Comparison of percutaneous endoscopic transforaminal discectomy, microendoscopic discectomy, and microdiscectomy for symptomatic lumbar disc herniation: minimum 2-year follow-up results

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OBJECTIVE This study aimed to evaluate the clinical outcomes of percutaneous endoscopic transforaminal discectomy (PETD), microendoscopic discectomy (MED), and microdiscectomy (MD) for treatment of symptomatic lumbar disc herniation (LDH).

METHODS One hundred ninety-two patients with symptomatic LDH at L3–4 and L4–5 were included in this study. The mean ($\pm$ SD) age of patients was 34.2 ± 2.6 years (range 18–62 years). The patients were divided into groups as follows: group A was treated with PETD and included 60 patients (31 men and 29 women) with a mean age of 36.2 years; group B was treated with MED and included 63 patients (32 men and 31 women) with a mean age of 33.1 years; and group C was treated with MD and included 69 patients (36 men and 33 women) with a mean age of 34.0 years. The Japanese Orthopaedic Association (JOA) scale for low-back pain (LBP), Oswestry Disability Index (ODI), creatine phosphokinase activity 3 days after surgery, and visual analog scale (VAS) scores for LBP and leg pain were used for evaluation of clinical results.

RESULTS There were no significant differences in mean preoperative JOA score, ODI score, and VAS scores for LBP and leg pain among groups A, B, and C. Incision length, duration of the operation, blood loss, creatine phosphokinase, length of hospital stay, and postoperative incision pain according to the VAS were best in the PETD group ($p < 0.05$). The number of seconds of intraoperative fluoroscopy was highest in the PETD group ($p < 0.05$), whereas there was no difference between the MED and MD groups. Three cases from the MED group and 2 cases from the MD group had an intraoperative durotomy. No CSF leakage was observed after surgery. One case from the MED group and 3 cases from the MD group had incision infections. There were no neurological deficits related to the surgeries in any of the groups. Fifty-five (91.6%), 59 (93.7%), and 62 patients (89.9%) had at least 2 years of follow-up in groups A, B, and C, respectively. At the last follow-up, JOA scores, VAS scores of LBP and leg pain, and ODI scores were significantly better than preoperative correlates in all groups. There were no differences among the 3 groups in JOA scores, JOA recovery rate, ODI scores, and VAS scores for leg pain. The VAS score for LBP was best in the PETD group ($p < 0.05$). No lumbar instability was observed in any group. Three cases (5.5%) in the PETD group had recurrent LDH, and 2 recurrent cases (3.4%) were confirmed in the MED group.

CONCLUSIONS PETD, MED, and MD were all reliable techniques for the treatment of symptomatic LDH. With a restricted indication, PETD can result in rapid recovery and better clinical results after at least 2 years of follow-up.

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KEY WORDS lumbar disc herniation; percutaneous endoscopic transforaminal discectomy; microendoscopic discectomy; microdiscectomy; clinical outcome; comparison

ABBREVIATIONS CPK = creatine phosphokinase; JOA = Japanese Orthopaedic Association; LBP = low-back pain; LDH = lumbar disc herniation; MD = microdiscectomy; MED = microendoscopic discectomy; MSU = Michigan State University; OD = open discectomy; ODI = Oswestry Disability Index; PEID = percutaneous endoscopy interlaminar discectomy; PELD = percutaneous endoscopy lumbar discectomy; PETD = percutaneous endoscopy transforaminal discectomy; VAS = visual analog scale.

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SURGICAL treatment options for lumbar disc herniation (LDH) include open discectomy (OD), microdiscectomy (MD), microendoscopic discectomy (MED), and percutaneous endoscopy lumbar discectomy (PELD). In 1934, Mixter and Barr were the first to treat LDH surgically by performing an open laminectomy and discectomy.¹³ With the introduction of the microscope, the original laminectomy was refined to an open MD.^{2,20} MED was first described in 1997 as a minimally invasive transmuscular approach using advanced optics.⁵

In the last decades, endoscopic techniques have become well-developed methods to perform discectomy under direct visualization and with a local anesthetic. Kambin reported the first intraoperative discoscopic view of a herniated nucleus pulposus in 1988.¹⁰ With the further improvement of scopes (e.g., variable angled lenses and working channels for different instruments), the procedure became more refined. Yeung and Tsou developed the commercially available Yeung Endoscopic Spine System in 1997,²¹ and in 1994, Hoogland et al. developed the Thomas Hoogland Endoscopic Spine System.⁸

PELD includes the transforaminal approach (percutaneous endoscopy transforaminal discectomy [PETD]) and the interlaminar approach (percutaneous endoscopy interlaminar discectomy [PEID]). Although many studies have compared the clinical outcomes between MD and OD, MED and MD, or PELD and OD, to our knowledge, no studies have compared PETD, MED, and MD. In this study, we compared 2-year follow-up results of PETD, MED, and MD for treatment of L3–4 and L4–5 symptomatic LDH.

Methods

Inclusion and Exclusion Criteria

The institutional review board of Qilu Hospital of Shandong University approved this study. We retrospectively reviewed data in 254 patients who underwent PETD, MED, or MD performed by the same spine surgeons between September 2011 and September 2014. Patients in this study had single-level L3–4 or L4–5 intracanal soft LDH associated with typical sciatica, which can be treated by MD, MED, or PETD.

Exclusion criteria were as follows: 1) a history of lumbar surgery; 2) bony spinal canal stenosis; 3) segmental instability; 4) LDH associated with any other neurological lesions; 5) obesity (patients with excess weight of 30 kg higher than: body weight – body length – 100 cm × 1 kg¹⁸); 6) severe calcification of the protruded disc or a huge osteophyte of the posterior vertebral body, which compresses the dural or nerve root; 7) LDH that could be treated by MD, but was not suitable for PELD or MED according to the surgeon's experience; and 8) presence of any other diseases that might affect precise clinical assessments.

Three experienced senior doctors (L.G., Y.Z., and J.L.) reviewed patients' clinical symptoms, physical examination charts, and radiological resources (radiographs, MR images, and CT scans). Patients were excluded if any of the 3 senior doctors thought that any of the exclusion criteria were met. Cases that were included or excluded are

shown in Fig. 1. One hundred ninety-two patients (99 men and 93 women) with symptomatic LDH at L3–4 or L4–5 were selected for inclusion in our study.

Patient Characteristics

The mean age ± SD of the 192 patients was 34.2 ± 2.6 years (range 18–62 years). The patients were divided into 3 groups according to the surgical technique performed: PETD (group A), MED (group B), and MD (group C). Patient characteristics are shown in Table 1.

Surgical Techniques of PETD, MED, and MD

Surgical Technique of PETD

The PETD procedure was performed while the patient was given a local anesthetic (0.5% lidocaine) and was lying prone. The skin entry point was located approximately 12–14 cm from the midline. An 18-gauge spinal needle was inserted into the target disc using fluoroscopic guidance. In the anteroposterior view, the needle tip was located at the medial pedicular line in the L4–5 level and at the midpedicular line in the L3–4 level. In the lateral view, the needle tip lay at the posterior vertebral bodyline. Then the needle could be further inserted to the protruded discs (Fig. 2A and B). The nucleus pulposus was stained blue with a 1-ml mixture of contrast media. A guide wire was then inserted through the spinal needle, and the spinal needle was removed. A 7-mm incision was made, and a tapered cannulated obturator was inserted along the guide-wire. Finally, a bevel-ended, oval-shaped working cannula was inserted (Fig. 2C and D). If it was difficult to insert the cannula, a trephine was used for foraminoplasty to facilitate cannula insertion. Then an endoscope was inserted through the cannula. The herniated disc was removed using endoscopic forceps (Fig. 3).

Surgical Technique of MED

After the induction of general anesthesia, patients were placed prone for surgical procedures. The affected level was checked using C-arm fluoroscopy, and then a Steinmann pin was docked onto the lamina or ligamentum flavum of the surgical level. A 2-cm incision was made, and a series of dilators was then placed over the Steinmann pin. Finally, a tubular retractor was placed over the final dilator and fixed with a table-mounted flexible arm (Fig. 2E). A rigid endoscope with a 30° lens was inserted into the working channel. Discectomy was performed using a video assistant system (Fig. 4).

Surgical Technique of MD

Patients were placed prone after the induction of general anesthesia. The affected level was confirmed using C-arm fluoroscopy. A 2.5-cm posterior midline incision was made to expose the lamina and ligamentum flavum of the affected level. A minimally invasive lumbar Casper retractor was used (Fig. 2F), and a Kerrison was subsequently used to remove part of the lamina and ligamentum flavum under direct microscopic visualization. Next, the dura mater, nerve root, and protruded disc were exposed, and discectomy was performed for complete decompression (Fig. 5).

FIG. 1. Study flow diagram showing the inclusion and exclusion of patients. Figure is available in color online only.

Assessment Methods

Oswestry Disability Index (ODI) and Japanese Orthopaedic Association (JOA) scores of low-back pain (LBP) were used for the preoperative and follow-up clinical evaluations. Follow-up examinations were conducted 3 months, 6 months, 1 year, and 2 years after surgery. The JOA recovery rate was calculated according to the following formula: $(\text{follow-up score} - \text{preoperative JOA score}) / (29 - \text{preoperative JOA score}) \times 100\%$.⁶ A visual analog scale (VAS) was used to assess LBP, leg pain, and incision pain (a score of 0 indicated no pain and 10 represented the worst pain). Creatine phosphokinase (CPK) activity 3 days after surgery was used to evaluate paraspinal muscle damage. Length of hospital stay was defined as the number

of days that a patient stayed at the hospital after surgery (including the day of surgery).

The Michigan State University (MSU) classification on MRI was used to evaluate the position and size of herniated lumbar discs.¹⁴ In reference to the intrafacet line, the size and location of disc herniation was described as 1, 2, 3 (white dashed lines) and A, B, C (solid vertical lines) (Fig. 6). According to the MSU classification, the herniated discs can be divided into 10 subtypes (1A, 1B, 1C, 2A, 2B, 2C, 3A, 3B, 2AB, and 3AB).

A migrated herniated disc was defined as a herniation that was displaced from the extrusion site, either above the endplate of the upper body or below the endplate of the lower body. The migration of herniated lumbar discs was

TABLE 1. Demographic data of patients in the PETD, MED, and MD groups

Variable	PETD (group A)	MED (group B)	MD (group C)
Sex			
M	31	32	36
F	29	31	33
Mean age in yrs $\pm$ SD	36.2 $\pm$ 5.9	33.1 $\pm$ 6.7	34.0 $\pm$ 3.8
Mean duration of sciatica in mos $\pm$ SD	7.4 $\pm$ 2.1	6.9 $\pm$ 2.6	6.3 $\pm$ 3.2
Affected level			
L3–4	6	8	11
L4–5	54	55	58
MSU classification of LDH			
2A	9	8	11
2B	22	23	25
2AB	26	28	29
3A	1	1	1
3B	1	2	1
3AB	1	1	2
LDH migration			
None	39	40	42
Low grade	20	21	25
High grade	1	2	2

Values are presented as the number of patients unless indicated otherwise.

classified according to 3 types: no migration, low-grade migration (migration extent was less than the disc space height), and high-grade migration (migration extent was more than the disc space height).³

Statistical Analysis

The SPSS version 12.0 software package was used for statistical analysis. When a statistically significant difference was detected, selected pairs of groups were analyzed using the Student t-test or the chi-square test. A *p* value < 0.05 was considered statistically significant.

Results

In this series, no PELD or MED cases were converted to MD or OD during surgeries. Only 1 case in the PELD group needed foraminoplasty due to an osteophyte of the superior articular process. Data regarding incision length, blood loss, duration of surgery, length of hospital stay, preoperative and last follow-up JOA score, ODI score, VAS scores for LBP and leg pain, recovery rate, and CPK activity 3 days after surgery are shown in Table 2.

There were no significant differences in age, sex, preoperative JOA score, ODI score, and VAS scores for LBP and leg pain among groups A, B, and C. The PETD group showed the best clinical outcome based on incision length, duration of operation, blood loss, CPK, length of hospital stay, and postoperative incision pain VAS score (*p* < 0.05). The number of seconds of intraoperative fluoroscopy was

highest in the PETD group (*p* < 0.05), whereas there was no difference in the MED and MD groups. Three and 2 patients in the MED and MD groups, respectively, had an intraoperative durotomy. No CSF leakage was observed after surgery. One and 3 patients in the MED and MD groups, respectively, had incision infections. There were no neurological deficits related to surgery in any of the groups (Table 3).

Fifty-five patients in group A (91.6%), 59 patients in group B (93.7%), and 62 patients in group C (89.9%) had at least 2 years of follow-up. The mean duration of follow-up in groups A, B, and C was 28.2 $\pm$ 2.5, 29.6 $\pm$ 3.7, and 30.1 $\pm$ 2.2 months, respectively. At the last follow-up, JOA scores, VAS scores for LBP and leg pain, and ODI scores were significantly better than preoperative scores in all groups. There were no differences in JOA scores, JOA recovery rate, ODI scores, and VAS scores for leg pain among the 3 groups (Table 2). No lumbar instability was observed in any of the groups. The change in the VAS score for LBP is shown in Fig. 4. The VAS score for LBP was best in the PETD group (*p* < 0.05) at the last follow-up. Two patients in the PETD group had persistent strong LBP (the VAS score for LBP was 5 in both of these patients), even at the last follow-up.

Recurrent LDH occurred in 3 patients (5.5%) in the PETD group, and 2 recurrent cases (3.4%) were confirmed in the MED group (Table 4). The recurrence rate in the PELD group was higher than in the MED and MD groups (*p* < 0.05). Two cases (1 each in the MED and PETD groups) had early recurrence (< 6 months) and underwent revision surgery (MD) because of incomplete removal of the protruded discs. The other 3 patients (2 in the PETD and 1 in the MED group) had disc herniation recurrence $\geq$ 1 year after the primary surgery. All of these patients underwent MD revision surgery and had good clinical results at the last follow-up.

Discussion

Although the indications for PELD are still limited, PETD has indication rates similar to those for OD or MD in the treatment of LDH. In this study, we only compared the clinical results of PETD, MED, and MD at L3–4 and L4–5 disc herniation. The reason is that L5–S1 disc herniation (except for zone C of the MSU classification) has only been treated by PEID at our institution because of the anatomy of the L5–S1 foramina and iliac. We selected patients who could be treated by PETD, MED, or MD, which meant that the indications were the same as those for PELD with the exception of zone C of the MSU classification. Moreover, because PETD is a relatively new technique, we also took into consideration the experience with performing PETD and the learning curve of the surgeons. We excluded patients with severe calcification of the protruded disc or a huge osteophyte, which is relatively difficult to be treat by PETD.

Many authors have compared the clinical results from PETD with MD or OD. However, current evidence of the effectiveness of transforaminal endoscopic surgery is weak and does not provide valid information in patients with symptomatic LDH. In a randomized controlled study

FIG. 2. Working channel positions in PETD, MED, and MD. **A–D:** Positions of the needle and working cannula in PETD. **E:** Working channel position in MED. **F:** Position of the minimally invasive lumbar retractor in MD.

FIG. 3. A 33-year-old woman had severe sciatica with LBP for 3 years, which was treated by PETD. **A and B:** MR images showing severe L3–4 disc herniation (MSU classification 3AB with no migration). **C:** Photograph obtained during the surgery showing complete decompression. **D and E:** MR images obtained 2 years after the operation showing that the protruded disc was removed, resulting in complete decompression. Figure is available in color online only.

of 162 cases, Ruetten et al.¹⁸ compared 2-year follow-up results of PELD (including PETD and PEID) with MD for the treatment of LDH. After 2 years, a significant and constant improvement was observed in patients treated by MD

or PELD, but with no significant differences between the groups. Nellensteijn et al.¹⁵ identified 1 randomized controlled trial, 7 nonrandomized controlled trials, and 31 observational studies in the literature. In the 8 controlled tri-

FIG. 4. A 45-year-old woman had severe sciatica and leg numbness on the left side for 6 months, which was treated by MED. **A and B:** MR images showing severe L4–5 disc herniation (MSU classification 3AB with no migration). **C:** Photograph obtained during the surgery showing complete decompression. **D:** CT scan obtained 3 years after the operation showing mild disc herniation on the left side without clinical symptoms. Figure is available in color online only.

FIG. 5. A 31-year-old woman had severe sciatica and LBP on both sides for 1 month, which was treated by MD (discectomy from the right side). **A and B:** MR images showing severe L4–5 disc herniation (MSU classification 3AB with low-grade up-migration). **C:** Photograph obtained during the surgery showing the retractor that was used in MD. **D and E:** MR images obtained 2 years after the operation showing complete decompression. Figure is available in color online only.

FIG. 6. Example of the MSU classification. The size and location of disc herniation is described as 1, 2, 3 (white dashed lines) and A, B, C (solid vertical lines).

als, no statistically significant differences were found in leg pain reduction between the PETD (89%) and MD (87%) groups; overall improvement (84% vs 78%), respectively.

In this series, the PETD group had 2-year follow-up results similar to those for MED and MD. According to our results, with restricted indications, PETD may achieve better clinical outcomes including shorter incision length, length of hospital stay, and operation time; and less blood loss, muscle damage (i.e., CPK), and postoperative incision pain, which means that patients who underwent PETD had rapid recoveries. Moreover, in our study, at least 2 years of follow-up demonstrated that patients in the PETD group had less LBP compared with those in the MED and MD groups. To reduce damage to the facet joint, we tried to avoid foraminoplasty. In most patients, the diameter of L3–4 and L4–5 was wide enough to insert a 7-mm cannula

TABLE 2. Comparison of clinical outcomes among PETD, MED, and MD groups

Variable	PETD (group A)	MED (group B)	MD (group C)
Preop			
JOA score	11.4 ± 1.3	10.9 ± 2.0	11.0 ± 1.7
VAS score of LBP	5.8 ± 1.1	6.0 ± 0.4	5.8 ± 1.6
VAS score of leg pain	7.1 ± 1.1	7.2 ± 0.6	6.9 ± 0.5
ODI score	71 ± 12	69 ± 18	70 ± 20
Length of incision (cm)	0.7 ± 0.1*	1.8 ± 0.6	2.2 ± 0.9
Duration of op (min)	43 ± 13*	57 ± 10	60 ± 15
Estimated blood loss (ml)	5 ± 3*	23 ± 10	26 ± 15
VAS score of incision pain			
Postop day 1	1.1 ± 0.5*	3.0 ± 0.7	2.9 ± 0.6
Postop day 3	0.8 ± 0.3*	2.1 ± 0.5	2.3 ± 1.0
Intraop fluoroscopy (sec)	15 ± 9*	5 ± 2	2 ± 1
CPK (μl)	38 ± 1*	110 ± 31	95 ± 26
Length of hospital stay (days)	2 ± 1*	3 ± 2	3 ± 1
Length of follow-up (mos)	28.2 ± 2.5	29.6 ± 3.7	30.1 ± 2.2
Last follow-up			
JOA score	23.9 ± 1.3	24.1 ± 1.0	24.2 ± 0.9
JOA recovery rate (%)	71.0 ± 5.9	72.9 ± 4.7	73.3 ± 5.1
VAS score of LBP	0.9 ± 0.7*	1.6 ± 0.4	1.4 ± 0.7
ODI score	19 ± 6	24 ± 11	23 ± 9
VAS score of leg pain	1.2 ± 0.5	1.1 ± 0.3	1.4 ± 0.7
Complication rate (%)	8.3	9.5	7.2
Recurrence rate	3/55 (5.5%)*	2/59 (3.4%)	0

Values are presented as the mean ± SD unless otherwise indicated.

* $p < 0.05$.

to the target protruded disc without foraminoplasty. Therefore, only 1 patient in this series required foraminoplasty because of an osteophyte of the superior articular process.

Reoperation rates of 2.3%–15% have been reported for PELD.^{1,8,9,12,15,18} Ruetten et al.¹⁷ reported that recurrence was observed in 11 patients (6.2%): 5 cases in the MD group (5.7%) and 6 cases in the PELD group (6.6%); 3 cases [7.8%] in PETD and 4 cases [5.7%] in PEID). In a systematic review, Nellensteijn et al.¹⁵ reported that the reoperation rate was 6.8% and the complication rate was 1.5%. Choi et al.⁴ reported 436 unsuccessful cases (4.3%) among 10,228 patients who underwent PELD. The causes were incomplete removal of herniated discs in 283 patients (2.8%), recurrence in 78 (0.8%), persistent pain even after complete herniated disc removal in 41 (0.4%), and approach-related pain in 21 (0.2%). Incomplete removal of the herniated disc was caused by inappropriate positioning (95 cases; 33.6%) of the working channel and occurred in central herniated discs (91 cases; 32.2%), migrated herniated discs (70 cases; 24.7%), and axillary-type herniated discs (63 cases; 22.3%).

Consistent with the above results, PETD had the highest recurrence rate (5.5%) at the last follow-up in our study. One case was related to incomplete removal of the protruded disc in a patient with a central LDH of high-canal

TABLE 3. Surgical complications among patients in the PETD, MED, and MD groups

Complication	PETD (group A)	MED (group B)	MD (group C)
Durotomy	0	3	2
Infection	0	1	3
Recurrence	3	2	0
Persistent strong LBP	2	0	0
Total no. of patients (%)	5 (8.3)	6 (9.5)	5 (7.2)

Values are presented as the number of patients.

compromise (MSU classification 3B). The other 2 patients had recurrence ≥ 1 year later, which might have been related to an early return (2 weeks after surgery) to normal life and long periods of seating because of study and work (cases 4 and 5, respectively, in Table 4). Moreover, although patients in the PETD group had less LBP compared with those in the MED and MD groups, at the last follow-up there were still 2 patients with persistent strong LBP, which might have been related to disc-generated pain caused by excessive removal of normal disc tissue or by damage to the cartilaginous endplate.

MED is a modified interlaminar surgery with a shorter learning curve for surgeons than PELD. It has similar indications to OD and MD, and it can also be used for treatment of LDH or lumbar spinal stenosis. Compared with OD and MD, incision length and paraspinal muscle damage are reduced with the MED technique. However, the incidence of lamina and ligament damage is similar to that of OD and MD. Furthermore, in some cases, it is difficult to control bleeding of the venous plexus during the surgery.

Many studies have investigated and compared clinical results between MED and OD. Righesso et al.¹⁶ compared OD with MED in patients with sciatica caused by LDH. There was no significant difference in ODI scores at any time point, and the mean time for return to work and normal activities was 21 days in both groups. Their study also showed that MED was a long procedure, and the VAS scores of patients in the MED group were significantly higher 12 hours postoperatively. Teli et al.¹⁹ reported sig-

nificantly smaller surgical incisions and shorter hospital stays for patients who were randomly assigned to undergo MED.

Garg et al.⁷ reported that the patients who received MED had a significantly shorter hospital stay and a smaller amount of intraoperative blood loss than those who had OD. They showed that there was no significant difference in ODI scores or complication rates between the groups, concluding that the interventions were equally effective. Garg et al.⁷ and Teli et al.¹⁹ also demonstrated that MED caused more severe complications than OD and thus cannot be recommended as routine practice, nor should it be attempted without appropriate training.

In our study, we found that patients in the MED group had clinical results similar to those in the MD group. Patients in the MED group did not have any neurological deficits or other severe complications. Because the MED technique has been used at our institution since 2000, the surgeons in this study had sufficient surgical experience, which may be why there were no severe complications in this series. In our study, the MED group had 9.5% complication rate and a 3.4% recurrence rate. One patient in this group had a surgery-related infection. This may have been related to the long duration of surgery (3.5 hours) because of bleeding of the venous plexus. Two patients in the MED group had recurrent LDH; in one of these patients, early recurrence was due to insufficient removal of the protruded disc.

MD is a well-developed and the most popular technique. Combined with a minimally invasive tube, MD is still the most reliable surgery for discectomy, especially for some difficult cases (e.g., high-grade migrated disc, severe calcified LDH, and so on). Consistent with previous reports,^{7,16,19} MD and MED achieved similar clinical results in this series. Lurie et al. reported 8-year results from the Spine Patient Outcomes Research Trial (SPORT), which was based on continued follow-up of patients with herniated discs in randomized and observational cohorts.¹¹ Recurrence rates in the randomized and observational cohorts were 7% (17 of 262 cases) and 11% (57 of 548 cases), respectively. In this series, there were no cases of recurrence in the MD group. However, considering the relatively small number of cases (69) and short duration of follow-up (2 years), long-term clinical results in the MD group need further investigation.

TABLE 4. Revision cases of PELD and MED

Case No.	Sex	Age (yrs)	Affected Level	MSU Classification	LDH Migration	Primary Op	Time Until Return to Work or Study	Time From Primary Surgery	Reason for Revision	Revision Op
1	M	34	L4–5	3B	High grade	MED	Patient did not return to work before primary op	2 days	Incomplete removal	MD
2	F	21	L4–5	3B	None	PETD	1 wk	3 mos	Incomplete removal	MD
3	M	31	L4–5	3A	Low grade	MED	1 mo	2 yrs	Same-level recurrence (same side)	MD
4	F	20	L4–5	2B	None	PETD	2 wks	1.5 yrs	Same-level recurrence (contralateral side)	MD
5	F	33	L4–5	2AB	None	PETD	3 wks	1 yr	Same-level recurrence (same side)	MD

Conclusions

PETD, MED, and MD are all reliable techniques for the treatment of LDH. With a restricted indication, PETD resulted in better clinical outcomes after 2 years of follow-up. For cases with high-canal compromise and migrated disc herniation, surgeons must carefully evaluate the amount of protruded disc removed in PETD and MED procedures to avoid early recurrence. Because this study is a retrospective study with only 2 years of follow-up, a prospective study or randomized controlled trial is needed for further research.

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Disclosures

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Author Contributions

Conception and design: Liu. Acquisition of data: Yuan, Tian, Wang. Analysis and interpretation of data: Tian, Wang. Drafting the article: Liu. Critically revising the article: Zheng, Li. Reviewed submitted version of manuscript: Wang, Gong, Zheng, Li.

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