

## SCIENTIFIC ARTICLE

# Evaluation of Percutaneous Transforaminal Endoscopic Discectomy in the Treatment of Lumbar Disc Herniation: A Retrospective Study

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**Objective:** The objective of the present study was to evaluate the safety and efficacy of percutaneous transforaminal endoscopic discectomy (PTED) and open fenestration discectomy (OFD) in the treatment of lumbar disc herniation (LDH).

**Methods:** Patients in our hospital with LDH who received PTED ( $n = 71$ ) and OFD ( $n = 39$ ) from 2013 to 2014 were retrospectively studied. Patient information, including age, gender, visual analogue scale (VAS) score for low back pain and leg pain, body weight, height, Oswestry disability index (ODI), Japanese Orthopedic Association (JOA), and recurrence, was collected. The patients in the two groups were followed up for an average of 63 months after surgery.

**Results:** A total of 136 patients completed the operation and 110 patients were followed up completely. There was no significant difference in baseline data between the two groups ( $P > 0.05$ ). The postoperative low back pain, leg pain, ODI, and JOA of the two groups were better than those preoperatively ( $P < 0.05$ ). One week after surgery, the recovery of PTED patients was better than that of OFD. The ODI score of the PTED group was lower than that of the OFD group (10 [8, 12] vs 14 [11, 16];  $P < 0.05$ ), the waist VAS score of the PTED group was lower than that of the OFD group (2 [2, 3] vs 3 [2, 4];  $P < 0.05$ ), the leg VAS score of the PTED group was lower than that of the OFD group (1 [0, 1] vs 1 [1, 2];  $P < 0.05$ ), while the JOA score of the PTED group was higher than that of OFD group [19(16, 20) vs 12(10, 17);  $P < 0.05$ ]. There were no significant differences in ODI, JOA, waist and leg VAS scores between the two groups at 1 month after surgery and at subsequent follow-up ( $P > 0.05$ ). At the end of the follow up, 89.7% (35/39) of patients in the OFD group had excellent improvement in the JOA score, and 88.7% (63/71) of patients in the PTED group had an excellent improvement. There was no significant difference between the two ( $P > 0.05$ ). There was also no significant difference in the recurrence rate between the two groups [(5/71) vs (3/39);  $P > 0.05$ ]. [Correction added on 05 March 2021, after first online publication: “3/29” was amended to “3/39” in the preceding sentence.]

**Conclusion:** Both PTED and OFD can achieve good mid-term efficacy in the treatment of LDH but PTED has certain advantages, including the small incision, a shorter hospital stay, and quicker, earlier recovery. However, prospective randomized controlled studies with a larger sample size are needed.

**Key words:** Lumbar disc herniation; Open fenestration discectomy; Percutaneous transforaminal endoscopic discectomy; Minimally invasive surgery; Transforaminal discectomy

Lumbar disc herniation (LDH) is the most common cause of low back and leg pain, which can seriously affect quality of life. Some patients can be relieved of symptoms

through conservative treatment, such as drugs, rest, and physiotherapy<sup>1, 2</sup>. However, some patients are refractory to conservative treatment or have recurrent and aggravated

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symptoms. Such patients require surgical treatment to improve their short-term symptoms and to maintain long-term efficacy and satisfaction<sup>3</sup>.

Currently, the available surgical methods include traditional open fenestration discectomy (OFD), microsurgical discectomy (MD), microendoscopic discectomy (MED), and percutaneous transforaminal endoscopic discectomy (PTED). The traditional OFD can achieve efficacy<sup>4</sup> and is the gold standard for the treatment of LDH. However, this procedure requires dissection of the muscle and excision of the ligaments, parts of the lamina, and facet joints, which is thought to result in epidural scarring and may lead to iatrogenic instability<sup>5</sup>. The results of the Spine Patient Outcomes Research Trial (SPORT) revealed that patients who underwent surgery had greater functional improvement and higher treatment satisfaction than those who were managed non-operatively<sup>6</sup>. In addition, in two decades, endoscopic techniques have improved to enable discectomy under direct visualization and with a local anesthetic<sup>7</sup>. Thus, MD, in which a microscope is used for better visualization, has gradually emerged and can achieve similar clinical efficacy to OFD with less structural damage<sup>8</sup>. Furthermore, minimally invasive spine surgery techniques, including PTED and MED, have been developed rapidly because of the increasing patient demand. PTED is a more minimally invasive technique than MED due to the posterior preserved column structures<sup>9</sup>.

Many published studies have reported that PTED can achieve similar short-term clinical efficacy to microscopic fenestration<sup>9–11</sup>, with less injury and faster recovery. A systematic review previously suggested that the clinical outcomes are comparable between PTED and MD<sup>10</sup>. In addition, patients who undergo PTED are likely to have smaller surgical scars, shorter hospital stays, and an earlier return to daily activities<sup>10</sup>. Another retrospective study involving 192 patients (99 men and 93 women) showed that PETD, MED, and MD were all reliable techniques for the treatment of LDH but PTED could result in better recovery. However, some studies have demonstrated that PTED has a higher cost, performs poorly in regard to relief of low back and leg pain, and has an unfavorable rehospitalization rate<sup>8</sup>, and that there is no significant difference compared with other methods<sup>12</sup>. In a randomized controlled study of 162 cases, Ruetten *et al.*<sup>13</sup> investigated and compared 2-year follow-up results of PETD with MD for the treatment of LDH. A significant and constant improvement was observed in patients treated by MD or PETD, but there were no significant differences between the groups after 2 years. Nellensteijn *et al.* identified 1 randomized controlled trial, 7 nonrandomized controlled trials, and 31 observational studies<sup>14</sup>. Among the 8 controlled trials, no statistically significant differences were found in leg pain reduction between the PTED (89%) and MD (87%) groups or in overall improvement (84% vs 78%), respectively. Because traditional OFD may lead to iatrogenic instability and lumbar failure syndrome as a result of muscle stripping and scar formation,

attempts should be made to obtain similar clinical outcomes with more minimally invasive techniques, such as PTED. Nevertheless, to our knowledge, few follow-up studies have been conducted on the medium-term clinical efficacy and recurrence rate of PTED. Current evidence of the effectiveness of transforaminal endoscopic surgery is weak and unclear, as valid information on patients with LDH has not been presented. Systematic study needs to be carried out to determine the clinical efficacy and recurrence rate of PTED for future guidance.

In an attempt to provide a solid reference for PTED in clinical practice, the present study investigated the mid-term clinical efficacy and recurrence rate of PTED through a retrospective case. Traditional OFD was selected for the control group, and the investigation of its mid-term clinical efficacy is of great significance. The Oswestry disability index (ODI) and Japanese Orthopedic Association (JOA) were used to assess the patient's pain intensity, personal care, lifting, walking, sitting, standing, sleeping, social life, and traveling. This study investigates: (i) the performance, including the mid-term clinical efficacy and the recurrence rate, of PTED in the treatment of LDH; (ii) whether PTED exhibits better safety and efficacy than OFD; and (iii) whether PTED should be commonly used in future clinical practice.

## Materials and Methods

### General Information

The present study was approved by the Ethics Committee of the Fuzhou Second Hospital Affiliated to Xiamen University. The cases of LDH with continuous surgical treatment in our hospital from January 2013 to December 2014 were collected. General information on patients had been recorded, including age, sex, visual analogue scale (VAS) scores for low back pain, leg pain, vertebral process segment, body weight, height, ODI score, JOA score, and 7-day, 1-month, and 1-year end-of-study follow-ups (*via* telephone or outpatient follow up). X-ray, CT, and MR examinations were performed preoperatively in all cases.

### Inclusion and Exclusion Criteria

The same inclusion and exclusion criteria were used for each group.

The inclusion criteria were: (i) typical symptoms of low back and leg pain, numbness, skin sensation, and reflex changes; (ii) definite CT or MR evidence for LDH and explainable symptoms; (iii) refractory to less than 6 weeks of conservative treatment; (iv) age 20–55 years; and (v) no history of lumbar surgery.

The exclusion criteria were: (i) several segmental protrusions requiring intervention; (ii) combined with lumbar instability; (iii) central canal stenosis, lateral recess stenosis; (iv) disc herniation combined with calcification; (v) recurrent cases; and (vi) combined with psychological diseases, tumors, or immune metabolic diseases.

### Surgical Procedures

**OFD:** Under general anesthesia, the patient lay prone on a spinal bed. Fluoroscopy was used to locate the gap, and a 3–4-cm skin incision was made centered on this. The skin and subcutaneous tissue were incised layer by layer, and the paravertebral muscles were separated subperiosteally to reach the facet. The exposure was maintained using a miniature vertebrae retractor and fluoroscopy was repeated to confirm the interlaminar space. The lower edge of the upper lamina was removed, and a small curette was used to separate the ligamentous point on the ventral side of the lamina. After separating the ligamentum flavum from the space, the ligamentum flavum was hooked up and removed to find and confirm the nerve roots and protrusions. The nerve roots were separated and pushed inward, and the annulus fibrosus was incised or the nucleus pulposus was directly removed. The loose nucleus pulposus in the space was then clamped to explore the nerve root canal and the axilla, and the nerve roots were fully released. The intervertebral space was flushed and bleeding was stopped. The muscle was reduced, negative pressure drainage was retained, and each layer was sutured.

**PTED:** In the healthy lateral position, the patients were padded with a thin pillow on the waist and received routine disinfection and draping. An incision was opened 12–14 cm from the midline at the level of intervertebral space and then 5 cm towards the midline. Local anesthesia was injected from the skin to the upper joint tip behind the target space, and an 18-gauge puncture needle was used to puncture the upper joint tip under fluoroscopy, followed by step-by-step soft tissue expansion after full anesthesia. Then the upper joint process tip and ventral side were cyclically cut step by step with a trephine. Anteroposterior and lateral fluoroscopy confirmed that the path reached the protrusion site through the safety triangle, as described in many reports<sup>15</sup>.

After placing the guide rod, the working sleeve was placed before the upper joint process, and fluoroscopy confirmed that the working sleeve entered the spinal canal through the foramen and pointed to the herniated nucleus pulposus. A 16-gauge puncture needle with the end-bent was inserted. After fluoroscopic confirmation of its entry into the intervertebral space, a mixture of contrast agent and methylene blue was injected to stain the degenerated nucleus pulposus for facilitating the removal. After that, the camera, light source, imaging system, and radiofrequency ablation equipment were connected. The cut surface of the superior articular process was first identified, and then the ligamentum flavum proximal to it was partially removed to expose the nerve roots. The nucleus pulposus compressing the nerve roots was carefully removed. The intervertebral space was explored and the loose nucleus pulposus was removed, as shown in Tables 6–9.

### Clinical Evaluation

The clinical results were evaluated based on the ODI and the JOA.

The evaluation also included symptom recurrence and complications, established *via* telephone or outpatient follow

up, while the initial data, such as length of hospital stay, length of surgery, and bleeding, were obtained in our hospital.

**Oswestry disability index:** A total of 10 items are used to evaluate a patient's functional disability related to pain. The scale includes pain intensity, personal care, lifting, walking, sitting, standing, sleeping, sex life, social life, and traveling. "Sex life" was not considered appropriate for inclusion in the questionnaire, and was, therefore, removed. The severity of symptoms is reflected by a scale of 0 to 10 (0: no pain or disability; 10: most severe pain and disability). Patient scores are between 0 and 90.

**Japanese Orthopedic Association score:** The total score is 29, with: 9 points for subjective symptoms, including low back pain, leg pain or tingling, and gait difficulties; 6 points for clinical symptoms, including straight leg raising test, dyskinesia, and sensory disturbance; and 14 points for daily activity limitation, including supine turning, standing, washing, forward flexion, sitting, lifting, and walking.

**Bladder function (–6 to 0):** 0, normal; –3, mild limitation; –6, urinary incontinence or urinary retention. The highest potential score is 29 points: <10, poor; 10–15, moderate; 16–24, good; 25–29, excellent. The treatment improvement rate = [(post-treatment score – pre-treatment score) ÷ (29 – pre-treatment score)] × 100%, where ≥75% is excellent, 50%–74% is good, 25%–49% is moderate, and 0%–24% is poor. The improvement index reflects the improvement in the lumbar function of patients before and after treatment, and the treatment efficacy can be measured by the improvement rate.

The improvement rate can also corresponds to the usual criteria for efficacy determination: 100%, cured; 60%, significantly effective; 25%–60%, effective; <25%, ineffective.

### Statistical Analysis

All statistical analyses were performed using the SPSS 20.0 software. The age and BMI of patients were normally distributed, expressed by the mean ± standard deviation and tested using the *t*-test. The data for the variation in the VAS scores before and after the operation, ODI, JOA, incision length, operation time, and fluoroscopy times showed a biased distribution, expressed by quartiles and tested using the Wilcoxon two-sample test. The recurrence in the two groups was analyzed using the exact probability method. A difference of  $P < 0.05$  is statistically significant.

**TABLE 1 Comparison of age and BMI in OFD and PTED**

		X ± Sed	t	P
Age	OFD	40.42 ± 14.68	0.12	0.906 > 0.05
	PTED	41.78 ± 13.00		
BMI	OFD	24.52 ± 2.88	–0.07	0.9445 > 0.05
	PTED	25.73 ± 4.90		

BMI, body mass index; OFD, open fenestration discectomy; PTED, percutaneous transforaminal endoscopic discectomy.

## Results

### General Information

#### Effects of Age and Body Mass Index on Open Fenestration Discectomy and Percutaneous Transforaminal Endoscopic Discectomy of the Clinical Subjects

A total of 136 subjects were included in the study, of which 110 were followed up. The mean follow-up time was

63 months, with a maximum of 75 months and a minimum of 55 month. As shown in the Table 2, the OFD included 24 men and 15 women, with a total of 39 subjects. In the PTED group, there were 42 men and 29 women, with a total of 71 subjects. There was no significant difference in the composition of the site of disease between the two groups. The mean age was  $40.42 \pm 14.68$  years in the OFD group and  $41.78 \pm 13.00$  years in the PTED group. No significant differences in age and BMI were observed between the two groups ( $P > 0.05$ ). See Table 1 for details.

		Z	P
Sex	OFD 39 (24 males and 15 females) PTED 71 (42 males and 29 females)	0.0596	0.0596 > 0.05
Affected site	OFD group (L3/4–2; L4/5–27; L5S1–10) PTED group (L3/4–6; L4/5–50; L5S1–6)	0.613	0.736 > 0.05

OFD, open fenestration discectomy; PTED, percutaneous transforaminal endoscopic discectomy.

#### Effects of Sex and Disease Site Composition on Open Fenestration Discectomy and Percutaneous Transforaminal Endoscopic Discectomy

As shown in Table 2, no significant differences were observed in the sex and the affected site between the OFD group and PTED group ( $P > 0.05$ ).

#### Perioperative Complications and Recurrence in the Open Fenestration Discectomy and Percutaneous Transforaminal Endoscopic Discectomy Groups

As shown in Table 3, no serious complications, such as cauda equina syndrome and macrovascular injury, were found in either group. In the OFD group, there was 1 case of dural tear, 1 case of weakened extensor strength, and 1 case of poor postoperative incision healing, which healed after

	OFD M (Q1 Qu)	PTED M (Q1 Qu)	Z	P
Preoperative VAS for low back	4 (3, 5)	4 (3, 5)	0.974	$P = 0.3321 > 0.05$
Preoperative VAS for legs	9 (8, 9)	8 (8, 9)	0.5405	$P = 0.5899 > 0.05$
Preoperative ODI	43 (42, 43)	43 (42, 44)	-1.0246	$P = 0.3077 > 0.05$
Preoperative JOA	9 (9, 10)	9 (9, 10)	-0.1317	$P = 0.8954 > 0.05$
Incision length	4.0 (4.0, 4.1)	2.0 (1.5, 2.0)	8.6062	$P < 0.05$
Operation time	69 (60, 85)	90.0 (90.0, 102.5)	-6.5764	$P < 0.05$
X-ray times	3 (3, 3)	25 (21, 27)	-8.4698	$P < 0.05$
Length of hospital stay	7 (5, 7)	3 (3, 3)	9.1860	$P < 0.05$
Day 7 after surgery VAS for low back	3 (2, 4)	2 (2, 3)	4.2906	$P < 0.05$
Day 7 after surgery VAS for legs	1 (1, 2)	1 (0, 1)	3.0263	$P = 0.0031 < 0.05$
ODI on day 7	14 (11, 16)	10 (8, 12)	4.9348	$P < 0.05$
JOA on day 7	12 (10, 17)	19 (16, 20)	-5.3217	$P < 0.05$
VAS for low back at 1 month	2 (1, 3)	1 (1, 2)	0.9975	$P = 0.3207 > 0.05$
VAS for legs at 1 month	0.5 (0, 1)	0 (0, 1)	1.0646	$P = 0.2893 > 0.05$
ODI at 1 month	16 (12, 13)	6 (4, 10)	1.9751	$P = 0.0507$ (cut point)
JOA at 1 month	22 (20, 24)	22 (21, 23)	0.8074	$P = 0.4211 > 0.05$
VAS for low back at 1 year	1 (0, 2)	1 (0, 2)	-0.1345	$P = 0.8933 > 0.05$
VAS for legs at 1 year	0 (0, 0)	0 (0, 1)	-0.7315	$P = 0.4660 > 0.05$
ODI at 1 year	6 (3, 10)	5 (3, 8)	1.0697	$P = 0.2870 > 0.05$
JOA at 1 year	25.5 (20.0, 27.0)	24 (22, 25)	1.6658	$P = 0.0985 > 0.05$
VAS for low back at 5 years	1 (0, 2)	1 (1, 2)	1.2760	$P = 0.2046 > 0.05$
VAS for legs at 5 years	0 (0, 1)	0 (0, 1)	-1.2559	$P = 0.2118 > 0.05$
ODI at 5 years	8 (8, 8)	4 (2, 8)	0.0739	$P = 0.9412 > 0.05$
JOA at 5 years	27 (20, 28)	25 (20.5, 26.0)	1.5824	$P = 0.1160 > 0.05$

JOA, Japanese Orthopedic Association; ODI, Oswestry disability index; OFD, open fenestration discectomy; PTED, percutaneous transforaminal endoscopic discectomy; VAS, visual analogue scale.

re-debridement and suture. In the PTED group, there was 1 case of postoperative transient anterior thigh dysesthesia and quadriceps weakness, which was relieved after 3 days, and 1 case of root injury, resulting in plantar numbness, which was significantly relieved by treatment. There were 8 cases of recurrence (7.3%), including 3 (7.7%) cases in the OFD group and 5 (7.0%) cases in the PTED group. No significant differences were noted between the two groups ( $P > 0.05$ ).

**TABLE 4 Comparison of recurrence rate between the OFD group and PTED group**

		Exact probability method (Fisher's)
OFD	Recurrence 3 Non-recurrence 36	0.7099 > 0.05
PTED	Recurrence 5 Non-recurrence 66	

OFD, open fenestration discectomy; PTED, percutaneous transforaminal endoscopic discectomy.

### Results of Clinical Evaluation

The ODI, JOA, VAS for low back, and VAS for lower extremities scores are shown in Tables 4–6 and Figs 1–4, respectively.

- (i) Overall, the ODI, JOA, and VAS scores were improved significantly in both groups postoperatively. The indexes were significantly improved in the early postoperative period. The VAS score for low back and legs was not significantly improved 1 month after surgery, while the ODI score in the OFD group continued to improve 1 year after operation. The JOA scores of both groups continued to improve 1 year after operation.
- (ii) Seven days after surgery, the VAS score and the ODI score for low back and legs in the OFD group were higher than those in the PTED group, while the JOA scores of the OFD group were lower than those of the PTED group ( $P < 0.05$ ).
- (iii) No significant differences were observed in the VAS, ODI, and JOA scores for low back and legs between the two groups at 1 month and 1 year after surgery ( $P > 0.05$ ). See Table 5 for details.

**TABLE 5 Intra-group comparison of adjacent time points**

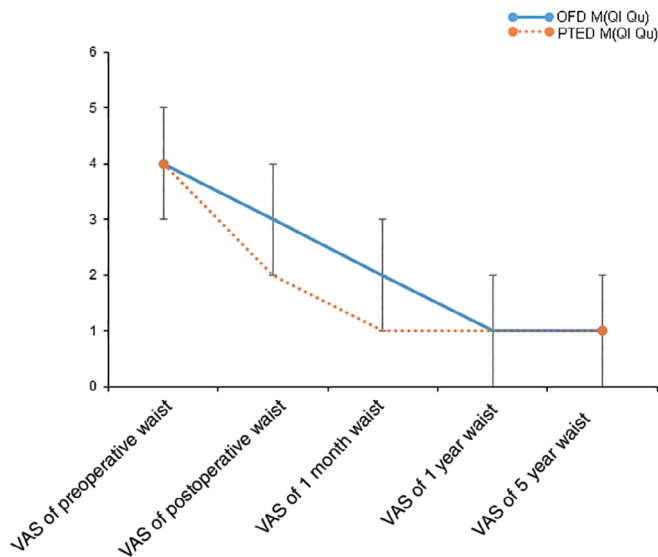
	OFD M (QI Qu)	Z	P	PTED M (QI Qu)	Z	P
Preoperative VAS for low back	4 (3, 5)	3.2785	$P = 0.001 < 0.05$	4 (3, 5)	7.7332	$P < 0.05$
Postoperative VAS for low back	2 (2, 3)			3 (2, 4)		
Preoperative VAS for legs	9 (8, 9)	7.9626	$P < 0.05$	8 (8, 9)	10.5473	$P < 0.05$
Postoperative VAS for legs	1 (0, 1)			1 (1, 2)		
Preoperative ODI	43 (42, 43)	7.9396	$P < 0.05$	43 (42, 44)	10.1532	$P < 0.05$
on day 7	10 (8, 12)			14 (11, 16)		
Preoperative JOA	9 (9, 10)	-6.0305	$P < 0.05$	9 (9, 10)	10.1844	$P < 0.05$
on day 7	19 (16, 20)			12 (10, 17)		
Postoperative VAS for low back	2 (2, 3)	4.7540	$P < 0.05$	3 (2, 4)	4.6944	$P < 0.05$
VAS for low back at 1 month	1 (1, 2)			2 (1, 3)		
Preoperative VAS for legs	1 (0, 1)	2.5613	$P = 0.0104 < 0.05$	1 (1, 2)	1.5202	$P = 0.1285 > 0.05$
VAS for legs at 1 month	0 (0, 1)			0.5 (0, 1)		
ODI on day 7	10 (8, 12)	4.3729	$P < 0.05$	14 (11, 16)	4.9131	$P < 0.05$
ODI at 1 month	6 (4, 10)			16 (12, 13)		
JOA on day 7	19 (16, 20)	-6.4325	$P < 0.05$	12 (10, 17)	7.2204	$P < 0.05$
JOA at 1 month	22 (21, 23)			22 (20, 24)		
VAS for low back at 1 month	1 (1, 2)	1.7017	$P = 0.0888 > 0.05$	2 (1, 3)	1.7761	$P = 0.0778 > 0.05$
VAS for low back at 1 year	1 (0, 2)			1 (0, 2)		
VAS for legs at 1 month	0 (0, 1)	1.9158	$P = 0.0554$	0.5 (0, 1)	0.5642	$P = 0.5735 > 0.05$
VAS for legs at 1 year	0 (0, 1)			0 (0, 0)		
ODI at 1 month	6 (4, 10)	1.5993	$P = 0.1098 > 0.05$	16 (12, 13)	2.2453	$P = 0.0248 < 0.05$
ODI at 1 year	5 (3, 8)			6 (3, 10)		
JOA at 1 month	22 (21, 23)	-2.9940	$P < 0.05$	22 (20, 24)	4.2265	$P < 0.05$
JOA at 1 year	24 (22, 25)			25.5 (20.0, 27.0)		
VAS for low back at 1 year	1 (0, 2)	0.4817	$P = 0.63 > 0.05$	1 (0, 2)	0.5537	$P = 0.5798 > 0.05$
VAS for low back at 5 years	1 (1, 2)			1 (0, 2)		
VAS for legs at 1 year	0 (0, 1)	-0.1473	$P = 0.8829 > 0.05$	0 (0, 0)	0.8881	$P = 0.3745 > 0.05$
VAS for legs at 5 years	0 (0, 1)			0 (0, 1)		
ODI at 1 year	5 (3, 8)	1.5725	$P = 0.1158 > 0.05$	6 (3, 10)	1.4535	$P = 0.1461 > 0.05$
ODI at 5 years	4 (2, 8)			8 (8, 8)		
JOA at 1 year	24 (22, 25)	1.4432	$P = 0.1491 > 0.05$	25.5 (20.0, 27.0)	1.4296	$P = 0.1528 > 0.05$
JOA at 5 years	25 (20.5, 26.0)			27 (20, 28)		

JOA, Japanese Orthopedic Association; ODI, Oswestry disability index; OFD, open fenestration discectomy; PTED, percutaneous transforaminal endoscopic discectomy; VAS, visual analogue scale.

**TABLE 6** Comparison of improvement rate between the OFD group and the PTED group

	Excellent	good	Moderate	Poor	$\chi^2$	P
OFD	9	21	6	3	0.0021	0.9632 > 0.05
PTED	16	38	12	5		

OFD, open fenestration discectomy; PTED, percutaneous transforaminal endoscopic discectomy.

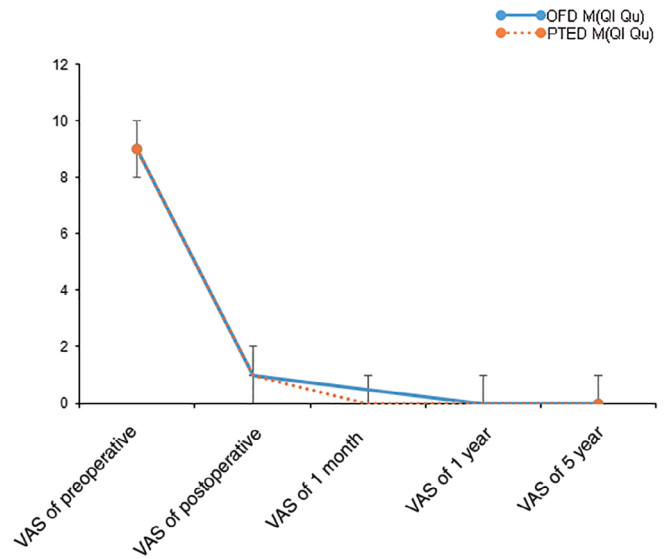
**Fig 1** Visual analogue scale (VAS) scores for low back pain. OFD, open fenestration discectomy; PTED, percutaneous transforaminal endoscopic discectomy.

(iv) End-of study follow ups: No significant differences were observed in the VAS, ODI, and JOA scores for the low back and legs between the two groups ( $P > 0.05$ ). Among them, 89.7% (35/39) of the OFD group and 88.7% (63/71) of the PTED group achieved excellent improvement in JOA scores, with no significant differences between the two ( $P > 0.05$ ).

## Discussion

### Summary of This Study

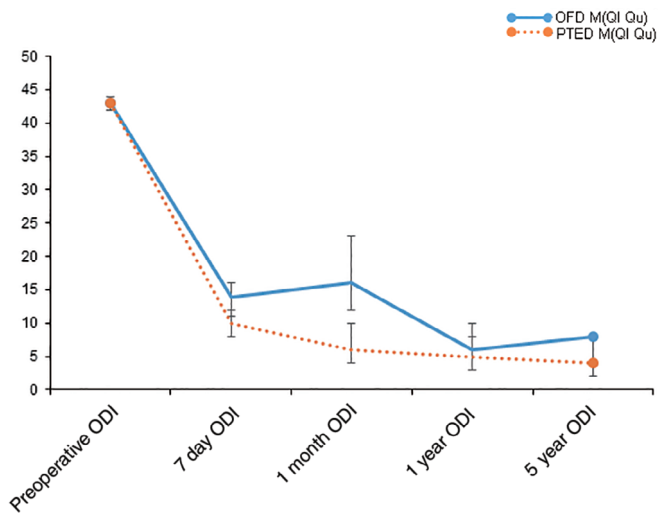
The traditional OFD and PTED techniques were included in this study. Obviously, there were no significant differences in age, BMI, sex, and affected site between these two groups (Tables 1 and 2). According to the basic characteristics, there were significant differences in incision length, operation time, X-ray times, length of hospital stay, VAS score for low back, day 7 for surgery, VAS score for legs, ODI score on day 7, and JOA score on day 7 between these two groups.

**Fig 2** Visual analogue scale (VAS) scores for leg pain. OFD, open fenestration discectomy; PTED, percutaneous transforaminal endoscopic discectomy. [Correction added on 05 March 2021, after first online publication: In the caption of Figure 2, 'low back pain' has been amended to 'leg pain'.]

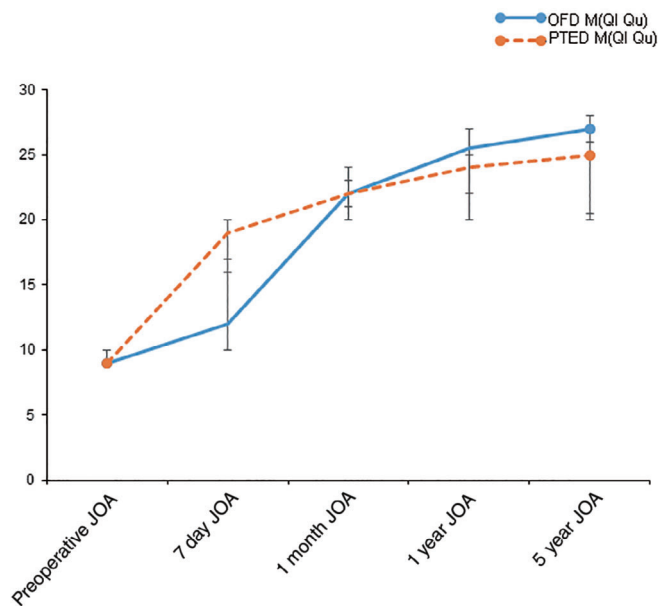
However, there were no differences in other indexes, including recurrence (Table 3). Furthermore, the recurrence rate, the adjacent time points, and the improvement rate in these two groups were almost the same (Tables 4–6). Their preoperative, postoperative, and end-of-study data were compared. The results showed that the VAS, JOA, and ODI scores for low back pain and leg pain were significantly improved after surgery (Fig. 1 to Fig. 4). In the early postoperative period, the improvements in the scores for low back and leg pain, JOA scores, and ODI scores were more significant in the PTED group than in the OFD group. During the end-of-study follow up, significant differences were noted in JOA scores, improvement rates, VAS scores, and ODI scores between the two groups, suggesting that both surgical methods can effectively treat LDH and may achieve good functional scores in the long term. However, the early postoperative pain was relieved and functional scores were improved faster in the PTED group, with long-term functional scores similar to those in the OFD group. Therefore, PTED is a good option.

### Clinical Application and Significance of Open Fenestration Discectomy as Well as Percutaneous Transforaminal Endoscopic Discectomy in Spinal Endoscopic Treatment

Traditional OFD is the gold standard for the treatment of LDH<sup>16</sup>. Some new surgical methods, such as microsurgical discectomy and microendoscopic discectomy, have been previously compared with traditional OFD<sup>17, 18</sup>.



**Fig 3** Oswestry disability index (ODI) scores. OFD, open fenestration discectomy; PTED, percutaneous transforaminal endoscopic discectomy.



**Fig 4** Japanese Orthopedic Association (JOA). OFD, open fenestration discectomy; PTED, percutaneous transforaminal endoscopic discectomy.

Percutaneous transforaminal endoscopic discectomy has gradually gained the attention of clinicians in two decades. In this study, PTED technique avoided the resection of the articular surface and the ligamentum flavum and the stripping of paraspinal muscles through the natural orifice of the intervertebral foramen. Thus, the PTED is currently the most minimally invasive technique for nucleus pulposus removal. In this study, the traditional

OFD was set as the control group, and the investigation of its mid-term clinical efficacy is of great significance.

The goal of the treatment of LDH is to obtain better or similar efficacy compared with the traditional OFD, while pursuing less surgical damage, quicker recovery, less recurrence, and better long-term efficacy. Traditional OFD may lead to iatrogenic instability and lumbar failure syndrome due to muscle stripping, bone resection of vertebral plates and facet joints, resection of ligamentum flavum, and scar formation. Attempts have been made to obtain similar clinical outcomes with more minimally invasive techniques, such as smaller skin incisions, less muscle stripping, less bone resection, and more careful and clear intraspinal manipulation with the aid of the magnification of a microscope<sup>19</sup>. With the magnifying effect of optical equipment, endoscopy is an effective means to reduce injury and realize rapid rehabilitation, and it is flourishing in all fields of surgery.

Microendoscopic discectomy, through the magnifying effect of endoscopy, reduces the size of the surgical excision and damage to the relevant structures on the surgical path, and achieves similar clinical efficacy to traditional surgical methods<sup>18, 20</sup>. However, it is like traditional OFD, with posterior interlaminar resection of the ligamentum flavum into the spinal canal. These methods still inevitably require resection of the ligamentum flavum and lead to epidural scar formation. The transforaminal approach has obvious advantages in avoiding ligamentum flavum damage and scar formation caused by it. With the help of the natural anatomical foramen and endoscopic magnification, PTED enables the display of a large field of view under a small cavity, and is currently the most minimally invasive intervertebral disc resection surgery. PTED has been increasingly recognized by clinicians in two decades. It has been demonstrated in the published literature that PTED can achieve the same short-term efficacy as microscopic and microendoscopic discectomy<sup>7,11,21</sup>. However, it has been questioned by some surgeons due to its small operating space, long learning curve, many steps, and uncertain mid-term and long-term outcomes<sup>8,22</sup>. The surgeons in this study were all physicians with more than 3 years of experience in endoscopic surgery. The results of this study showed that the PTED group had smaller surgical incisions and shorter hospital stay ( $P < 0.05$ ), which was associated with less damage to spinal structures by PTED. In addition, PTED patients had longer operation and fluoroscopy times ( $P < 0.05$ ), resulting from the use of X-ray required to accurately locate and cut the joint process in the surgical channel establishment stage. However, there were no adverse clinical findings related to the incision, bleeding, and fluoroscopy times.

Lumbar disc herniation is mainly characterized by low back and leg pain, with functional disability, affecting bending, lifting, and walking.

### **Assessment of Oswestry Disability Index and Japanese Orthopedic Association Scores in Spinal Endoscopic Treatment**

In this study, the ODI and JOA were used to assess patients' pain intensity, personal care, lifting, walking, sitting, standing, sleeping, social life, and traveling. As common outcome measures for patients with spinal diseases, the ODI and JOA have been translated into Chinese and are well recognized by most Chinese spinal surgeons.

The ODI is significantly correlated with SF-36 (Short Form 36) and VAS<sup>23,24</sup>, which are functional disability scores, with greater scores for worse disability. JOA is a functional score, with greater scores for better function. In this study, no significant differences were noted in VAS scores and JOA scores between the two groups. At the end-point of follow up, the excellent and good rate of VAS, ODI, and JOA score improvement was similar between the two groups, suggesting that PTED can achieve similar functional improvement efficacy to traditional OFD in the mid-term.

However, the comparison of the postoperative 7-day data between the two groups revealed that the relevant indexes improved faster in the PTED group, while no significant differences were observed between the two groups 1 month and 1 year after surgery. Subjects in the PTED group had faster improvement in symptoms and function in the early postoperative period, and their scores for low back pain in this period were also significantly smaller than those in the OFD group, which was consistent with the findings in several reports<sup>25,26</sup>. This may be related to less damage of the foramen approach and micromanipulation.

Surgical complications of LDH treatment include incision infection, dural injury, cerebrospinal fluid leakage, nerve root injury, inadequate relief of symptoms, structural stability damage, and abdominal macrovascular injury. In this group, there were no cases of macrovascular injury or important organ injury, while the OFD group had 1 case of dural tear, 1 case of poor incision healing, and 1 case of weakened extensor strength. In the PTED group, there was 1 case of transient root nerve stimulation, thigh numbness, and quadriceps weakness, and 1 case of nerve root injury and residual plantar numbness. Both were relieved with conservative treatment. Overall, the PTED group had fewer complications than those in the OFD group.

The overall recurrence rate was 7.3% in this study, which was in line with the findings of previous studies<sup>11, 27, 28</sup>.

The recurrence rate was 7.6% and 7.0% in the two groups, respectively, with no significant differences between them ( $P > 0.05$ ). Therefore, there was no obvious increase in the recurrence in the PTED group at the end of mid-term follow up. In addition, the VAS scores increased significantly and JOA and ODI scores decreased after recurrence. Most patients were reluctant to undergo minimally invasive or open revision surgery, with revision rates of 2.6% (1/39) and 2.8% (2/71), respectively.

In terms of intraoperative conditions, PTED postoperative revision still had adhesions in the foramen area and ventral side, but dorsal adhesions were significantly less than those of the revision cases in the OFD group. The weakness of this study lies in that it is a retrospective study and may have selection bias. Some patients were lost to follow up, particularly those with good efficacy, which may affect the results. Prospective randomized controlled studies with a larger sample size are needed.

[Correction added on 05 March 2021, after first online publication: The subsection, "Difficulties in the surgery", under the section, "Discussion" has been removed.]

### **Limitations of This Study**

This study has some shortcomings. First, this therapy has the defect of a longer course of treatment. Second, PTED is a new intervertebral foramina system designed because of the deficiencies of the YESS technique (It is also a percutaneous trans-Kambin triangle endoscopic nucleotomy, but his channel is more posterior, that is, it points to the back of the intervertebral cavity rather than in the more posterior spinal canal. His decompression starts from the back of the intervertebral disc and gradually decompresses backwards towards the spinal canal, so he is more suitable for tolerant protrusions (See reference 10)). The surgical approach dispenses with the Kambin triangle, allowing the more secure foramina to enter the spinal canal. The intervertebral foramen was enlarged and cannulated directly into the vertebral canal. Under endoscopy, the free intervertebral disc was taken out under the direct vision through the predural space, and the expanded Foramina was formed simultaneously. Compared to the YESS technique, the PTED technique has expanded surgical indications and improved safety. A defect of the technique is that the target of puncture is difficult to reach in the case of L5-S1 disc protrusion with a high ILIAC crest. The operation difficulty is higher, and it is more challenging to grasp in a short period of time.

### **Conclusion and Complications**

In conclusion, the retrospective analysis of the data of the two groups revealed that both techniques could achieve good mid-term clinical efficacy, but subjects in the PTED group had faster and earlier improvement of symptoms and function without increasing surgical complications and the recurrence rate, suggesting that PTED is worth considering as a novel surgical option for patients with LDH. However, attention should be paid to the learning curve of this procedure, and the efficacy of experienced, skilled surgeons may be better than that of beginners. The complications of PELD surgery are not uncommon. It is necessary to master the indications, improve the required surgical skills, and take corresponding measures. The common complications include: compression of nerve roots by the nucleus pulposus, tears of the dura mater, nerve injury, infection of the intervertebral space, retroperitoneal hematomas, and abnormal sensation.



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