

CLINICAL ARTICLE

Transforaminal Endoscopic Discectomy and Foraminoplasty for Treating Central Lumbar Stenosis

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Objective: Lumbar spinal stenosis is a medical condition characterized by the narrowing of the spinal canal as a consequence of bone and soft tissue degeneration, including disc herniation, facet and ligamentum flavum hypertrophy, and osteophyte formation. The percutaneous transforaminal endoscopic discectomy (PTED) technique is one of the emerging surgical alternatives for treating central lumbar stenosis. The present study aims to describe the present techniques of PTED and foraminoplasty for central lumbar stenosis, and discuss the feasibility and advantages of this technique.

Methods: A total of 55 patients with an average age of 50 years were recruited in this study. They were operated on between August 2017 and June 2018 by a single surgeon for symptomatic lumbar stenosis using the PTED and foraminoplasty technique, along with a detailed description of the present technique. The retrospective analysis of 55 patients operated between August 2017 and June 2018 by a single surgeon for symptomatic lumbar stenosis using the PTED and foraminoplasty techniques, and the detailed description of the present technique were the focus of the present study. For all patients, the PTED and foraminoplasty procedure was performed under local anaesthesia in the lateral position on a radiolucent table using C-arm fluoroscopy. The retrospective analysis evaluated the outcomes of symptoms through follow-up interviews at six weeks, six months, and one year after surgery. The analyzed parameters included surgery time, intraoperative blood loss, postoperative complications, visual analog scale (VAS) score, Japan Orthopedic Association (JOA) score, and the Oswestry Disability Index (ODI). The modified MacNab criteria were adopted.

Results: The average duration of symptoms was 15.6 weeks. The mean operative time was 161 minutes. The mean volume of intraoperative blood loss was 21 mL. The mean follow-up period was 14.6 months. The average preoperative VAS score for leg pain and low back pain was 6.8 and 5.5, respectively. The preoperative ODI and JOA score was 49.2 and 14.6, respectively. At the final follow-up, all 55 patients had an average VAS score of 1.1 for leg pain and 0.5 for low back pain. At the same time, the average ODI and JOA score was seven and 24.5, respectively. The statistical analysis showed that the VAS score, ODI value, and JOA score were significantly lower in all time-points at post-operation, when compared to those at pre-operation. For the modified MacNab criteria, the final outcome results were excellent in 39 patients (70.9%), good in nine patients (16.4%), fair in four patients (7.3%), and poor in two patients (3.6%), and the overall success rate was 89.1%. Two patients underwent a second operation during the follow-up period, and their symptoms were released after the reoperation.

Conclusion: PTED and foraminoplasty technique showed promising outcomes in the treatment of central lumbar stenosis in a 1-year follow-up period. It suggested that PTED and foraminoplasty might be applied as a safe and effective therapeutic option for patients with lumbar stenosis.

Key words: Central lumbar stenosis; Foraminoplasty; Percutaneous transforaminal endoscopic discectomy

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Introduction

The basic objective of surgery is to treat pathology effectively with minimal disturbance of normal anatomy. This is being accomplished more effectively by designing procedures that require smaller incisions, result in less soft-tissue disruption, and involve limited surgical corridors. Percutaneous endoscopic lumbar discectomy has become a representative, minimally invasive spine surgery for lumbar disc herniation in the past 2 decades. The development of these procedures has been implemented through technological advances in illumination, magnification, and instrumentation¹. Kambin *et al.*² reported an endoscopic disc surgery to treat lateral recess stenosis in 1996. The transforaminal endoscopic spine system technique advocated by Hoogland *et al.*³ made it possible to operate inside the spinal canal by foraminoplasty to enlarge the intervertebral foramen near the facet joint with special reamers. The inside-out and outside-in techniques are presently well-introduced. In 2007, Lee *et al.*⁴ introduced the half-and-half technique and epiduroscopic approach. In 2009, the suprapedicular approach was introduced by Kim *et al.*⁵ for high-grade inferior migrated discs. In 2015, Jha *et al.*⁶ used percutaneous endoscopic lumbar discectomy to treat patients with cauda equina syndrome caused by a huge herniated disc. In 2017, Liu and Zhou⁷ concluded that percutaneous endoscopic lumbar discectomy technology exhibits favorable clinical outcomes for recurrent disc herniation.

Lumbar spinal stenosis is a commonly diagnosed spinal disorder characterized by the narrowing of the spinal canal as a consequence of bone and soft tissue degeneration, including disc herniation, facet and ligamentum flavum hypertrophy, and osteophyte formation⁸. Lumbar spinal stenosis can be classified into three categories, according to pathological zones, as follows: central stenosis, lateral recess stenosis, and foraminal stenosis. To date, open microscopic laminotomy and/or foraminotomy have been considered as the gold standard surgical options for lumbar stenosis⁹.

In the past, the main indication for percutaneous endoscopic surgery was soft disc herniation, and lumbar stenosis was actually a contraindication for the technique¹⁰. Percutaneous transforaminal endoscopic discectomy (PTED) and foraminoplasty techniques has been adopted merely for limited indications. The technical evolution has been remarkable due to the improvement in surgical approaches, optics design, and surgical instruments. Surgical instruments, such as different forceps, biters, cutters, radiofrequency coagulation systems, drills, shavers, scopes, and monitors with superior quality, are continuously being improved to simplify surgical procedures. With the evolution in available techniques, the paradigm of spinal endoscopy is shifting from treatments for soft disc herniation to treatments for lumbar spinal stenosis. Kambin *et al.*² first described the transforaminal arthroscopic decompression of lateral recess stenosis in 1996. In 2014, Knight *et al.*¹¹ and Lewandrowski¹² described PTED is a beneficial intervention for the treatment of spinal or foraminal stenosis. Lee *et al.*¹³ considered percutaneous endoscopic lumbar decompression as a safe, clinically-feasible and effective surgical technique, and that this technique could be adopted as the primary treatment

for lumbar canal and lateral recess stenosis. However, the learning curve remains steep and additional surgical experience may be needed to overcome the learning curve.

The percutaneous endoscopic decompression (PED) technique is also one of the emerging surgical alternatives for treating central lumbar stenosis. In the present study, a total of 55 patients operated on by a single surgeon for symptomatic lumbar stenosis using the PTED and foraminoplasty technique were recruited. By performing the retrospective analysis, we aimed: i) to describe the present techniques of PTED and foraminoplasty for central lumbar stenosis; ii) to assess the functional and surgical outcomes at 6 weeks, 6 months, and 1 year after surgery; and iii) to discuss the feasibility and advantages of these techniques.

Materials and Methods

Inclusion Criteria and Exclusion Criteria

The retrospective analysis of 55 patients operated on between August 2017 and June 2018 by a single surgeon for symptomatic lumbar stenosis using the PTED and foraminoplasty techniques, and providing a detailed description of the present technique, were the focus of the present study.

Inclusion criteria: i) clinical signs of neurogenic claudication with or without sciatica; ii) concordant imaging evidence of central lumbar canal stenosis (the anteroposterior diameter of the central canal was less than 10 mm) with or without disc herniation on the preoperative magnetic resonance images (MRI); and iii) failure of conservative treatment for 12 weeks.

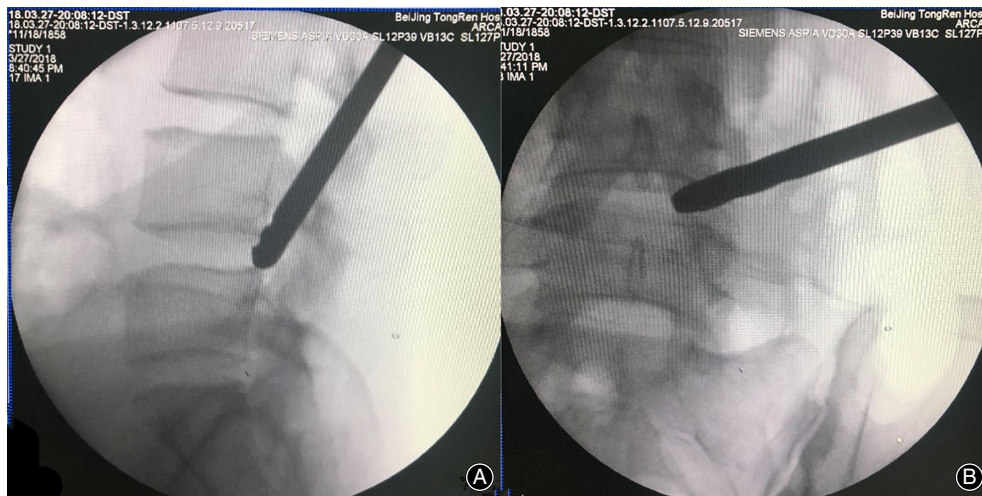
Exclusion criteria: i) multi-level lumbar stenosis; ii) combined migrated herniation; iii) associated bony central or lateral recess stenosis; iv) calcified disc herniation; v) segmental instability on preoperative extension–flexion radiographs; vi) cauda equina syndrome; vii) herniation at the L₅–S₁ level in patients with a high iliac crest and thick transverse process; viii) patients with lumbar spondylolisthesis; ix) patients with elevated infection indicators, including erythrocyte sedimentation rate and C-reactive protein; x) patients with lumbar trauma, cancer, severe osteoporosis, or congenital malformations; xi) patients with rheumatoid arthritis disease or other serious systemic diseases; and xii) patients with incomplete data or patients who were lost to follow-up.

Approval to conduct the study was granted by the Ethics Committee of Beijing Tongren Hospital. Furthermore, the Institutional Review Board approved the informed consent and protocols provided for all participants, which described the details of the surgery, including mechanism of treatment, outcome, potential risks, and side effects.

Surgical Technique

For all patients, the PTED and foraminoplasty procedure was performed under local anesthesia in the lateral position on a radiolucent table using C-arm fluoroscopy. Surgery was performed on the side with severe symptoms or imaging findings. The entry point of the needle was determined at the intersection of

Fig. 1 Proper position of the drill:
(A) the tip of the trephine should lay at the posterior rim of the upper endplate of the distal vertebrate in the lateral fluoroscopic view; (B) the tip of the trephine should lay at the medial pedicle line in the AP fluoroscopic view.

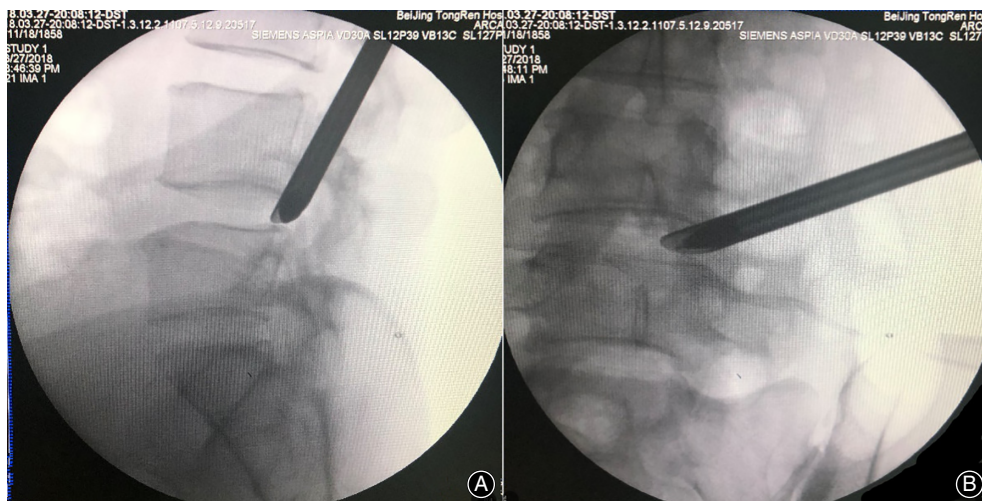


the skin and horizontal line from the posterior aspect of the spinal process, and the needle trajectory was planned on the preoperative MRI/computed tomography (CT) to target the intervertebral foramen, while avoiding the contents of the peritoneal sac.

After infiltrating the intended needle entry tract with eight to 10 ml of 0.5% lidocaine, an 18-gauge needle was inserted using the posterolateral approach. The angle was approximately 40° – 50° in the craniocaudal direction to the superior articular process (SAP) of the lower level for L_5S_1 , and 30° – 40° and 20° – 25° for the L_{4-5} and L_{3-4} levels, respectively. The skin incision was marked at eight to 13 cm from the midline, depending on the level of surgery: the $L_{3,4}$ and $L_{4,5}$ incision were marked at 10 cm from the midline, and the L_5S_1 incision was marked at 12 cm from the midline¹⁴. In the lateral view, the needle tip was positioned at the posterior rim of the upper endplate of the distal vertebra, while the tip of the needle in the anteroposterior (AP) view was positioned at the medial pedicular line.

After infiltrating 15–20 ml of 0.5% lidocaine into the intervertebral foramen, the needle is replaced with a 1-mm diameter guide wire. Drilling through the SAP in the direction of the disk was initiated using a 4-mm drill. Using the transarticular approach, the foramen was widened up to nine or 10 mm, with different reusable drills and a blunt tip, in order to prevent damage to neuronal structures. A 10-mm diameter trephine was used to perform the foraminoplasty through the transforaminal approach, when necessary¹⁵. Trephine was advanced with careful rotation under fluoroscopic guidance. The ventral portion of the SAP and part of the inferior articular process (IAP) was taken out along with the trephine once these were cut off (Fig. 1). A blunt tapered cannulated obturator was passed over the guide wire under fluoroscopic control until its tip reached the posterior rim of the endplate in the lateral view. Then, the obturator was inserted into the enlarged foramen. Sequential protective cannulas were introduced over the obturator until the final protective cannula was placed in proper

Fig. 2 Proper position of the cannula:
(A) the tip of the protective cannulas should be fixed on the posterior rim of the upper endplate of the distal vertebrate in the lateral fluoroscopic view; (B) the tip of the protective cannulas should be positioned at the medial pedicle line in the AP fluoroscopic view.



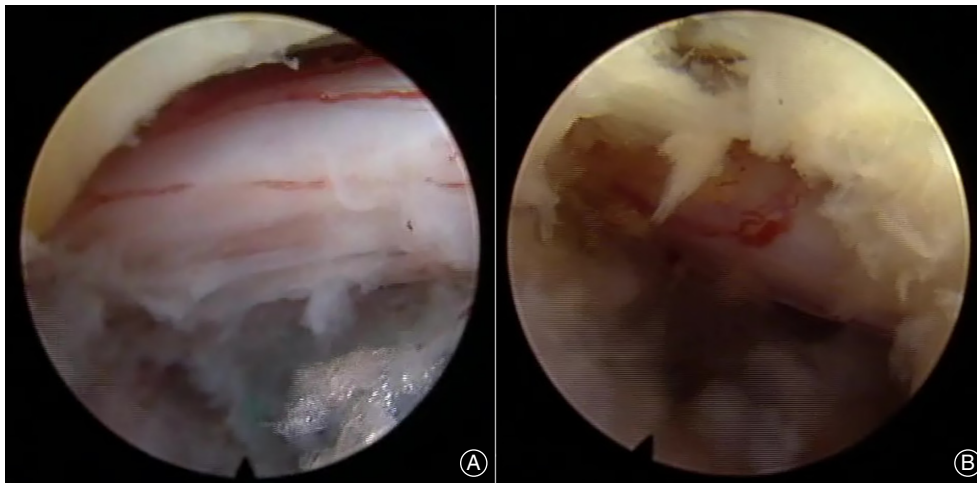


Fig. 3 Transforaminal percutaneous endoscopic decompression: (A) exploration of the ipsilateral transversing nerve root after decompression; endoscopic dissection and resection of the hypertrophied flavum ligament; (B) exploration of the contralateral transversing nerve root after decompression; transversing nerve root; hypertrophied flavum ligament after dissection.

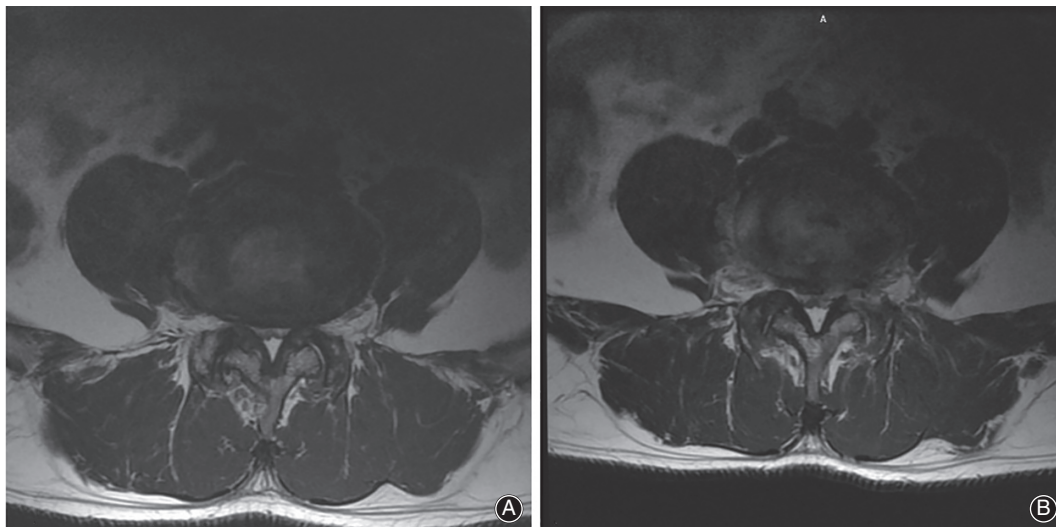


Fig. 4 Preoperative and postoperative MRI: (A) the pre-operation MRI scan shows the central lumbar stenosis; (B) the postoperative MRI scan shows the decompression of the lateral recess at the L₅ upper endplate level. Red dotted rectangle: the planned decompression zone.

TABLE 1 Demographics of included patients

Demographic	Value
Age (years)	50 (22–77)
Sex (female/male)	19 (34.5)/36 (45.5)
Duration of symptoms (weeks)	15.6 (4–40)
Blood loss (mL)	21 (10–30)
Duration of surgery (min)	161 (60–300)
Follow-up (months)	14.6 (12–16)
Level	
L _{3, 4}	1 (1.8)
L _{4, 5}	33 (60)
L ₅ S ₁	21 (38.2)

Values are median(range) or number of patients(%).

position. The tip of the cannulas was fixed on the posterior rim of the upper endplate of the distal vertebrae in the lateral view while positioned at the medial pedicular line in the AP view (Fig. 2). The protective cannula was replaced with a 10-mm working cannula. A 25° endoscope with a working channel of 4.3 mm and a length of 205 mm was introduced.

A pressure regulated pump was used for rinsing with 9% saline. The working cannula was further advanced into the epidural space anterior to the dural sac under endoscopic visualization. After intradiscal decompression is first performed, the working cannula was adjusted to detect and remove the migrated or sequestered discs and hypertrophied posterior longitudinal ligament (PLL). Since the intervertebral foramen was adequately enlarged, additional

maneuvers were performed, such as levering the cannula in order to make it more horizontal, downward, or upward tilting, allowing the contralateral exploration to be easily achieved, and the direct visualization and excision of the herniated discs and hypertrophied PLL could be finished. Afterwards, the decompression of the traversing root and dura sac could be easily confirmed. The evaluation of the amount of decompression was debatable, but was concluded sufficient when there was a clear increase in pulsations of the dura, or when there was a clear view of a pulsating nerve root (Fig. 3). Venous bleeding was stopped by increasing the pressure in the working channel, or using bipolar coagulation. After removing the rinsing water by introducing the largest cannulated rod, the working channel was removed. Then, the skin was closed with one suture (Fig. 4).

Postoperative Management

A drainage tube was placed for 24 hours. If neural disturbance was noted, a small amount of diprospan was injected into the operative site before removing the working tube to prevent nerve swelling. Mannitol and dexamethasone were used for 1 day to reduce nerve root swelling. Antibiotics were given at postoperative 1–3 days to prevent infection. After 1 day of bed rest, the patients were allowed to walk with the protection of a waist brace. Normal work and activities of daily living were permitted at postoperative 3 weeks. However, heavy lifting was prohibited. Lower-extremity activities, including the straight-leg raising test, were encouraged.

Pain Measurement (Visual Analog Scale)

The outcomes of symptoms were evaluated through follow-up interviews at 6 weeks, 6 months, and 1 year after surgery. Low back pain and leg pain were measured using the Visual Analog Scale (VAS) score. It is a continuous scale composed anchored by a score of zero, indicated no pain, and a score of 10, represented the worst pain.

Assessment of the Severity of Clinical Symptoms (Japan Orthopaedic Association Scores)

The Japan Orthopaedic Association (JOA) scores was used to assess the severity of clinical symptoms. It is comprised of six domain scores, which are motor dysfunction in the upper extremities, motor dysfunction in the lower extremities,

sensory function in the upper extremities, sensory function in the trunk, sensory function in the lower extremities, and bladder function, scaling from zero to four, four, two, two, two, and three, respectively. The minimum total score is zero and the maximum total score is 17.

Assessment of Disability

The Oswestry Disability Index (ODI) is a principal outcome measure designed to evaluate patient progress in routine clinical practice. It is a self-administered questionnaire divided into 10 sections: pain intensity, personal care, lifting, walking, sitting, standing, sleeping, sex life, social life, and traveling. Each section is scored on a zero to 5 scale, and five representing the greatest disability. The index is calculated by dividing the total score by the total possible score, and then multiplying the results by 100. The intervals of 0%–20%, 21%–40%, 41%–60%, 61%–80%, and 81%–100% were considered as mild dysfunction, moderate dysfunction, severe dysfunction, disability, and long-term bedridden, respectively.

The modified MacNab criteria were applied to evaluate the surgical outcomes: excellent indicates no pain and no restriction of movement, allowing the patient to work normally; good indicates occasional pain, allowing the patient to work normally; fair indicates slight progress; poor indicates no progression.

Statistical Analysis

Statistical analyses were performed using the SPSS 25.0 software (IBM Corp., Armonk, NY, USA). The preoperative and postoperative (6 weeks, 6 months, and 1 year) VAS scores of low back pain and leg pain, JOA scores, and ODI values were analyzed with repeated measures MANOVA. $P < 0.01$ was considered statistically significant.

Results

Operation Time and Intraoperative Blood Loss

Among the 55 patients (male, 36; female, 19), the average age of these patients was 50 years (range, 22–77 years). Furthermore, 33 cases affected the L_{4, 5} level, one case involved the L_{3, 4} level, and 21 cases affected the L₅S₁ level. The average duration of symptoms was 15.6 weeks. All patients had associated neurogenic claudication, with or without sciatica.

TABLE 2 Changes of preoperative and postoperative ODI, JOA, VAS of low back pain and leg (mean ± SD)

Indexes	Pre-operation	6 weeks post-operation	6 months post-operation	1 year post-operation
VAS of low back	5.564 ± 0.254	1.818 ± 0.107*	0.764 ± 0.093*	0.527 ± 0.077*
VAS of leg	6.782 ± 0.146	1.673 ± 0.094*	1.527 ± 0.081*	1.145 ± 0.099*
ODI	49.236 ± 1.448	17.964 ± 0.891*	7.782 ± 0.489*	7.164 ± 0.513*
JOA	14.636 ± 0.594	20.018 ± 0.416*	23.800 ± 0.399*	24.509 ± 0.427*

* $P < 0.001$, compared to pre-operation.; VAS, visual analog scale; ODI, Oswestry Disability Index, JOA, Japan Orthopaedic Association.

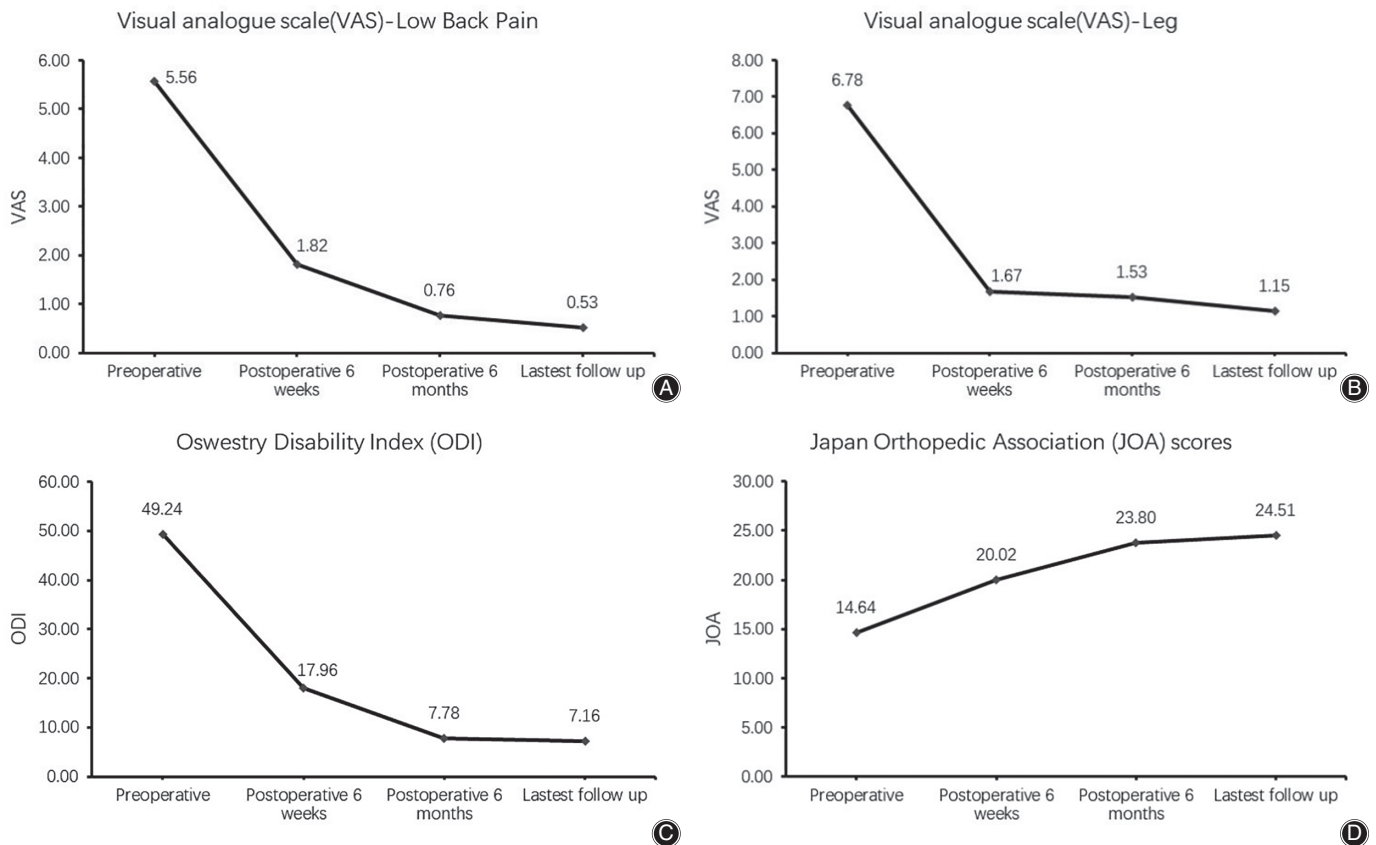


Fig. 5 (A) VAS low back pain changes from pre-operation to final follow-up. (B) VAS leg changes from pre-operation to final follow-up. (C) ODI changes from pre-operation to final follow-up. (D) JOA changes from pre-operation to final follow-up.

However, none of these patients had a history of previous spine surgery at the same level. The mean operative time was 161 min (range, 60–300 min), and the mean volume of intraoperative blood loss was 21 mL (range, 10–30 mL). The mean follow-up period was 14.6 months (range, 12–16 months, Table 1).

VAS, ODI, and JOA Scores

The average preoperative VAS score for leg pain and low back pain was 6.8 (range, 4–9) and 5.5 (range, 0–9), respectively. The preoperative ODI and JOA score was 49.2 (range, 20–80) and 14.6 (range, 6–22), respectively. All 55 patients had an average VAS score of 1.1 (range, 0–3) for leg pain and 0.5 (range, 0–2) for low back pain at the final follow-up.

At the same time, the average ODI and JOA score was seven (range, 0–14) and 24.5 (range, 19–29), respectively. The improvements in VAS and ODI were statistically significant ($P < 0.05$ for both values). As shown in the data, the VAS scores, ODI values, and JOA scores were significantly lower in all time-points at post-operation, when compared to those at pre-operation (Table 2 and Fig. 5).

Neurogenic Claudication

Neurogenic claudication improvement was observed in all 55 patients. For the modified MacNab criteria, the final outcome result was excellent in 39 patients (70.9%), good in nine patients (16.4%), fair in four patients (7.3%), and poor in two patients (3.6%). The overall success rate was 89.1%, and the symptomatic improvement was 96.4%.

Recurrence and Adverse Events

Two patients underwent a second operation during the follow-up period. Their symptoms were released after the reoperation. A hidden disc extrusion missed during an earlier endoscopic foraminotomy was found during the second surgery. Four patients had a transient recurrence of the patient's predominant presenting symptoms, and their symptoms improved over a 2-week period. There were no cases of neurologic injury or cerebrospinal fluid leak in the present series, although some cases had transient paresthesias after surgery, which decreased within 2–3 weeks, and were not present at the time of the final follow-up. Furthermore, there were no cases of infection, instability, or further recurrence at the time of the final follow-up.

Discussion

Clinical Outcome and Surgical Data

The paradigm of percutaneous endoscopic spine surgery is shifting from the treatment of soft disc herniation to the treatment of lumbar stenosis thanks to the revolutionary advances in technology and instruments¹⁶. In the present study, the PTED and foraminoplasty procedures were performed for 161 minutes on average for patients under local anesthesia with negligible blood loss. The mean operative times reported for open decompression surgery were 106 minutes (range, 60–194 minutes)¹⁷, and the mean blood loss was 514 mL (range, 200–1,350 mL)¹⁸ for a single-level operation. Therefore, the operation time was longer. This may be correlated to the steep learning curve of surgery, and the difficulty in decompression for the central lumbar stenosis. In subsequent cases, the operation time was significantly shorter, when compared to the earlier stage. However, the present surgical data demonstrated relatively less blood loss, when compared to open decompression surgery.

A reduction in the ODI score of more than 20% was considered clinically relevant¹⁹. Lee *et al.*¹³ described the VAS score and ODI score as significant improved after endoscopic lumbar decompression. Consistently, we found significant improvements in VAS, ODI, and JOA scores at 6 weeks, 6 months, and 1 year compared to those at pre-operation. These data indicated that this technique is efficient for decompressing the exiting nerve root over a 1-year follow-up period.

According to the modified MacNab criteria, the success rate in the present series was 89.1%, and the symptomatic improvement was 96.4%. Komp *et al.*²⁰ reported that 70.8% of patients exhibited complete pain relief and 86.5% of them reported subjective satisfaction in the 2-year follow-up following interlaminar endoscopic decompression treatment. Chiu *et al.*²¹ reported the use of the transforaminal endoscopic procedure for disc herniation combined with central lumbar stenosis, and had satisfactory results. For open decompression with and without interbody fusion surgery, a meta-analysis demonstrated a 79.8%–88.6% satisfaction rate for post-posterior lumbar interbody fusion (PLIF) surgery²². These results were comparable to the data obtained in this study.

Surgical Technique

Several techniques may be used to approach the spinal canal depending on the target region and the surgeon's selection. Ahn¹⁶ claimed that posterior interlaminar endoscopic discectomy (PIED) *via* the posterior interlaminar approach should be mainly used for the decompression of central and/or lateral recess stenosis. PTED *via* the lateral approach is suitable for lateral recess stenosis, with or without foraminal stenosis. The posterolateral extraforaminal approach is adequate for foraminal or extraforaminal stenosis. In the present study, the authors preferred the transforaminal approach to treat patients with central lumbar stenosis. First,

the interlaminar approach usually needs general anesthesia. At the same time, the transforaminal approach is performed under local anesthesia. Therefore, neural irritation by approach instruments and discectomy may cause severe pain, which may cause the procedure to be stopped, in order to minimize the possibility of postoperative dysesthesia. Second, the ideal end point of the surgery can be recognized by observing the whole annular fissure and epidural pulsation of the dural sac and free mobilization nerve root. It is hard to decompress the contralateral nerve root through the unilateral interlaminar approach. Here, we carefully inserted the cannula into the spinal canal space, and provided direct observation of the contralateral nucleus fragment through the unilateral transforaminal approach.

Ren *et al.*²³ increased the water pressure by sealing the endoscope to raise up the dural sac and reveal the contralateral nerve root. Although the decompression of the contralateral ligamentum flavum and lateral recess was not possible, it was considered that the release of bilateral nerve roots and the decompression of the ventral dural sac can achieve the goal of spinal canal decompression. Finally, the axilla between the traversing and exiting nerve was the location of the missed patho-anatomy in patients with lumbar lateral recess stenosis, which hides the pain generators²⁴. The compressed, scarred, and fibrotic nerve roots in the axilla between the traversing and exiting nerves served as a “hidden zone” of pathology. A completely decompressed axilla would allow the surgeon to determine that both exiting and traversing nerves are decompressed. However, the investigators do not recommend to skeletonize the exiting root. An attempt to achieve the wide exposure of neural tissue involves the risk of dural tear or neural damage by instruments or electrocoagulation. Hence, the recommended end point is free mobilization of neural tissue with visualization of natural pulsation, without the full exposure of the exiting nerve root.

Complication

In this study, two patients (3.6%) needed a second surgery. The need for a second surgery would probably decrease with further experience through this technique. The symptoms of two patients recurred at 1 week after the first operation. After the MRI, it was considered that incomplete decompression leads to the recurrence of symptoms. This occurs due to the missed fragment or remnant lateral recess stenosis that significantly compresses the nerve root²⁵. In addition, this is more likely to occur in cases of central lumbar stenosis. It remains difficult to recognize whether the decompression is sufficient. In order to prevent this problem, the surgeon should estimate the mobilization of neural tissue, and repeatedly decompress the ventral of the dural sac. Complete decompression, which refers to the removal of the whole fragment (including the epidural and intradiscal hidden fragments), is important to prevent recurrence. A reliable reoperation rate of lumbar stenosis after PTED and foraminoplasty has not been established. The re-operating

rate for traditional open decompression surgery is 10.6%²⁶. A meta-analysis demonstrated that the overall complication rate for TLIF and PLIF was 8.7% (range, 0%–25%) and 17.0% (range, 4.7%–28.8%), respectively²⁶, which is comparable to the present data.

Four (7.3%) patients had a transient recurrence of predominant presenting symptoms, which commenced 1 week after surgery. Two weeks after the treatment with oral neurotrophic drugs and nonsteroidal anti-inflammatory therapy, the symptoms were completely relieved. Knight *et al.*¹¹ reported that transient post-operative “flares” were noted in 19% of cases. The “flare” is typified by a transient recurrence of a patient’s predominant presenting symptoms that commence at 1 week after surgery, and lasts for 2–4 weeks. These short-lived symptoms were most likely due to irritation of the nerve in the narrow confines of the spinal foramen, since these are consistent with the phase of engorgement noted in the healing phase following surgery, and coincides with the normal pattern of post-surgical recuperation.

Limitation

The present study has some limitations. First, this is a retrospective study, in which the results were reviewed by the investigators. Second, the follow-up period was relatively

short and the sample size was small. A longer follow-up period with a larger number of cases is necessary to evaluate the definitive effect of PTED treatment for patients with central lumbar stenosis. Finally, the postoperative anteroposterior diameter of the central canal was not measured. In future studies, the postoperative diameter of the lumbar canal would be measured to evaluate the effect of the surgery.

Conclusion

In this study, PTED and foraminoplasty technique showed promising outcomes in the treatment of central lumbar stenosis in a 1-year follow-up period. A steep learning curve is required to successfully perform this without complications. Our data suggested that PTED and foraminoplasty might be applied as a safe and effective therapeutic option for patients with lumbar stenosis. Further investigations will be needed to evaluate the long-term maintenance of the treatment effect of PTED and foraminoplasty.

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