Retrospective Study

Comparison of Percutaneous Endoscopic Transforaminal and Interlaminar Approaches in Treating Adjacent Segment Disease Following Lumbar Decompression Surgery: A Clinical Retrospective Study

Jialuo Han, MD[1], Wei Tang, MD[2], Guanghui Li, MD[1], Xiangli Ji, BS[3], Xiaoqi Wu, BS[1], Kai Zhu, MMed[1], Guoqing Zhang, MD[1], Chuanli Zhou, MD[1], Xuexiao Ma, MD[1], and Jianwei Guo, MD[1]

From: [1]Department of Spine Surgery, The Affiliated Hospital of Qingdao University, Shandong Province, People's Republic of China; [2]Department of Orthopedics, People's Hospital of Rizhao Lanshan, Shandong Province, People's Republic of China; [3]Department of Intensive Care Unit, Qilu Hospital of Shandong University (Qingdao), Shandong Province, People's Republic of China

Address Correspondence:
Jianwei Guo, MD
Department of Orthopedics, The Affiliated Hospital of Qingdao University
16 Jiangsu Rd
Qingdao 266003, Shandong Province, People's Republic of China
E-mail: guojw_qdfy@163.com

Disclaimer: J Han and W Tang contributed equally to this paper. C Zhou, X Ma, and J Guo contributed equally to this paper. This work was supported by Taishan Scholars Program, Shandong province, China (NO. ts20190985), National Natural Science Foundation of China (NO. 81871804) and Qingdao 2022 Annual Medical and Health Research Guidance Project (2022-WJZD187).

Conflict of interest: Each author certifies that he or she, or a member of his or her immediate family, has no commercial association (i.e., consultancies, stock ownership, equity interest, patent/licensing arrangements, etc.) that might pose a conflict of interest in connection with the submitted manuscript.

Background: Adjacent segment disease (ASD) is a common complication following posterior disc decompression and fusion surgery. Percutaneous endoscopic lumbar decompression surgery (PELD) has been used to treat ASD through either a transforaminal or interlaminar approach. However, to our limited knowledge there are no reports comparing the 2 approaches for treating ASD.

Objective: To evaluate clinical outcomes of PELD in treating ASD and comparing the surgical results and complications between the 2 approaches. This may be helpful for spinal surgeons when decision-making ASD treatment.

Study Design: A clinical retrospective study.

Setting: This study was conducted at the Department of Orthopedics of the Affiliated Hospital of Qingdao University.

Methods: From January 2015 through December 2019, a total of 68 patients with ASD who underwent PELD after lumbar posterior decompression with fusion surgery were included in this study. The patients were divided into a percutaneous endoscopic transforaminal decompression (PETD) group and a percutaneous endoscopic interlaminar decompression (PEID) group according to the approach used. The demographic characteristics, radiographic and clinical outcomes, and complications were recorded in both groups through a chart review.

Results: Of the 68 patients, 40 underwent PEID and 28 patients underwent PETD. Compared with their preoperative Visual Analog Scale (VAS) pain score and Oswestry Disability Index (ODI) score, all patients had significant postoperative improvement at 3 months, 6 months, one year and at the latest follow-up. There were no significant statistical differences in the VAS and ODI scores between PETD and PEID groups with a P value > 0.05. There was a significant statistical difference in the average fluoroscopy times between the PETD and PEID groups with a P value = 0.000. Revision surgery occurred in 8 patients: 6 patients who underwent PETD and 2 patients who underwent PEID. The revision rate showed a significant statistical difference between the 2 approaches with a P value = 0.039.

Limitations: Firstly, the number of patients included in this study was small. More patients are needed in a further study. Secondly, the follow-up time was limited in this study. There is still no conclusion about whether the primary decompression with instruments will increase the reoperation rate after a PELD, and a longer follow-up is needed in the future. Thirdly, this study was a clinical retrospective study. Randomized or controlled trials are needed in the future in order to achieve a higher level of evidence. Fourthly, there were debates about PELD approach choices for ASDs, which may affect the comparison results between PETD and PEID. In our study, the approaches were mainly determined by the level and types of disc herniation, and the surgeons' preference. More patients with an ASD with different levels and types of disc herniation and surgical approaches are needed in the future to eliminate these biases.

Manuscript received: 06-18-2023
Revised manuscript received: 08-09-2023
Accepted for publication: 08-29-2023

Free full manuscript: www.painphysicianjournal.com

Conclusion: Percutaneous endoscopic lumbar decompression surgery is a feasible option for ASD following lumbar decompression surgery with instruments. Compared with PETD, PEID seems to be a better approach to treat symptomatic ASDs.

Key words: Lumbar degenerative disease, adjacent segment disease, percutaneous endoscopic lumbar decompression surgery, outcome

Pain Physician 2023: 26:E833-E842

Lumbar degenerative disease is one of the most common causes of low back pain, radiculopathy, and/or neurogenic claudication among the adult population (1). The development of degenerative changes can lead to symptomatic compression of a neural element, which decreases the quality of life and limits the functions of the musculoskeletal system. Medical or surgical treatment can be chosen according to the clinical signs and symptoms of a patient. Conservative management is recommended for the treatment of early and mild lumbar degenerative diseases, including bed rest, oral anti-inflammatory drugs and analgesics, spinal anesthetic blocks, and/or physical therapy (2). For patients whose symptoms do not resolve in 2 months, or who have cauda equina syndrome, muscle weakness, or progressive neurologic deficit after medical treatment, surgical intervention is advised (3).

Posterior decompression and fusion surgery have been widely used to manage this kind of disease. Compared with decompression and fusion without internal fixation, pedicle screw fixation after lumbar fusion can permit early mobilization and increase the fusion rate during follow-up (4). Posterior decompression and fusion surgery were once been believed to be the ideal procedure to treat lumbar degenerative disease. Unfortunately, the use of pedicle screws eliminates the motion of the fused segment, increases the mechanical stress at the adjacent segments, and irreversibly alters normal spine biomechanics (5-7). These abnormal loading and motions can accelerate degeneration at the adjacent segments and cause corresponding clinical symptoms, which may require a second surgery (8-10).

Posterior revision surgery has been performed to treat adjacent segmental diseases, especially with implantation (11,12). In recent years, with the development of endoscopic equipment and surgical skills, percutaneous endoscopic lumbar decompression surgery (PELD) has been used to treat lumbar herniation and lumbar spinal stenosis and is considered to be an effective and minimally invasive option for lumbar degenerative disease (13,14). During the procedure, PELD only requires a minimal incision, does not damage facet joints and posterior ligaments, does substantially less damage to soft tissue, and maintains the stability of the surgical vertebral segment (15,16).

Therefore, it is hypothesized that PELD may be effective in the treatment of adjacent segment disease (ASD), which is associated with spinal stenosis or lumbar herniated discs, without any obvious segmental instability. PELD can be carried out through either a transforaminal (PETD) or interlaminar approach (PEID). Although there have been reports comparing surgical outcomes between the 2 approaches in treating lumbar disc herniation, to our knowledge there are no reports comparing the 2 approaches for treating ASD. The purpose of our study was to evaluate the clinical outcome of PELD in treating ASD and to compare the surgical results and complications between the 2 approaches. We believe this may be helpful for spinal surgeons in their decision-making for treating ASD.

Methods

This study was a clinical retrospective cohort study. It was approved by the Ethics Committee of the Affiliated Hospital of Qingdao University (Qingdao, People's Republic of China).

The inclusion criteria were: 1) patients had either neurogenic claudication or radiculopathy symptoms for at least 6 months follow-up after posterior decompression with fusion surgery; 2) radiographic images confirmed lumbar spinal stenosis or disc herniation adjacent to surgical segments, which corresponded to the patient's symptoms; 3) radiographic images showed no obvious lumbar intervertebral instability; 4) failure of conservative therapies at > 2 months; 5) patients received PELD in the revision surgery.

The exclusion criteria were: 1) a lumbar degenerative disease not adjacent to the surgical segments; 2) the patient's symptoms do not correspond to adjacent segmental degeneration; 3) other spinal pathologic conditions, including trauma, tumor or infection; and 5) a follow-up time less than 6 months.

From January 2015 through December 2019, a total of 68 patients met the inclusion criteria and were included in this study, including 40 men and 28 women. Among the 68 patients, 26 had hypertension, 18 had diabetes mellitus, 10 had a cardiovascular disease, 2 patients had a respiratory disease, and 2 patients had a renal disease.

All patients received a routine lumbar imaging examination. Lumbar anteroposterior x-ray and flexion-extension radiographs were used to determine lumbar degeneration and radiographic stability of the adjacent level. Lumbar computed tomography and magnetic resonance imaging were used to indicate the disc herniation and compression condition at the adjacent levels. Among the 68 patients, 40 were identified as having lumbar spinal stenosis at an adjacent level; 28 were identified as having lumbar disc herniation at an adjacent level. The demographic characteristics; radiographic and clinical outcomes; and surgery were recorded through chart review.

Surgical Techniques

PELD was performed through either a transforaminal or interlaminar approach. The PELD approach was determined by the level and types of disc herniation, and the surgeon's preference. All patients were placed prone with their hips and knees flexed.

PETD

For patients undergoing PETD, the skin entry point and needle trajectory toward the superior articular process (SAP) of the inferior vertebra on the symptomatic side and level were calculated based on preoperative magnetic resonance imaging or computed tomography and adjusted by intraoperative C-arm monitoring (Fig. 1).

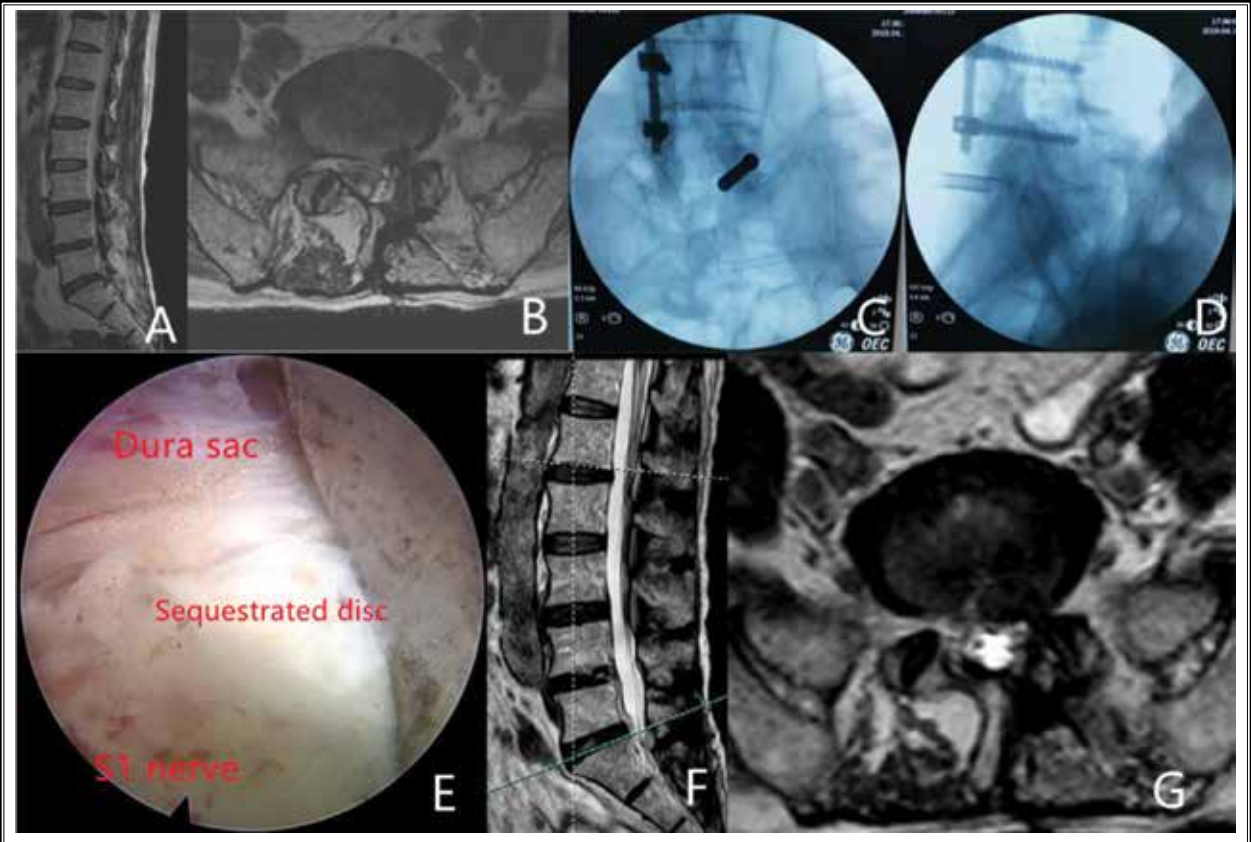

Fig. 1. *A 39-year-old woamn complained about numbness and pain of left lower limb for 3 months. He was performed with L3/4 discectomy 21 years ago and L4/5 decompression surgery with implants 8 years ago. A. Sagittal T2 MRI showed L3/4 disc herniation and interbody fusion with implants at L4/5. B. Axial T2 MRI shows L3/4 disc herniation and left narrowed lateral recesses at L3/4. C. Lateral fluoroscopic view shows the beveled tubular retractor positioned in the L3/4 foramen. D. AP fluoroscopic view showed the beveled tubular retractor in the left L3/4 foramen and the reamer reached internal margin connection of L3 and L4 pedicles. E. Endoscopic view after the foraminoplasty showed decompressed L4 nerve and resected L3/4 disc. F. Postoperative sagittal T2 MRI showed discectomy at L3/4. G. Postoperative axial T2 MRI shows L3/4 disc herniation and left narrowed lateral recesses were fully decompressed.*

Once the needle reached the SAP of the inferior vertebra, the needle tract was dilated with a series of dilators. Then foraminoplasty was performed to dilate the intervertebral foramen. The hypertrophic ligamentum flavum, the medial aspect of the hyperplastic SAP, and the herniated disc were identified under an endoscope and removed with the appropriate type of forceps and a bipolar electrode. For patients with bilateral symptoms, central and contralateral disc herniation was removed until the contralateral nerve roots could be seen.

PEID

For patients undergoing PEID, the skin entry point toward the lateral edge of the interlaminar window on the symptomatic side and level were identified under fluoroscopic guidance (Fig. 2). A 10 mm skin incision was created through subcutaneous tissue and thoracolumbar fascia, and then a blunt dilator was inserted through the incision toward the inferior border of the upper lamina. The paraspinal muscles were dissected from the lamina using a blunt dilator.

After dilation, a working cannula with a bevel was placed on the lamina's surface with the bevel placed on the inferior border of the upper lamina. The level and the entry trajectory were re-identified using a C-arm. Then the endoscope was introduced. The inferior border of the upper lamina, the ligamentum flavum, the superior border of the inferior lamina, and the medial aspect of the facet joint were identified and removed with a full-endoscopic reamer and Kerrison rongeur, revealing the neural tissue as well as the herniated disc which were removed using a bipolar electrode and the appropriate forceps.

For patients with obvious disc herniation, a discectomy was performed while protecting the nerve root and neural sac using the working cannula. For patients with bilateral stenosis, the endoscope was directed toward the contralateral side above the dural sac and ligamentum flavum was removed using an undercut-

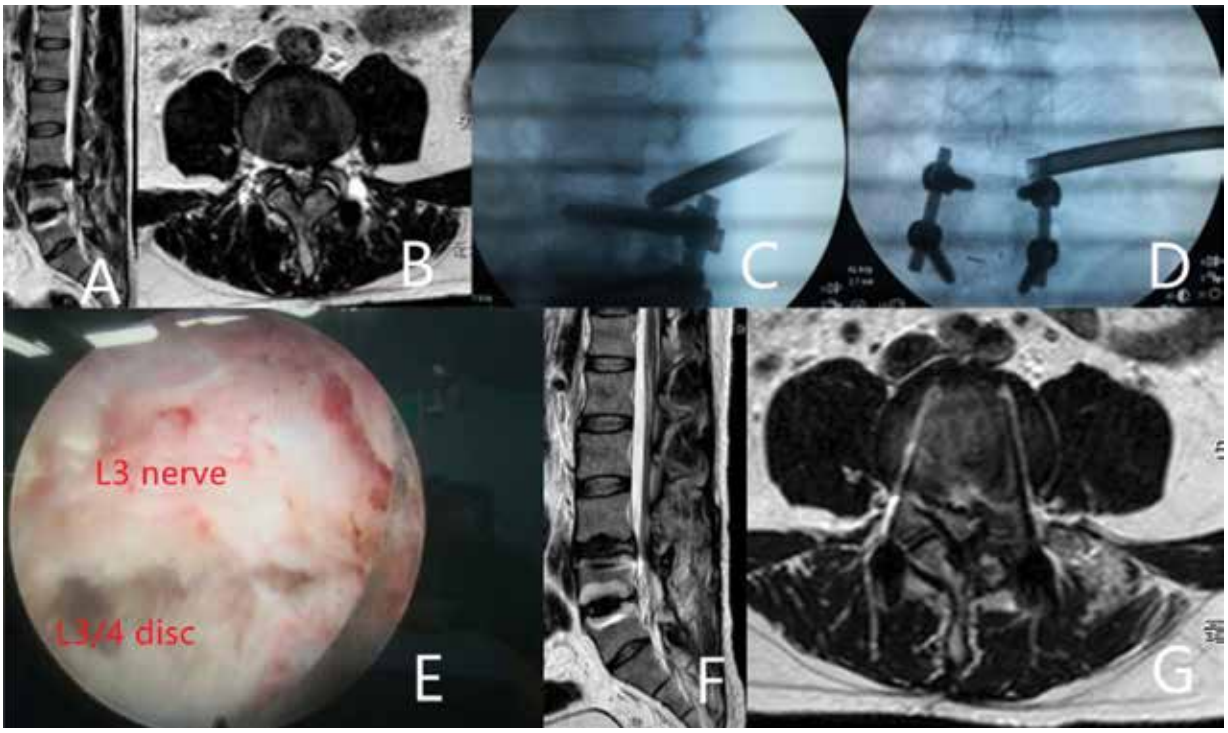

Fig. 2. *A 73-year-old male patient complained about lumbar pain and numbness and pain of right lower limb for 2 months. He was performed with L4/5 discectomy and fusion surgery with implants 17 years ago. A. Sagittal T2 MRI showed interbody fusion with implants at L4/5 and L5/S1 sequestrated disc. B. Axial T2 MRI shows L5/S1 nucleus pulposus sequestrated. C and D. AP fluoroscopic view showed the beveled tubular retractor in the right L5/S1 interlaminar space. E. Endoscopic view after the foraminoplasty showed dura sac, S1 nerve and sequestrated disc. E and F. Postoperative sagittal and axial T2 MRI showed L5/S1 sequestrated disc was completely removed.*

ting technique until the medial aspect of the contralateral side could be reached. Decompression was finished until free movement and pulse of the dura mater and traversing root and no more residual nucleus pulposus was left.

After the surgery, the patients were transferred back to the spinal ward in order to monitor postoperative problems. When no complications occurred, patients were allowed to move with waist protection one day later. Most patients were discharged within 48 hours after finishing their postoperative examination.

Outcome Assessment

Patients were required to follow-up at 3 months, 6 months, one year, and at yearly intervals for at least 2 years. Clinical outcomes and complications were collected through chart review. Clinical outcomes were determined by the average Visual Analog Scale (VAS) score, Oswestry Disability Index (ODI) score, and modified MacNab criteria at both preoperation and postoperation. VAS scores (0 – 10 mm scale) were used to measure pain severity before and after surgery and at follow-up. ODI scores were used to describe the extent to which back or leg pain interfered with the patient's life and to evaluate the effectiveness of the surgical treatments. Modified MacNab criteria was used to assess the postoperative satisfaction of the patient with the surgery's outcome. This criteria consists of 4 categories: excellent, good, fair and poor. All variables were collected preoperatively, at postoperative 3 months, 6 months, and one year, and the last follow-up in our study.

Statistical Analysis

Statistical analysis was conducted with IBM SPSS Statistics 19.0 (IBM Corporation). All continuous data are presented as mean plus SD. VAS and ODI scores at preoperative; postoperative 3 months, 6 months, and one year; and at the last follow-up were matched and compared with a paired t test. The comparison between PETD and PEID in operative time, fluoroscopy time, hospital stay time, complications, and VAS and ODI scores were analyzed using the independent samples t test. A P value < 0.05 was considered statistically significant.

Result

In this study, a total of 68 patients were included; their average age was 63.6 years old. Their mean body mass index (kg/m^2) was 25.3 ± 2.6. The interval between the reoperation and the primary operation was 6.0 ± 3.9 years. The average follow-up period was 31.7 ± 18.5 months. The location of ASDs was as follows: 2 cases at L1/L2, 4 cases at L2/L3, 16 cases at L3/L4, 24 cases at L4/L5, and 22 cases at L5/S1. Before the revision surgery, 32 patients had radicular pain, 26 patients had lower limb numbness, and 40 patients had neurologic intermittent claudication (Table 1).

Among the 68 patients, 40 patients underwent PEID and 28 patients underwent PETD. The location of ASDs in the PEID and PETD groups is presented in Table 2.

The average operation time in the PETD group and PEID group was 96.0 ± 35.6 and 95.7 ± 38.8 minutes respectively, with a P value = 0.970. The average fluoroscopy time in the PETD group and PEID group was 11.8 ± 2.4 and 5.3 ± 1.6 respectively. with a P value = 0.000. The average hospital stay time in the PETD group and

Table 1. *Demographic characteristics and clinical data of included patients.*

Variables	
Number of patients included	68
Gender	
Men	40
Women	28
Age, years	63.6 ± 11.6
BMI (kg/m^2)	25.3 ± 2.6
Interval between the reoperation and primary operation	6.0 ± 3.9
ASD segment distribution	
L1/L2	2
L2/L3	4
L3/L4	16
L4/L5	24
L5/S1	22
Follow-up time, months	31.7 ± 18.5
Patients' symptoms	
Radicular pain (Right/Left leg pain)	32
Sphincter dysfunction	0
Lower limb numbness/weakness	26
Intermittent claudication	40
Comorbidities	
Hypertension	26
Diabetes mellitus	18
Cardiovascular diseases	10
Respiratory diseases	2
Renal/ureteral disease	2

BMI: body mass index, ASD: adjacent segment disease

PEID group was 5.7 ± 1.9 and 5.2 ± 2.3 days respectively, with a *P* value = 0.289.

Modified MacNab criteria were applied to evaluate the outcomes in this study (Table 2). The good-to-excellent rate was 88.2%. Eight patients did not achieve a good outcome until they underwent a second revision surgery. The preoperative VAS score in the PETD group and PEID group was 7.14 ± 1.01 and 7.15 ± 1.29 respectively, with a *P* value = 0.981. The preoperative ODI score in the PETD group and PEID group was 43.00 ± 4.20 and 42.00 ± 5.36 respectively, with a *P* value = 0.412.

All the patients had significant improvement at postoperative 3 months, 6 months, one year, and at the last follow-up. There were no significant statistical differences in the VAS and ODI scores at postoperative 3 months, 6 months, one year, and at the last follow-up between the PETD and PEID groups, with a *P* value > 0.05 (Figs. 3 and 4).

No dural tear, nerve root injury, iatrogenic segmental instability, or infection was found in this study. Revision surgery occurred in 8 patients, including 6 patients who had PETD and 2 patients who had PEID. Five patients who had PETD underwent decompression surgery with instruments and one patient received a second PETD surgery because of the re-herniation of the lumbar disc. One patient who had PEID received revision surgery to remove the residual bone which was causing postoperative lower limb numbness, and one patient who had PEID underwent posterior decompression surgery with instruments because of lumbar disc herniation recurrence. There was a significant statistical difference in the revision rate between the 2 approaches with a *P* value = 0.039.

Table 2. *Summary of operative features, clinical outcomes and complications.*

Variables	PETD	PEID	*P* value
ASD segment distribution			0.458
L1/L2	2	0	
L2/L3	2	2	
L3/L4	8	8	
L4/L5	12	12	
L5/S1	4	18	
Operative time, min	96.0 ± 35.6	95.7 ± 38.8	0.970
Fluoroscopy time, s	11.8 ± 2.4	5.3 ± 1.6	0.000*
Hospital stays, days	5.7 ± 1.9	5.2 ± 2.3	0.289
Complications			0.039*
Dural tear	0	0	
Postoperative dysesthesia	0	0	
Recurrence	6	1	
Residual bone compression	0	1	
Modified MacNab satisfaction			
Good-Excellent	22	38	0.039*
Poor-Fair	6	2	
VAS			
Preoperative	7.14 ± 1.01	7.15 ± 1.29	0.981
Postoperative	2.71 ± 0.60	2.60 ± 0.93	0.569
3-month follow-up	2.50 ± 0.51	2.40 ± 0.67	0.509
6-month follow-up	2.64 ± 0.49	2.45 ± 0.81	0.267
1-year follow-up	2.14 ± 0.65	2.25 ± 0.63	0.498
Last follow-up	1.75 ± 0.80	1.90 ± 0.84	0.463
ODI		±	
Preoperative	43.00 ± 4.20	42.00 ± 5.36	0.412
Postoperative	16.00 ± 4.75	16.4 ± 3.98	0.708
3-month follow-up	15.20 ± 3.66	16.30 ± 3.09	0.191
6-month follow-up	15.36 ± 3.54	15.40 ± 1.71	0.934
1-year follow-up	14.57 ± 2.23	14.65 ± 1.76	0.872
Latest follow-up	11.57 ± 3.00	12.10 ± 3.42	0.512

VAS: Visual Analog Scale, ODI: Oswestry Disability Index

Discussion

Lumbar degenerative disease is one of the most common causes of low back pain, radiculopathy, and/or neurogenic claudication among the adult population (1). Earlier reports have assumed that dehydration within the nucleus pulposus and shrinkage, a mechanical retraction of herniated material back into the annulus fibrosus, and enzymatic degradation and phagocytic reduction via immunohistologic mediators are 3 leading causes of lumbar disc degeneration (1,17-20).

With disc degeneration and disc herniation, intervertebral height loss will occur. This may produce instability and cause osteophyte formation, ligamentum flavum degeneration, and facet hypertrophy (21). These changes will cause spinal canal narrowing and dural sac and nerve root compression, producing neurogenic symptoms.

When conservative treatment is ineffective, surgical treatment is recommended. Posterior decompression and fusion surgery have been widely used to manage this kind of disease and have achieved excellent surgical outcomes, adequate dural sac decompression, and neurological symptoms relief. Compared with fusion without instruments, instruments can increase

earlier stability and fusion rate in the follow-up period and permit early patient mobility.

However, fusion eliminates the motion of the surgical segments, increases mechanical stress at the adjacent segments, and irreversibly alters normal spine biomechanics (5-7). Abnormal loading and motion can accelerate degeneration at the adjacent segments and may cause corresponding clinical symptoms (8-10). A comprehensive review article reported that the incidence of radiographic adjacent segment degeneration ranged from 8% to 100%, while the incidence of symptomatic adjacent segment degeneration varied from 5.2% to 18.5% (21-23). However, only a small percentage of symptomatic adjacent segment degeneration required a second surgery.

Revision surgery has been recommended to treat symptomatic adjacent segmental disease after ineffective conservative treatment (24-28). Several procedures have been reported to treat symptomatic ASD, including extension fusion surgery with instruments, decompression alone, oblique lumbar interbody fusion, and percutaneous endoscopic lumbar decompression surgery (24,26,28).

Previously, posterior extension fusion surgery has been the main surgical method for ASD. This surgery not only can achieve adequate decompression, but it also can restore earlier stability and a higher fusion rate at follow-up. Besides implant replacement with longer rods, several different methods have been used to perform extension surgery, including cortical bone trajectory (CBT) screws and rod connectors. Rodriguez, et al (29) performed revision surgery in 5 patients with symptomatic ASD using CBT screws in the pedicle of the fused upper vertebra without removing the original fixation. Satisfactory outcomes and solid interbody fusions were achieved within 10 to 15 months without complications. Tan et al (30) performed revision surgery in a patient with symptomatic ASD and achieved satisfactory results using a designed connector rod to connect the primary implants with new pedicle screws. However, these methods were limited by the primary surgery, which had left enough of a gap to insert CBT screws or connect the rod connectors. However, these methods had to expose the adjacent implant, which still caused great damage to the facet joints, spinous processes, and lumbar vertebrae ligaments (28).

With the development of endoscopic equipment and surgical skills, PELD is widely used to treat lumbar herniated discs and lumbar spinal stenosis. It is considered to be an effective and minimally invasive option for lumbar degenerative disease (31-34). For ASD without instability, PELD is a feasible surgical option (35-37) that can remove the protruded disc, hyperplastic ligaments, and articular processes to achieve a good surgical outcome with a smaller incision while preserving the paraspinal muscles. In addition, due to less damage to vertebral elements and the endoscope's magnification, PELD causes fewer dural sac injuries. What's more, PELD was not restricted by the primary surgery. Telfeian (38) reported surgical outcomes of 9 patients with an ASD using transforaminal endoscopic surgical access; 66.7% of them (6/9) achieved good results. In Gu, et al's report (37), 25 elderly patients with ASD underwent PTED; 84.0% (21/25) achieved excellent or good clinical outcomes. In our study, 68 patients with ASD underwent PELD, and 88.2% achieved good-to-excellent outcomes.

However, PELD is not suitable for all types of

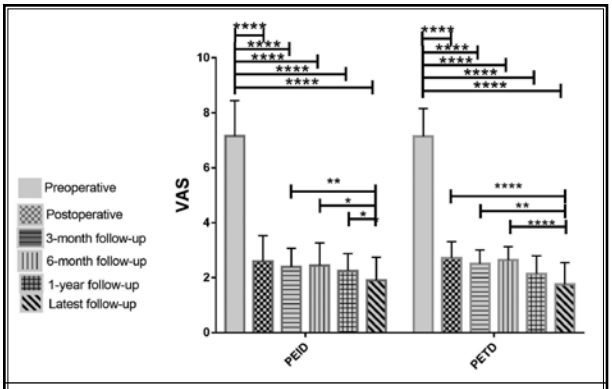

Fig. 3. *Comparisons of VAS scores between preoperative, postoperative, at 3-month, 6-month, 1-year, and latest follow-up.*

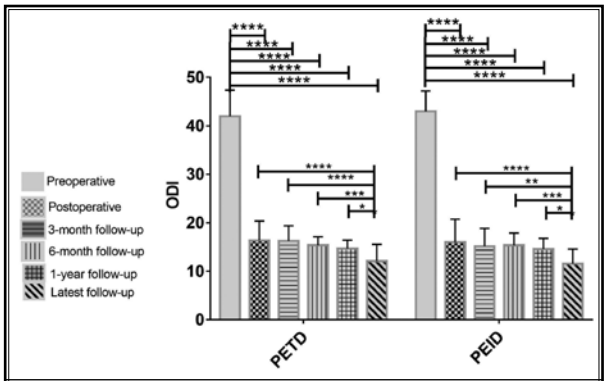

Fig. 4. *Comparisons of ODI scores between preoperative, postoperative, at 3-month, 6-month, 1-year, and latest follow-up.*

ASDs. In our opinion, PELD can be applied to single adjacent segment degeneration due to disc herniation or moderate lumbar stenosis without instability. For those patients who have instability, multiple segment degeneration, acute cauda equina syndrome, or severe lumbar stenosis, we think conventional extension surgeries are more suitable.

The debate about performing PELD for ASD is whether PELD will cause instability and have a higher recurrence rate chance. Posterior fusion with implants can increase the mechanical stress at the adjacent segments and alter normal spine biomechanics irreversibly, which may increase the recurrence rate of ASD. Telfeian et al (38) reported 3 failures in 9 consecutive patients with ASD who underwent transforaminal endoscopic treatment. However, Gu et al (37) reported just one case of recurrence in 25 patients with ASD who underwent transforaminal endoscopic treatment. In our study, 8 of 68 patients received revision surgery; 6 of them had undergone PETD. Compared with PEID, PETD seems to have a higher revision rate in treating ASD.

We think PEID may be a better approach to treat ASD. Firstly, the etiology of ASD is hypertrophic articular processes and a thickened ligamentum flavum. With the help of progressive endoscopic tools like trephines and burs, the PEID approach can remove the blocked hypertrophic facet joint and thickened ligamentum flavum under completely direct vision; help the working sheaths reach the target area; and completely decompress the central, paracentral, and even contralateral type disc herniation with better mobility (39).

Secondly, a high iliac crest and narrow foramen may restrict PETD's ability to access the foramen when treating L5/S1 disc herniation. The small foramen, the hypertrophic facet joint and the large punching angle prevent the working cannula to get access to the extruded angle. The PEID approach can access the target area and remove the sequestered or dislocated fragments without the limitation of a bony foramen and blockage of the pelvis (39,40).

Thirdly, the PEID approach is more akin to open surgery and offers a clearer microscopic view of anatomical structures compared to PETD, which aligns better with the operating habits of most spine surgeons (39,40). In addition, PEID utilizes a posterior interlaminar approach and can get to the target area easily, which significantly reduces radiation times (39,40). This is beneficial for the health of both patients and surgeons. However, the PEID approach has its limitations. For certain types of ASD, such as foraminal stenosis, foraminal disc herniations, or lateral disc herniations, PETD has more advantages than PEID.

Limitations

Our study has several limitations. Firstly, the number of patients included in this study was small. More patients are needed in any further study. Secondly, the follow-up time was limited. There is still no conclusion about whether primary decompression with instruments increases the reoperation rate after PELD; a longer follow-up is needed in the future. Thirdly, this study was a clinical retrospective study. Randomized or controlled trials are needed in the future in order to achieve high levels of evidence. Fourthly, there were debates about PELD approach choices which may affect the comparison results between PETD and PEID. In our study, the approaches were mainly determined by the level and types of disc herniation, and the surgeons' preference. More patients with ASD patients at different levels and types of disc herniation and surgical approaches in the future are needed to eliminate these biases.

Conclusion

PELD surgery is a feasible option for ASD following lumbar decompression surgery with instruments. It not only can achieve good surgical outcomes, but also has the advantage of less trauma, a shorter treatment time, less blood loss, and a quick recovery. However, the instruments will continue to increase the mechanical stress at the adjacent segments, and there is still no conclusion about whether the primary decompression with instruments increases the reoperation rate after this PELD. In our study, patients undergoing PETD seem to have a higher recurrence rate than those undergoing PEID. Also, PEID seems to be a better approach for treating ASD. More patients and a longer follow-up are needed in further studies in order to better understand the possible utility of endoscopic surgery in symptomatic ASD.

Data Availability

The data used in this study are available from the corresponding author upon request.

Ethical Approval

This study was approved by the Affiliated Hospital of Qingdao University's Institutional Review Board. All study patients signed a consent form for this study.

Author Contributions

XM and JG designed the study, CS and WT drafted the manuscript, and GL, XJ, XW and KZ were responsible for the data collection. CZ and GZ measured the radiographic data, carried out the statistical analyses, and revised the article. All authors read and approved the final manuscript.

Acknowledgements

We acknowledge CZ and GZ for assistance with the statistical analysis and article revision.

References

1. Hakan T, Gürcan S. Spontaneous regression of herniated lumbar disc with new disc protrusion in the adjacent level. *Case Rep Orthop* 2016; 2016:1538072.
2. Macki M, Hernandez-Hermann M, Bydon M, et al. Spontaneous regression of sequestrated lumbar disc herniations: Literature review. *Clin Neurol Neurosurg* 2014; 120:136-141.
3. Rahmathulla G, Kamian K. Lumbar disc herniations 'to operate or not' patient selection and timing of surgery. *Korean J Spine* 2014; 11:255-257.
4. Lai PL, Chen LH, Niu CC, et al. Relation between laminectomy and development of adjacent segment instability after lumbar fusion with pedicle fixation. *Spine (Phila Pa 1976)* 2004; 29:2527-2532; discussion 2532.
5. Chen CS, Cheng CK, Liu CL, et al. Stress analysis of the disc adjacent to interbody fusion in lumbar spine. *Med Eng Phys* 2001;23:483-491.
6. Dekutoski MB, Schendel MJ, Ogilvie JW, et al. Comparison of in vivo and in vitro adjacent segment motion after lumbar fusion. *Spine (Phila Pa 1976)* 1994; 19:1745-1751.
7. Weinhoffer SL, Guyer RD, Herbert M, et al. Intradiscal pressure measurements above an instrumented fusion. A cadaveric study. *Spine (Phila Pa 1976)* 1995; 20:526-531.
8. Ekman P, Möller H, Shalabi A, et al. A prospective randomised study on the long-term effect of lumbar fusion on adjacent disc degeneration. *Eur Spine J* 2009; 18:1175-1186.
9. Lee JC, Kim Y, Soh JW, et al. Risk factors of adjacent segment disease requiring surgery after lumbar spinal fusion: Comparison of posterior lumbar interbody fusion and posterolateral fusion. *Spine (Phila Pa 1976)* 2014; 39:E339-E345.
10. Ghiselli G, Wang JC, Bhatia NN, et al. Adjacent segment degeneration in the lumbar spine. *J Bone Joint Surg Am* 2004; 86:1497-1503.
11. Tan Q, Wang D, Yang Z, et al. Implant preservation versus implant replacement in revision surgery for adjacent segment disease after thoracolumbar instrumentation: A retrospective study of 43 patients. *World Neurosurg* 2021; 150:e511-e519.
12. Dantas FL, Dantas F, Caires A, Cariri GA, Fonseca Filho GA, Botelho RV. Adjacent segment degeneration after posterolateral lumbar fusion: results and complications of posterior revision surgery. *J Neurosurg Sci* 2023; 67:446-453.
13. Allen RT, Garfin SR. The economics of minimally invasive spine surgery: The value perspective. *Spine (Phila Pa 1976)* 2010; 35:S375-S382.
14. Li XF, Jin LY, Lv ZD, et al. Efficacy of percutaneous transforaminal endoscopic decompression treatment for degenerative lumbar spondylolisthesis with spinal stenosis in elderly patients. *Exp Ther Med* 2020; 19:1417-1424.
15. Cheng XK, Cheng YP, Liu ZY, et al. Percutaneous transforaminal endoscopic decompression for lumbar spinal stenosis with degenerative spondylolisthesis in the elderly. *Clin Neurol Neurosurg* 2020; 194:105918.
16. Sriphirom P, Siramanakul C, Chaipanha P, et al. Clinical outcomes of interlaminar percutaneous endoscopic decompression for degenerative lumbar spondylolisthesis with spinal stenosis. *Brain Sci* 2021; 11:83.
17. Orief T, Orz Y, Attia W, et al. Spontaneous resorption of sequestrated intervertebral disc herniation. *World Neurosurg* 2012; 77:146-152.
18. Macki M, Hernandez-Hermann M, Bydon M, et al. Spontaneous regression of sequestrated lumbar disc herniations: Literature review. *Clin Neurol Neurosurg* 2014; 120:136-141.
19. Geiss A, Larsson K, Rydevik B, et al. Autoimmune properties of nucleus pulposus: an experimental study in pigs. *Spine (Phila Pa 1976)* 2007; 32:168-173.
20. Tsarouhas A, Soufla G, Katonis P, et al. Transcript levels of major MMPs and ADAMTS-4 in relation to the clinicopathological profile of patients with lumbar disc herniation. *Eur Spine J* 2011; 20:781-790.
21. Park P, Garton HJ, Gala VC, et al. Adjacent segment disease after lumbar or lumbosacral fusion: Review of the literature. *Spine (Phila Pa 1976)* 2004; 29:1938-1944.
22. Xia XP, Chen HL, Cheng HB. Prevalence of adjacent segment degeneration after spine surgery: A systematic review and meta-analysis. *Spine (Phila Pa 1976)* 2013; 38:597-608.
23. Booth KC, Bridwell KH, Eisenberg BA, et al. Minimum 5-year results of degenerative spondylolisthesis treated with decompression and instrumented posterior fusion. *Spine (Phila Pa 1976)* 1999; 24:1721-1727.
24. Ryu DS, Park JY, Kuh SU, et al. Surgical outcomes after segmental limited surgery for adjacent segment disease: The consequences of makeshift surgery. *World Neurosurg* 2018; 110:e258-e265.
25. Drysch A, Ajiboye RM, Sharma A, et al. Effectiveness of reoperations for adjacent segment disease following lumbar spinal fusion. *Orthopedics* 2018; 41:e161-e167.
26. Miwa T, Sakaura H, Yamashita T, et al. Surgical outcomes of additional posterior lumbar interbody fusion for adjacent segment disease after single-level posterior lumbar interbody fusion. *Eur Spine J* 2013; 22:2864-2868.
27. Phillips FM, Carlson GD, Bohlman HH, et al. Results of surgery for spinal stenosis adjacent to previous lumbar fusion. *J Spinal Disord* 2000; 13:432-437.
28. Yang Z, Chang J, Sun L, et al. Comparing oblique lumbar interbody fusion with lateral screw fixation and

transforaminal full-endoscopic lumbar discectomy (OLIF-TELD) and posterior lumbar interbody fusion (PLIF) for the treatment of adjacent segment disease. *Biomed Res Int* 2020; 2020:4610128.

29. Rodriguez A, Neal MT, Liu A, et al. Novel placement of cortical bone trajectory screws in previously instrumented pedicles for adjacent-segment lumbar disease using CT image-guided navigation. *Neurosurg Focus* 2014; 36:E9.
30. Tan QC, Liu ZX, Zhao Y, et al. Biomechanical comparison of four types of instrumentation constructs for revision surgery in lumbar adjacent segment disease: A finite element study. *Comput Biol Med* 2021; 134:104477.
31. Heo DH, Quillo-Olvera J, Park CK. Can percutaneous biportal endoscopic surgery achieve enough canal decompression for degenerative lumbar stenosis? Prospective case-control study. *World Neurosurg* 2018; 120:e684-e689.
32. Ahn Y. Percutaneous endoscopic decompression for lumbar spinal stenosis. *Expert Rev Med Devices* 2014; 11:605-616.
33. Li X, Bai J, Hong Y, et al. Minimum seven-year follow-up outcomes of percutaneous endoscopic lumbar discectomy for lumbar degenerative disease. *Int J Gen Med* 2021; 14:779-785.
34. Wang Y, Dou Q, Yang J, et al. Percutaneous endoscopic lumbar decompression for lumbar lateral spinal canal stenosis: Classification of lateral region of lumbar spinal canal and surgical approaches. *World Neurosurg* 2018; 119:e276-e283.
35. Ba Z, Pan F, Liu Z, et al. Percutaneous endoscopical transforaminal approach versus PLF to treat the single-level adjacent segment disease after PLF/PLIF: 1-2 years follow-up. *Int J Surg* 2017; 42:22-26.
36. Liu XM, Liu ZH, Pan YQ, et al. Full-endoscopic transforaminal procedure to treat the single-level adjacent segment disease after posterior lumbar spine fusion: 1-2 years follow-up. *Math Biosci Eng* 2019; 16:7829-7838.
37. Gu G, Wang C, Gu X, et al. Percutaneous transforaminal endoscopic discectomy for adjacent segment disease after lumbar fusion in elderly patients over 65 years old. *World Neurosurg* 2018; 112:e830-e836.
38. Telfeian AE. Transforaminal endoscopic surgery for adjacent segment disease after lumbar fusion. *World Neurosurg* 2017; 97:231-235.
39. Nie H, Zeng J, Song Y, et al. Percutaneous endoscopic lumbar discectomy for L5-S1 disc herniation via an interlaminar approach versus a transforaminal approach: A prospective randomized controlled study with 2-Year follow up. *Spine (Phila Pa 1976)* 2016; 41 Suppl 19:B30-B37.
40. Huang Y, Yin J, Sun Z, et al. Percutaneous endoscopic lumbar discectomy for LDH via a transforaminal approach versus an interlaminar approach: A meta-analysis. *Orthopade* 2020; 49:338-349.