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Outcomes of percutaneous endoscopic lumbar discectomy via transforaminal approach in stable low-grade single level lumbar spondylolisthesis: a retrospective study

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ABSTRACT

Background: Lumbar spondylolisthesis (LS) is a common degenerative spinal disease treated by fusion. Percutaneous endoscopic lumbar discectomy (PELD) reduces damage to tissues, blood loss, and hospital stay. Transforaminal PELD in stable low-grade LS has limited clinical and radiological outcomes, and inpatient department (IPD) cost comparisons with transforaminal lumbar interbody fusion (TLIF) are rare. This study evaluated clinical and radiographic outcomes and PELD versus TLIF IPD cost.

Methods: This retrospective study included 24 patients with stable low-grade single-level LS who underwent transforaminal PELD between December 2021 and November 2022. Clinical outcomes were assessed using visual analogue scale (VAS), Oswestry disability index (ODI), modified MacNab criteria, walking distance improvement, and patient satisfaction. Radiographic outcomes were evaluated by percentage slip preoperatively and at final follow-up. IPD costs were compared between PELD and TLIF.

Results: The mean age was 52 years, and L4-5 was the most common level. All patients had Grade 1 spondylolisthesis. Mean operative time was 53.17±26.14 minutes, blood loss was 8.29±10.45 mL, hospital stay was 2.96±1.16 days, and follow-up was 6.7 months. VAS, ODI, and walking distance improved significantly ($p<0.001$). Modified MacNab outcomes were excellent in 75% and good in 20.8%. Mean slip percentage showed no significant change ($p=0.458$). Mean IPD cost was 64,785.95 THB (1,754.69 EUR) for PELD and 98,392.36 THB (2,664.90 EUR) for TLIF.

Conclusions: Transforaminal PELD is a safe and effective minimally invasive option for stable low-grade single-level LS, providing favorable short-term outcomes without radiographic progression and lower IPD cost than TLIF.

Keywords: Spondylolisthesis, Percutaneous endoscopic lumbar discectomy, Endoscopic discectomy, Transforaminal full endoscopic discectomy

INTRODUCTION

Lumbar spondylolisthesis (LS) is a common spinal disorder which described as an upper vertebra slipping from normal alignment upper vertebra slipping from normal alignment over the vertebra below it. The incidence of LS has been reported approximately 4-8% across all ages and with a higher prevalence in elderly patients.[1,2] This pathological abnormality leads to narrowing of the spinal canal and neural foramen. The clinical presentation of these patients is pain radiate into the lower extremity, numbness in the legs and feet. Traditional open approach for decompression with instrumented and fusion procedures has been performed as a gold standard for the treatment of LS due to the extensive decompression of the nerve roots.[3] Nevertheless, LS often

occurs in elderly patients with complex medical conditions causing a high risk of major surgery.

In recent years, PELD has become increasingly popular and has been widely used in clinical practice, its indication has been extended to foraminotomy and endoscopic assisted interbody fusion, not only discectomy alone.[4,5] PELD has many advantages, for instance, less soft tissue traumatization, lower blood loss, shorter hospital stay compared with traditional open approach. Importantly, PELD can be used to treat LS patients under local anesthesia and to preserve the posterior structure especially transforaminal approach.[6-8] Short and middle term outcomes following PELD for LS patients in several studies have provided good results and the patients can return to normal life without any impact on instability.[9-12]

At the present, there are very few studies of PELD via transforaminal approach evaluated both clinical and radiographic outcome in the same study. Moreover, there is no study evaluated IPD cost comparing between PELD and fusion surgery TLIF.

The purpose of this study was to evaluate the clinical, radiographic outcome of patients with stable low-grade single level LS who underwent PELD via transforaminal approach in one year and IPD cost comparing between PELD and TLIF.

METHODS

Patient selection

This study was approved by the ethics committee of the medical institution and written informed consent was obtained from all participants.

We conducted a retrospective study collecting data from 24 consecutive patients who underwent percutaneous transforaminal endoscopic discectomy surgery out of the patients who were diagnosed low-grade single level spondylolisthesis since December 2021 to November 2022 in our hospital (Thabo Crown Prince Hospital, TCPH).

Patients were selected for treatment based on the results of their physical exam, characteristic of dermatomal pain pattern, film radiograph and magnetic resonance imaging (MRI).

The inclusion criteria were as follows: patients diagnosed with low-grade spondylolisthesis according to the Meyerding classification were included (grade I: 0-25%, grade II: 25-50%), without dynamic instability by flexion-extension lumbar film x-rays, neurogenic claudication with unilateral or bilateral leg symptoms, failed conservative treatments which included medication, physical therapy and epidural steroid injections more than 3 months.

The exclusion criteria were as follows: The percent slippage of spondylolisthesis was over 50%, segmental instability (translation >3 mm from dynamic radiographs), pathological conditions such as, history of lumbar spine surgery, spinal inflammation, infection, trauma, or tumor. Preoperative demographic characteristics, surgical data, outcomes and complications were recorded.

Surgical procedures

In the PELD procedure, patients received either general or local anesthesia, depending upon the preferences of the anesthesiologist and the patients. Patients were positioned prone on a radiolucent table for standard anteroposterior and lateral radiographs during intraoperative fluoroscopy, with the surgical level indicated by C-arm fluoroscopy. The Joimax TESSYS endoscopic equipment had been used for the procedure (Foraminoscope; WL 171 mm/OD 6.3 mm/30°/WchD 3.7 mm/2×IC 1.5 mm). The entry point was located on the more symptomatic side and formed by penetrating the skin 10 to 15 cm lateral to the midline. During the surgery, we administered 2% lidocaine for local anesthesia. The patient was able to communicate with the surgeon during the procedure, so avoid intraoperative nerve root damage. Under both general anesthesia and local anesthesia, an 18-G (150 mm) needle has been used to to anesthetize the trajectory with 5 mL of lidocaine, targeting the foramen and the articular process with 3-5 mL of the anesthesia. A guidewire was inserted through the needle, and a skin incision measuring 0.8 to 1 cm was created at the guidewire's entry position.

Inside-out technique (intradiscal) for discectomy

A guide wire was inserted through the spinal needle, a tapered cannulated obturator was inserted along the guide wire, and last a bevel-ended, oval-shaped, working cannula was inserted into the disc along the obturator. (The Joimax TESSYS) endoscopic system was inserted through the cannula. The disc material was removed using endoscopic forceps by moving from the central portion to the lateral portion of the disc space (Figure 1 A). The herniated tissues were released and removed using endoscopic forceps rotating the working bevel toward the migrated disc fragment. If the disc fragment remained in the epidural space, the working cannula was retrieved to the epidural space to locate the remnant disc using a flexible curved probe and forceps after cutting the posterior longitudinal ligament. After the herniated fragment was completely removed, the endoscope was removed, and the surgical wounds were sutured (Figure 1 B).[15]

Outside-in technique (intracanal) for discectomy

The needle was advanced and placed in the disc space through Kambin’s triangle, between the exiting and traversing nerves. An AP fluoroscopic view was used so the disc space was not entered before the needle was past medial border of the pedicle and on the posterior vertebral

line on the lateral view. This ensured that the needle was not in the central spinal canal, avoiding the dural sac.[2]

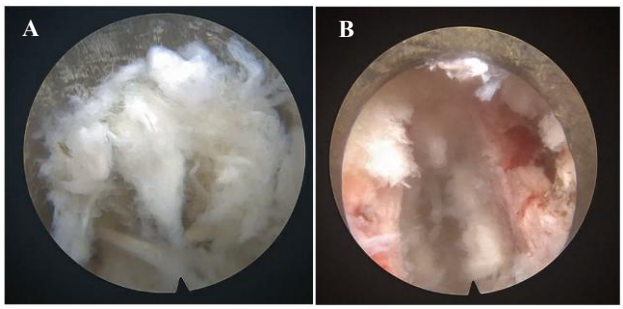

Figure 1: (A) (Inside-out technique) intradiscal disc removal and (B) (inside-out technique) complete discectomy and free form compression by removing disc remnant backward.

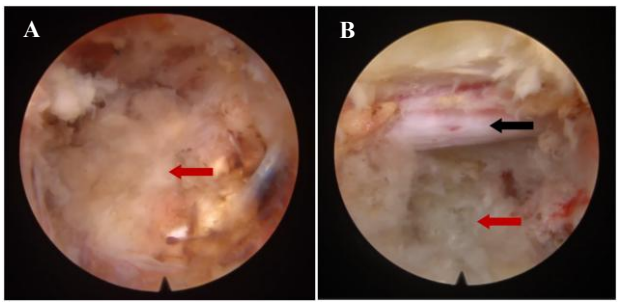

Figure 2: (A) (Outside-in technique) identified disc and structure, annulus and disc protrusion (red arrow) and (B) (outside-in technique) the area is decompressed, and the traversing nerve root (black arrow) is identified through direct visualization until it's free from disc compression (red arrow).

Rotating the beveled cannula and endoscope allowed for visualization of the annulus and exiting and traversing nerve roots. When the scope is docked in the neural foramen, the anatomical view is that of Kambin's triangle. The epidural space, traversing nerve root, and SAP are visualized above the horizon line of the scope and the disc pathology below the horizon line. The beveled end of the working cannula was also used as a nerve root retractor. The herniation is then located under direct visualization from the annulus of the disc (Figure 2 A). Portions of the herniation are removed with forceps graspers until the neural foramen is open enough for structures to be identified clearly. The bipolar radiofrequency is used for further blunt dissection and hemostasis. The area is decompressed, and nerves roots are identified under direct visualization until noted to be free of compression from disc (Figure 2 B). Finally, adequate hemostasis was performed, and the surgical wounds were sutured.

Outcomes measurement

The clinical outcomes were evaluated by an independent assessor using the (VAS, full score=10) for back pain and leg pain, ODI scores for determination of impairment (scores of ODI range from 0 to 100; 100 represented the highest level of impairment).[16]

These clinical outcomes were evaluated preoperatively, at 1-month, 3-month and final follow-up postoperatively. The global outcome was evaluated using the modified MacNab criteria defined as excellent, good, fair, and poor at final follow-up.[17] Walking distance improvement prior to and after the operation was rated by using better, no change, or worse. Patient's satisfaction was rated by using very satisfied, satisfied, or unsatisfied at the final follow-up.

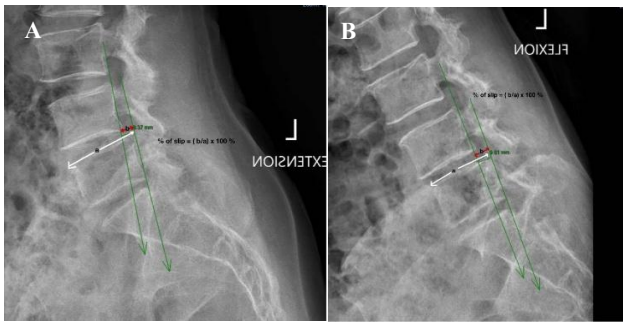

Figure 3 (A and B): The percentage of slippage in spondylolisthesis was assessed using lateral radiographs of the lumbar spine.

*The measurement was calculated as the distance between the posterior line of the vertebral body between the displaced vertebrae and the parallel line extending through the posterior rim of the displaced vertebrae (b) to the anterior and posterior dimensions of the sliding vertebral body (a): Percentage of slide=(b/a)×100%.

The radiological outcome was also evaluated by an independent assessor using percent slippage of spondylolisthesis for the progression of LS assessment. All patients underwent preoperatively evaluated with anteroposterior, lateral, flexion-extension lumbar radiographs and MRI. The percentage of slippage in spondylolisthesis has been measured from the lateral radiographs of the lumbar spine. The measurement was calculated as the distance between the posterior line of the vertebral body between the displaced vertebrae and the parallel line extending through the posterior rim of the displaced vertebrae (b) to the anterior and posterior dimensions of the sliding vertebral body (a): Percentage of slip=(b/a)×100% (Figure 3 A-B).[6,7]

IPD cost comparing between PELD and fusion (TLIF) surgery was evaluated by overall IPD cost data collected from patients who underwent PELD and fusion (TLIF) surgery.

Statistical analysis

All statistical analyses were performed using SPSS version 23.0 (IBM, Amonk, USA). Collected demographic data were computed as mean±standard deviation, percentage,

minimum-maximum value. Friedman test and Wilcoxon signed ranks test analysis of variance were used to compare the differences in the mean clinical outcome scores (VAS, ODI) and radiographic outcome (percent slippage of spondylolisthesis) from pre- and postoperative variables. P value<0.05 was considered statistically significant.

RESULTS

A total of 24 LS patients who underwent percutaneous transforaminal endoscopic discectomy surgery since December 2021 to November 2022 in our hospital (Thabo Crown Prince Hospital, TCPH) were collected, including 9 women and 15 men. The mean age was 52 years. The mean BMI was 25.13 kg/m^2. There were 1 case at the L2-3 level, 3 cases at the L3-4 level and 20 cases at the L4-5 level. The type of lumbar disc herniation, 12 patients (50%) were extrusion and 12 patients (50%) were sequestration. The compression (stenosis) type, 17 patients (70.8%) were paracentral (lateral recess), 6 patients (25%) were foraminal and only 1 patient (4.2%) was extraforaminal (far-lateral) stenosis. The mean preoperative percent slippage of spondylolisthesis was 10.1%. All cases were grade 1. The majority of anesthesia was general anesthesia (70.8%), and 29.2% of patients received local anesthesia. Side of operation via transforaminal approach, 10 patients (41.7%) were left side and 14 patients (58.3%) were right side. The majority of PELD via transforaminal technique was inside-out (70.8%), and 29.2% of patients underwent outside-in technique. The mean operation time was 53.17±26.14 mins, the mean blood loss was 8.29±10.45 mL, the mean hospital stay was 2.96±1.16 days and the mean follow up was 6.7 months. The most common underlying disease was hypertension (HT) (54.2%), followed by diabetes mellitus (DM), dyslipidemia, allergy, GERD (4.2% per disease). There were 7 patients without underlying diseases (Table 1).

Table 1: Demographics of the included patients.

Demographics	Value (mean±SD), N
Age (in years)	52±11.27
Gender	
Male	15 (62.5%)
Female	9 (37.5%)
BMI (kg/m^2)	25.13±3.51
Underlying diseases	
Hypertension (HT)	13 (54.2%)
Diabetes mellitus (DM)	1 (4.2%)
Dyslipidemia (DLP)	1 (4.2%)
GERD	1 (4.2%)
Allergy	1 (4.2%)
Lumbar level	
L1-2	0 (0%)
L2-3	1 (4.2%)
L3-4	3 (12.5%)
L4-5	20 (83.3%)
L5-S1	0 (0%)
Type of lumbar disc herniation)	
Bulge	0 (0%)
Protrusion	0 (0%)
Extrusion	12 (50%)
Sequestration	12 (50%)
Compression types	
Central	0 (0%)
Paracentral (Lateral recess)	17 (70.8%)
Foraminal	6 (25%)
Extraforaminal (Far lateral)	1 (4.2%)
Grading of spondylolisthesis (Meyerding)	
Grade 0 (spondylolysis)	0 (0%)
Grade 1 (0-25%)	24 (100%)
Grade 2 (25-50%)	0 (0%)
Grade 3 (50-75%)	0 (0%)
Grade 4 (75-100%)	0 (0%)
Grade 5 (spondyloptosis)	0 (0%)

Continued.

Demographics	Value (mean±SD), N
Anesthesia	
GA	17 (70.8%)
LA	7 (29.2%)
Side	
Left	10 (41.7%)
Right	14 (58.3%)
Discectomy technique (transforaminal approach)	
Outside-in	7 (29.2%)
Inside-out	17 (70.8%)
Operative data	
Operation time	53.17±26.14
Blood loss	8.29±10.45
LOS	2.96±1.16
Follow up (months)	6.73

Table 2: The clinical outcomes (VAS back and leg, ODI score).

Variables	Pre-operative	1-month	3-month	Final follow-up	P value
VAS back pain	5.25±4.70	2.75±3.10	1.88±2.51	1.29±2.53	<0.001
VAS leg pain	7.96±3.01	3.17±2.71	2.04±2.26	1.50±2.52	<0.001
ODI (%)	92.63±8.39	13.03±7.07	13.44±7.42	13.59±7.79	<0.001

Table 3: The modified MacNab criteria, patients' walking distance and the patients' satisfaction.

Variables	N	Percentage (%)
MacNab		
Excellent	18/24	75
Good	5/24	20.8
Fair	1/24	0
Poor	0/24	0
Walking distance		
Better	21/24	87.5
No change	3/24	12.5
Worse	0/24	4.2
Satisfaction		
Very satisfied	19/24	79.1
Satisfied	4/24	16.7
Unsatisfied	1/24	4.2

Table 4: Percent slippage.

Variables	Percent slippage	P value
Pre-op	10.1±3.25	0.458
Final follow up	9.56±3.35	

Table 5: The mean PELD IPD cost.

Mean IPD cost (THB/USD) 1 USD=34.91 THB	PELD	Fusion (TLIF)
	64,785.95 THB (1,855.51 USD)	98,392.36 THB (2,818.01 USD)

All patients experienced significant relief of back pain, leg pain and ODI scores at 1, 3 months postoperative and at the final follow-up examination was significantly improved ($p<0.001$). The mean preoperative VAS back pain, VAS leg pain and ODI scores were 5.25±4.70, 7.96±3.01 and 92.63±8.39, respectively. All mean back pain, leg pain and ODI scores improved postoperatively to 2.75±3.10, 1.88±2.51, 1.29±2.53, 3.17±2.71, 2.04±2.26, 1.50±2.52 and 13.03±7.07, 13.44±7.42, 13.59±7.79 at 1, 3 months postoperative and final follow-up, respectively (Table 2).

The global results using the modified MacNab criteria were rated as follows: 18 patients were rated as excellent (75%), 5 as good (20.8%), 1 as fair (4.2%), but no one as poor (0%). Therefore, the clinical improvement rate was 95.8%.

In 87.5% of cases, patient's walking distance, prior to and after the operation, improved and 12.5% of cases, patient's walking distance was not changed.

Patients' satisfaction was rated by using very satisfied, satisfied, or unsatisfied at final follow-up. In this study, 19 patients (79.1 %) were very satisfied, 4 patients (16.7 %) were satisfied and only 1 patient (4.2%) was not satisfied (Table 3).

The preoperative and final follow-up imaging findings are compared in Table 4. The mean percent slippage was 10.1±3.25% and 9.56±3.35 at preoperative and final follow-up, respectively which was not significantly different (p=0.458).

The mean PELD IPD cost was 64,785.95 THB (1,855.51 USD). The mean fusion (TLIF) surgery IPD cost was 98,392.36 THB (2,818.01 USD) which was higher than PELD IPD cost (Table 5).

Among 24 LS patients who underwent PELD via transforaminal approach, complication occurred in only 1 patient which is a burning sensation. This complication exhibited after surgery and patient received an oral medication. One patient required further fusion surgery due to persistent symptoms. No post-op major complications occurred, including infection, thrombophlebitis, vascular injury and cauda equina syndrome.

DISCUSSION

Patients with LS may have mechanical back pain, radicular pain, and symptoms related to lumbar canal stenosis. An open approach for decompression with instrumented fusion that requires general anesthesia tends to have a higher perioperative risk, especially those with multiple medical comorbidities. PELD has acquired popularity in recent years and is now extensively used in clinical practice. Its indication has been expanded to include foraminotomy and endoscopic-assisted interbody fusion, in addition to discectomy alone.[4,5] In comparison to the conventional open approach, PELD offers many advantages, including reduced soft tissue traumatization, reduced blood loss, and a shortened hospital stay. It is important to note that PELD can be used to treat LS patients under local anesthesia and to preserve the posterior structure, specifically in the transforaminal approach.[6-8] Several studies have shown that short and middle-term outcomes for LS patients following PELD are favorable, and the patients may return to a normal life without experiencing any negative impacts on their instability.[9-12] There are several studies that have described percutaneous full endoscopic surgery in low grade spondylolisthesis, both interlaminar and transforaminal approaches, with generally positive results.

Sripirom et al conducted a retrospective study including twenty-eight patients with stable degenerative spondylolisthesis to evaluate the clinical and radiologic outcomes of interlaminar percutaneous endoscopic decompression, with a follow-up period of about 2 years. They showed that VAS and ODI were significantly improved at their final follow-up. There was no discernible difference in the ratio of disc height and vertebral slippage percentage between the preoperative and postoperative periods.[18]

While on the transforaminal approach side, there are studies that discuss the results of transforaminal endoscopic discectomy in degenerative spondylolisthesis. Jasper et al conducted a retrospective including twenty-one patients with L4-L5 or L5-S1 spondylolisthesis and complaints of lower back and radicular pain who underwent transforaminal endoscopic discectomy and foraminotomy. They showed that VAS and ODI were significantly improved at 1 year follow-up. The average pain relief one year postoperatively was reported to be 71.9%, good results as defined by MacNab.[2] Wu et al conducted a retrospective study involving twenty-four patients with degenerative LS who had transforaminal endoscopic discectomy and foraminotomy to evaluate long-term clinical results and the degree of slippage. VAS and ODI showed significant improvements at the final follow-up. The disc height decreased at the final follow-up prior to surgery; however, no significant changes in slippage, segmental lordosis, or lumbar lordosis were seen.[11] All of the studies cited here are consistent with our study. Our study evaluated both clinical and radiographic outcomes. Twenty-four patients showed significant improvement in back and leg pain, as well as in the ODI, at 1-3 months postoperatively, with notable improvements found at the last follow-up ($p<0.001$). The improved MacNab criteria showed 75% excellent and 20.8% good outcomes. His walking distance improved by 87.5%. 95.8 percent of patients were satisfied. The average slippage rate was 10.1±3.25% at both preoperative and final follow-up assessments. In the study of postoperative complications, Sripirom et al performed interlaminar percutaneous endoscopic decompression, resulting in two patients requiring further treatment. One patient reported buttock pain post-surgery and was administered a caudal epidural steroid injection. One patient did not have improvement of radicular pain following endoscopic surgery and subsequently needed further fusion surgery.[18] While the transforaminal approach, Rhee and Ahn had temporary surgical dysesthesia. Within four weeks, oral medicine relieved symptoms, and no further serious perioperative problems occurred and one patient complained of severe pain and underwent open surgery (TLIF with dural repair).[9,10] Our study presents only one patient who has a burning sensation. This problem occurred post-surgery, and the patient received an oral medicine. No major postoperative problems occurred, including infection, thrombophlebitis, vascular damage, or cauda equina syndrome. There is no study discussing the medical expenses and the cost of endoscopic surgery inside IPD costs. Our study evaluated the IPD cost, including the actual costs of hospitalization and each surgical procedure, by comparing transforaminal

endoscopic surgery with open TLIF surgery in cases with spondylolisthesis. The mean PELD IPD cost was 64,785.95 THB (1,855.51 USD). The mean fusion (TLIF) surgery IPD cost was 98,392.36 THB (2,818.01 USD) which was higher than PELD IPD cost. However, this measures only the IPD treatment cost. Comparing the cost-effectiveness of two operations is difficult. This data was collected to show that endoscopic surgery pays a cheaper IPD cost than TLIF for spondylolisthesis per hospital stay. This information may be used to evaluate the cost-effectiveness of endoscopic surgery in the treatment of stable low-grade spondylolisthesis cases.

Limitations

This study has some limitations. First, the sample size was relatively small, due to the limited quantity of stable low-grade single level LS patients underwent PELD with transforaminal approach in one year. Therefore, a larger number of cases is required to verify the effectiveness of PELD with transforaminal approach. Second, this study was conducted retrospectively without a control group. Selection bias may have existed in the enrollment. Therefore, a prospective randomized trial comparing between PELD with transforaminal approach and traditional open approach in LS cases is warranted. Finally, the one-year follow-up period may be relatively short to draw a conclusive result and assess only IPD cost. Because further slippage or instability may develop over time that will make overall cost increase. Therefore, a long-term follow-up study and further overall cost-effectiveness evaluation are required to verify the effectiveness of PELD via transforaminal approach.

CONCLUSION

The present study indicated that PELD via transforaminal approach is an effective and safe procedure with favorable results in short term for patients with stable low-grade single level LS. Most patients were satisfied. No significant difference was indicated in the percentage of slippage between preoperative and final follow-up. The IPD cost of transforaminal PELD was significantly lower than that of the traditional open approach. PELD via transforaminal approach may also be efficient alternative to traditional open approach for treatment of LS patients. Nevertheless, efficacy and overall cost effectiveness of this technique require to be further evaluated by a long-term follow-up study, larger number of cases.

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