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Comparative Study of Three Minimally Invasive Surgical Approaches for the Treatment of L5/S1 Lumbar Intervertebral Disc Herniation

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ABSTRACT

AIM: To compare the efficacy and safety of minimally endoscopic discectomy (MED), percutaneous endoscopic transforaminal discectomy (PETD) and percutaneous endoscopic interlaminar discectomy (PEID) in the treatment of L5/S1 lumbar disc herniation (LDH).

MATERIAL and METHODS: From May 2012 to January 2017, 317 patients with L5/S1 LDH treated with MED, PETD or PEID were reviewed. Pre- and postoperative pain was measured using a visual analog scale (VAS; 0 –10), and functional status was assessed using the Oswestry Disability Index (ODI; 0 – 100%). Clinical outcomes, SF-36 scores and CK levels were compared between the 3 groups.

RESULTS: There were 177 females and 140 males; the ages ranged from 22 to 74 years; and the course of disease was 15 to 85 days, with an average of 42.8 days. The postoperative bed rest time and average hospital stay in the MED group were higher than in the other two groups, and the differences were statistically significant. There was no significant difference in the results evaluated by the MacNab criteria. There were no significant differences in the levels of CK between the three groups before and after surgery ($p>0.05$).

CONCLUSION: Three minimally invasive surgeries for the treatment of L5/S1 LDH achieved satisfactory clinical outcomes; however, each procedure has its own advantages, disadvantages and indications. Surgeons need to choose the most appropriate surgery according to the individual condition of the patient to achieve the best therapeutic effect.

KEYWORDS: Percutaneous endoscopic lumbar discectomy, Minimally endoscopic discectomy, Lumbar disc herniation, Transforaminal, Interlaminar

ABBREVIATIONS: MED: Endoscopic discectomy, **PETD:** Percutaneous endoscopic transforaminal discectomy, **PEID:** Percutaneous endoscopic interlaminar discectomy, **LDH:** Lumbar disc herniation, **VAS:** Visual analog scale, **ODI:** Oswestry disability index, **SF-36:** Quality of life, **CK:** Creatine kinase

INTRODUCTION

Lumbar intervertebral disc herniation (LDH) is one of the most common diseases of the skeletal muscle system, often resulting in symptoms of low back pain and sciatica due to mechanical compression and inflammatory stimulation (10). In recent years, with the change in lifestyles, the prevalence rate of LDH has increased yearly. For some patients, conservative treatment is ineffective, and they

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need to undergo surgical treatment (1,22). In 1997, Foley et al. applied microendoscopic discectomy (MED) for the treatment of far-lateral LDH under general anesthesia and obtained satisfactory clinical results (6). In 2002, Yeung and Tsou performed percutaneous endoscopic lumbar discectomy (PELD) to treat symptoms of low back pain and sciatica in patients with LDH, which significantly alleviated symptomatology (26). Currently, with the progress in PELD technology and equipment, according to differences in the PELD surgical approaches, PETD and PEID technologies are commonly used under local anesthesia with conscious sedation in awake LDH patients.

Fifty-three to 56% of LDH occurs in the L5/S1 intervertebral disc segment, which has the anatomical characteristics of being high on the iliac crest, with small intervertebral foramen and transverse hypertrophy (5). In the past, most patients with L5/S1 LDH were treated with traditional lamina decompression and disc resection, which achieved satisfactory clinical outcomes; however, this treatment may lead to instability of the spine and scar formation around nerve tissues (9,15), and symptoms of chronic low back pain often occur after surgery (11). The development of minimally invasive technology provides a new choice for the treatment of L5/S1 LDH. These techniques often cause minimal trauma to the surrounding soft tissue in the process of completely releasing the nerve roots to achieve satisfactory clinical outcomes. How to choose the best surgical method is a hot spot of discussion for surgeons (19,20).

Presently, MED, PETD, and PEID are the main treatment options for L5/S1 LDH. This study reviews and analyzes the clinical data of 317 patients with L5/S1 LDH treated with minimally invasive surgery in our hospital from May 2012 to Jan 2017 and compares the efficacy and safety of these three minimally invasive surgeries in the treatment of L5/S1 LDH to guide clinical application.

MATERIAL AND METHODS

Patients

This study was approved by the Ethics Committee of The Tianjin Union Medical Center, and all patients signed an informed consent. Patients were screened using the findings from the history and physical examination, and the diagnosis of L5/S1 LDH was confirmed by magnetic resonance imaging (MRI). The inclusion criteria were (1) single segment L5/S1 LDH, (2) clear sciatica of the lower extremities, clear location of symptoms from neurological damage, poor curative effect or recurrent symptoms after more than 3 months of formal conservative treatment, with a serious impact on the patients' quality of life, (3) age ≥ 18 years, (4) initial surgery, (5) good lumbar stability, (6) complete relevant clinical and imaging data, and (7) postoperative follow-up time ≥ 18 months. The exclusion criteria were (1) mental illness that hinders patients' ability to clearly express their will, (2) lumbar spinal stenosis, spondylolysis or spondylolisthesis, (3) cauda equina syndrome, (4) scoliosis or kyphosis, (5) spinal infection, and (6) spinal tumor.

Surgical Techniques

MED Technique. The patient is placed in a prone position on the operating table under general anesthesia. A paramedian skin incision is made approximately 2 cm lateral to the spinous process and a retractable tube (METRx MD; Medtronic Sofamor Inc., Minneapolis, Minnesota, USA) is accurately placed into the interlaminar space under C-arm fluoroscopy. After partial removal of the lamina and ligamentum flavum with the aid of an operating microscope (OPMI VARI, Zeiss, Germany), the nerve root is loosened, and the intervertebral disc is resected (Figure 1A-G).

PETD Technique. The patient is placed in a lateral position on the operating table under local anesthesia. A determination is made of the body surface projection of the lesion intervertebral space by C-arm fluoroscopy, and a 0.8 cm incision is made 10-14 cm from the posterior middle line. A guidewire is tapped to the L5/S1 segment, and the foramina are enlarged with a saw. The intervertebral disc is excised with the aid of an endoscope (joimax GmbH, Karlsruhe, Germany) (Figure 2A-G).

PEID Technique. The patient is placed in a prone position on the operating table under local anesthesia. A determination is made of the body surface projection of the lesion intervertebral space by C-arm fluoroscopy, and a 0.8 cm incision is made 2 cm from the posterior middle line. A guidewire is tapped to the L5/S1 segment, and the interlaminar space is enlarged with a saw. After retracting the dural sac and S1 root, the intervertebral disc is excised with the aid of an endoscope (joimax GmbH, Karlsruhe, Germany) (Figure 3A-G).

Patients in the MED group underwent straight leg raising on the first postoperative day. On the second day after surgery, patients could walk with a brace, and the back muscle was exercised. Patients in the PETD and PEID groups were able to walk with a brace on the first postoperative day. All three groups of patients wore the brace for 3 to 4 weeks, and lumbar weight-bearing activity was avoided for 3 months after surgery.

Clinical and Radiologic Evaluation

A detailed recording of the operation time, intraoperative blood loss, intraoperative and postoperative complications, postoperative bed rest time, and length of hospital stay; additionally, patients were monitored for recurrence, which was defined as relief of postoperative symptoms for more than 6 months with repeat herniation of the ipsilateral and/or contralateral disc of the same segment. The visual analog scale (VAS), Oswestry Disability Index (ODI), quality of life (SF-36) scores, and creatine kinase (CK) levels at different time points before and after surgery were compared between the patient groups. The MacNab scale scores were used to evaluate pain relief. The scores were divided into the following four grades: 75–100% (excellent outcomes, can perform normal work), 50–74% (good outcome, can perform less work), 25–49% (fair outcomes, cannot work) and 0–24% (poor outcomes, may need a reoperation) (21).

All patients had complete imaging data before surgery, including lumbar X-rays (anterior-posterior position, lateral

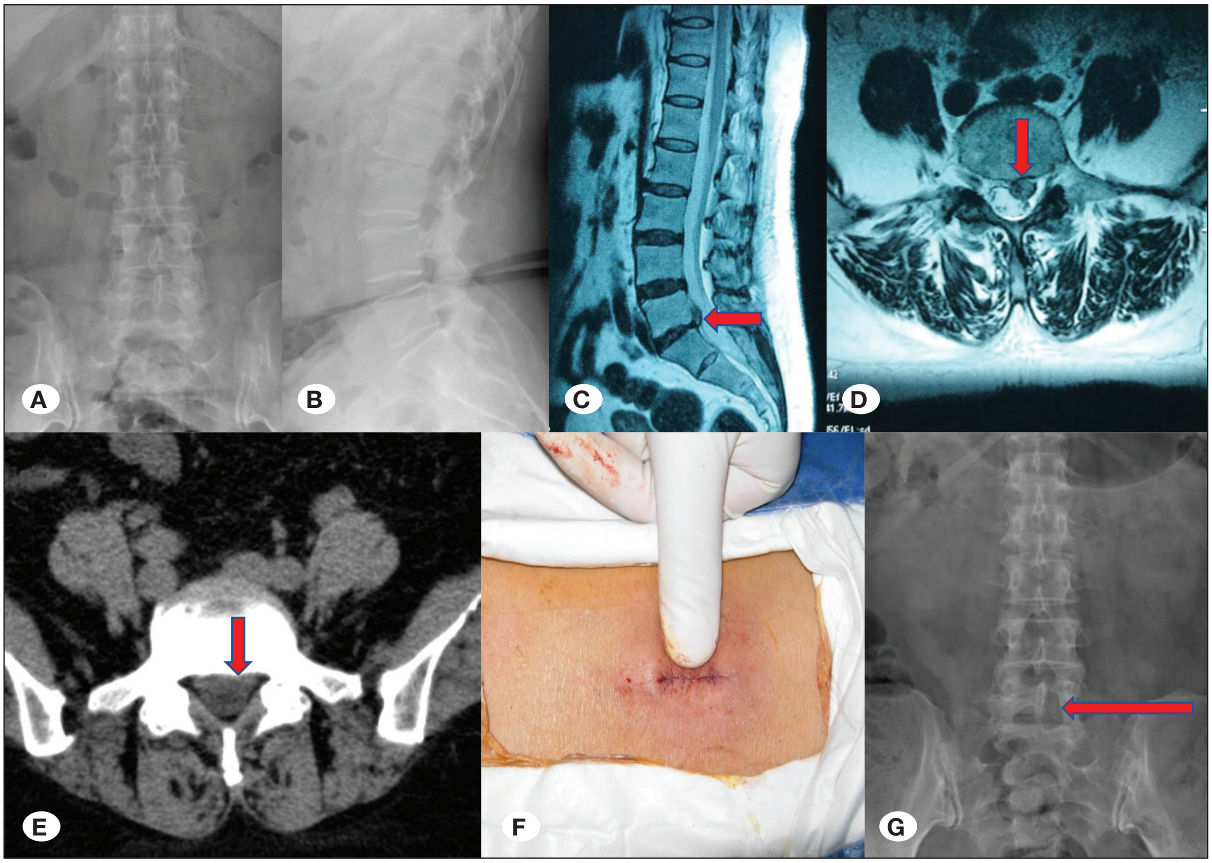

Figure 1: MED group, male, 52 years old, L5/S1 left side LDH (red arrow). **A)** Anterior-posterior X-ray; **B)** Lateral position X-ray; **C)** Preoperative sagittal section MR T_2WI; **D)** Preoperative cross section MR T_2WI; **E)** Preoperative CT scan; **F)** Surgical incision; **G)** Postoperative lumbar positive X-ray showed L5 left partial laminar resection (red arrow).

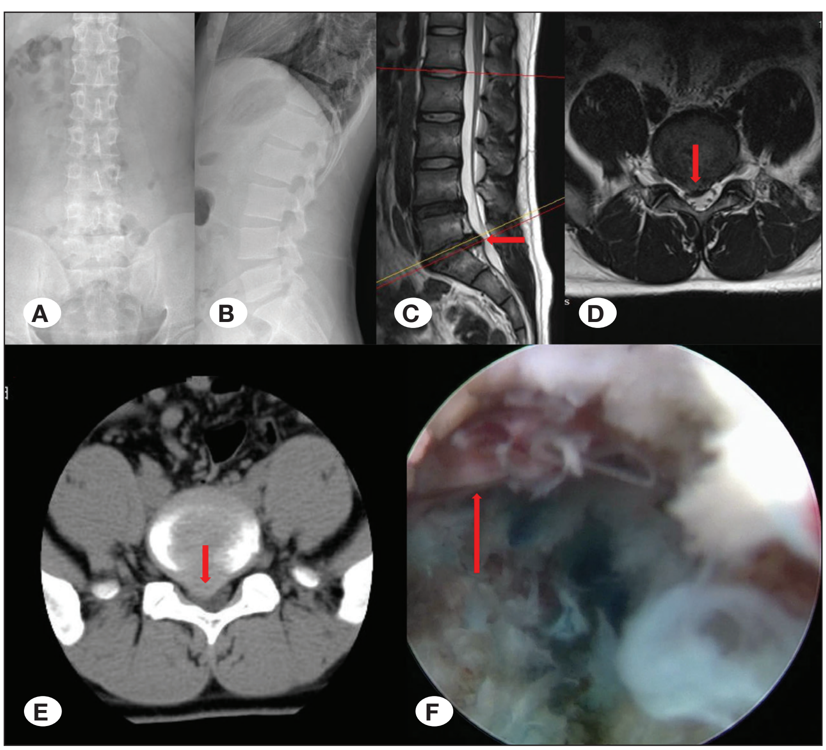

Figure 2: PETD group, 21 years old, L5/S1 right side LDH (red arrow). **A)** Anteriorposterior X-ray; **B)** Lateral position x-ray; **C)** Preoperative sagittal section MR T2WI; **D)** Preoperative cross section MR T2WI; **E)** Preoperative CT scan; **F)** The nerve root was fully decompressed after intermediate disc resection during the surgery (long arrow).

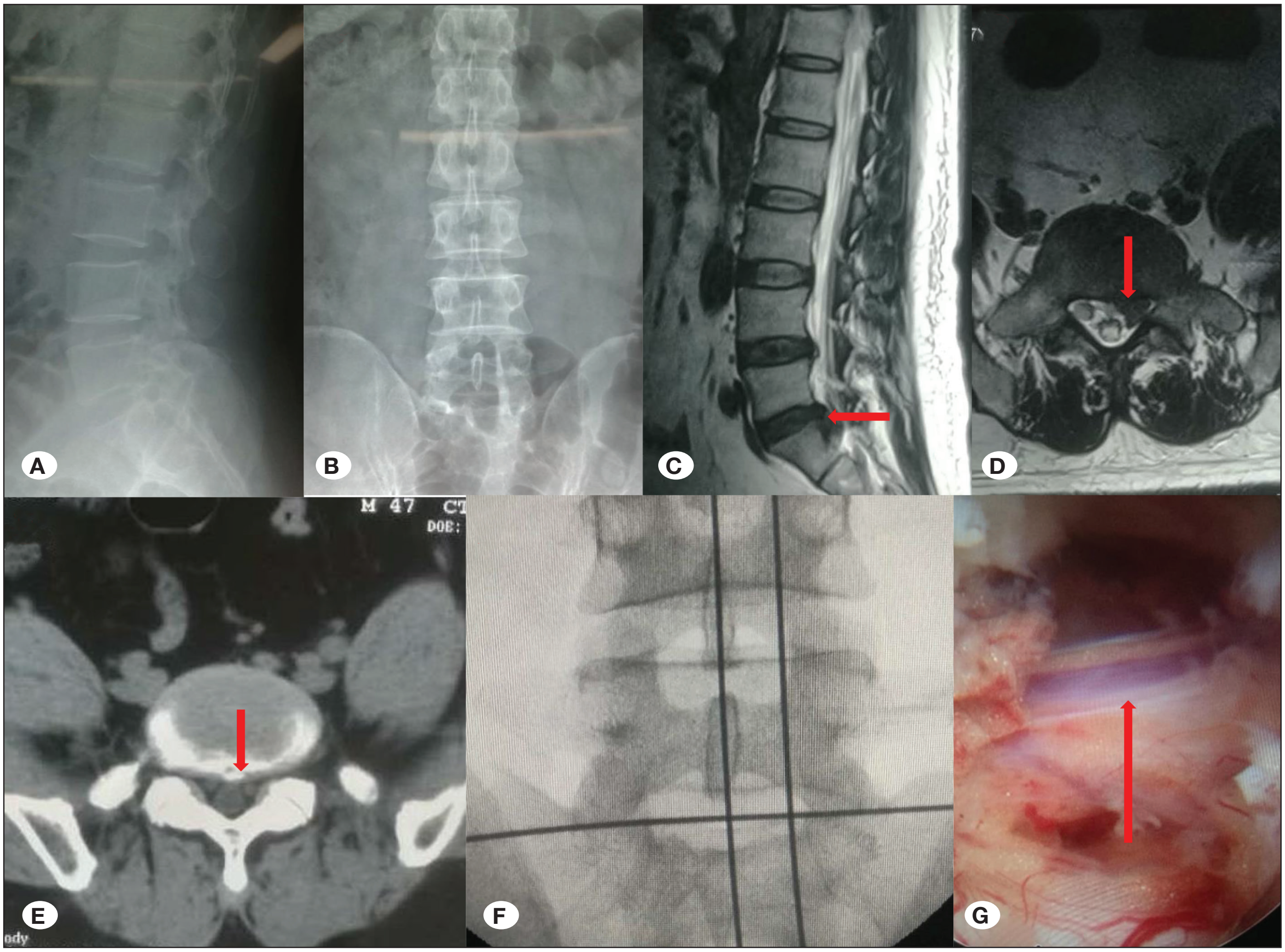

Figure 3: PEID group, 47 years old, L5/S1 left side LDH (red arrow). **A)** Anterior-posterior X-ray; **B)** Lateral position X-ray; **C)** Preoperative sagittal section MR T2WI; **D)** Preoperative cross section MR T2WI; **E)** Preoperative CT scan; **F)** Intraoperative operative segment localization; **G)** The nerve root was fully decompressed after intermediate disc resection during the surgery (long arrow).

position, overextension and flexion position, oblique position), CT, and MRI. According to the imaging data, the diagnosis and type of L5/S1 disc herniation were confirmed, and the height of the iliac crest and the stability of the lumbar were judged. Adjacent segment disease (ASD) was defined as a radiologic change based on previous reports (17).

Statistical Analysis

All analyses were performed using SPSS for Windows Version 19.0 (SPSS Inc., Chicago, IL, USA). The mean and standard deviation were determined for quantitative data. The paired sample t-test was used for intragroup comparisons. One-way analysis of variance (ANOVA) and the SKN-q test were used to compare the three groups. The χ^2 test was used to compare the data between groups and the Fisher's exact test was used when the number was less than five. The grade data were tested using the Kruskal-Wallis rank sum test. The difference was considered statistically significant at $p<0.05$.

RESULTS

From May 2012 to May 2017, 317 patients with L5/S1 LDH diagnosed by MRI in the Spinal Surgery Department and who underwent MED, PETD or PEID surgery were retrospectively enrolled. There were 177 females and 140 males; the ages ranged from 22 to 74 years; the course of disease was 15 to 85 days, with an average of 42.8 days. According to the different surgical methods, there were 125 patients in the MED group, 87 patients in the PETD group, and 105 patients in the PEID group. There was no significant difference in the baseline data between the three groups ($p>0.05$) (Table I).

In the MED, PETD and PEID groups, the bleeding volumes were 13.5 ± 12.1, 11.2 ± 8.2 and 10.9 ± 6.8, respectively. There was no significant difference in the bleeding volume and operation time between the three groups ($p>0.05$). In the MED group, the average blood loss was 15 mL (5-30 mL), while in the PETD and PEID groups, the average blood loss was 10 mL (5-20 mL). The postoperative bed rest time and average hospital stay in the MED group were higher than those in the other two groups, and the differences were statistically significant ($p<0.05$) (Table II).

The mean duration of the postoperative follow-up was 16.5 ± 4.5 months. There were 4 patients (3.20%) with LDH recurrence in the MED group, which was significantly less than 8 patients (9.19%) in the PETD group and 8 patients (7.62%) in the PEID group. The difference was statistically significant ($\chi^2=0.956$, $p<0.05$). There were no serious complications in the 3 groups. There were 3 patients (3.45%) in the PETD group with lower extremity pain and numbness after surgery, which had either worsened or had not undergone any obvious remission when compared with their presurgery status; there were 2 patients (1.90%) in the PEID group and 2 patients (1.60%) in the MED group whose symptoms of numbness and lower limb pain were significantly relieved after nerve nutrition, dehydration and hormone shock were given; there was no significant difference between the three groups ($\chi2=0.000$, $p>0.05$). In the MED group, 2 patients (1.60%) developed a postoperative hematoma, and 2 patients (1.60%) had delayed wound healing, all of whom were cured with symptomatic treatment. Two patients (1.60%) in the MED group developed an intervertebral space infection that occurred within 1 week after the operation. The patients received antibiotic treatment for 6 to 8 weeks, and after 3 months of absolute bed rest, the infection was controlled (Table III). No ASD occurred in any of the groups.

There were no significant differences in VAS and ODI scores between the three groups before and after surgery ($p>0.05$), though there were significant differences between the 12-month pre- and postoperation scores in each group ($p<0.01$) (Tables IV, V).

The follow-up 12 months postoperation was evaluated by the MacNab criteria, and there was no significant difference between the three groups ($p>0.05$) (Table VI).

There were no significant differences in the SF-36 scores between the three groups before and after surgery ($p>0.05$), though there were significant differences between the 12-month pre- and postoperation scores in each group ($p<0.05$) (Table VII).

There were no significant differences in the CK levels between the three groups before and after surgery ($p>0.05$). There were significant differences between the 12-h pre- and postoperation levels ($p<0.01$) (Table VIII).

Table I: Patient Demographics

Group	Cases number	gender		Age (years, mean ± SD)	Disease course (d, mean ± SD)	Type of LDH	
		male	female			central	paracentral
MED	125	50	75	44.9 ± 12.6	82 ± 16.3	31	94
PETD	87	43	44	45.9 ± 10.6	84 ± 12.9	25	62
PEID	105	47	58	43.5 ± 11.8	85 ± 10.6	36	89
p Value		>0.05		>0.05	>0.05	>0.05	

Table II: Perioperative Data ($\bar{x}$ ± s)

Group	Bleeding (ml)	Operatation time (min)	Best rest time (h)	Hospital stay (d)
MED	13.5 ± 12.1	53.2 ± 11.9	60 ± 26	6 ± 3
PETD	11.2 ± 8.2	48.6 ± 8.7	26 ± 10a	4 ± 2a
PEID	10.9 ± 6.8	46.9 ± 9.5	24 ± 5a	4 ± 1a
p values	>0.05	>0.05	<0.05	<0.05

Notes: *SNK-q test compared with MSL group, p <0.05.*

Table III: Postoperative Adverse Reactions (n)

Group	Recurrence LDH	lower extremity pain or numbness	Postoperative hematoma	Delayed wound healing	intervertebral space infection	ASD
MED	4	2	2	2	2	0
PETD	8	3	0	0	0	0
PEID	8	2	0	0	0	0
p values	<0.05	>0.05	>0.05	>0.05	>0.05	

Table IV: Perioperative VAS Scores ($\bar{x}$ ± s)

Group	1 day preop	1 day postop	1 month postop	6 months postop	12 months postop	t values[a]	p values
MED	7.1 ± 0.8	3.3 ± 1.2	2.5 ± 1.4	2.2 ± 1.5	1.5 ± 0.8	24.653	<0.05
PETD	7.2 ± 1.2	3.2 ± 1.3	2.4 ± 1.2	2.1 ± 1.7	1.4 ± 0.4	21.452	<0.05
PEID	6.9 ± 1.3	3.2 ± 1.8	2.4 ± 1.5	2.1 ± 1.3	1.3 ± 0.7	22.213	<0.05
F values	0.681	0.752	1.261	0.793	0.842		
p values	>0.05	>0.05	>0.05	>0.05	>0.05		

Notes: *[a]Paired t test was used to compare 12 post operation with preoperation.*

Table V: Perioperative ODI Scores ($\bar{x}$ ± s, %)

Group	1 day preop	1 day postop	1 month postop	6 months postop	12 months postop	t values[a]	p values
MED	47.2 ± 8.8	14.3 ± 2.8	12.2 ± 3.4	8.1 ± 2.1	5.1 ± 2.9	34.325	<0.01
PETD	45.9 ± 9.1	12.1 ± 3.5	11.8 ± 2.6	7.8 ± 1.3	5.1 ± 2.3	22.815	<0.01
PEID	46.1 ± 7.3	13.2 ± 4.3	12.3 ± 4.3	7.7 ± 2.3	4.9 ± 1.3	25.125	<0.01
F values	0.926	1.173	0.843	0.931	0.842		
p values	>0.05	>0.05	>0.05	>0.05	>0.05		

Notes: *[a]Paired t test was used to compare 12 post operation with preoperation.*

Table VI: Comparison of Clinical Outcomes 12 Months Post Operation [n, (%)]

Group	Excellent	Good	Fair	Poor
MED	93 (74.40%)	15 (12.00%)	10 (8.00%)	7 (5.60%)
PETD	64 (73.56%)	11 (12.64%)	8 (9.19%)	4 (4.60%)
PEID	178 (74.29%)	14 (13.33%)	8 (10.26%)	5 (6.41%)
χ^2 values		0.395		
p values		>0.05		

Table VII: SF-36 scores ($\bar{x}$ ± s)

Group	preop	1 month postop	6 months postop	12 months postop	t values[a]	p values
MED	46.6 ± 17.2	49.3 ± 18.2	51.6 ± 18.2	53.2 ± 18.1	2.128	<0.05
PETD	47.8 ± 19.1	50.3 ± 20.2	51.3 ± 21.9	53.4 ± 18.6	1.737	<0.05
PEID	47.3 ± 18.8	52.6 ± 19.7	52.1 ± 18.7	54.1 ± 17.8	2.214	<0.05
F values	0.381	0.442	0.375	0.321		
p values	>0.05	>0.05	>0.05	>0.05		

Notes: *[a]The last follow-up in the group was compared with that before surgery, p<0.05.*

Table VIII: CK Lever (u/l, $\bar{x}$ ± s)

Group	preop	12 hours postop	24 hours postop	48 hours postop	t values[a]	p values
MED	64.86 ± 5.21	97.64 ± 11.92	118.45 ± 18.31	140.09 ± 13.62	42.564	<0.05
PETD	66.29 ± 6.87	97.47 ± 12.46	117.84 ± 12.64	137.97 ± 11.26	38.286	<0.05
PEID	65.34 ± 7.21	97.52 ± 11.34	117.64 ± 11.37	138.78 ± 15.21	37.834	<0.05
F values	0.485	0.726	0.647	0.938		
p values	>0.05	>0.05	>0.05	>0.05		

Notes: *[a]The last follow-up in the group was compared with that before surgery, p<0.05.*

DISCUSSION

Compared to the other windows of upper lumbar anatomy, the transforaminal window of L5/S1 becomes progressively smaller and, simultaneously, the facet joint overlaps the disc space; however, the interlamina window can be enlarged with the development of MED and PELD techniques. The choice of the most reasonable approach for L5–S1 discs usually depends on the surgeon's experience and the anatomical features of the patient (23,28). Kyung-Chul et al. compared the radiologic features and results of PETD and PEID, and both the clinical symptoms of patients and the radiologic features were significantly improved (3). For the shoulder type, with centrally located and recurrent LDH, PETD is the preferable choice, and PEID is recommended for management of the axillary type and for migrated discs. However, the MED route, which was widely used in the clinic in this study, is not often considered. Li et al. compared the clinical outcomes of MED and PELD in the treatment of LDH in a long-term retrospective follow-up and reported that all patients showed improvements in the ODI and VAS scores; however, though the study included several surgical lumbar spine levels, the sample size that included the L5/S1 level was small, and a statistical analysis of the data of L5/S1 was not specifically performed (12). In this study, we compared 3 different routes, including MED, PETD and PELD, for the treatment of L5/S1 LDH. The MacNab criteria were used for postoperative evaluation (2). The results showed that the three surgical treatments for L5/S1 LDH achieved good clinical results, and the difference was not statistically significant (p>0.05). There were no significant differences in VAS, ODI and SF-36 scores between the three groups at different time points (p>0.05). Although the surgical methods are different, the objective lens of the microscope with PELD can be amplified several times, and the possibility of nerve root injury is decreased. Because all three surgical procedures are designed to remove the nucleus pulposus and relieve nerve compression, we were able to achieve good clinical effects.

Lumbar stability is one of the main factors influencing surgical outcomes. Yang et al. analyzed the factors that may cause postoperative spinal instability and found that facet joint tropism and asymmetry of the paraspinal muscle volume may lead to spinal instability (25). Hubbe et al. treated 30 patients with recurrent lumbar disc herniation with MED, and in 2 patients, instability occurred (7). Liu et al. evaluated the clinical outcomes of PETD, MED and microdiscectomy (MD) for the treatment of LDH (13). No lumbar instability was observed in any of the groups. The learning curve involved in mastering the surgical procedure will definitely affect the surgical outcome (14). In this study, although the MED group underwent a larger resection of the lamina and ligamentum flavum than the other two groups, during the follow-up period, no significant imaging findings or symptoms of lumbar instability or low back pain were observed in any of the groups. This may be due to the complexity of the factors leading to lumbar instability. If the surgeon is skilled in the MED technique, a limited resection of the lamina and ligamentum flavum by MED does not necessarily cause lumbar instability.

If LDH recurrence occurs, patients may experience recurrent symptoms and may need to undergo additional treatments. The risk factors are multifactorial and include age, sex, smoking, body mass index (BMI), diabetes mellitus, radiographic findings, MRI findings, and the type of initial herniation and surgical techniques. In the first 3 months, the LDH recurrent rate may be higher after MED (8). When LDH recurrence occurs within 6 months postoperatively after PELD, upper lumbar disc and central disc herniation may be independent risk factors (27). The results of this study showed that recurrence of lumbar disc herniation occurred in all three groups. The recurrence rate in patients who underwent PEID and PETD was higher than that of patients in the MED group (p<0.05). MED surgery offers a broad field of view, which can be combined with preoperative imaging findings to determine the range of decompression, and the procedure can be adapted to different types of LDH. In the PETD and PEID groups, only the resected discs in the field of view were removed. The operation was terminated after the nerve root was released, and the disc in the special position can make surgery difficult. Therefore, it is very important to select the appropriate patient and obtain informed consent before making a reasonable choice of treatment strategy.

Postoperative lower extremity numbness and pain were common complications in the PETD group. Compared with the MED group, ring saws of different diameters were used in the PETD group to remove the anterior lateral bone of the upper joint and enlarge the intervertebral foramen. When the working channel sheath tube is placed in the vertebral canal to remove the protruding medullary nucleus, the nerve root may be stimulated during the surgical process, especially in the early stages of performing the surgery, due to the relative inexperience of the surgeon (24). PEID exposes the nerve tissue first, then the intervertebral disc is treated, which further stimulates the nerve tissue and leaves the nerve prone to injury. However, for L5/S1 LDH, many scholars believe that the use of PEID is superior to PETD because PEID can effectively avoid the obstruction of the iliac crest in this section. We performed a precise imaging evaluation of the patient before surgery to confirm the height of the iliac crest. When the iliac crest height was beyond the horizontal line of the lower margin of the L4 pedicle, PEID was selected to avoid a failed operation caused by obstruction of the iliac crest (16). In this study, patients with nerve injury in the PELD group were in the first half of the year postoperation, which may be related to the unskilled surgical technique and a relatively rough operation. Aseptic and skilled operative techniques may be effective ways to reduce complications.

Infection after PELD or MED is a rare complication. A systematic review and meta-analysis showed that infection after MED occurred at a rate of 2.1% (18,28). Infection has not been reported after PELD, which may be related to continuous lavage during surgery. In the present study, 2 patients in the MED group had intervertebral space infections in the early postoperative period and were given antibiotic treatment for 6-8 weeks. After 3 months of absolute bed rest, the infection was controlled. The author's previous studies have shown that intraoperative intervertebral space lavage can effectively reduce the occurrence of intervertebral space infection (29). When the surgical trauma or operation time increases, CK activity also increases (4). There were no significant differences in postoperative CK levels in the three groups. We considered that the procedures in the three groups were minimally invasive surgery, and the intraoperative soft tissue trauma was small.

CONCLUSION

This study is a retrospective study with a small sample size and a short follow-up period. In the future, a larger, longerlasting clinical randomized controlled trial is needed to further explore the conclusions of this study. Although the three surgical treatments for L5/S1 LDH can achieve better clinical outcomes, the most appropriate procedure needs to be selected based on the patient's specific condition and the surgeon's skills and ability.

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DISCLOSURE and CONFLICTS of INTEREST

The submitted manuscript does not contain information about medical devices / drugs. The subject matter of this manuscript has no direct or indirect interest in business. All authors claim that this manuscript has no competing interests.

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