: 1.29–6.51,  $P = 0.025$ ), pre-ODI score  $\geq 40\%$  (OR = 5.97, 95% CI: 2.41–14.86,  $P = 0.003$ ) were all associated with poor functional outcomes. There was no significant difference in the excellent/good ratio between the two groups and the mean operation time of the retention group was 71.5% of that of the resection group (82.7 ± 18.5 min vs 115.6 ± 24.6 min,  $P < 0.01$ ). In the patients, no serious complications, such as dural tear, wound infection, or persistent nerve root injury, were observed during the follow-up period. There was no significant difference in the complication rate between the two groups (6/68 vs 6/67,  $P = 0.979$ ). Although the recurrence rate was higher in retention group, there was no significant difference between the two groups (1/68 vs 2/67,  $P = 0.551$ ).

**Conclusion:** The PLL is recommended to be retained for inside-out PETD surgery.

**Key words:** Clinical outcomes; Lumbar disc herniation; Percutaneous endoscopic lumbar discectomy; Percutaneous endoscopic transforaminal discectomy; Posterior longitudinal ligament

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## Introduction

Lumbar disc herniation (LDH) is a common disease with a reported prevalence of 4%–6%, and is a major cause of lower back pain (LBP) with radiation to the legs<sup>1</sup>. Although conservative treatment is usually proposed for patients with LDH, some patients whose symptoms are not improved using conservative management might still require surgical intervention<sup>2</sup>. Among the surgical methods, open lumbar discectomy and fusion is considered the gold standard treatment for LDH<sup>3</sup>. However, the procedure might damage the muscular and ligamentous structures, requires a prolonged hospital stay, and incurs high hospitalization costs. In the mid-1980s, Onik *et al.*<sup>4</sup> proposed a new percutaneous discectomy technique developed using a motorized aspiration shaver, which entailed gaining access to the disk space through the use of an introduction system and a cannula. A 2-mm aspiration probe, called a nucleotome, was then placed through the cannula into the disk space, and the nucleus pulposus was aspirated. A real percutaneous endoscopic lumbar discectomy was described by Mayer and Brock in 1993<sup>5</sup>. During this procedure, the disc space is opened with anulus trephines and the nucleus pulposus is removed using rigid and flexible forceps. In 1997, Kambin *et al.*<sup>6</sup> reported an arthroscopic discectomy for the treatment of contained and non-migrated sequestered herniated discs. Since then, percutaneous endoscopic lumbar discectomy (PELD) has become increasingly popular for the management of LDH, with advantages of shorter operative time, minimal blood loss, and less muscle injury. Moreover, this minimally invasive spine surgery does not require excessive bone removal and neural manipulation, which maintains the stability of the spine and promotes faster functional recovery<sup>7–9</sup>.

Based on the approach to the herniation disc materials, PELD is classified into percutaneous endoscopic transforaminal discectomy (PETD) and percutaneous endoscopic interlaminar discectomy (PEID). PEID employs a posterior approach, in which the working channel is inserted through the lamina and ligamentum flavum to the disc, which was first introduced by Ruetten *et al.* in 2006.<sup>10</sup> PEID is not limited by the high iliac crest; therefore, it is more suitable for disc herniation of L<sub>5</sub>S<sub>1</sub>. However, this technique requires traction of the calcus to deal with disc fragments, which could cause dural laceration and other complications.<sup>11</sup> The PETD technique is relatively simple and is used more widely in clinical practice. There are two main types of PETD: The inside-out technique developed by Yeung *et al.*<sup>12</sup> and the outside-in technique<sup>13</sup>. For the inside-out technique, the working channel is first inserted into the disc just underneath the herniated nucleus pulposus, while in the outside-in technique, the working channel is placed on the disc surface, just outside of the intervertebral foramen. Notably, no technology is perfect. Although PETD is safe and precise, Gore *et al.*<sup>14</sup> concluded less than 90% of patients were satisfied with the technique. Sairyo *et al.*<sup>15</sup> studied the clinical outcome and surgery related complications in PELD under local anesthesia, and revealed that the rate of complication was

5% in 100 cases. A retrospective review, including 10,228 patients who had undergone PELD, was performed by Choi *et al.*<sup>16</sup>, who found that 436 cases were unsuccessful and 283 patients had incomplete nucleus pulposus removal. Moreover, Morgenstern *et al.*<sup>17</sup> studied 144 patients who had an endoscopic lumbar discectomy with an average of 24 months of follow-up and developed a methodology to calculate the learning curve for the procedure, concluding that 72 cases were needed to reach the goal of 90% of good/excellent results for this surgery. Lee *et al.*<sup>18</sup> analyzed the operative failure of PELD in 1586 cases, which indicated that the main reason for the failure of PELD is residual herniated nucleus pulposus resulting in inadequate decompression of nerve roots. To guarantee sufficient decompression, the working channel must be adjusted when passing through the posterior longitudinal ligament to detect residual nucleus pulposus tissue during surgery. For the outside-intransforaminal technique, in a retrospective study of 55 patients, Bao *et al.*<sup>19</sup> suggested that the hypertrophied posterior longitudinal ligament (PLL) should be removed, and there was no missed hidden disc in 53 (96.4%) cases. For the inside-out procedure, Wang *et al.*<sup>20</sup> recommended that the ruptured PLL should be resected intraoperatively. However, if the PLL is intact, whether its resection is required during surgery is controversial. To the best of our knowledge, no research has been performed to compare the curative effect of resecting the PLL or not during inside-out PETD surgery.

Therefore, this retrospective study aimed to: (i) report the clinical and surgical outcomes of PETD surgery and explore related factors affecting the functional outcomes; (ii) compare the efficacy and safety of the two surgical methods (resecting and retaining the PLL) and determine whether resecting the PLL is reasonable during inside-out PETD surgery; and (iii) demonstrate the surgical complication.

## Materials and Methods

### Inclusion and Exclusion Criteria

The inclusion criteria in the present study were: (i) patients with symptomatic radiating leg pain and a positive straight leg-raising test result; (ii) computed tomography (CT) and magnetic resonance imaging (MRI) suggesting a single level disc herniation that correlated with the clinical findings; (iii) significant pain that was refractory to conservative treatment for at least 4 weeks, such as bed rest, immobilization, and a pain management program; and (iv) patients had undergone inside-out PETD surgery, during which the PLL was resected or retained. In the current study, patients were included when they met all these inclusion criteria.

The exclusion criteria were as follows: (i) back pain as the main symptom; (ii) segmental lumbar spinal stenosis or degenerative scoliosis; (iii) rupture of the posterior longitudinal ligament preoperatively displayed on MRI; (iv) high iliac crest or large L<sub>5</sub> transverse process which required an interlaminar approach; (v) infection, tumor, or other pathological

condition; and (vi) previous surgical history at the same level.

A total of 135 patients with symptomatic LDH who were treated using inside-out PETD surgery from January 2015 to January 2017 were included in this retrospective analysis. The PLL was resected in 68 cases and retained in 67 cases during surgery. The study was conducted with approval from the Ethics Committee of our Hospital. Written informed consent was obtained from all participants. All procedures involving human participants were carried out in accordance with the Declaration of Helsinki. All cases underwent lumbar spine anteroposterior, lateral, X-ray, CT, and MRI to confirm the diagnosis and pathological type. In this study, all cases had single-segment disc herniation and the surgical segment was L<sub>3/4</sub>, L<sub>4/5</sub>, or L<sub>5</sub>S<sub>1</sub>. In terms of the location of the herniated disc on MRI, the cases were divided into four groups: “superior migration” and “inferior migration” means that the protrusion was located above and below the disc level in the sagittal plane. When the protrusion was located at the disc level, “central” and “paracentral” were defined using the medial edge of the articular facets as landmarks in the axial plane. “Central” means the zone between the medial edge of the articular facets.

#### **Operative Technique**

1. Position: patients were placed in the prone position on a radiolucent surgery table. Local anesthesia was selected to monitor of any intraoperative changes in the patients' symptoms and signs.
2. Working channel placement: before surgery, C-arm X-ray fluoroscopy was used to confirm the target segment. The surgical puncture point and distance depended on the body type of each patient, and the distance was usually 11–14 cm from the midline. 1% Lidocaine was applied from the skin fascia to the surface of the annulus fibrosus. An 18G needle was inserted into target intervertebral foramen. Anteroposterior fluoroscopy confirmed the position of the needle on the medial pedicle edge. Lateral fluoroscopy confirmed the position of the needle on the posterior edge of the vertebral body. Then, an endoscope was positioned through a working channel that was inserted *via* a 0.8-cm skin incision at the entry point of the puncture needle.
3. Decompression: under endoscopy, the PLL was usually in the middle of the field, with the spinal canal above and the intervertebral disc below. First, a pituitary rongeur was used to remove the prominent intervertebral disc under the posterior longitudinal ligament. Next, the working channel was rotated upwards to detect residual nucleus pulposus tissue in the spinal canal. During the procedure, the PLL was resected for 68 patients. Decompression is considered sufficient when the nerve root has good mobility and the dural sac beats with the heartbeat<sup>19</sup>.
4. Suture: an intraoperative straight leg raising test was also performed to confirm sufficient decompression. Bipolar radio frequency was used for annulus fissure coagulation

and hemostasis. After the endoscope and the working channel were removed, the skin was sutured with a single stitch.

In the PLL resection procedure, the most critical and difficult part is to identify the PLL. Under the endoscopic view, we found that sometimes the nerve root appeared very similar to the PLL, both being white, and we must be very careful to remove the PLL ligament using the forceps. For this technique, the most difficult part is to confirm sufficient decompression of the nerve root.

#### **Postoperative Care**

PETD is a daytime surgery at our hospital, and patients were discharged after resting in bed for 1–2 hours postoperatively. One day later, patients were recommended to begin lumbodorsal muscle exercise and straight leg-raising exercise, together with a protective belt.

#### **Clinical and Surgical Assessments**

All patients were followed up for at least 24 months. The VAS score, ODI, and modified MacNab criteria were used to evaluate the clinical outcomes. Operation time, blood loss, recurrence of LDH, and complications were recorded. At 3 months after surgery, MRI was performed to confirm that the nerve root compression was relieved. In this retrospective study, clinical outcomes (visual analogue scale (VAS) score, Oswestry disability index (ODI), and modified MacNab criteria) and surgical outcomes (operation time, blood loss, recurrence rate, and complications) were recorded immediately postoperatively, and at each follow-up visit (1 month, 3 months, and at final follow-up).

#### **Visual Analogue Scale (VAS)**

The radiating leg pain was measured using the VAS score, which is a continuous scale comprising a score between 0 and 10, in which 0 indicates no pain, 1–3 indicates mild tolerable pain, 4–6 means the pain is worse and disrupts sleep; and 7–10 means the pain was intolerable.

#### **Oswestry Disability Index (ODI)**

The ODI is a principal condition-specific outcome measure used to evaluate patient progress in routine clinical practice. It comprises 10 sections: pain intensity, personal care, lifting, walking, sitting, standing, sleeping, sex life, social life, and traveling. For each section of six statements, the total score is 5, indicating the greatest disability. If all 10 sections are completed, the score is calculated as follows:

total scored out of the total possible score × 100.

If one section is missing (or not applicable) the score is calculated as:

(total score/(5 × number of questions answered)) × 100%.

For this parameter, 0%–20% means mild dysfunction, 21%–40% represents moderate dysfunction, 41%–60% represents severe dysfunction, 61%–80% represents disability, and 81%–100% represents long-term bedridden or the pain has a large impact on their quality of life.

### Modified MacNab Criteria

The modified MacNab criteria were used to evaluate the clinical outcomes after surgery. It can be divided into four grades: Excellent, good, fair, and poor, which indicate no pain and no restriction of movement, allowing the patient to work normally; occasional pain, allowing the patient to work normally; slight progress; and no progress, respectively.

### Statistical Analysis

Statistical analyses were carried out using SPSS version 19.0 software (IBM Corp., Armonk, NY, USA). The continuous variables were expressed as the mean  $\pm$  standard deviation (SD). The intergroup operation time, mean blood loss, VAS, and ODI scores at different time points were compared using a two-sample independent *t*-test one-way analysis of variance (ANOVA) test was used to compare differences between pre- and postoperative VAS and ODI scores. Qualitative data were expressed accounts and percentages and evaluated using the chi-squared test. We conducted univariate and multivariate analyses to identify factors that influenced functional outcomes. The logistic regression model included the following variables: Sex, age, fracture type, operative procedure, pain duration, and health status. Patients with outcomes of “excellent” or “good” according to the modified MacNab criteria<sup>21</sup> were included in the “curative effect” group, while those with outcomes of “fair” and “poor” were classed as “noncurative effect.” Health status was evaluated by pre-ODI scores<sup>22</sup> and cases whose pre-ODI scores less than 40% were defined as the

healthy group, while those with an ODI great than or equal to 40% were defined as the unhealthy group. Fracture types were classified as paracentral and others. A value of  $P < 0.05$  was considered statistically significant.

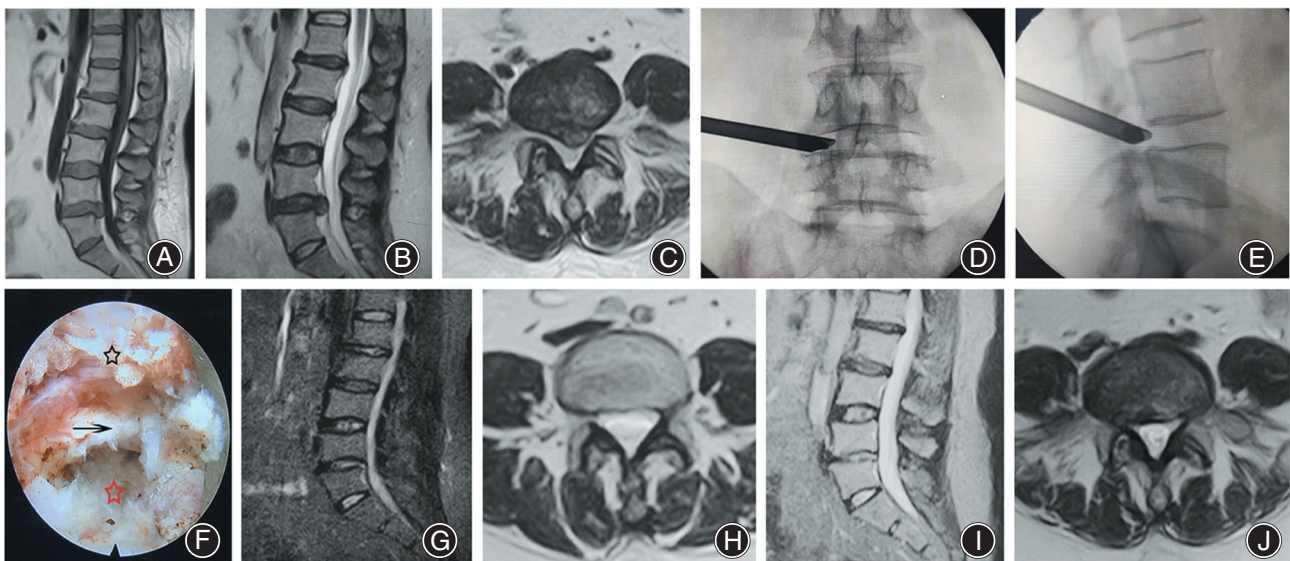
### Results

#### Baseline and Follow-Up

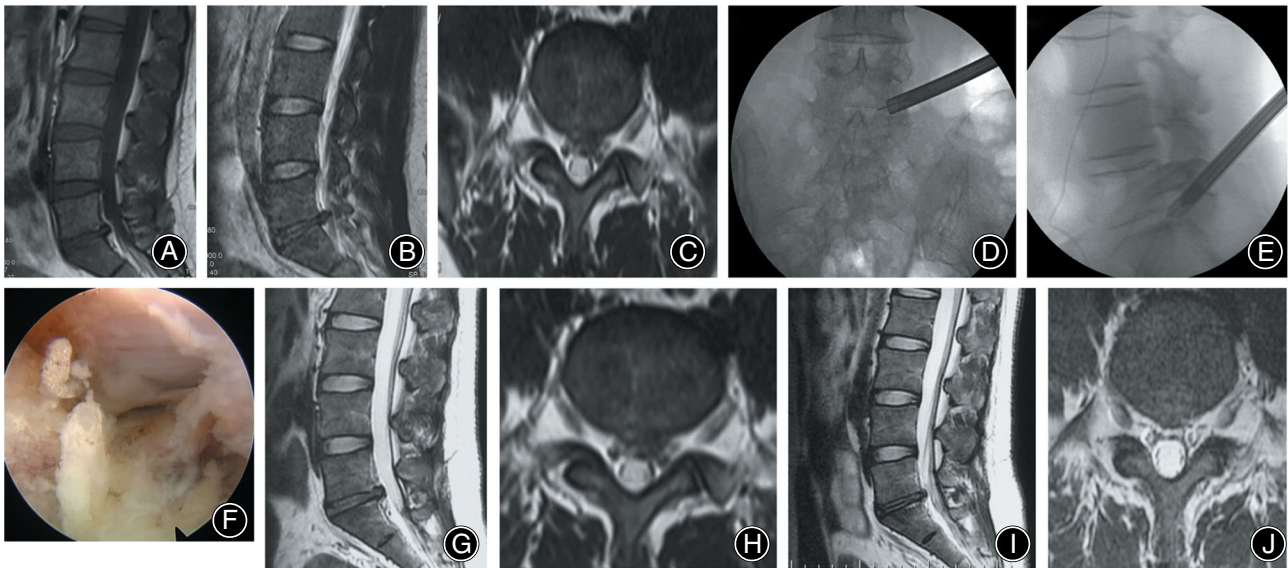
Inside-out PETD surgery was performed in all patients. Patients ( $n = 135$ ) were grouped to undergo either of the surgical methods. Three typical cases were shown in Figs 1–32. There were 38 males and 30 females in the group that received resection of the PLL (mean age =  $52.40 \pm 8.73$  years) and 35 males and 32 females in the group that retained the PLL (mean age =  $53.50 \pm 9.24$  years). There were no statistically significant difference between the two groups in terms of demographic data such as age, sex, and follow-up time. Subgroup analyses were performed and the data are shown in Table 1. All patients were followed up postoperatively for 24–32 months, with an average of  $26.9 \pm 4.3$  months.

#### General Results

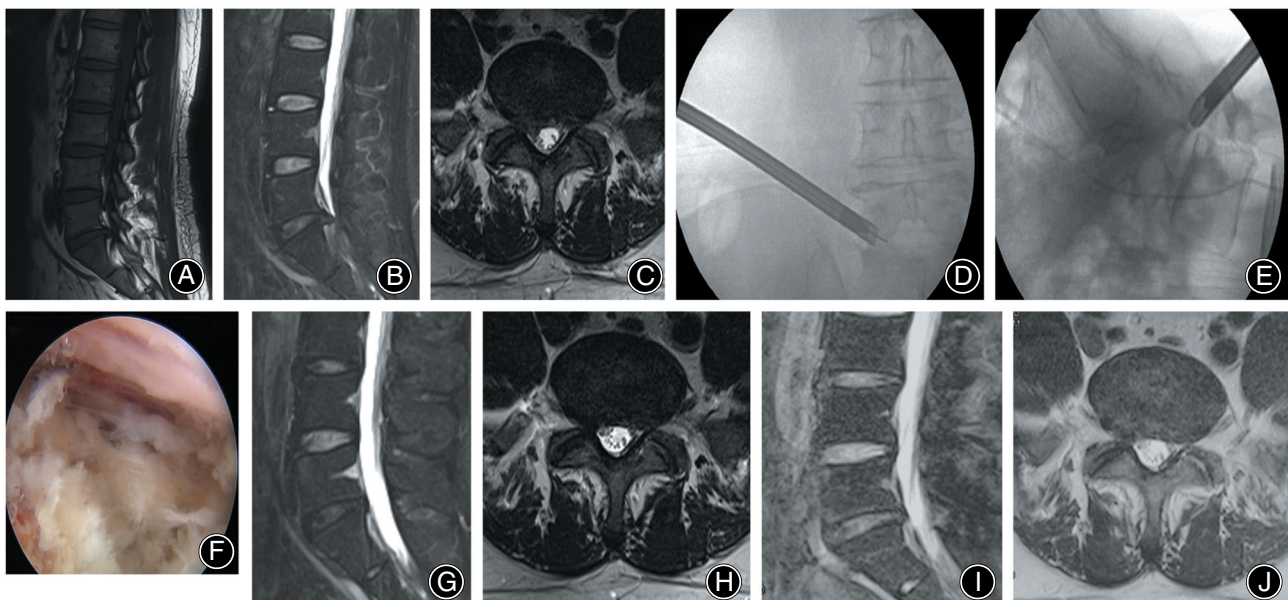
In the resection group, surgery was performed at the L<sub>3/4</sub>, L<sub>4/5</sub>, and L<sub>5</sub>S<sub>1</sub> levels in six (8.8%), 51 (75%), and 11 patients (16.1%), respectively. The herniated disk types were central in seven patients (10.3%), paracentral in 32 patients (47.1%), superior migration in nine patients (13.2%), and inferior migration in 20 patients (29.4%). In the retention group, surgery was



**Fig. 1** The inside-out PETD surgery for a 50-year-old female patient with the posterior longitudinal ligament remained. A, B, C: Preoperative MRI images show L4/5 disc herniation disc and compression of left L5 nerve root. D, E: Intraoperative anteroposterior fluoroscopy confirming the needle positioned on the medial pedicle edge and Lateral fluoroscopy confirming that the needle positioned on the posterior edge of the vertebral body. F: Intraoperative view: the posterior longitudinal ligament was in the middle (arrow), the top part is spinal canal (black star) and the bottom part is herniation (red star). G, H: 3 months after surgery, MRI images show adequate decompression of nerve root and dura. I, J: 12 months after surgery, MRI images show there was no recurrent disc herniation



**Fig. 2** The inside-out PETD surgery for a 42-year-old male patient with the posterior longitudinal ligament resected. A, B, C: Preoperative MRI images show L5/S1 disc herniation disc and compression of left S1 nerve root. D, E: Intraoperative anteroposterior fluoroscopy confirming the needle positioned on the medial pedicle edge and Lateral fluoroscopy confirming that the needle positioned on the posterior edge of the vertebral body. F: Intraoperative view: the posterior longitudinal ligament was resected. G, H: 3 months after surgery, MRI images show adequate decompression of nerve root and dura. I, J: 12 months after surgery, MRI images show there was no recurrent disc herniation



**Fig. 3** The inside-out PETD surgery for a 36-year-old female patient with the posterior longitudinal ligament remained. A, B, C: Preoperative MRI images show L5/S1 disc herniation disc and compression of right S1 nerve root. D, E: Intraoperative anteroposterior fluoroscopy confirming the needle positioned on the medial pedicle edge and Lateral fluoroscopy confirming that the needle positioned on the posterior edge of the vertebral body. F: Intraoperative view: the posterior longitudinal ligament was remained. G, H: 3 months after surgery, MRI images show adequate decompression of nerve root and dura. I, J: 12 months after surgery, MRI images show there was no recurrent disc herniation

**TABLE 1 Correlation between different surgical groups and clinical characteristics**

Items	Resecting group n(%)	Remaining group n(%)	Statistic value	P value
Age (years)				
<50	45(66.2%)	36(53.7%)	2.178 <sup>a</sup>	0.14
≥50	23(33.8%)	31(46.3%)		
Gender				
Female	30(44.2%)	32(47.7%)	0.18 <sup>a</sup>	0.671
Male	38(55.8%)	35(52.3%)		
Surgical Segment				
L <sub>3/4</sub>	6(8.8%)	7(10.4%)	0.11 <sup>a</sup>	0.947
L <sub>4/5</sub>	51(75%)	49(73.2%)		
L <sub>5</sub> /S <sub>1</sub>	11(16.2%)	11(16.4%)		
Types				
Central	7(10.3%)	6(9.0%)	0.239 <sup>a</sup>	0.971
Paracentral	32(47.1%)	31(46.3%)		
Superior migration	9(13.2%)	8(11.9%)		
Inferior migration	20(29.4%)	22(32.8%)		
Pain duration(months)			0.191 <sup>a</sup>	0.662
<6	33(48.5%)	30(44.8%)		
≥6	35(51.5%)	37(55.2%)		
Follow-up period (months)			0.952 <sup>a</sup>	0.329
<26	31(45.6%)	25(37.3%)		
≥26	37(54.4%)	42(62.7%)		

<sup>a</sup> Pearson chi-squared test.

**TABLE 2 Summary of clinical outcomes**

Items	Resecting group	Remaining group	Statistic value	P value
Operation time(min)	115.6 ± 24.6	82.7 ± 18.5	-8.765 <sup>a</sup>	<0.01
Blood loss (ml)	14.2 ± 7.3	12.6 ± 5.5	-1.463 <sup>a</sup>	0.146
Follow-up period (months)	26.8 ± 2.5	27.2 ± 3.1	-1.448 <sup>a</sup>	0.15
MacNab evaluation(n)			0.514 <sup>a,b</sup>	0.916
Excellence	35	33		
Good	27	28		
Fair	4	5		
Poor	2	1		
Excellence -good proportion	91.2%	91.0%		
Complications(n)			0.444 <sup>a,b</sup>	0.505
Dural tear	0	0		
Wound infection	0	0		
Nerve root injury	0	0		
Dysesthesia	4	5		
Transient motor weakness	2	1		
Complication rate	8.80%	8.90%	0.001 <sup>a,b</sup>	0.979
Recurrence (n,%)	1(1.5%)	2(2.9%)	0.356 <sup>a,b</sup>	0.551

<sup>a</sup> Two-sample independent t-test.; <sup>b</sup> Pearson chi-squared test or Fisher's exact test.

performed at the L<sub>3/4</sub>, L<sub>4/5</sub>, and L<sub>5</sub>/S<sub>1</sub> levels in seven (10.4%), 49 (73.2%), and 11 patients (16.4%), respectively. The herniated disk types were central in six patients (9.0%), paracentral in 31 patients (46.3%), superior migration in eight patients (11.9%), and inferior migration in 22 patients (32.8%).

The mean operation time of the retention group was 71.5% of that of resection group, (82.7 ± 18.5 min vs 115.6 ± 24.6 min,  $P < 0.01$ ). The average blood loss was 14.2 ± 7.3 mL and 12.6 ± 5.5 mL in the two groups, with no significant difference (Table 2).

### Clinical Evaluation Results

#### VAS

In resection group, the VAS score was 8.15 ± 0.93 before surgery, 3.67 ± 1.1 immediately after surgery, 2.65 ± 1.25 at 1 month after surgery, 2.52 ± 1.16 at 3 months after surgery, and 2.30 ± 1.5 at last follow-up. The VAS score decreased significantly immediately after surgery (to 4.48), at 1 month after surgery (to 5.5), 3 month after surgery (to 5.63) and at last follow-up (to 5.85) compared with that before surgery

**TABLE 3 Preoperative and postoperative VAS and ODI scores**

Scores	Resecting group	Remaining group	t	P value
VAS				
Preoperation	8.15 ± 0.93	8.23 ± 0.87	-0.579	0.936
Postoperation	3.67 ± 1.1	3.86 ± 0.8	1.317	0.254
1 month	2.65 ± 1.25	2.68 ± 0.95	-0.416	0.876
3 months	2.52 ± 1.16	2.6 ± 0.82	1.243	0.363
Last follow-up	2.30 ± 1.5	2.56 ± 1.84	0.544	0.617
F	343.07	311.53		
P value	< 0.01	< 0.01		
ODI				
Preoperation	63.1 ± 17.2	65.0 ± 15.4	-0.623	0.326
Postoperation	33.6 ± 13.7	35.1 ± 16.2	-0.592	0.511
1 month	14.4 ± 10.2	15.1 ± 11.2	1.651	0.834
3 months	12.5 ± 9.4	12.8 ± 10.2	-0.743	0.318
Last follow-up	10.5 ± 5.3	11.6 ± 4.6	0.486	0.645
F	222.33	243.15		
P value	< 0.01	< 0.01		

VAS: Visual analogue scale; ODI: Oswestry disability index

**TABLE 4 Univariate and multivariate analysis of clinical parameters for the functional outcomes**

Items	Univariate			Multivariate		
	OR	95% CI	P	OR	95% CI	P
Gender (Female/Male)	1.16	0.53-1.78	0.757			
Age (<50/≥50)	5.41	1.18-18.27	0.027	6.33	1.64-21.98	0.014
Fracture type (Paracentral/non-Paracentral)	1.24	0.32-2.95	0.511			
Operative procedure (Resecting group/Remaining group)	1.51	0.34-1.62	0.652			
Pain duration (< 6/≥ 6)	3.17	1.33-7.29	0.002	4.68	1.29-6.51	0.025
Health status (Healthy or Unhealthy)	4.95	1.57-10.55	0.018	5.97	2.41-14.86	0.003

( $F = 343.07$ ,  $P < 0.01$ ). The VAS score decreased significantly between immediately after surgery and 1 month after surgery ( $3.67 \pm 1.1$  vs  $2.65 \pm 1.25$ ,  $P < 0.01$ ). In the retention group, the VAS score was  $8.23 \pm 0.87$  before surgery,  $3.86 \pm 0.8$  immediately after surgery,  $2.68 \pm 0.95$  at 1 month after surgery,  $2.6 \pm 0.82$  at 3 months after surgery, and  $2.56 \pm 1.84$  at last follow-up ( $F = 311.53$ ,  $P < 0.01$ ). The VAS scores decreased significantly. Immediately after surgery ( $4.37$ ), at 1 month after surgery ( $5.5$ ), at 3 months after surgery ( $5.63$ ), and at last follow-up ( $5.67$ ) compared to those before surgery. The VAS score decreased significantly between immediately after surgery and 1 month after surgery in the two groups ( $P < 0.01$ ). There was no significant difference between the two groups at each time point.

#### ODI

In the resection group, the ODI was  $63.1 \pm 17.2$ ,  $33.6 \pm 13.7$ ,  $14.4 \pm 10.2$ ,  $12.5 \pm 9.4$ , and  $10.5 \pm 5.3$  at each time point, and for the retention group, the ODI was  $65.0 \pm 15.4$ ,  $35.1 \pm 16.2$ ,  $15.1 \pm 11.2$ ,  $12.8 \pm 10.2$ , and  $11.6 \pm 4.6$ , respectively. There was no significant difference between the two groups at each time point. The ODI improved significantly

immediately after surgery, at 1 month after surgery, at 3 months after surgery, and at last follow-up compared to those before surgery ( $P < 0.01$ ), and also improved significantly between immediately after surgery and 1 month after surgery ( $P < 0.001$ ) in both groups (Table 3).

#### Modified MacNab Criteria

For the modified MacNab criteria, the clinical outcome at final follow-up in the resection group was excellent in 35 patients, good in 27, fair in 4, and poor in two, with an excellent-good proportion of 91.2%. In the retention group, the modified MacNab criteria score was excellent in 33 patients, good in 28, fair in five, and poor in one, with an excellent-good proportion of 91.0%. There was no significant difference in the excellent-good proportion between the two groups (91.2% vs 91.0%,  $P = 0.514$ ).

#### Univariate and Multivariate Logistic Regression of Functional Outcomes

In this study, univariate and multivariate logistic regression were conducted, with adjustment for confounding factors in the regression analysis (age, sex, fracture type, operative

procedure, pain duration, and health status) (Table 4). Significant factors identified in the univariate analysis (age, pain duration, and health status) were subjected to multivariate logistic regression, which indicated that age  $\geq 50$  years (odds ratio (OR) = 6.33, 95% confidence interval (CI): 1.64–21.98,  $P = 0.014$ ), pain duration  $\geq 6$  months (OR = 4.68, 95% CI: 1.29–6.51,  $P = 0.025$ ), pre-ODI score  $\geq 40\%$  (OR = 5.97, 95% CI: 2.41–14.86,  $P = 0.003$ ) were all associated with poor functional outcomes.

### Intraoperative Results

The intraoperative straight-leg raising test was conducted and the result was positive in four cases. Then, the test was repeated and the migrated or sequestered disc was removed. Thereafter, the straight-leg raising test was conducted again during surgery and the result was negative in all four patients.

### Complications

In this series of patients, no serious complications, such as dural tear, wound infection, or persistent nerve root injury, were observed during the follow-up period. Four patients in resection group and five patients in retention group developed postoperative dysesthesia in the unilateral lower extremity. Their symptoms were relieved at 3 months after surgery using acupuncture and physiotherapy. Three patients (two in the resection group, one in the retention group) experienced transient tibialis anterior muscle weakness. They all recovered after functional exercise and electrical stimulation for 4 to 12 weeks. There was no significant difference in the complication rate between the two groups (6/68 vs 6/67,  $P = 0.979$ ). One patient in resection group and two patients in retention group had are current disc herniation 3–6 months after surgery. Revision surgery was recommended and the symptoms improved immediately after surgery. Although the recurrence rate was higher in retention group, there was no significant difference between the two groups (1/68 vs 2/67,  $P = 0.551$ ).

## Discussion

### Clinical Outcome and Surgical Data

According to the revolutionary advances in technology and instruments, PETD is used widely, and is an effective option for almost all types of disc herniation<sup>23–25</sup>. Theoretically, minimally invasive technology could shorten the operation time and reduce the blood loss compared with open lumbar decompression surgery. For a single-level disc herniation, the mean operative time reported for open decompression surgery was  $112.7 \pm 20.7$  min, and the mean blood loss was  $119.7 \pm 28.5$  mL<sup>26</sup>. Eighty patients with single-level disc herniation undergoing open decompression surgery in our hospital were analyzed retrospectively, and the mean blood loss was  $108.7 \pm 21.6$  mL. In the present study, the operative times of the resection group were longer than those of the retention group, possibly because of the difficulty in

identifying and resecting the PLL, especially in the earlier stage. The blood losses of the two groups were significantly less than that of open decompression surgery ( $P < 0.01$ ).

According to the clinical outcome of PETD, Ren *et al.*<sup>24</sup> reported that the VAS and ODI scores were improved significantly in patients with lumbar disc herniation causing bilateral symptoms. Yeung *et al.*<sup>27</sup> stated that the VAS score was reduced significantly after treatment of symptomatic degenerative conditions using the inside-out transforaminal technique. Moreover, they believed that the long-term clinical outcomes using the inside-out technique were better than those of the outside-in technique because of the ability to visualize and decompress underneath the dural sac, the ventral facet, and the axilla. Consistently, we found significant improvements in the VAS and ODI scores at follow-up compared to those before surgery. For the modified MacNab criteria, Choi *et al.*<sup>28</sup> demonstrated that 94% of the patients reported good or excellent results for single level herniated lumbar discs and spinal stenosis treated with transforaminal endoscopic micro decompression. Similarly, the excellent-good rates were 91.2% and 91.0% in the resection group and retention group, respectively, in the present series. These data indicated that the inside-out transforaminal technique, regardless of whether the PLL is removed or not, is efficient for hernial decompression.

In the current study, we also explored independent and related factors affecting the functional outcomes of inside-out PETD surgery. Our results indicated that better clinical efficacy was achieved in patients under 50 years old than in those aged 50 years or above. Consistent with our research, Jiang *et al.*<sup>29</sup> reported that age was independently associated with the clinical efficacy of lumbar disc surgery. The multivariate analysis showed that patients with an interval between injury and surgery of less than six months were more likely to show optimal functional outcomes. This finding concurs with the results of Manchikanti *et al.*'s research.<sup>30</sup> They believed that surgery is most effective when performed after symptoms have been present for less than 6 months, because the degree of lumbar disc degeneration and nerve injury remain limited at that time.

### Choice between Two Surgical Techniques

For inside-out PETD surgery, the working channel is first inserted into the disc just underneath the herniated nucleus pulposus, and then the channel is gradually diverted into the spinal canal to perform the decompression. During the procedure, whether an intact PLL requires resection is controversial. Theoretically, retaining the PLL is beneficial to maintain spinal stability and prevent reherniation of the nucleus pulposus. However, retention of the PLL might increase the risk of free nucleus pulposus tissues left in the spinal canal leading to inadequate decompression. Gore *et al.*<sup>14</sup> used the inside-out transforaminal technique to treat lumbar spinal pain under local anesthesia. They described the surgical method but did not state whether the PLL was



excised. In a retrospective review reported by Wang *et al.*,<sup>20</sup> the PLL was resected in 35 patients; however, the study lacks the detailed clinical and surgical outcomes of these patients. In the current study, the results showed both methods had the same satisfactory clinical efficacy, with a similar complication rate. For the patients in retention group, although the PLL was not resected, careful inspection underneath the herniated nucleus pulposus and in the spinal canal was carried out to confirm no residual nucleus pulposus tissues, which guaranteed adequate decompression. The recurrence rate was non-significantly higher in retention group. Increased spinal instability after surgery was not reported in either group. We believe that this was because the PLL is only one aspect of maintaining spinal stability, the supraspinous ligament, interspinous ligament, and the capsule of the facet joint, which play an important role in maintaining the spinal stability, were intact in both groups. The main difference between the two methods is that the patients in the resection group experienced a longer surgery. In our opinion, resection of the PLL is unnecessary when the ligament is intact.

### **Surgical Complications and Prevention**

In 135 patients, the overall complication rates of the resection group and the retention group were 10.3% and 11.9%, respectively, which were comparable to the data obtained in previous research<sup>31</sup>. The most common surgical complication is transient dysesthesia. Ruetten *et al.*<sup>32</sup> reported that postoperative dysesthesia was noted in 3.9% (9/232) of cases. This complication occurs mainly as a result of existing dorsal root ganglion (DRG) injury<sup>33</sup>. The synesthesia incidence in our study was higher than that reported previously, which might be related to the steep learning curve of the surgery, and the increased possibility of DRG compression in the early stages. Three patients in this study experienced tibialis anterior muscle weakness after surgery, which we believe was also caused by DRG compression. Two patients had L5-S1 herniated discs and their iliac crests were relatively high; therefore, the working channel was placed at

a greater incline. They recovered after functional exercise and electrical stimulation at 12 weeks after surgery. To prevent this problem, the surgeon should carefully evaluate the size of the foramen and the location of the existing nerve root before surgery.

Three patients had a recurrent disc herniation in this study, and the re-operation rate was 2.2%. Li *et al.*<sup>34</sup> reported that one patient (2.1%) experienced recurrent lumbar disc herniation. In our study, recurrent disc herniation was more likely to occur in obese people who take early out-of-bed activity. The body mass index (BMI) value of these three patients were all over 30 kg/m<sup>2</sup>. Therefore, it is suggested that obese people should prolong their duration of postoperative bed rest.

### **Limitations**

This study had limitations. First, the relatively small sample size and the retrospective nature of the study resulted in insufficient evidence to confirm the efficiency of the two surgical techniques, thus more clinical research should be performed. Second, the surgical outcomes mainly depended on the surgeon's technique, and all surgeries of this study were performed by one surgeon in a single medical center; therefore, multicenter, randomized controlled trials should be conducted in the future.

### **Conclusions**

In the present study, whether the PLL is resected does not make any difference to the curative effect of inside-out PETD surgery, there is no significant difference in the improvement of VAS score and ODI, complication rate and recurrence rate between the two groups. Retaining the ligament when it is intact is preferred because of the shorter associated operation time.

### **Conflict of interest**

The authors have declared that no competing interest exists.

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