CLINICAL ARTICLE

Percutaneous Endoscopic Lumbar Discectomy Using a Double-Cannula Guide Tube for Large Lumbar Disc Herniation

Hongwei Wang, PhD[1,2,3], Hong Yuan, PhD[1], Hailong Yu, PhD[1], Changqing Li, PhD[3], Yue Zhou, PhD[3], Liangbi Xiang, MD[1]

[1]Department of Orthopedics, General Hospital of Northern Theater Command of Chinese PLA and [2]State Key Laboratory of Robotics, Shenyang Institute of Automation, Chinese Academy of Science, Shenyang and [3]Department of Orthopedics, Xinqiao Hospital, the Army Medical University, Chongqing, China

Objective: To compare the effect of percutaneous endoscopic lumbar discectomy (PELD) using a double-cannula guide tube (DGT), traditional PELD, and open lumbar discectomy (OLD) to treat large lumbar disc herniations (LLDHs).

Methods: Seventy patients who presented with LLDH without cauda equina syndrome and were treated with surgery in our hospital from October 2015 to October 2017 were included. The detailed index included the visual analog scale (VAS) for back and radicular leg pain and the Oswestry Disability Index (ODI) in the immediate preoperative period and at the final follow-up. The operation time, radiation exposure time, surgical satisfaction rate, and modified MacNab criteria score were also recorded.

Results: The leg and back pain of the patients in these groups improved significantly in the postoperative period. No significant differences were observed in leg pain improvement between the other two groups; however, patients in the PELD group (with or without DGT) presented with significantly higher improvement in back pain than the OLD group ($t = 9.965$, $p < 0.001$). The final ODI scores were 12.1 ± 4.9, 11.2 ± 2.9, and 16.4 ± 3.6 in the PELD, PELD-DGT, and OLD groups, respectively. Patients in the PELD and PELD-DGT groups presented with significantly lower postoperative ODI scores than those in the OLD group ($t = 20.834$, $p < 0.001$). The mean postoperative hospital stays were significantly shorter in the PELD group and PELD with DGT group than in the OLD group ($t = 46.688$, $p < 0.001$). The mean operation time was significantly shorter in the PELD-DGT group than those in the PELD group ($t = 25.281$, $p = 0.001$). No perioperative complications were observed in either group. Based on the modified MacNab criteria, excellent and good outcomes were achieved in 20 out of 21 patients (95.2%) in the PELD group, 23 out of 24 patients (95.8%) in the PELD-DGT group, and 22 out of 25 patients (88.0%) in the OLD group. The rates of excellent and good outcomes were higher in the PELD and PELD-DGT groups than in the OLD group, but there were no significant differences ($\chi^2 = 1.454$, $p = 0.835$).

Conclusions: PELD using DGT is a safe and effective option for LLDH and features advantages such as improvements in back pain, a lower hospitalization cost than OLD, a shorter operation time, and less fluoroscopy than traditional PELD.

Key words: Guide tube; Large lumbar disc herniation; Minimally invasive; Open lumbar discectomy; Percutaneous endoscopic lumbar discectomy

Address for correspondence Hongwei Wang, Department of Orthopedics, General Hospital of Northern Theater Command of Chinese PLA, Shenyang 110016, China, Email: cplawhw@163.com; Changqing Li, Department of Orthopedics, Xinqiao Hospital, the Army Medical University, Chongqing 400037, China, Email: yonglee_xinqiao@163.com
Hongwei Wang, Hong Yuan and Hailong Yu contributed equally to this work.
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Introduction

With the development of surgical techniques, medical equipment, and instruments, percutaneous endoscopic lumbar discectomy (PELD) has been advocated as a useful and minimally invasive technique for the treatment of symptomatic lumbar disc herniations (LDHs)[1–5]. Safe placement of the working cannula and successful foraminoplasty are the keys for PELD, especially for complicated and difficult cases, such as large lumbar disc herniation (LLDH). LLDHs are disc herniations that occupy over 50% of the lumbar spinal canal and press on neural structures[6–8]. Many researchers have pointed out that normal disc tissue removal may cause reduced disc height, segmental instability, and spondylolisthesis through pathoanatomical and clinical studies[9–12]. Due to heavy loss of the nucleus pulposus and massive defects in the annulus fibrosus, surgeries for LLDH may have detrimental effects on long-term prognosis, such as a higher risk of postoperative spinal instability and chronic back pain[13–15]. PELD with targeted and quantificational foraminoplasty is accepted as the leading minimally invasive technique for treating LDHs.

The Kambin's triangle in traditional transforaminal approach for PELD is not completely safe in the case of LLDH because the dural sac becomes flat and laterally expanded due to the extreme compression caused by the LLDHs[16]. In this procedure, the isocentric trephine makes contact with the exiting nerve root, traversing the nerve root and para-foramen soft tissue, which is risky and brings up concerns of damage to nerves. To avoid injuries to the dura or cauda equina, targeted and quantificational foraminoplasty is very important for LLDHs. Recently, several researchers have emphasized the significance of foraminoplasty[16–19]. However, PELD has a demanding learning curve especially for complicated case. We recently reported a targeted foraminoplasty technique using a double-cannula guide tube (DGT) for LDH[20], and it can reduce the difficulty of PELD learning, minimizes radiation exposure, and decreases intraoperative pain associated with foraminoplasty, so we want to investigate the technique used in LLDHs.

In the current study, the feasibility and effectiveness of the double-cannula guide tube used in PELD for LLDH were investigated, and we retrospectively compared and assessed the clinical results of PELD using DGT, traditional PELD, and open lumbar discectomy (OLD) in LLDH patients. The major outcomes were evaluated: (i) to compare the perioperative index, including the operation time, intraoperative bleeding, intraoperative fluoroscopy times, postoperative drainage, postoperative hospital stay, and total hospitalization cost; (ii) to compare the pain score, such as back and leg visual analog scale (VAS) scores; and (iii) to compare the quality of life using the Oswestry Disability Index (ODI) and the modified MacNab criteria.

Materials and Methods

Patients' Characteristics

Seventy patients who had single-level LLDH at our institution who underwent surgery from October 2015 to October 2017 were enrolled in the study: 45 patients underwent surgery with the PELD technique (with or without DGT), while the other 25 patients underwent surgery with OLD. The surgeon had performed >1000 OLD cases and >400 PELD procedures. The inclusion criteria for patients in this study were as follows: (i) patients over 18 years old; (ii) single-level intracanal LLDH (occupied >50% of the spinal canal and limited to L4-5 or L5-S1) on CT and magnetic resonance imaging (MRI); (iii) failure of conservative treatments; (iv) progressive neurologic deficit or debilitating leg pain associated with LLDH; and (v) minimum 18-month follow-up. The exclusion criteria were as follows: (i) lumbar spondylolisthesis, instability, calcified disc, sequestrated disc herniation, cauda equina syndrome, or high iliac crest; (ii) severe heart, lung and brain diseases, coagulation dysfunction, and intolerance of operation; (iii) previous lumbar surgery, fracture, infection, or tumor. The study protocol and publication of the study were approved by the committee on ethics and the institutional review board of our institution.

Surgical Operation

The special instrument named the ZESSYS system consists of an obturator with a 7-mm diameter, four graded duck-mouth protective cannulas, and graded trephines (Figure 1). ZESSYS is a novel targeted and quantificational foraminoplasty device that originated from a modified version of the traditional TESSYS technique. The novel effective foraminoplasty tool was designed by Yue Zhou *et al.* from the Xinqiao Hospital of Army Medical University in Chongqing, China. PELD using a double-cannula guide tube was performed in the prone position and under local anesthesia. After traditional acupuncture and graded dilation, a 2.5-mm K wire or a rod was fixed at the posterior superior aspect of the lower vertebra in the lateral view. Then, foraminoplasty was performed by graded trephine to create a trajectory from the superior articular process to the spinal canal between the superior articular process and the exiting nerve root[20]. After foraminoplasty, the working channel with an endoscope was inserted, and the subsequent surgical procedure was the same as the routine PELD technique. A schematic diagram showing the PELD using DGT is shown in Figure 2. A TESSYS instrument system (Joimax, Germany) was used in PELD. Illustrated cases are shown in Figures 3–6.

Open lumbar discectomy (OLD) was performed on both sides under general anesthesia according to a previous study[8]. With the patient in the prone position, a 3-cm skin midline incision was made, and the paravertebral muscles were dissected. Under microscopic visualization, partial laminectomy, medial facetectomy, and excision of ligamentum flavum were performed; the same procedure was subsequently performed on the other side. The ruptured disc fragment was exposed by gentle retraction of the thecal sac and traversing nerve root. Discectomy was performed on one side and usually on the other side as well. After adequate decompression of neural structures, closure was performed.

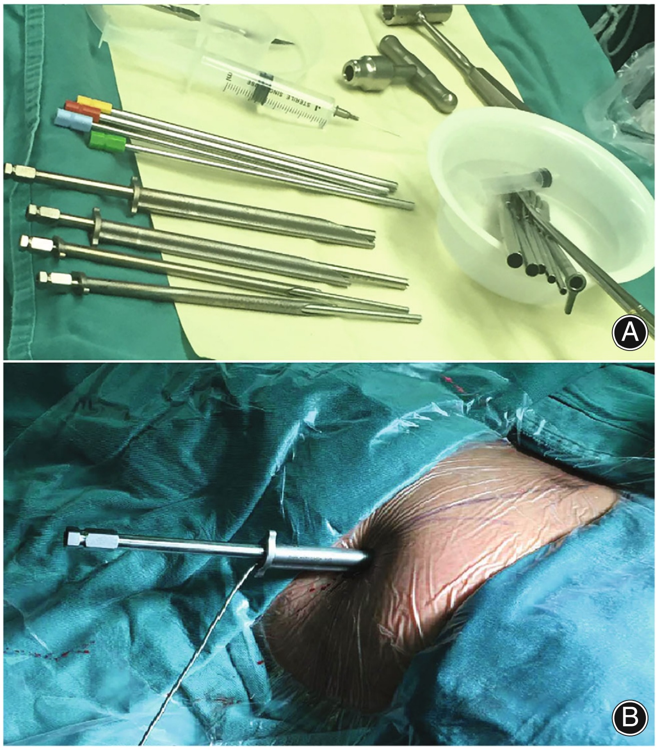

Fig. 1 ZESSYS system. (A) Composition of the ZESSYS system. (B) Intraoperative figure showing the application of the ZESSYS system. We can rotate the double-cannulas by the center of the fixed K wire

Perioperative Observational Index

Operation time, intraoperative bleeding, intraoperative fluoroscopy times, postoperative drainage, postoperative hospital stay, and total hospitalization cost were recorded and compared.

Clinical Evaluation

The detailed index included the visual analog scale (VAS) for back and radicular leg pain and the Oswestry Disability Index (ODI) in the immediate preoperative period, immediately postoperatively, and at the final follow-up. The 1-week postoperative modified MacNab criteria score was also recorded.

Visual Analog Scale

The VAS is used to evaluate the degree of pain using a ruler that provides a range of scores from 0 to 10, where 0 means no pain and 10 represents unbearable pain. A higher score indicates greater pain intensity.

Oswestry Disability Index

The ODI is a measure to evaluate spinal disorders and to assess patient progress in clinical practice. Scores of 0%–20% are considered mild dysfunction, 21%–40% are considered moderate dysfunction, 41%–60% are considered severe dysfunction, and 61%–80% are considered disability. Cases with scores of 81%–100% are either long-term bedridden or exaggerating the impact of pain on their life.

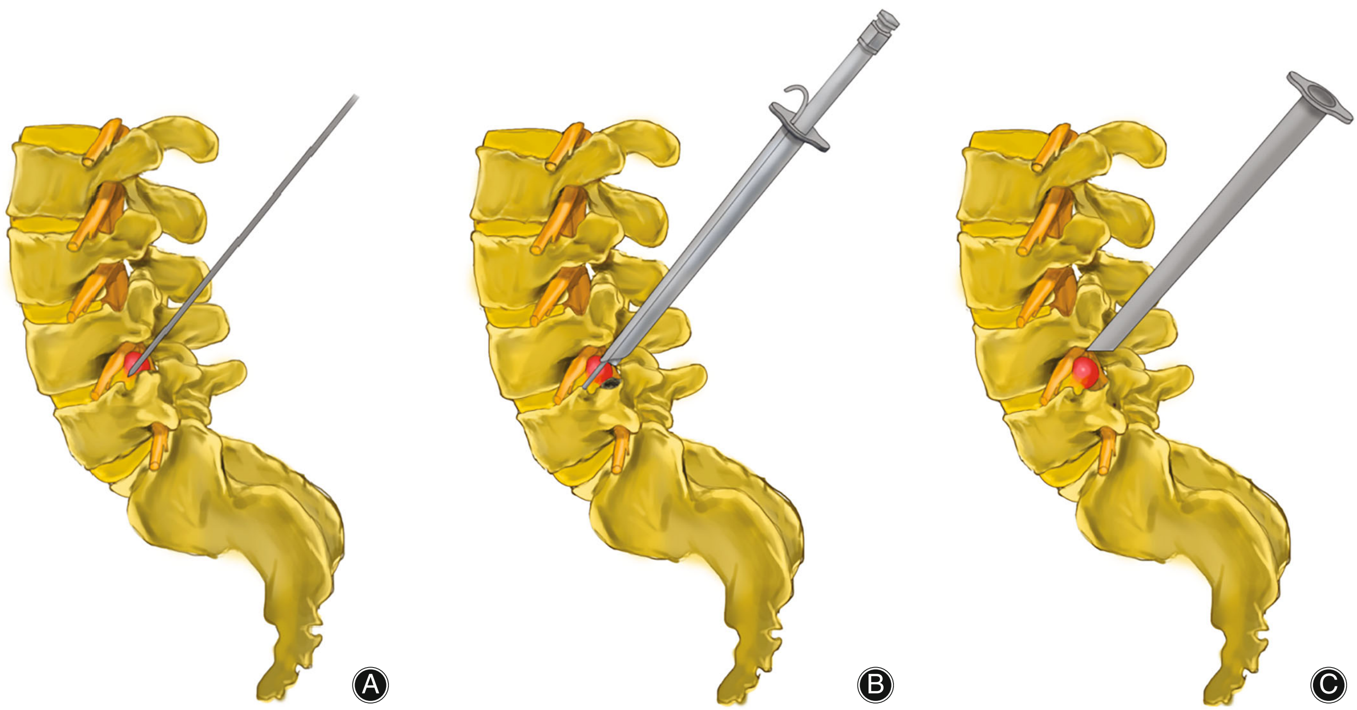

Fig. 2 Schematic diagram showing the surgical operation of PELD using DGT. (A) The tip of the rod/K wire inside the thinner cannula was fixed on the posterior aspect of the superior endplate of the distal vertebra, and the larger cannula was docked on the superior articular process. (B) Targeted foraminoplasty: rotating the larger cannula around the center of the fixed thinner cannula, the targeted superior articular process can be removed easily and precisely. (C) After foraminoplasty, the working channel is inserted

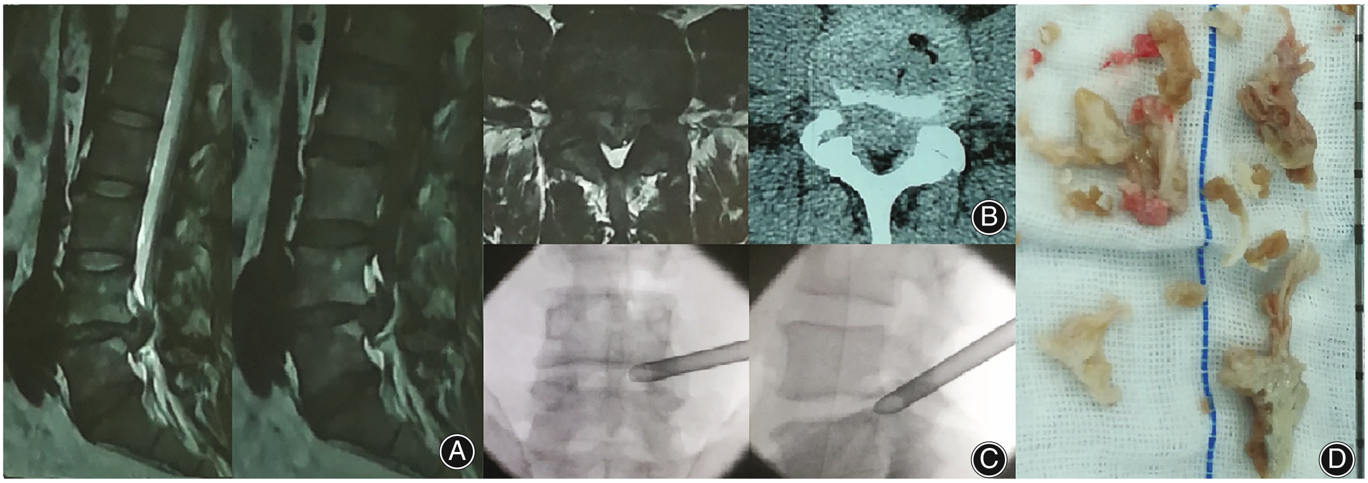

Fig. 3 Illustrated case 1. (A, B) Preoperative CT and MRI showed severe central disc herniation at the L4-5 level without calcification. (C, D) Intraoperative fluoroscopy of the operative region after placement of the working channel and the removed lumbar disc

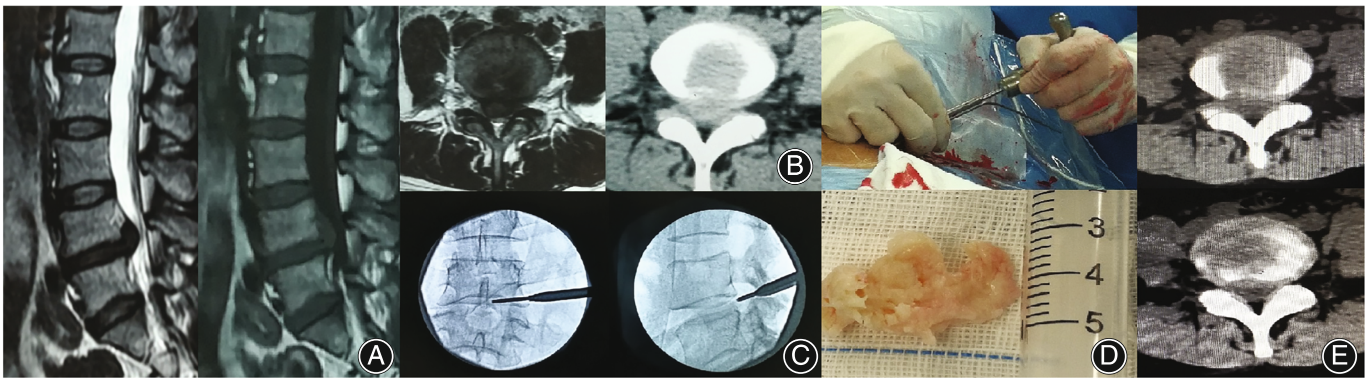

Fig. 4 Illustrated case 2. (A, B) Preoperative CT and MRI showed severe central disc herniation at the L4-5 level without calcification. (C, D) Intraoperative fluoroscopy of the operative region and the removed lumbar disc. (E) Postoperative CT showed that the herniated disc had been removed

Modified MacNab Criteria

A common version of this modified MacNab criteria scale is as follows: Excellent: No pain, No restriction of mobility, return to normal work and level of activity. Good: Occasional nonradicular pain, relief of presenting symptoms, able to return to modified work. Fair: Some improved functional capacity, still handicapped and/or unemployed. Poor: Continued objective symptoms of root involvement, additional operative intervention needed at the index level irrespective of the length of postoperative follow-up.

Statistical Analysis

All data were analyzed using SPSS software (version 24.0, SPSS Inc., Chicago, IL). The chi-square test or fisher's precise test was used for frequency data. The Shapiro–Wilk method was used for the normality test of measurement data, the Student's t test was used for the comparison between groups of measurement data which obey normal distribution, and the Mann–Whitney rank sum test was used for the comparison between groups of measurement data which obey partial distribution. Bonferroni method was used for significant level correction of two-to-two comparisons between groups. $p < 0.05$ was considered statistically significant.

Results

Patients

We performed a minimum 18-month follow-up for 70 patients. The mean follow-up period was 24.8 ± 3.6 months (range, 18–30 months). There were no significant differences in baseline demographic characteristics, including age, sex, operative segment, disc location, history of disease, smoking, and neurologic dysfunction. The clinical and sociodemographic characteristics

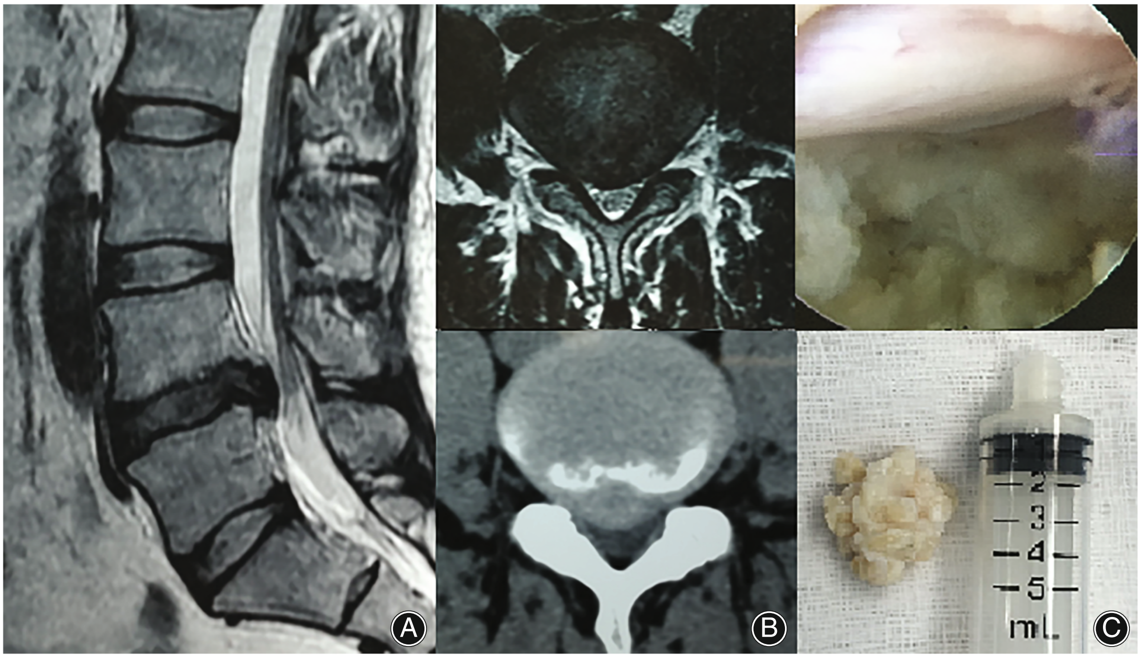

Fig. 5 Illustrated case 3. (A) Preoperative CT and MRI showed severe central disc herniation at the L4-5 level without calcification. (B, C) The intraoperative endoscopic image showed the herniated disc and the removed lumbar disc

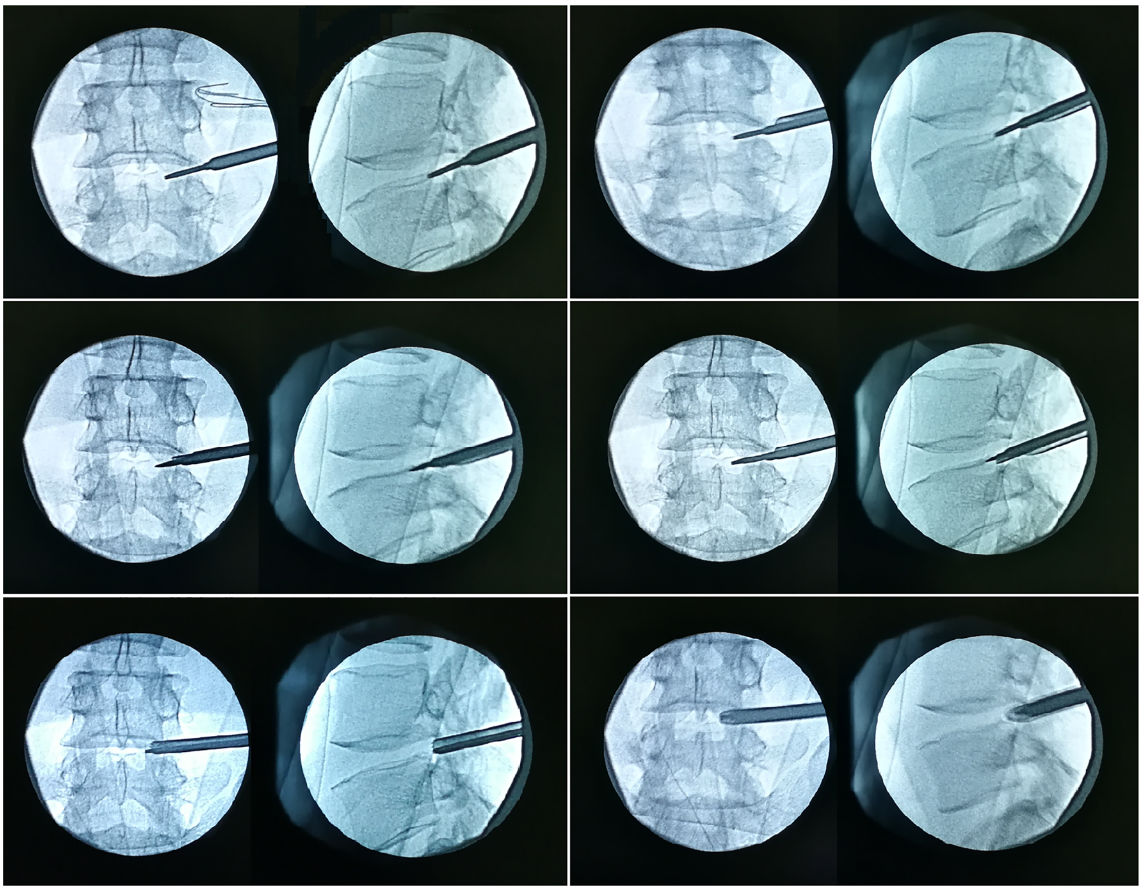

Fig. 6 Illustrated case 3. Intraoperative fluoroscopy of the operative region by the PELD technique using a double-cannula guide tube

TABLE 1 Sociodemographic, clinical, and radiological characteristics of the patients

Data	Number	Age (years)	Gender		Operative segment		Disc location		History of disease	Smoking	Sensory deficits	Motor deficits	Follow-up time (m)
			Male	Female	L4/5	L5/S1	Central	Paramedian					
OLM	25	47.2 ± 16.1	17	8	16	9	8	17	7.9 ± 6.5	10	17	19	24.1 ± 3.5
PELD	21	50.3 ± 13.8	18	3	13	8	6	15	8.1 ± 5.0	9	11	9	23.8 ± 3.8
PELD-DGT	24	48.3 ± 16.1	15	9	16	8	6	18	8.2 ± 7.3	11	18	18	24.9 ± 3.5
t/χ^2		0.401	3.182		0.112		0.294		0.244	0.170	2.633	6.962	1.057
P		0.818	0.204		0.946		0.863		0.885	0.918	0.268	0.031	0.590

TABLE 2 Perioperative observational index of PELD, PELD-DGT, and OLD

Data	Number	Operation time (min)	Intraoperative bleeding (ml)	Intraoperative fluoroscopy times	Postoperative drainage (ml)	Postoperative hospital stay (days)	Total hospitalization cost (CNY)
OLD	25	72.6 ± 19.0	88.0 ± 32.7	1.2 ± 0.4	43.5 ± 23.6	10.2 ± 3.9	10855.8 ± 3500.0
PELD	21	64.8 ± 9.5	14.5 ± 9.9	19.4 ± 3.2	0	3.7 ± 1.9	8319.2 ± 2688.1
PELD-DGT	24	51.0 ± 9.0	11.7 ± 12.1	14.6 ± 4.3	0	3.2 ± 1.1	8883.4 ± 2089.7
t		25.281	50.572	54.294	64.778	46.688	9.512
P		<0.001	<0.001	<0.001	<0.001	<0.001	0.009
P_1		>0.999	<0.001	<0.001	<0.001	<0.001	0.016
P_2		<0.001	<0.001	<0.001	<0.001	<0.001	0.038
P_3		0.001	0.398	0.065	>0.999	>0.999	>0.999

Note: P, general comparing; P_1, OLM *vs* PELD; P_2, OLM *vs* PELD-DGT; P_3, PELD *vs* PELD-DGT.

of the patients in these three groups are summarized in Table 1.

Perioperative Observational Index

Compared with patients in the OLD group, the mean operation time, intraoperative bleeding, and postoperative hospital stay of patients in the PELD and PELD-DGT groups were significantly shorter. The mean operation time was significantly shorter in the PELD-DGT group than in the PELD group ($t = 25.281$, $p = 0.001$). The total hospitalization cost was significantly lower ($t = 9.512$, $p < 0.05$) in the PELD group (8319.2 ± 2688.1 CNY) and the PELD-DGT group (8883.4 ± 2089.7 CNY) than in the OLD group (10855.8 ± 3500.0 CNY) (Table 2).

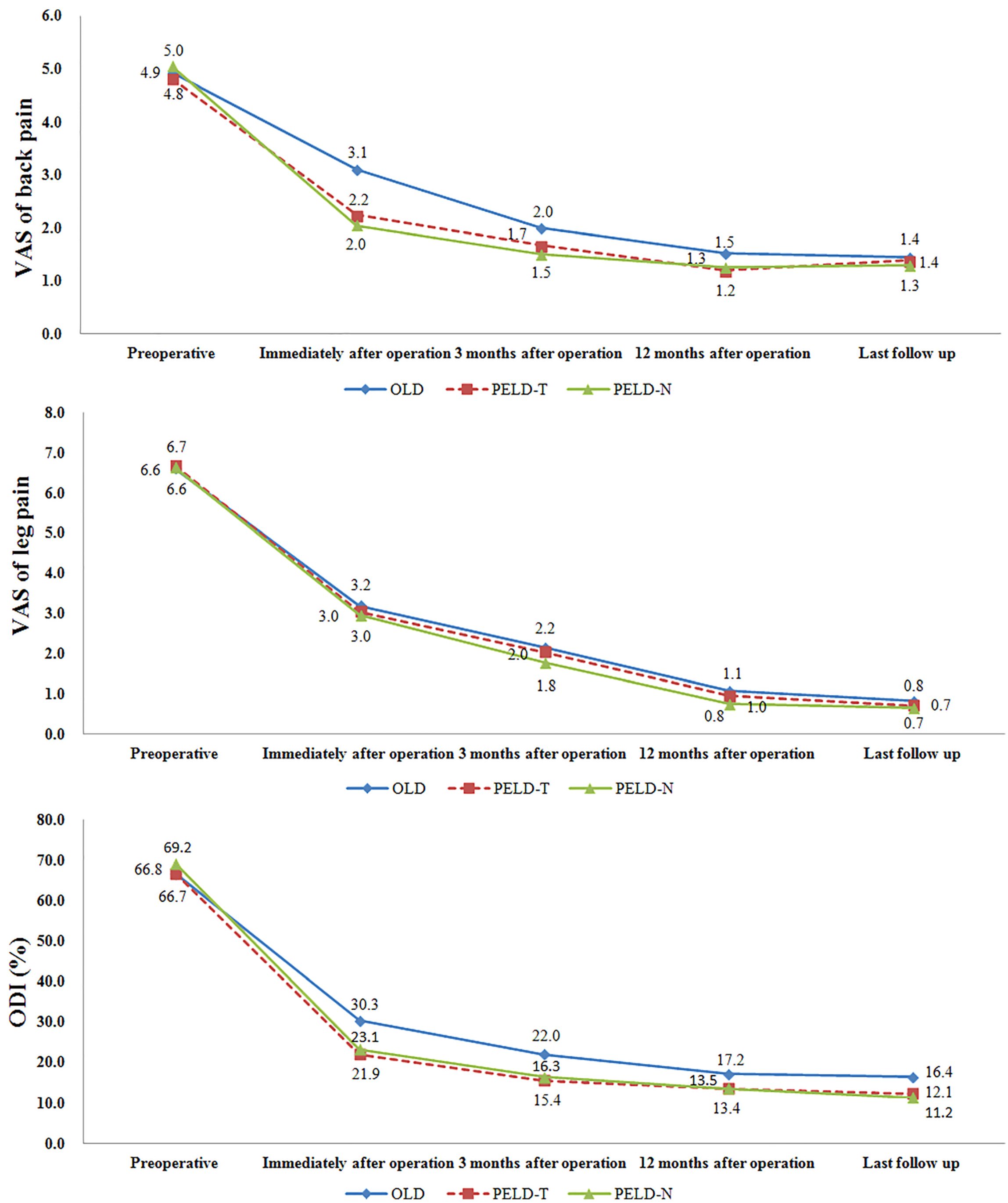

Fig. 7 Surgical outcomes during follow-up (1, 3, 12 months, and the last follow-up)

TABLE 3 Clinical evaluation of PELD, PELD-DGT, and OLD

Data	Number	Back VAS			Leg VAS			ODI			Modified MacNab criteria		
		Preoperative	Postoperative	Improvement	Preoperative	Postoperative	Improvement	Preoperative	Postoperative	Improvement	Excellent	Good	Fair
OLD	25	4.9 ± 1.7	3.1 ± 1.3	1.8 ± 1.2	6.6 ± 1.4	3.2 ± 0.8	3.4 ± 1.3	66.8 ± 13.1	30.3 ± 6.3	36.5 ± 9.7	12	10	3
PELD	21	4.8 ± 1.5	2.2 ± 0.7	2.6 ± 1.2	6.7 ± 1.4	3.0 ± 0.7	3.6 ± 1.1	66.7 ± 9.7	21.9 ± 6.0	44.8 ± 9.3	12	8	1
PELD-DGT	24	5.0 ± 1.8	2.0 ± 0.8	3.0 ± 1.3	6.6 ± 1.2	3.0 ± 0.9	3.7 ± 1.1	69.2 ± 10.2	23.1 ± 4.4	46.0 ± 9.3	13	10	1
t/χ^2		0.526	12.378	9.965	0.180	1.137	0.583	0.644	20.834	11.605		1.454	
P		0.769	0.002	0.007	0.914	0.566	0.747	0.879	<0.001	0.003		0.835	
P_1		—	0.029	0.150	—	—	—	—	<0.001	0.034		—	
P_2		—	0.003	0.006	—	—	—	—	<0.001	0.004		—	
P_3		—	>0.999	0.911	—	—	—	—	>0.999	>0.999		—	

Note: P, general comparing; P_1, OLM vs PELD; P_2, OLM vs PELD-DGT; P_3, PELD vs PELD-DGT.

Clinical Evaluation

Visual Analog Scale

The leg and back pain of the patients in the three groups improved significantly postoperatively ($p < 0.05$). No significant differences were observed in leg pain improvement between the other two groups; however, patients in the PELD group (with or without DGT) presented with significantly higher improvement in back pain than the OLD group ($t = 9.965$, $p < 0.001$).

Oswestry Disability Index

The final ODI scores were 12.1 ± 4.9, 11.2 ± 2.9, and 16.4 ± 3.6 in the PELD, PELD-DGT, and OLD groups, respectively (Figure 7). Patients in the PELD and PELD-DGT groups presented with significantly lower postoperative ODI scores than those in the OLD group ($t = 20.834$, $p < 0.001$).

Modified MacNab Criteria

Based on the modified MacNab criteria, excellent and good outcomes were achieved in 20 out of 21 patients (95.2%) in the PELD group, 23 out of 24 patients (95.8%) in the PELD-DGT group, and 22 out of 25 patients (88.0%) in the OLD group. The rates of excellent and good outcomes were higher in the PELD and PELD-DGT groups than in the OLD group, but there were no significant differences ($\chi^2 = 1.454$, $p = 0.835$) (Table 3).

Complications

All patients underwent surgery successfully, and none of the patients were transferred to open or other surgery. There were no serious complications, such as cauda equina syndrome, infection, or cerebrospinal fluid leakage.

Discussion

Percutaneous Endoscopic Lumbar Discectomy Has Specific Advantages for LLDH

Microendoscopic discectomy or tubular discectomy was recently introduced as an effective treatment for LLDH[21,22]. Percutaneous endoscopic lumbar discectomy (PELD), which presents many advantages such as less damage, reduced hemorrhage, quick recovery, less pain, and good cosmetic effects, has been advocated as a useful and minimally invasive technique for the treatment of symptomatic LDHs[2,21]. Several researchers[10,12] pointed out the relationship between instability and clinical outcomes, so we tended to adopt a minimally invasive PELD technique to avoid spinal instability.

Open discectomy may often cause postoperative mechanical back pain, and the pain may affect quality of life[23,24]. PELD provides direct access to pathological disc fragments that press on nerve roots or dural sacs. Working cannula penetration may increase discal pressure, which may result in injury to the thecal sac and nerve root, and as a result, patients may experience approach-related back pain. Compared to conventional OLD, PELD avoids excessive nerve root retraction and preserves more structures, such as the lamina, facet joint, posterior ligament, and intradiscal tissue. In the current study, patients in the PELD group (with or without DGT) presented with significantly higher improvement in back pain, significantly lower postoperative ODI scores, significantly shorter postoperative hospital stays than those in the OLD group. Based on the modified MacNab criteria, the rates of excellent and good outcomes were higher in the PELD and PELD-DGT groups than in the OLD group. So, we can see that the PELD technique presented with several advantages for LLDH such as less damage, quicker recovery, and better feelings than the open discectomy.

Appropriate Positioning of the Working Channel, Such As the Entry Point and Trajectory, Is Important for the PELD

Twelve years of experience with 10,228 cases performed in a single center shows that inappropriate positioning of the working channel was the main factor influencing the surgical outcomes[25]. After repeated PELD, the skin entry point and the trajectory of the endoscope are predictors of successful outcomes[26]. As the endoscopic guidance technique progresses, the accumulated experience of the surgeons increases, the incomplete removal of the herniated fragment can be reduced[8,27,28], and the learning curve can also be influenced[29,30]. The major disadvantage of the PELD technique is the steep learning curve, especially for surgeons who are not familiar with endoscopic systems and the local anatomical structures under endoscopy. Radiation exposure is always a significant concern in spine surgery, especially for minimally invasive spine surgery. To date, there has been no device to assist targeted foraminoplasty, especially for beginners. Therefore, it is necessary to use the double-cannula guide tube to guide the punctures and grind the bone in PELD for a novel targeted foraminoplasty. The ZESSYS, a targeted and quantificational foraminoplasty device with double cannula which contains a thin cannula containing a Kirschner wire for orientation and a larger cannula for bony abrasion by a trephine can reduce the difficulties of acupuncture. The double-cannula system takes advantage of rotation and can be easily adjusted to find a proper and targeted entry point on the superior articular process (SAP), which can compensate for the Kirschner wire primary puncture point[31].

Effectiveness of the Double-Cannula Guide Tube Used in PELD for LLDH

In the conventional TESSYS technique, the foramen is widened gradually by an isocentric trephine. During the process of foraminoplasty, the trephine blade makes close contact with foramen soft tissue and nerve roots, leading to a risk of damage. During the PELD process with ZESSYS, a Kirschner wire is passed between the SAP and exiting nerve root and fixed on the posterior aspect of the distal vertebra, which acts as a steady pivot for the double-cannula device. When the predefined cannula is inserted to dock on the SAP at posterior orientation, it can be easily rotated to find the proper trajectory and achieve quantificationally decompression. If needed, the foramen can be enlarged by a second cannula rotation. The double cannulas greatly reduce the difficulty of foraminoplasty and enable foraminoplasty to be performed more precisely.

The device simplifies the process of acupuncture and foraminoplasty and makes the technique easy for doctors to master. Damage to nerves may occur when the trephine blade gradually widens the foramen through the conventional TESSYS technique. The DGT excludes the exiting nerve root from the working zone of the trephine, and the risk of nerve injury can be reduced. In the current study, PELD-DGT group presented with decreased intraoperative fluoroscopy times with no significant difference and significantly shorter operation time than the PELD group, and none of the patients presented with cauda equina syndrome or cerebrospinal fluid leakage and were transferred to open or other surgery. The fluoroscopy time and operation time decreased with the application of ZESSYS, which was beneficial for both the patients and surgeons. The preliminary postoperative outcomes seemed to be equal between the ZESSYS group and the traditional PELD group.

Limitations

The study has some limitations that need to be acknowledged. First, the retrospective design of the study may have led to selection bias. Second, the sample sizes were small, and the follow-up time was short. The clinical outcome was preliminary, and a larger randomized controlled trial needs to be conducted in the future to verify the reliability of the ZESSYS system.

Conclusion

The results showed that PELD using DGT is a safe and effective option for LLDH. PELD using DGT demonstrated potential advantages, such as improvements in back pain, a lower hospitalization cost than OLD, a shorter operation time, and less fluoroscopy than traditional PELD. The tool can be used as an assistive tool in the treatment of LLDH.

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Conflict of Interest

All authors listed meet the authorship criteria according to the latest guidelines of the International Committee of Medical Journal Editors, and all authors are in agreement with the manuscript and do not have any conflicts of interest.

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