Research Article

Trans-sacral epiduroscopic laser decompression versus the microscopic open interlaminar approach for L5-S1 disc herniation

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Context/Objective: Trans-sacral epiduroscopic laser decompression (SELD) is an alternative to microscopic open lumbar discectomy (OLD). SELD and OLD for L5-S1 lumbar disc herniation (LDH) have not been compared. We compared clinical results, including pain control, between SELD and OLD.

Design: Retrospective analysis.

Setting: Korean hospital.

Participants: Eighty patients treated with SELD (n = 40) or microscopic OLD (n = 40) for L5-S1 LDH.

Interventions: N/A.

Outcome Measures: Clinical data were compared over 6 months. Functional status was evaluated using Oswestry Disability Index (ODI, 0–100%) and time to return to work. Preoperative and postoperative pain was measured using a visual analog scale (VAS, 0–10). Radiological assessment was performed preoperatively and postoperatively.

Results: The ODI and VAS scores for leg and back pain significantly improved in both groups. At 6-months after the procedure, the average ODI decreased to 13.2 ± 11.2 from 54.5 ± 14.5 for SELD and 9.5 ± 10.4 from 57.5 ± 16.0 for OLD. The average leg VAS decreased to 1.9 ± 1.2 from 6.0 ± 1.4 for SELD and 2.3 ± 1.3 from 6.7 ± 1.6 for OLD. Back VAS reduced to 2.6 ± 1.3 from 7.2 ± 1.5 for OLD. Time to return to work was 1.1 ± 1.1 weeks for SELD and 5.4 ± 2.1 weeks for OLD. Clinical outcomes of SELD were non-inferior to those of OLD in terms of pain control.

Conclusion: A scar-free procedure and early return to normal life are advantages of SELD.

Keywords: Minimally invasive surgery, Endoscopic surgical procedure, Intervertebral disc displacement, Laser surgery, Endoscopic spine surgery

Introduction

Lumbar disc herniation (LDH) is a clinically symptomatic condition caused by compression of the spinal nerve roots by a protruded disc.¹ The main symptoms of LDH are lower back pain and sciatica.¹ Treatment for LDH can be classified into microscopic open lumbar discectomy (OLD) or minimally invasive procedures. OLD has been regarded as a standard treatment for LDH for many years since 1934, when Mixter and Barr reported partial laminectomy and disc removal for treating LDH.^{2,3} With the introduction of the microscope, Caspar *et al.* refined the traditional laminectomy into a more minimally invasive OLD.⁴

However, in OLD, this technique requires nerve traction, bone removal, and skin injury. Trans-sacral epiduroscopic laser decompression (SELD) is a non-operative, minimally invasive spinal procedure. SELD has many advantages, including rapid recovery, the absence of paravertebral muscle injury, and preservation of bony structure.⁵ Since Choy *et al.*⁶ first introduced laser ablation of the intervertebral disc, the technique and instrumentation of SELD has significantly improved. Given the anatomic characteristics of the L5-S1 level, which include easy accessibility from the sacral hiatus, we have considered a non-invasive endoscopic route: SELD. SELD has become the alternative for OLD because of improvement of visibility of the camera equipped with an epiduroscope and the efficacy of laser ablation.⁵ To date, no study has compared SELD with OLD for the treatment of LDH at the

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L5-S1 level. With this in mind, the goal of this study was to compare the clinical and radiological outcomes of SELD and OLD.

Materials and methods

This study was approved by our institutional review board (KWNUIRB-2017-05-010-003) and was conducted in accordance with the Declaration of Helsinki. Informed consent was not required for this work due to the retrospective nature of the investigations. SELD and OLD were performed at a single institution, and a retrospective chart review of 40 consecutive patients treated with SELD for LDH at the L5-S1 level (by Author) between November 2015 and April 2016 was performed. Forty consecutive patients were treated with OLD (by Author) during the same period. Inclusion criteria were patients with back pain and unilateral radicular pain, those with single-level intra-canal disc herniation, and those who failed to respond to conservative treatment for more than 2 weeks. The exclusion criteria were as follows: patients with definite foraminal/extra-foraminal disc herniation and definite congenital anomalies, including lumbarization, spondylolysis, instability, lateral recess stenosis, multiple segments of LDH, and tuberculosis.

Preoperative and postoperative data were obtained from a chart review and radiological examination. An independent observer other than the treating surgeons performed radiologic assessments preoperatively. Functional status was evaluated using the Oswestry Disability Index (ODI, 0–100%)⁷ and time to return to work, and preoperative and postoperative back and leg pain was measured using the visual analog scale (VAS, 0–10).⁸ Clinical outcomes were assessed preoperatively and at the last follow-up (6 months later). The location of the disc was classified as central or paracentral. The herniated disc was classified as either of the shoulder or axillary type. The size of the disc was measured as the degree of herniation compromising the spinal canal (canal involvement $\geq 50\%$ or $< 50\%$).⁹ LDH was described as high-grade if the amount of migration was larger than the height of the posterior marginal disc space. Migration of less than the height of the posterior marginal disc space was described as low-grade migration.⁹ Preoperative (Fig. 1A) magnetic resonance imaging (MRI) scans were compared to postoperative (Fig. 1B) MRI scans obtained 2 weeks later.

Surgical techniques

SELD

SELD was performed with the patient in the prone position. The skin entry point was generally the middle

Figure 1 Preoperative magnetic resonance imaging scans showing a ruptured L5-S1 disc (A, arrow). After sacral epiduroscopic laser decompression, the disc is removed and neural compression is relieved (B, arrow).

point of the sacral hiatus. After the entry point was locally infiltrated with anesthetic, a 20-gauge needle was introduced under fluoroscopic guidance. The final target point of the endoscopic catheter was the posterior vertebral line in the anteroposterior (Fig. 2A) and lateral views (Fig. 2B). Next, epidurography was performed using contrast media to confirm the location of the spinal root (traversing and exiting) and LDH. The following steps were then performed: a small insertion point was made in the skin at the entry point, a tapered cannula was inserted through the sacral hiatus, and a laser and camera equipped for epiduroscopy (Meta Biomed Co., Ltd.; I Dolphin) were inserted below the disc along the cannula. An elevated pathological nucleus and ruptured fragment helped with disc discrimination.

When the targeted disc had central disc herniation, an epiduroscopic catheter was targeted more centrally than usual in the anterior-posterior (AP) view (Fig. 2A) and on the posterior line in the lateral view (Fig. 2B). The pathologic disc was decompressed using a holmium: yttrium-aluminium-garnet (Holm: YAG) laser (Fig. 3A and 3B). After the herniated fragment was decompressed, the epiduroscope was removed (Fig. 3C and 3D) and a sterile dressing was applied without sutures.

Figure 2 Endoscopic image showing the endoscopic catheter in the paracentral area of the disc (A, arrow). The endoscopic catheter is shown in the ventral area of the epidural space (B, arrow).

Figure 3 Endoscopic image of a 26-year-old woman with right leg pain showing paracentral disc herniation compressing the right S1 nerve root (A, arrow). A holmium: yttrium-aluminium-garnet electrode is inserted into the herniated lumbar disc (B, arrow). The herniated disc is decompressed after laser vaporization (C, arrow). The internal surface of the ruptured disc is vaporized (white arrow) and detached from the disc (D, black arrow).

OLD

OLD was performed under general or spinal anesthesia. The procedure was performed with the patient in the prone position on a radiolucent table. The incision point was at the inferior edge of the superior lamina of the lesion side in the AP view parallel to the disc space in the lateral view. After a 3-cm incision was made in the midline, the fascia was dissected to the lateral edge of the inferior articular facet. Soft tissues, including the paraspinal muscles, were cleaned to

expose the ligamentum flavum. After partial hemilaminectomy was performed, the ligamentum flavum was removed for disc discrimination. After the operative site was established in the epidural space, the dura margin and nerve root were exposed. Generally, epidural dissection was performed with retraction of the root. The protruded disc particles were located and removed with pituitary forceps. The mobility of the root was assessed after removing the pathological disc particles. Wound closure was performed in a layer-by-layer manner after removing the muscle retractor.

Statistical analysis

The paired-sample test and Wilcoxon-signed rank test were used to compare differences in the preoperative and postoperative parameters and clinical and radiological outcomes between the groups. The independent t-test, chi-square test, and Fisher's exact test were then used to compare differences in clinical and radiological outcomes between the two groups. All statistical analyses were performed using SPSS for Windows (version 22.0; SPSS, Inc., Chicago, IL, USA). Statistical significance was considered if the p-value was < 0.05.

Results

Forty patients each underwent disc removal with SELD or OLD. Mean ages were 40.4 ± 13.2 years in patients who underwent SELD and 57.4 ± 18.8 years in those who underwent OLD (Table 1); this difference was not statistically significant. For SELD, the mean VAS scores for back and leg pain decreased from 7.0 ± 1.2 to 2.6 ± 1.3 and 6.0 ± 1.4 to 1.9 ± 1.2 (Table 2), respectively. For OLD, the mean VAS scores for back and leg pain decreased from 7.2 ± 1.5 to 2.3 ± 1.3 and from 6.7 ± 1.6 to 2.3 ± 1.3 , respectively. The mean ODI (%) in the SELD and OLD groups improved

Table 1 Demographic findings of patients in the SELD and OLD groups.

		SELD group (40 patients)	OLD group (40 patients)	P-value
Age (years)		40.4 ± 13.2	57.4 ± 18.8	5.23
Sex	M	22	20	2.10
	F	18	20	
Disc location	Central	26	35	0.01*
	Paracentral	14	5	
Disc type	Shoulder	19	35	0.01*
	Axillary	21	5	
Disc size	$\geq 50\%$ canal compromise	2	7	0.25
	$< 50\%$ canal compromise	38	33	
Migration	Up-migrated	1	6	0.41
	Down-migrated	18	10	
	Low-grade	16	22	
	High-grade	5	2	

SELD, trans-sacral epiduroscopic laser decompression; OLD, open lumbar discectomy; F, female; M, male.

Table 2 Clinical characteristics of patients in the SELD and OLD groups.

		SELD group	Open LD group	P-value (inter-group differences)
Preoperative	VAS Back	7.0 ± 1.2	7.2 ± 1.5	0.85
	VAS Leg	6.0 ± 1.4	6.7 ± 1.6	0.57
	ODI (%)	54.5 ± 14.5	57.5 ± 16.0	0.55
Postoperative (P-value of improvement)	VAS Back	2.6 ± 1.3 (0.01*)	2.3 ± 1.3 (0.01*)	0.95
	VAS Leg	1.9 ± 1.2 (0.01*)	2.3 ± 1.3 (0.01*)	0.56
	ODI (%)	13.5 ± 11.2 (0.01*)	9.5 ± 10.4 (0.01*)	0.48
Postoperative MRI findings	Complete decompression	28 (70%)	40	0.01*
	Incomplete decompression	12 (30%)	0	
Recurrence rate (%)		3 (7.5%)	0	0.01*
Time to return to work (week)		1.1 ± 1.1	5.4 ± 2.1	0.01*
Follow-up period (months)		9.9 ± 2.3	12.4 ± 1.5	0.85

SELD, trans-sacral epiduroscopic laser decompression; OLD, open lumbar discectomy; MRI, magnetic resonance imaging; VAS, visual analog scale; ODI, Oswestry disability index.

from 54.5 ± 14.5 to 13.5 ± 11.2 and from 57.5 ± 16.0 to 9.4 ± 10.4 , respectively. The intergroup differences in clinical outcomes were not statistically significant. However, in both groups, back and leg VAS and ODI improved significantly. The respective times to return to work were 1.1 ± 1.1 weeks and 5.4 weeks in the SELD and OLD groups. The mean follow-up durations were 9.9 (range, 9–12) years and 12.4 months for the SELD and OLD groups, respectively. Radiological operative failure due to incomplete decompression occurred in 12 patients in the SELD group (30%) and no patients (0%) in the OLD group. During the follow-up period, disc herniation recurred in three patients (7.5%) in the SELD group and in no patients (0%) in the OLD group. Return to work was shorter in the SELD group but radiological outcomes and recurrence rates were significantly superior in the OLD group. Postoperative dysesthesia developed in two patients after OLD (5%). No dysesthesia or L5 exiting nerve injury was observed after SELD.

A statistically significant difference was observed in disc type and disc location between patients who underwent SELD and OLD. The prevalence of axillary HLD (21 patients, 52.5%) was higher than that of shoulder

HLD (19 patients, 47.5%) in the SELD group. In the OLD group, shoulder HLD (35 patients, 87.5%) was more prevalent than axillary HLD (five patients, 12.5%). The prevalence of central HLD was higher in the SELD group (26 patients, 65%) than in the OLD group (five patients, 12.5%; $P = 0.01$). Two patients (5%) with high-grade migration were treated with OLD and five patients (12.5%) were treated with SELD.

Discussion

SELD is a minimally invasive technique for the direct visualization and therapeutic treatment of spinal disorders that can be performed under local anaesthesia.¹⁰ This procedure demonstrates superior effectiveness compared with both physical therapy¹¹ and caudal epidural injection.¹² However, recent systematic reviews have indicated that this painful procedure is still controversial; some studies have reported positive results for short-term and medium-term pain relief,^{12–15} whereas other studies have shown negative results with relapse of pain.¹³ Dashfield *et al.* performed a randomized, double-blinded study and found that both a caudal injection and epiduroscopic targeted drug injection are ineffective for decreasing back and leg pain.¹⁶ In the

Table 3 The characteristics and outcomes of SELD studies.

Study	Study design	Participants	Follow up (months)	Preoperative VAS	Postoperative VAS	Preoperative ODI	Postoperative ODI
Park CH 2017 ²⁷	RCT	97	6	7.3 ± 0.8	2.8 ± 1.1	52.4 ± 20.6	28.6 ± 16.6
Lee GW 2014 ¹⁰	Retrospective	27	24	8.1 ± 0.7	4.4 ± 0.5	13.2 ± 0.9	8.5 ± 0.3
Lee SH 2016 ⁵	Prospective case series	250	3	7.1 ± 0.0	3.6 ± 0.0	50 ± 0.0	19 ± 0.0
Kim SK 2017 ²⁸	Retrospective	126	12	6.1 ± 1.1	1.3 ± 1.2	65.2 ± 1.0	12.1 ± 1.4

SELD, trans-sacral epiduroscopic laser decompression; RCT, randomized control study; VAS, visual analogue scale; ODI Oswestry disability index.

lower lumbar spine, especially at the L5-S1 level, the unique anatomical features are a large facet, narrow foramen, small disc height, an inclination of disc space, concealment of the L5-S1 foramen by the iliac crest, and easy accessibility from the sacral hiatus. These anatomical features seem to explain why the trans-sacral route is more reasonable than others. In our study, SELD decreased leg and back pain effectively compared to OLD and this was statistically significant. Although 30% of patients in the SELD group showed radiological incomplete decompression, only three patients required an invasive operation.

Since the use of a laser and high-resolution lens was recently adapted during epiduroscopy, SELD has been reported to be very helpful for relieving chronic back pain resulting from intervertebral disc prolapse.^{17,18} A high-resolution camera-equipped endoscope allows same-field viewing of the epidural space, annular wall, and intradiscal space. Various tissue, disc, bone, fat, ligament, vessel, nerve, and dura tissues are readily identifiable with an epiduroscope. Although it is widely accepted that the L5-S1 disc space and large herniation were generally inaccessible before the advent of endoscopic visualization,¹⁹⁻²¹ recent adaptations provide surgeons with a wide-angle view of the surgical field and decompression of nerve roots under direct vision through the trans-sacral approach in most cases. In the 40 consecutive cases of SELD for LDH at the L5-S1 level, the authors did not experience equipment problems or issues with identifying the disc and thecal sac.

Axillary herniated discs can be removed easily using the trans-sacral endoscopic approach. The S1 nerve root exits at the L5-S1 level. The S1 root is already separated from the thecal sac.⁵ The angle between the S1 root and thecal sac allows surgeons to access the axillary portion of the S1 nerve root.²² Axillary disc herniation increases the root thecal sac angle and creates more space for the endoscope without causing root damage. SELD can directly access the axillary herniated disc and decompress the disc fragment without general anesthesia, and muscle and bone injury with minimal manipulation of the neural structure. However, sometimes during SELD, which is associated with the risk of incomplete decompression or a remnant disc, invasion into the epidural space is required after incising the posterior longitudinal ligament to completely remove the dorsally migrated disc fragment. Shoulder-type disc herniation can be treated using either technique. However, with OLD, nerve traction is required to approach the shoulder area of the nerve root. Nerve traction of the S1 nerve root can cause damage

because the S1 root emerges from the thecal sac at the L5-S1 disc space. Sufficient medial facetectomy is required to create space. In this case series, 30% of patients required medial facetectomy. Although updated instruments such micro-retractors and drills have been developed, bone manipulation can potentially cause instability.²³

SELD can be used to approach a centrally extruded disc and decompress the disc fragment without neural retraction. It does not require bony manipulation to access the central region. There is a concern surrounding open operation about the possibility of durotomy and cauda equine injury because of excessive neural retraction and the manipulation of neural tissue.²⁴ It is possible for SELD to have a lower revision rate for recurrent disc herniation than OLD. However, OLD is a more challenging procedure than SELD.²⁵ During recurrent disc herniation, it is necessary to apply sufficient decompression and minimize iatrogenic neural injury. The incidence of dural tears in open revisions ranged from 8% to 18%;^{24,26} SELD can be used to pass unscarred virgin tissue and can minimize muscle and iatrogenic neural injury. SELD was used for radiologically incomplete decompression in 12 patients. However, additional therapeutic options during the epiduroscopic procedure, such as mechanical and chemical adhesiolysis, help surgeons to overcome this limitation.¹⁰

In this study, the clinical features of migration of the disc and disc size were not significantly different between the two groups. All discs in this study were accessible during SELD and OLD. Operative failure resulting from incomplete decompression that required open revision operation was observed in three patients who underwent SELD and in no patients who underwent OLD. Lee *et al.* reported that 71.4% of patients experienced symptom relief after SELD; this result is similar to that of the present study.⁵ Given the conflicting and relatively unsatisfying results of epiduroscopy, removing degenerated discs using a Holm: YAG laser is still controversial.¹⁰ However, the future development of lasers will increase the removal rate of protruded discs.

The key step of performing SELD at the L5-S1 level is the location of the epiduroscope. At other levels (L1-5), the epiduroscope has to overcome several intervertebral structures. A relatively short distance from the sacral hiatus and wide disc space permits surgeons to adjust the endoscope to approach the disc and provide symptom relief by internal decompression. Furthermore, epidural fat arrangement by a laser catheter provides a clear and wide operative zone to enter

the epidural and disc spaces, minimizing exiting nerve injury. During OLD, foraminoplasty for foraminal stenosis and lateral exit zone stenosis can be performed using a bone reamer, bone cutter, and diamond drill. These are the absolute advantages of OLD, but the development of endoscopic tools, such as forceps and reamers, will overcome its disadvantages in the future.

Limitations

There are some limitations to the current study that should be discussed, including the fact that the study was retrospective, included a small number of patients, and had a short follow-up period. We did not consider the medication requirements or psychological effects of either treatment. A prospective, randomized trial would provide further elucidation of these issues and remove selection bias, which is a considerable limitation of this study.

Conclusions

When treating disc disease at the L5-S1 level, characteristics of the disc herniation, such as the location and type of the disc, should be considered. This study demonstrated that SELD is preferred for axillary-type HLD, whereas OLD is preferred for shoulder type herniation and foraminal disc lesions. Additionally, SELD proved to be advantageous, with significantly shorter hospital stays, and was not inferior to OLD in terms of back and leg pain control. SELD can be a treatment option for LDH at the L5-S1 level as it is a non-invasive operative procedure.

Disclaimer statements

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Conflicts of interest The authors report no conflict of interest.

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Ethical approval This study was approved by the Institutional Review Board of Kangwon National University Institutional Review Board (approval number KWNUIRB-2017-05-010-003).

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