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Outcomes of epiduroscopic laser ablation in patients with lumbar disc herniation

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Abstract

Recently, trans-sacral epiduroscopic laser decompression (SELD) using flexible epiduroscopy and laser system is 1 of the options for minimally invasive surgery in herniated lumbar disc. However, outcomes after SELD in patients with disc herniation of lumbar spine are not proven worldwide. The authors reported clinical, surgical, and radiological outcome after SELD in patients with mild to moderate disc herniation.

Between 2015 and 2018, eighty-two patients who underwent SELD for single level disc herniation with a minimum follow-up of 6.0 months were investigated retrospectively. Clinical outcomes were assessed using the visual analog scale for low back and leg pain and Odom's criteria for patient satisfaction. Also, surgical outcomes, including complications, recurrences, and revision surgeries, and radiological outcomes using regular simple radiograph were analyzed.

The mean visual analog scale score of low back pain and leg pain improved from 5.43 ± 1.73 and 6.10 ± 1.67 to 2.80 ± 1.43 and 3.58 ± 2.08 at the final follow-up ($p < 0.001$). On the other hand, according to Odom's criteria, the success rate (excellent or good results at 6 months after surgery) was 58.5%. Surgical complications occurred in 7 patients (8.5%), including dura puncture during the procedure, transient headache or nuchal pain, and transient mild paralysis. The rate of additional procedures after SELD was 17.1% (6 patients of revision surgery and 8 patients of an additional nerve block).

Our findings demonstrated that SELD for lumbar disc herniation achieved less favorable patient satisfaction compared with previous studies. Further study is needed to clarify the influencing factors on the clinical outcomes of SELD.

Abbreviations: CI = confidence interval, MRI = magnetic resonance imaging, SELD = trans-sacral epiduroscopic laser decompression, VAS = visual analog scale.

Keywords: disc, lumbar spine, trans-sacral epiduroscopic laser decompression

1. Introduction

Lumbar epiduroscopy is the percutaneous minimally invasive technique to assess the lesion of the epidural space with the assistance of a flexible endoscope through the sacral hiatus. It permits various clinical applications in the epidural space of the lumbosacral spine, such as epidural catheter placement and diagnosis, delivery of epidural drug agents, epidural adhesiolysis, and decompression of disc herniation.

Since 2000s, in the early days of trans-sacral epiduroscopic decompression (SELD), some reports have suggested its clinical effect in various lumbar spinal diseases including adhesion or fibrosis around nerve roots, failed back surgery, disc herniation, and even spinal stenosis.[1–10] However, considering the principles of SELD, the distinctive difference from conventional procedures of drug injection or adhesiolysis like epiduial neuroplasty is the effect of laser ablation on hydrated soft tissue.[11,12] In other words, laser ablation of soft disc herniation could lead to the permanent effect of decompression.[13–15]

Recently, based on this principle of lasers to condense the hydrated herniated disc, mild to moderate disc herniation is considered as the optimal indication of SELD.[16] However, few reports have methodologically reported the clinical results of SELD for lumbar disc herniation.

In this study, we reviewed the clinical, surgical, and radiological outcomes of SELD in patients with mild to moderate lumbar disc herniation with a follow-up of minimum 6 months.

2. Materials and methods

2.1. Indications and patient population

The study was approved by the Institutional Review Board of our institute (GAIRB2018-214).

The indications for SELD was patient with magnetic resonance imaging (MRI) confirming mild to moderate soft disc herniation features concordant with the clinical symptoms of low back pain

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The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

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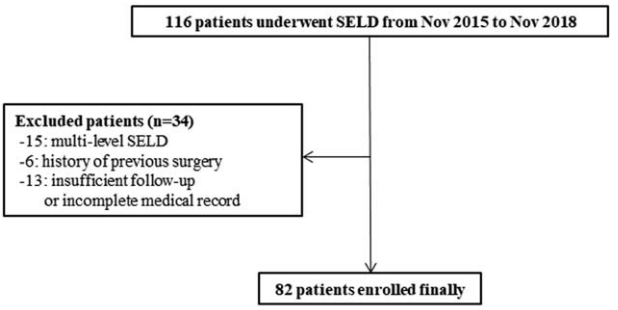

Figure 1. Flowsheet of patient selection.

and/or radicular leg pain despite adequate conservative. On the other hand, the contraindications for SELD included cauda equina syndrome or severe paresis (motor grade 3 or less), hard disc, foraminal disc herniation which is inaccessible using SELD, significant spinal stenosis or instability, hemorrhagic diathesis, and anatomical abnormalities such as anomaly of sacral hiatus or peridural cyst.

Among the 116 patients underwent SELD in a single institution between November 2015 and November 2018, 82 patients were retrospectively enrolled in the final cohort. The study exclusion criteria were as follows:

1) multi-level procedure,
2) previous history of surgery in the lumbar spine,
3) insufficient follow-up duration of 6 months or an incomplete medical record (Fig. 1).

Data were based on regular follow-up data obtained from the medical records.

2.2. Operative technique

The procedure was performed in prone position under local anesthesia using lidocaine over the sacral hiatus.

A 5 mm sized samll skin incision was made on the sacral hiatus, followed by a sacrococcygeal ligament puncture using a trocar under fluoroscopic guidance. After the advancement of the trocar to the S2–3 level, a video guided catheter of 3.2 mm in diameter (Spinaut V, Imedicom Inc., Seoul, Korea) containing 2 lumens (1.2 mm in diameter) was inserted through the trocar to the target level. Consequently, the video guided catheter was advanced to the target level using bi-directional steering characteristics and the injection of radio-opaque dye via an infusion port, and fluoroscopic pictures were obtained to verify the position of the catheter in the ventral epidural space and confirm the outline of herniated disc and flow obstruction caused by disc herniation and adhesion around the pathologic site. Through the video guided catheter, the flexible epiduroscope of 1.0 mm in diameter (Spinaut S, Imedicom Inc., Seoul, Korea) and flexible fiber of a Ho:YAG laser of 550 μm in diameter were advanced into the end of the catheter to visualize the epidural space and condense pathologic lesion.

The Ho:YAG laser generated by Litho (Quanta system Inc, Milan, Italy) was used in this study because of its high quality ablation of the hydrated disc without significant thermal injury to the neural structures.[11] The laser has a 2100 nm wavelength and a 0.4 mm depth of penetration.[1]

Under direct vision via flexible epiduroscope, after confirmation that the tip of the catheter was located at the most inferior part of the herniated disc covered by the posterior longitudinal ligament, adhesiolysis around the target site and laser ablation of the herniated disc were performed. First, the bulging posterior longitudinal ligament was shrunk using a Ho:YAG laser at 2.5W (0.5 J and 5 Hz), checking the patient's response. Once the patient tolerated the low grade laser, the posterior longitudinal ligament was penetrated using the laser of 5 W (0.5 J and 10 Hz). Then the herniated disc under the posterior longitudinal ligament was shrunk and decompressed by high energy laser of 8 to 10W (0.8–1.0 J and 10 Hz). Protruded or ruptured discs were decompressed until the direct images confirmed a decompressed nerve root or thecal sac (Fig. 2).

As the herniated disc decreased, the epidural space between the dura and pathologic lesion became wider. Repeated epidurograms should show a flattened outline and free flow at the target site after sufficient decompression.

The wounds were closed by 1-point subcutaneous suture and skin tape.

All procedures were performed by 1 surgeon.

2.3. Outcome evaluation

Demographic data and baseline characteristics, including age, sex, body mass index, surgical level, and preoperative symptom duration were investigated. Lumbar MRI was performed prior to surgery, and preoperative state including grade of disc degeneration using Pfirrrmann grade,[17] disc height, presence of annular tearing known as high intensity zone, degree of disc protrusion (bulging, protrusion, or extrusion), the volume of disc herniation (determined as transverse diameter × depth × height of disc herniation × 1/2), location of protruded disc (central, right, or left), degree of combined stenosis (none/mild/moderate/severe), and degree of root compression (abutting/displace/near obliteration/obliteration) were evaluated.

Clinical outcomes were assessed using visual analog scale (VAS) scores of low back pain and leg pain. Data were collected preoperatively and at each follow-up visit (at 1 week, 1 month, and 6 months). Patient satisfaction was surveyed using Odom's criteria at each follow-up visit (at 1 week, 1 month, and 6 months).

Surgical outcomes were evaluated using operation time, surgical failures, surgical complications, length of hospital stay, and return-to-work timing. Long-term surgical outcomes were assessed according to performance of additional procedures, including revision surgeries and nerve blocks during follow-up period.

Plain radiography was performed at pre-operation and 6 months after surgery to assess the change in lumbar alignment. Segmental angle and range of motion at the surgery level, and total lumbar lordosis were measured using Cobb method to evaluate radiological outcomes.

2.4. Statistical analysis

Data management and statistical analysis were performed using SPSS version 23.0 (SPSS Inc., Chicago, IL). Pearson's chi square test, Wilcoxon signed-rank test, the paired samples t-test, Friedman test (a nonparametric multiple comparison test), 1-way analysis of variance (ANOVA), independent *t*-test, and non-parametric Mann-Whitney *U*-test were used for univariate

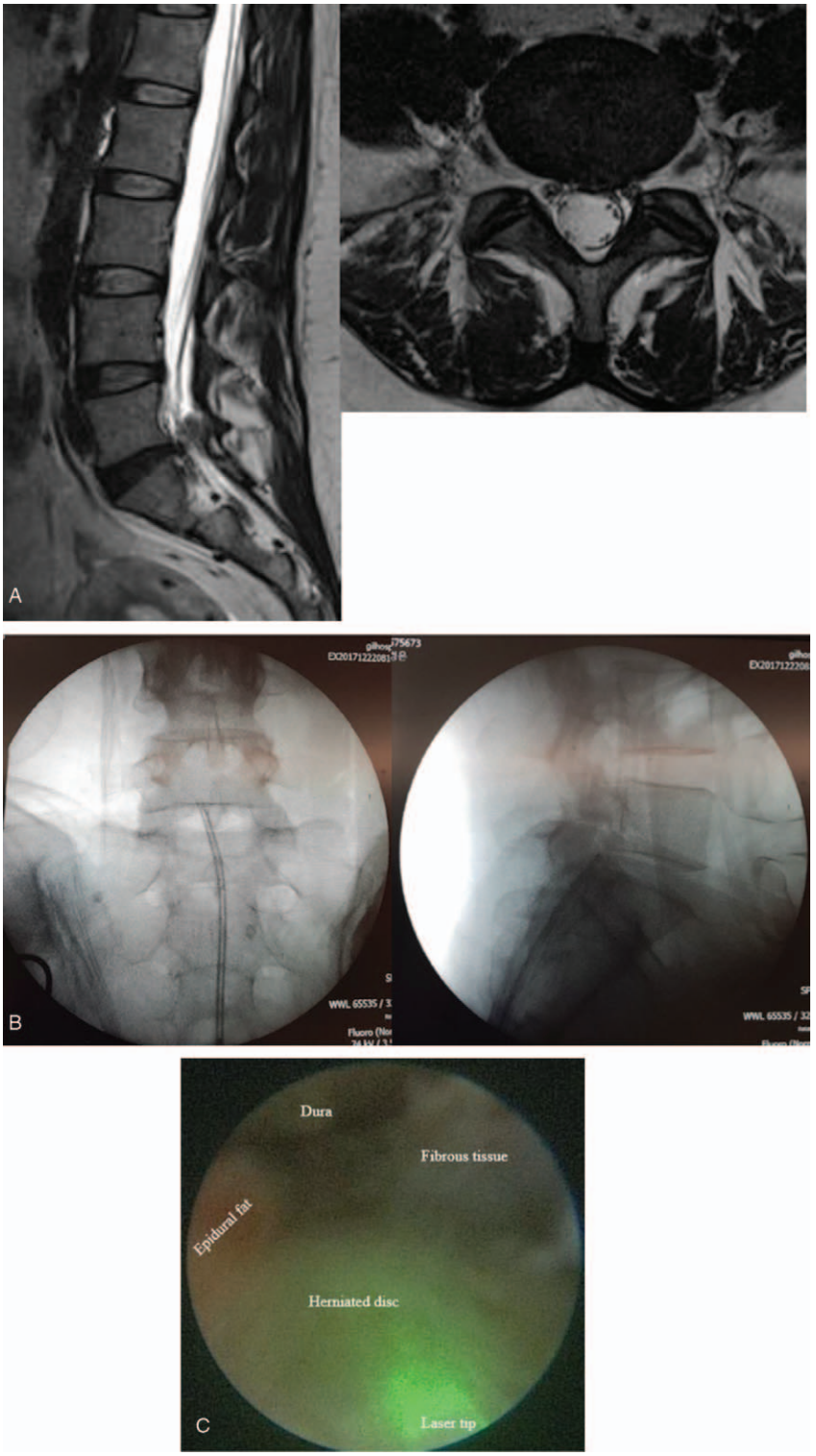

Figure 2. Surgical illustration of trans-sacral epiduroscopic laser decompression. A. Preoperative magnetic resonance imaging showing mild disc herniation at the left side of the L5-S1 level. B. Intraoperative fluoroscopic picture showing the catheter tip at the ventral epidural space at the left side of the L5-S1 level. C. Intraoperative endoscopic view showing green laser tip and laser ablation of herniated disc during surgery.

comparison according to characteristics of the factors. Kaplan-Meier survival analysis was used for the analysis of survival without additional procedures.

Results were expressed as means ± standard deviations, medians with ranges, or mean and 95% confidence interval (CI), and statistical significance was accepted for P values of $<.05$.

3. Results

3.1. Demographic data and baseline characteristics

The 82 study subjects were comprised of 52 men and 30 women, with an overall mean age of 40.78 ± 15.24 years and mean body mass index of 24.15 ± 3.99.

Table 1

Demographic data and baseline characteristics.

Characteristics	Number (n = 82)
Age	40.78 ± 15.24 (95%CI 35.97–45.59)
Sex, male/female	52/30 (63.41%)
Occupation, white/blue/etc.	36/18/28
Smoking, yes/no	26/56 (31.7%)
packs-year	3.74 (95%CI 1.50–5.99)
Alcohol consumption (g/week)	0 (range, 0–120.0)
Height (cm)	169.46 ± 10.24 (95%CI 166.23–172.70)
Weight (kg)	69.50 ± 13.77 (95%CI 65.15–73.84)
Body mass index (kg/m^2)	24.15 ± 3.99 (95% CI 22.88–25.40)
Diabetes Mellitus, yes/no	6/76 (7.32%)
Hypertension, yes/no	18/64 (21.95%)
Symptom duration (weeks)	1.0 (range, 0.1–12.0)
Admission route, outpatient/emergency room	72/10
Previous block, yes/no	48/34 (58.54%)
Trauma history, yes/no	12/70 (14.63%)
Dominant symptom, low back pain/leg pain	26/56
Follow-up duration (mo)	23.0 (range, 6.0–30.0)

The median duration of symptoms was 1.0 weeks (range, 0.1–12.0). Twelve patients (14.6%) had a minor trauma history related to symptom aggravation, and 26 patients (31.7%) had a low back pain dominant symptom other than radicular leg pain. The median follow-up period was 23.0 months (range, 6.0–30.0) (Table 1).

According to preoperative MRI, the surgical levels were the followings: L3–4 in 6 patients, L4–5 in 22 patients, and L5–S1 in 54 patients. A high intensity zone was revealed in 28 patients (34.2%) and the herniated disc volume was 0.30 ± 0.12 mL (Table 2).

3.2. Clinical outcomes

For all 82 study subjects, the mean preoperative VAS for low back pain was 5.43 ± 1.73, and this decreased to 3.22 ± 1.44 at 1-week post-operation, 2.59 ± 1.56 at 1-month post-operation, and 2.8 ± 1.43 at the final follow-up ($P < .001$, 1-way ANOVA). Pre-operation to 1-week post-operation, pre-operation to 1-month post-operation, and pre-operation to the final follow-up differences in VAS for low back pain were significant (2.22 ± 0.34 [95% CI, 1.32–3.12], 2.85 ± 0.36 [95% CI, 1.91–3.79], 2.61 ± 0.40 [95% CI, 1.56–3.65], $p < 0.001$, respectively, ANOVA with post-hoc), but the differences between 1-week post-operation, 1-month post-operation and the final follow-up of VAS for low back pain were not significant (Table 3).

Table 2

Baseline characteristics determined by preoperative magnetic resonance imaging and intraoperative findings.

Characteristics	Number (n = 82)
Surgical level, L3–4/L4-5/L5-S1	6/22/54
Pfirrmann grade, I/II/III/IV	0/22/50/10
High intensity zone, yes/no	28/54 (34.2%)
Disc morphology, bulging/protrusion/extrusion	10/46/26
Location of herniation, central/right/left	26/20/36
Degree of canal compromise, mild/moderate/severe	60/22/0
Root compression grade, abutting/displace/near obliteration/obliteration	42/28/10/2
Herniated disc volume (mL)	0.30 ± 0.12 (95% CI 0.26–0.34)
Degree of stenosis, none/mild/moderate/severe	54/26/2/0
Adhesion during surgery, mild/moderate/severe	5/22/45

Table 3

Clinical outcomes.

Characteristics		*P* value
VAS for low back pain		<.001†
Preoperative	5.43 ± 1.73	
1 wk	3.22 ± 1.44	
1 mo	2.59 ± 1.56	
final follow-up	2.80 ± 1.43	
ΔVAS for low back pain		
Preoperative – 1 wk	2.22 ± 0.34 (95% CI, 1.32–3.12)	<.001†
Preoperative – 1 mo	2.85 ± 0.36 (95% CI, 1.91–3.79)	
Preoperative – final f/u	2.61 ± 0.40 (95% CI, 1.56–3.65)	
1 wk – 1 mo	0.63 ± 0.36 (95% CI, -0.31–1.57)	.304†
1 wk – final follow-up	0.39 ± 0.40 (95% CI, -0.66–1.43)	.770†
1 mo- final follow-up	-0.25 ± 0.42 (95% CI, -1.33–0.84)	.935†
VAS for leg pain		<.001†
Pre OP	6.10 ± 1.67	
1 wk	3.90 ± 1.83	
1 mo	3.35 ± 2.36	
final follow-up	3.58 ± 2.08	
ΔVAS for leg pain		
Pre OP – 1 wk	2.20 ± 0.44 (95% CI, 1.06–3.33)	<.001†
Pre OP – 1 mo	2.74 ± 0.46 (95% CI, 1.55–3.93)	
Pre OP – final f/u	2.51 ± 0.51 (95% CI, 1.20–3.83)	
1 week – 1 mo	0.55 ± 0.46 (95% CI, -0.64–1.74)	.627†
1 week – final f/u	0.32 ± 0.51 (95% CI, -1.00–1.64)	.922†
1 month - final f/u	-0.23 ± 0.53 (95% CI, -1.60–1.14)	.972†
Odom criteria		.551‡
1 wk, Excellent/Good/Fair/Poor	10/40/30/2	
1 mo, Excellent/Good/Fair/Poor	20/28/34/0	
final follow-up, Excellent/Good/Fair/Poor	16/32/30/4	
Success rate at 1 wk	61.0% (50 patients)	
Success rate at 1 mo	58.5% (48 patients)	
Success rate at final follow-up	58.5% (48 patients)	

† one-way ANOVA.
‡ Pearson Chi square test.

The mean preoperative VAS for leg pain was 6.10 ± 1.67, and this decreased to 3.90 ± 1.83 at 1-week post-operation, 3.35 ± 2.36 1-month post-operation, and 3.58 ± 2.08 at the final follow-up ($P < .001$, 1-way ANOVA). Pre-operation to 1-week post-operation, pre-operation to 1-month post-operation, and pre-operation to the final follow-up differences in VAS for leg pain were significant (2.20 ± 0.44 [95% CI 1.06–3.33], 2.74 ± 0.46 [95% CI 1.55–3.93], 2.51 ± 0.51 [95% CI 1.20–3.83], $p < 0.001$, respectively, ANOVA with post-hoc), but the differences between 1-week post-operation, 1-month post-operation and final follow-up of VAS for leg pain were not significant (Table 3).

According to Odom criteria, the results were excellent in 10 (12.2%) and good in 40 patients (48.8%) at 1-week after the operation, excellent in 20 (24.4%) and good in 28 (34.1%) at 1-month after the operation, and excellent in 16 (19.5%) and good in 32 (39.0%) at the final follow-up. In other words, the success rate of the surgery (excellent or good according to Odom criteria) was 61.0% at 1-week after operation, 58.5% at 1-month after operation, and 58.5% at the final follow-up. Odom criteria distributions at all points of time after surgery were not significantly different ($P = .551$, Pearson Chi square test) (Table 3).

Table 4

Surgical outcomes.

Characteristics	Number (n = 82)
Operation time (minutes)	50.0 (range, 30.0–100.0)
Hospital stay (days)	3.60 ± 0.80
Time to return-to-work (days)	15.41 ± 6.92
Surgical complication	7 (8.5%)
Headache or nuchal pain during procedure	4 (4.9%)
Transient motor weakness	2 (2.4%)
Dural puncture	1 (1.2%)
Additional procedure	14 (17.1%)
Additional epidural block	8 (9.8%)
Revision surgery	6 (7.3%)

3.3. Surgical outcomes

The median operation time was 50.0 minutes (range, 30.0–100.0), the mean hospital stay was 3.60 ± 0.80 days, and the mean time return-to-work was 15.41 ± 6.92 days (Table 4).

Surgical complications occurred in 7 patients (8.5%), including 4 patients with transient headache or nuchal pain during the procedure, 2 patients with transient motor weakness, and 1 patient with dura puncture during the procedure. Fortunately, there were no surgical site infections or permanent neurologic deficits after the surgery. In addition, there was no perioperative morbidity related to the procedure, such as a cardiopulmonary problem or deep vein thrombosis.

Eight patients (9.8%) underwent an additional nerve block for persistent pain or pain recurrence during the follow-up. Six patients (7.3%) underwent revision surgery at the index level due to aggravation of symptoms during their follow-ups (discectomy for 5 patients and fusion for 1 patient) (Table 4).

The 6-month procedure-free survival rate was 82.9%, and the mean overall time before an additional procedure, including a nerve block or revision surgery, was 25.86 ± 1.56 months (95% CI, 22.79–28.92). (Fig. 3)

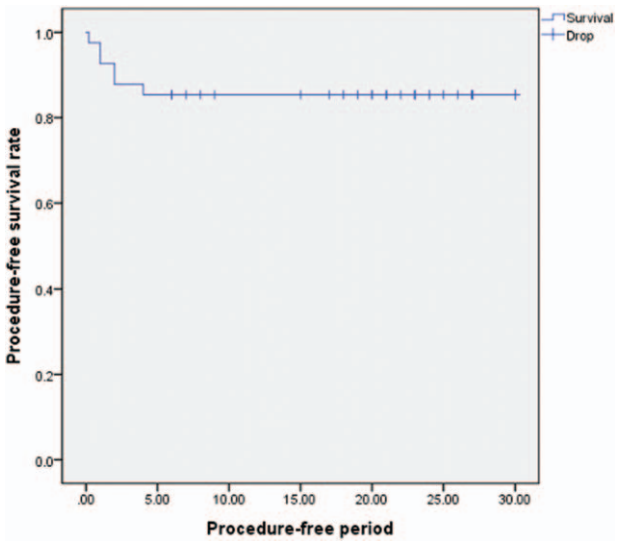

Figure 3. Kaplan-Meier survival analysis of survival without additional procedures.

Table 5

Radiological outcomes.

Characteristics		*P* value
Disc height (mm)		
Preoperative	18.21 ± 1.18	
6 mo	18.02 ± 1.44	
Δ Preoperative – 6 months	0.21 ± 1.25	.670†
	(95% CI -1.43–1.96)	
Segmental angle at the surgery level (°)		
Preoperative	7.70 ± 4.69	
6 mo	7.97 ± 4.20	
Δ Preoperative – 6 mo	-0.28 ± 2.23	.571†
	(95% CI, -1.26–0.72)	
Range of motion at the surgery level (°)		
Preoperative	5.94 ± 4.48	
6 months	7.32 ± 6.16	
Δ Preoperative – 6 mo	-1.38 ± 6.23	.312†
	(95% CI, -4.14–1.39)	
Total lumbar lordosis (°)		
Preoperative	31.25 ± 16.44	
6 months	35.83 ± 11.01	
Δ Preoperative – 6 months	-1.38 ± 10.73	.058†
	(95%CI, -9.33–0.18)	

† Paired *t*-test.

3.4. Radiological outcomes

All radiological findings, including disc height of index level, segmental angle of index level, range of motion of index level, and total lumbar lordosis, were not significantly different between the pre-operation and 6 months after surgery (Table 5).

4. Discussion

With development of the flexible small caliber endoscopy and Ho:YAG laser, clinical implication of SELD was expanded during past decade. High resolution of endoscopic view via flexible catheter make it possible to investigate in narrow epidural space. In addition, steerable catheter allows to reach to the target lesion easily. The Ho:YAG laser has a new wavelength and consequently offers precise cutting with minimal damage to adjacent tissue compared to CO_2 lasers.[11] The depth of penetration of Ho YAG laser is only 0.4 mm and the energy of Ho laser used during SELD is quite lower than that used in operations of other fields (2–10W versus more than 20W). These instruments can guarantee the feasibility and safety of SELD for lumbar disc herniation.

Several previous studies demonstrated that the clinical outcomes of SELD were favorable, as there was a significant decrease of low back pain or radiating leg pain, patient satisfaction higher than 70%, and a low rate of failure or recurrence rate.[11,13,14,16,18] However, according to this study, the clinical results after SELD were not all favorable. Although the mean VAS of low back pain and leg pain were decreased significantly, the satisfaction and surgical failure rates were not all good. According to Odom's criteria, the patient satisfaction rate was 58.5%, and surgical failure rate, including additional nerve blocks or revision surgeries, was 17.1% during the follow-up period of a minimum of 6 months. This result was not favorable compared with not only the previous study of SELD but also the results of another surgical technique for lumbar disc herniation.

The authors raise several hypotheses about the reasons for this discordance with previous studies. First, the effect of decompression after laser ablation might be lower than expected. Although the surgeon confirmed decompression of the target during the procedure, the objective reduction of the herniated disc could be minimal in immediate postoperative MRI.[14] Also, because of the delayed effects of laser ablation and dehydration of herniated soft disc, clinical results could vary in many patients.[16] However, the final cohort in this study had a minimum of 6 months of follow-up, and this sufficient follow-up period could rule out this hypothesis.

Second, the learning curve of SELD of surgeons could affect the result. The result may be less favorable in the early stages of clinical application than in the later stages. Further study is needed to clarify the effect of surgeon learning curve in clinical outcomes.

Third, the selection of different patients could cause varied clinical outcomes. Even in the similar patients with soft disc herniation, differences in detailed baseline characteristics, such as demographic data, location of disc herniation, or morphology of pathology could affect the clinical outcome. To clarify whether these baseline factors have an influencing effect on outcomes, further research is needed.

This study has some limitations. Due to its retrospective nature, it was impossible to control for all variations. Nevertheless, we tried to minimize errors by precluding the variables associated with results; for example, we excluded patients with multi-level procedures or previous histories of lumbar spine surgery, and who received insufficient follow-up. Also, the number of patients in the final cohort was not large enough, and the study was conducted at a single center. However, this single center study could maintain the quality of follow-up and exclude the factor of the diversity of surgeons. Of course, further studies with large numbers of subjects are mandatory to confirm the clinical results and to clarify the influencing factors on the clinical outcomes of SELD.

5. Conclusion

The clinical outcomes of SELD with minimum 6 months follow-up were not favorable compared to those of previous studies, as patient satisfaction was 58.5% and additional procedure rate was 17.1%. According to these results, we believe that there could be several reasons for this variation in clinical outcomes, including a learning curve and baseline influencing factors on outcomes; thus further study with a larger cohort is needed.

Author contributions

Conceptualization: Seong Son, Sang Gu Lee.
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Formal analysis: Seong Son.
Funding acquisition: Seong Son.
Investigation: Seong Son.
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Supervision: Sang Gu Lee, Woo Kyung Kim.
Validation: Seong Son.
Visualization: Seong Son.
Writing – original draft: Seong Son.
Writing – review & editing: Seong Son.

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