ORIGINAL ARTICLE

A Novel Combination Technique: Three Points of Epiduroscopic Laser Neural Decompression and Percutaneous Laser Disc Decompression With the Ho:YAG Laser in an MSU Classification 3AB Herniated Disc

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■ **Abstract**

Aim: The aim of this study was to examine the effects of simultaneous epiduroscopic laser neural disc decompression (ELND) and percutaneous laser disc decompression (PLDD) applications using a holmium:yttrium-aluminum-garnet (Ho:YAG) laser in Michigan State University (MSU) classification 3AB herniated discs on VAS and Oswestry Disability Index (ODI) scores.

Methods: In this prospective observational study, ELND and PLDD procedures performed between January 2016 and December 2017 were examined. Preoperative, postoperative week 2, postoperative month 2, and postoperative month 6 ODI and VAS scores were obtained from patient files, and postoperative month 12 ODI and VAS scores were obtained from face-to-face interviews with patients and recorded.

Results: The data of 41 patients treated with simultaneous ELND and PLDD using a Ho:YAG laser were included in this study. Postoperative VAS scores of the patients were compared with preoperative values, and it was found that postoperative week 2, postoperative month 2, postoperative month 6, and postoperative month 12 VAS and ODI scores were significantly different compared to preoperative scores ($P = 0.001$; $P < 0.01$). 17.1% ($n = 7$) of the patients had a history of postoperative open surgery. Although dural puncture occurred in 7 patients (17%), only 1 patient had headache.

Conclusion: We believe that the new combined technique of ELND and PLDD using a Ho:YAG laser is a reliable method in patients with MSU classification 3AB herniated discs, with an acceptable success rate and a low complication rate within 12 months after treatment. We think that randomized controlled studies are

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required for this method to be included in treatment algorithms. ■

Key Words: epiduroscopic laser neural decompression, Ho:YAG laser, percutaneous laser disc decompression, MSU classification, low back pain, pain

INTRODUCTION

Many adults suffer from low back pain at least once in their lifetime. Although low back pain can be treated mostly by conservative methods such as medication and physiotherapy, approximately 20% of patients develop chronic pain. Due to advances in percutaneous techniques, minimally invasive methods used in the treatment of low back pain have become popular. Specifically, percutaneous laser disc decompression (PLDD) is a treatment option for patients suffering from back and leg pain. Water is the main component of intervertebral discs. In a herniated nucleus pulposus, evaporation of a small portion of the nucleus pulposus makes the disc smaller and reduces pain.[1]

Epiduroscopy is a minimally invasive technique that has been frequently used in recent years for spinal diseases.[2] Fundamentally, epiduroscopic procedures enable direct imaging of spinal structures in the treatment of lumbar spinal stenosis and chronic lumbar and/or leg pain; dilution of biomechanical irrigators such as phospholipase A2 and tumor necrosis factor with saline; and targeted injections.[3] It has been shown that epiduroscopy can reduce pain and improve functional status by various therapeutic means as described above. Epiduroscopy is one of the most frequent interventions for managing spinal problems. However, only a portion of patients show pain and functional improvement after epiduroscopic procedures.[4]

Epiduroscopic laser neural disc decompression (ELND) can be an effective method in the treatment of intraspinal pathologies such as herniated nucleus pulposus and pain-causing microscopic adhesions. Although evidence on the long-term effects of epiduroscopic laser treatment supports the benefits of the procedure, its effectiveness in eliminating pathological adhesions is still controversial.[5] Specifically, the failure of eliminating the pathology in epidural adhesiolysis and thus unsatisfactory results obtained in patients with failed back surgery syndrome demonstrate the necessity of investigating additional methods to increase the effectiveness of epiduroscopic procedures.[4] The laser ablation method has been reported to be preferable to open surgery because of its advantages such as not requiring dissection, not causing bleeding or causing less bleeding, causing less tissue damage, and having a lower risk for re-fibrosis.[6]

The aim of this study was to examine the effects of simultaneous ELND and PLDD applications using a holmium:yttrium-aluminum-garnet (Ho:YAG) laser in Michigan State University (MSU) classification 3AB herniated discs on VAS and Oswestry Disability Index (ODI) scores over a 1-year period.

METHODS

In this prospective observational study, ELND and PLDD procedures performed in the Sakarya University Training and Research Hospital, Anesthesiology and Reanimation AD Algology Clinic between January 2016 and December 2017 were examined. Ethics Committee approval was obtained from the Sakarya University Faculty of Medicine. Patient information was obtained from the Karmed (Kardelen Software, Mersin, Turkey) hospital information system. Patient files were scanned through the hospital archive. Patients with incomplete information in the hospital system or their files were contacted by telephone and the missing information was obtained. Age, gender, weight, level of discopathy, history of preoperative and postoperative surgery, amount of physiological saline used during the procedure, duration of the procedure, whether lumbar epidural steroid application was made, amount of epiduroscopic and percutaneous laser used during the procedure, and postoperative complications were examined. In addition, preoperative, postoperative week 2, postoperative month 2, and postoperative month 6 ODI and VAS scores were obtained from patient files, and postoperative month 12 ODI and VAS scores were obtained from face-to-face interviews with patients and recorded.

Inclusion criteria were: patients who had experienced low back/leg pain for at least 3 months, had not benefitted from conservative treatment, had no motor deficit in the examination, had not accepted open surgery, and had an MSU classification 3AB herniated disc in the axial section as confirmed by MRI. Exclusion criteria were: patients who had extraforaminal disc extrudation in the axial section as confirmed by MRI, had previously undergone endoscopic and/or open lumbar surgery, had a bleeding diathesis as confirmed by preoperative laboratory tests, had a local

infection at the site of intervention, or had a systemic infection.

In the Algology Service, the IV route was opened in patients with a fasting duration of 6 to 8 hours, and 1 g ceftriaxone IV was administered 1 hour before the operation for antibiotic prophylaxis. Patients were taken to the operating room and placed in the prone position. A 0.9% IV saline infusion was initiated. After standard monitorization, sacral and caudal areas of the patient were cleaned, and septic conditions were achieved. After the patient was covered with sterile drapes, the cutaneous/subcutaneous and caudal regions were anesthetized using a 22-gauge black spinal needle with a Quincke tip. The sacral hiatus was reached using a trocar with a 4.2 mm outer diameter and a 3.5 mm inner diameter. C-arm fluoroscopy-guided lateral and anteroposterior imaging confirmed that the trocar was in the midline and then the Spinaut-V video-guided catheter (IMEDICOM Co. Ltd, Gyeonggi-do, Korea) was placed in the trocar. The epiduroscopy catheter was directed to the anterior epidural region. Levels L5–S1, L4–5, and L3–4 were displayed. Once the herniated disc pathology was seen, a 400-µm diameter Ho:YAG laser probe (ACCU-Tech Co., Ltd, Beijing, China) was placed in the disc at 3 different points: right paramedian, median, and left paramedian, respectively (Figure 1). Maximal pulse repetition rates from 50 to 80 Hz were tested with pulse energy levels of 0.5 and 0.8 J. Following this, the holmium laser was applied, and the data that emerged during the decompression were recorded. In the epiduroscopic image, if there was any herniation simultaneously applying pressure on another thecal sac, the Ho:YAG laser was also applied on these herniations. In PLDD, after visualization using C-armed fluoroscopy, the disc pathology at the MSU 3AB herniated disc level was simultaneously entered percutaneously to the midpoint of the disc with the help of a 16-gauge working cannula. Then the Ho:YAG laser probe used in the ELND procedure was applied on 3 different points from the midpoint of the disc to the annulus fibrosis (Figure 2). If there were no other herniations, an epidurogram was performed using a non-ionic contrast agent (iohexol 180 mg/mL). After the radiopaque material was observed to form a straight line in the anterior epidural area, the procedure was completed. All interventional procedures were performed by the first author (S.G.B). Pain and disability assessments were performed based on VAS and ODI findings. The selected patients were evaluated before the procedure and at the 2nd week after the procedure, and at the 2nd, 6th, and 12th months after the procedure, and the pain and disability scales were applied. In this study,

1. Compared to the preoperative values, postoperative 12th month VAS scores decreased by 50%;
2. The postoperative 12th month VAS scores fell to 3 and below;
3. Compared to the preoperative values, a decrease of 40% or more was observed in postoperative 12th month ODI scores; and

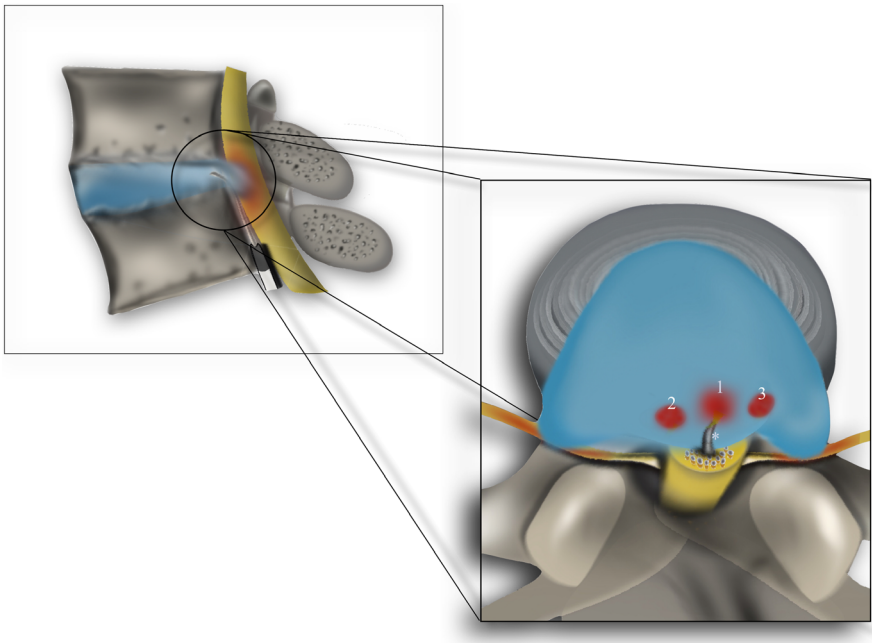


Figure 1. Sagittal view of the epiduroscopy catheter can be seen in front of the thecal sac at the ventral epidural distance. 3-point Ho:YAG laser application (median, left paramedian, and right paramedian) for epiduroscopic laser neural decompression is depicted.

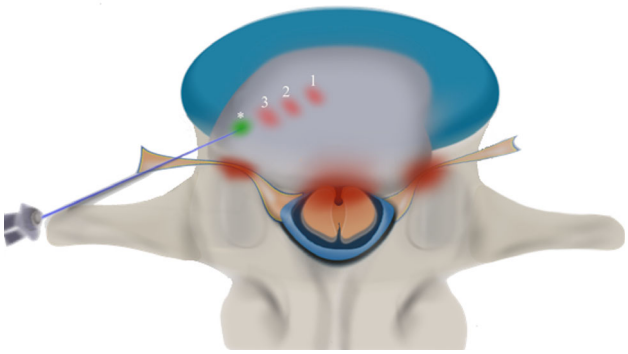


Figure 2. 3-point Ho:YAG laser application in nucleus pulposus for percutaneous laser disc decompression.

4. The postoperative 12th month ODI scores were below 40% and were evaluated as successful.

The patient progress levels in the hospital system and files were scanned. Complications (bleeding, infection, dural puncture, and neurological signs) that emerged during and after the procedure were recorded.

Statistical Analysis

The 2007 Number Cruncher Statistical System (NCSS, Kaysville, UT, U.S.A.) program was used for statistical analysis. Student's *t*-test and the Mann–Whitney *U* test were used for descriptive statistical methods (mean, standard deviation, median, frequency, ratio, and range) in 2 groups, as well as for the normal distribution of quantitative data. The Friedman and Wilcoxon signed-rank tests were used in the evaluation of 3 or more follow-up parameters without normal distribution. Diagnostic screening tests (sensitivity, specificity) and receiver operating characteristic (ROC) analysis were used to determine the cutoff value for age. Significance was evaluated at the level of $P < 0.01$.

RESULTS

Sixty-two patients treated with ELND and PLDD in the Algology Clinic of Anesthesiology and Reanimation Department, Sakarya University, Training and Research Hospital, between January 2016 and December 2017 were included in this prospective observational study. Two of these patients (3.2%) did not want to participate in the study, 7 (11.3%) could not be reached by phone, and 12 (19.4%) had a history of preoperative open surgery; thus, these patients were excluded from the study. The study was completed with 41 patients (66.1%) (Figure 3); 39.6% ($n = 15$) of the patients were female and 63.4% ($n = 26$) were male, and patient age ranged from 23 to 72 years, with a mean of 46.57 ± 13.02 years. The patients' weight ranged from 50 to 115 kg, with a mean weight of 83.53 ± 14.21 kg; height measurements ranged from 151 to 195 cm, with a mean of 171.57 ± 10.07 cm; and body mass index (BMI) measurements ranged from 17.9 to 40.4 kg/m^2, with a mean BMI of 28.43 ± 4.67 kg/m^2. Demographic characteristics of the patients are shown in Table 1.

When disc herniation levels were examined, it was observed that the levels most frequently affected by MSU 3AB disc herniation were L3–L4 (7.3%; $n = 3$), L4–L5 (53.7%; $n = 22$), and L5–S1 (39%; $n = 16$). The amount of administered fluid ranged from 60 mL to 200 mL, with a mean of 117.21 ± 39.81 mL. The duration of ELND ranged from 10 to 50 minutes, with a mean of 28.17 ± 9.31 minutes. The energy level of the percutaneous Ho:YAG laser ranged from 80 to 760 J, with a mean of 335.35 ± 176.76 J; and the energy level of the epiduroscopic Ho:YAG laser ranged from 50 to 695 J, with a mean of 322.14 ± 151.38 J (Table 2).

When postoperative VAS scores of the patients were compared with preoperative scores, it was found that postoperative 2nd week, 2nd month, 6th month, and 12th month VAS scores were significantly lower compared to preoperative VAS scores ($P = 0.001$; $P < 0.01$; Table 3). Based on the results of pairwise comparisons, no difference was found between postoperative 2nd week ($P = 0.001$), postoperative 2nd month ($P = 0.001$), postoperative 6th month ($P = 0.001$), and postoperative 12th month ($P = 0.001$) VAS scores ($P > 0.05$; see Table 3). When postoperative ODI scores were compared with preoperative values, it was found that postoperative 2nd week, 2nd month, 6th month, and 12th month ODI scores were statistically lower compared to preoperative ODI scores ($P = 0.001$; $P < 0.01$; see Table 3). Based on the results of pairwise comparisons, no difference was found between postoperative 2nd week ($P = 0.001$), postoperative 2nd month ($P = 0.001$), postoperative 6th month ($P = 0.001$), and postoperative 12th month ($P = 0.001$) ODI scores ($P > 0.05$, see Table 3). The mean postoperative 12th month ODI scores of the patients were 47.26 ± 28.74% lower compared to preoperative scores, and the decrease was more than 40% in 67.9% ($n = 28$) of the patients. The mean postoperative 12th month VAS measurements of the patients were decreased by 50.07 ± 32.04% compared to preoperative measurements, and the

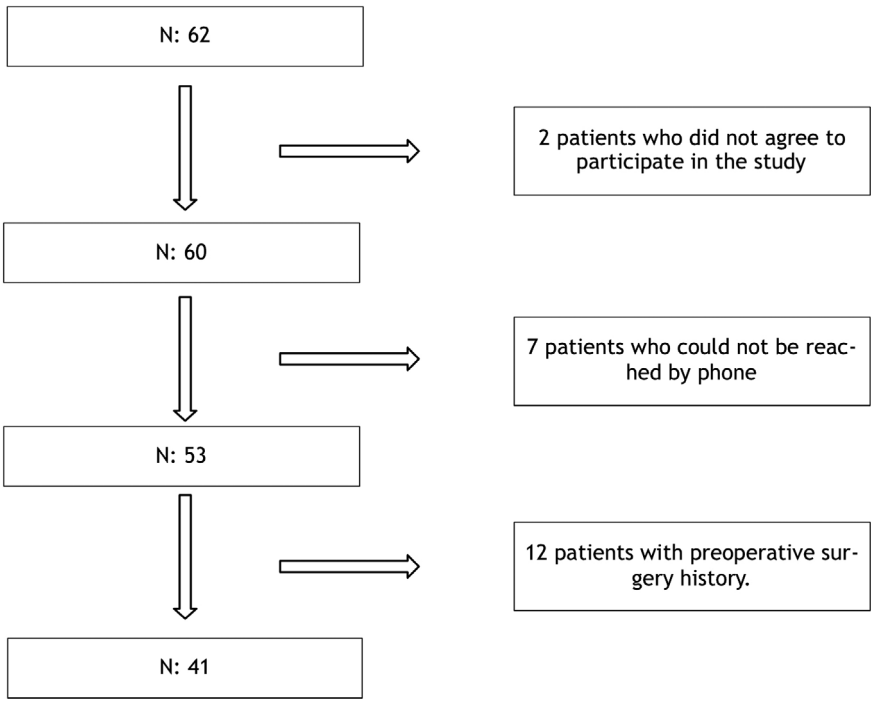


Figure 3. Flow diagram of patient selection criteria.

Table 1. Demographic Characteristics of ELND- and PLDD-Treated Patients

Age (years)	Range (median)	23 to 72 (45)
	Mean ± SD	46.57 ± 13.02
Age groups, *n* (%)	<35 years	10 (24.4)
	35 to 44 years	10 (24.4)
	45 to 54 years	10 (24.4)
	≥55 years	11 (26.8)
Gender, *n* (%)	Female	15 (39.6)
	Male	26 (63.4)
Weight (kg)	Range (median)	50 to 115 (84)
	Mean ± SD	83.53 ± 14.21
Height (cm)	Range (median)	151 to 195 (170)
	Mean ± SD	171.57 ± 10.07
BMI (kg/m^2)	Range (median)	17.9 to 40.4 (28.65)
	Mean ± SD	28.43 ± 4.67

BMI, body mass index; ELND, epiduroscopic laser neural disc decompression; PLDD, percutaneous laser disc decompression; SD, standard deviation.

Table 2. Procedural Characteristics of ELND- and PLDD-Treated Patients

Amount of liquid supplied	Range (median)	60 to 200 (114)
	Mean ± SD	117.21 ± 39.81
ELND duration	Range (median)	10 to 50 (27)
	Mean ± SD	28.17 ± 9.31
Percutaneous Ho:YAG laser amount (joules)	Range (median)	80 to 760 (252.5)
	Mean ± SD	335.35 ± 176.76
Epiduroscopic Ho:YAG laser amount (joules)	Range (median)	50 to 695 (266)
	Mean ± SD	322.14 ± 151.38

ELND, epiduroscopic laser neural disc decompression; PLDD, percutaneous laser disc decompression; SD, standard deviation.

decrease was more than 50% in 50.9% (n = 21) of the patients. It was seen that 40.4% (n = 16) of the patients had postoperative 12th week VAS measurements of 3 and below.

It was found that 17.1% (n = 7) of the patients had a history of postoperative open surgery. Although dural puncture was seen in 7 patients (17%), only 1 patient developed headache.

DISCUSSION

In this study, it was found that combined application of ELND and PLDD with a new technique in the minimally invasive treatment of MSU 3AB disc herniation significantly decreased the 1-year VAS and ODI scores in these patients. In the experimental study of Moon et al.,[5] the effect of a 1,414-nm Nd:YAG laser on epidural and intradiscal pressure and temperature was examined in a porcine model and in human cadavers, and 2 different results were obtained. Their first result was that when the 1,414-nm Nd:YAG laser was used for 23, 54, 86, 108, and 181 seconds at the maximum 60-J setting, the postablation temperature increased in the ipsilateral spinal nerve, ipsilateral epidural area, intradural area, and contralateral spinal nerves. This temperature did not exceed 40°C and returned to preoperative levels 472 seconds after ablation. They also stated that the temperature would not exceed 40°C even in places closest to the laser probe, and a further temperature increase would not occur due to the blood circulation in the living human body and the subsequent heat sink

Table 3. Evaluation of VAS and ODI Scores of ELND and PLDD Treated Patients

	Preoperative	Postoperative 2nd Week	Postoperative 2nd Month	Postoperative 6th Month	Postoperative 12th Month	*P* value
VAS score	9.77 ± 0.46	5.09 ± 2.69	4.77 ± 2.95	4.83 ± 3.11	4.89 ± 3.17	0.001*,† Preop vs. 2nd week‡ 0.001† Preop vs. 2nd month‡ 0.001† Preop vs. 6th month‡ 0.001† Preop vs. 12th month‡ 0.001†
ODI score	64.55 ± 14.82	32.53 ± 12.30	30.70 ± 13.22	31.26 ± 14.02	31.34 ± 14	0.001*,† Preop vs. 2nd week‡ 0.001† Preop vs. 2nd month‡ 0.001† Preop vs. 6th month‡ 0.001† Preop vs. 12th month‡ 0.001†

*Friedman test. †$P < 0.001$. ‡Wilcoxon signed-rank test. ELND, epiduroscopic laser neural disc decompression; ODI, Oswestry Disability Index; PLDD, percutaneous laser disc decompression; SD, standard deviation.

effect.[1] Secondly, there was a significant decrease in postoperative epidural and intratemporal pressure compared to the preoperative condition. Studies on animal and cadaveric models showed that intradiscal pressure dropped from 60.2 ± 22.3 psi to 14.3 ± 12.1 psi after ablation, and epidural pressure dropped from 34.6 ± 9.7 psi to 4.6 ± 2.5 psi.[5]

The Ho:YAG laser has a wavelength of 2.1 μm and creates a lesion of <0.5 mm depth in the tissue. Tissue permeability is low, tissue vaporization is near perfect, and damage to surrounding tissues is minimal.[6] It has been reported that the Ho:YAG laser emits more heat compared to the Nd:YAG laser; consequently, it can cause damage in the end plates.[7] In his experimental study on rabbits, Hirohashi[8] stated that using a high-power Ho:YAG laser resulted in increased heat in the surrounding tissues. However, the Ho:YAG laser has been reported to be effective and safe in both spinal diseases and other procedures.[9–12] In a cadaveric study, the dura and nerve root were exposed to a Ho:YAG laser with 2.5, 5, and 10 J of power for 1, 2, and 3 seconds, and histological examinations of the tissues exposed to the Ho:YAG laser beam revealed that necrotic cells were formed in all tissues treated by both parallel and vertically placed laser probes.[13] It is obvious that damage can be seen even at 2.5 J, which is the energy level used for the test dose at the beginning of the epiduroscopic discectomy procedure. However, according to the experimental study of Moon et al.[5], even though the Nd:YAG laser was used, there was no increase in temperature around the ipsilateral and contralateral nerve roots and in the annulus. Cernavin[7] reported that the use of the Ho:YAG laser was more appropriate than use of the Nd:YAG laser. Although the Ho:YAG laser is reported to be mostly reliable, extreme care should be taken even if the laser is used at the test dose since the localization of the nerve structures in the epidural region may change in patients with disc herniation.

In this study, significant disc decompression was achieved with the help of the Ho:YAG laser applied epiduroscopically at 3 different points in patients with advanced lumbar disc herniation with MSU classification 3AB (Figures 4–7). The laser vaporizes the water content of the tissue and causes decompression by denaturing tissue proteins, particularly when applied to herniated discs, which cause compression to the thecal sac. In addition, percutaneous Ho:YAG laser application inside the disc at 3 different points that follows this procedure enables the pressure in the disc and in the epidural area to be significantly lowered. The amount of Ho:YAG laser administered percutaneously and epiduroscopically for these MSU classification 3AB herniated discs was 335.35 ± 176.76 J and 322.14 ± 151.38 J, respectively (see Table 2). Considering that 8,000 to 12,000 J of laser energy was used for percutaneous laser discectomy cases in one study, the amounts in the present study are considerably low.[1] Choy[14] argued that 1,000 J of Nd:YAG laser energy vaporized 98.52 mg of disc tissue, while Lane et al.[15] argued that 1,200 J of Ho:YAG laser energy was superior to other laser types in vaporizing 2.4 g of disc tissue, and they claimed that removal of 2 to 7 g of disc tissue was sufficient. In addition, the application of the percutaneous Ho:YAG laser to the inside of disc at the three different points, provided to significantly decreasing the pressure in the disc and the epidural area. In this study, we attributed the significant benefit to the VAS and ODI scores of the patients to the Ho:YAG laser ablation method applied to both

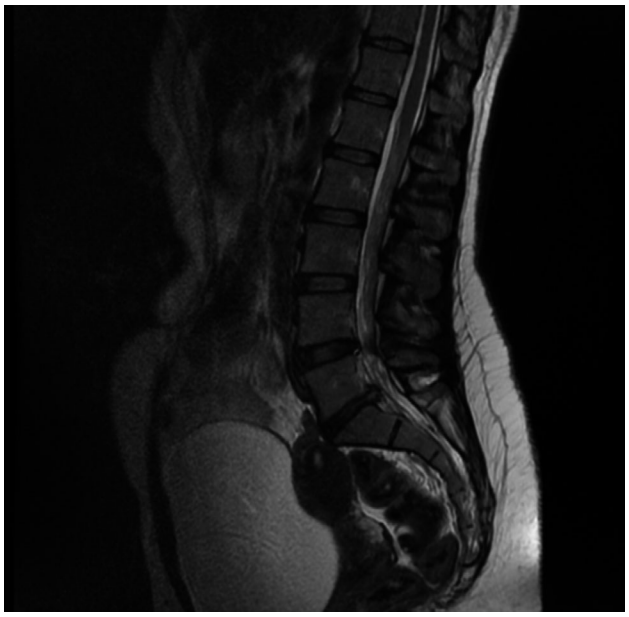


Figure 4. Preoperative MRI sagittal image of patient.



Figure 5. Preoperative MRI axial image of patient.

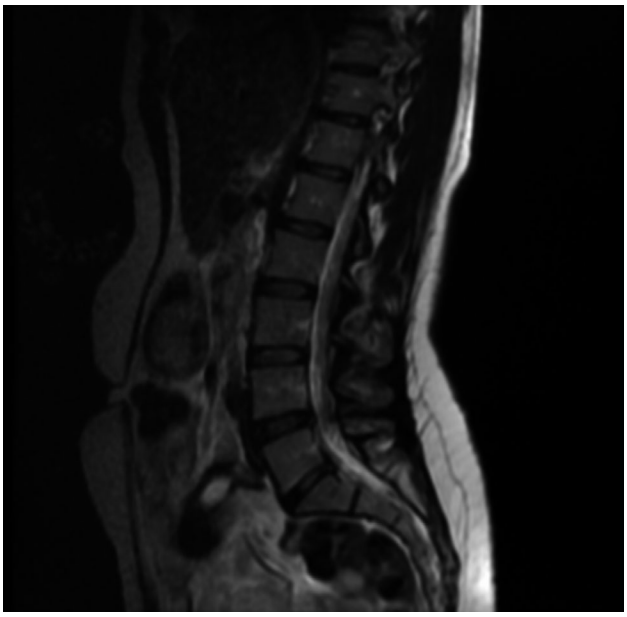


Figure 6. MRI sagittal image after epiduroscopic laser neural disc decompression and percutaneous laser disc decompression.

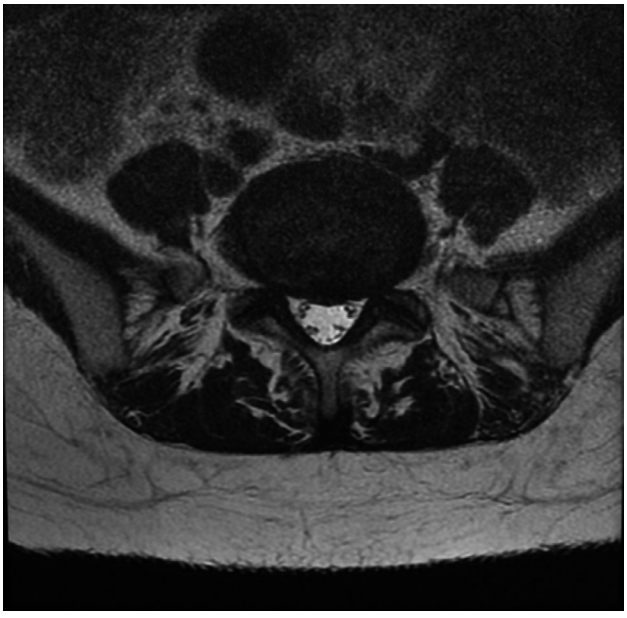


Figure 7. MRI sagittal image after epiduroscopic laser neural disc decompression and percutaneous laser disc decompression.

the main pathology site and the middle of the intervertebral disc.

Compared to the results of percutaneous technical applications applied in lower severity herniations that are MSU classifications 1 and 2, this new combined technique provides similar success rates and outcomes, which is an invaluable result. Because, this combined novel procedure a minimally invasive technique which has many advantages, such as placement of a thin needle at any point during the open surgical technique in MSU classification 3AB herniations, easy access to the L5–S1 disc, a short and ambulatory procedure, and minimal epidural scarring and postoperative pain. This technique is expected to provide a new perspective to the literature and can be an alternative method to open surgical

techniques. Once this technique is supported with enough studies, open surgery will only be used as a rescue technique.

While a 2.5-J level of stimulation for the test dose is not completely safe and carries a risk of undesired tissue damage, the safety of Ho:YAG laser application in these amounts is of course a matter of discussion. However, in the study of Patel and Singh[1], 65 patients who underwent PLDD were evaluated, and the investigators reported that the total energy they used on each disc level varied between 8,000 to 12,000 J. While bleeding, discitis, and infection were not observed in these patients, only 4 patients had neuritis. The amount of energy used was really high. Using this much energy, especially in a narrow region such as the ventral epidural area and in a region completely closed with extruded hernia, may expose the area to catastrophic complications. While the average amount of Ho:YAG laser energy that achieves disc compression in the epidural area is not known, the type of laser used, the power and duration, the size of the herniated disc, whether it is fragmented, the presence or absence of migration, and disc content all will affect this condition. Discitis is a known complication of laser discectomy. We attribute the fact that no discitis cases were encountered in the present study to the very low amounts of Ho:YAG laser energy used in this technique.

Percutaneous discectomy using the Ho:YAG laser began in 1992 and became popular after Choy employed the technique for the first time in Europe and obtained a 75% success rate; it has been shown to be a reliable and successful technique in selected patients.[1,16–18] Kyung-Chul Choi et al.[19] vaporized a down-migrated L4–5 disc by epiduroscopic Ho:YAG laser application in 1 case and successfully removed the disc by the endoscopic method. Beyaz et al.[20] reported that they treated a patient with far-lateral extruded disc herniation and a low foot with percutaneous discectomy and radiofrequency ablation. In this study, we treated patients with MSU 3AB herniated discs using a combined technique of percutaneous and epiduroscopic routes with a success rate of 82.9%.

The main objective of percutaneous techniques is to reduce intradiscal pressure by applying the Ho:YAG laser to the disc. It is not applied to the actual pathology site and it is not possible to do so. The heat from the laser probe leads to denervation of the annulus and pain relief. Denaturation of collagen fibers is thought to stabilize the disc and potentially seal annular fissures.[21] In this new combined technique, laser application was not performed in 1 place. Lesions were created by the laser in 3 separate locations in the disc. When we consider that a 15 × 15 mm diameter lesion is developed when the laser is applied to one point, it can be argued that intradiscal and epidural pressure will be considerably reduced.[13] In addition, it can be thought that disc compression is achieved by safe and reliable application of the laser to the main problem (ie, the herniated disc fragment) from 3 different points.

Although a small number of new or combined techniques have been developed recently by reducing the diameter and size of surgical incisions, laminectomy-discectomy still remains up to date. Although their success rates are claimed to be high, major potential effects, such as a high incidence of failed back surgery syndrome, are still an important problem.[22,23]

There are certain limitations of this study. The small number of cases and the lack of a control group are chief among these limitations. The number of cases remained limited due to the restricted inclusion criteria. The patients were followed up for 12 months after the interventional procedure and were not followed for recurrence after this period. Another limitation of the study is that the follow-up period was limited to 12 months.

In conclusion, we believe that this new combined technique of ELND and PLDD with the Ho:YAG laser is a reliable method in patients who have MSU classification 3AB herniated discs, with an acceptable success rate and a low complication rate within 12 months after treatment. We think that randomized controlled studies are needed for this method to be included in treatment algorithms.

AUTHOR CONTRIBUTIONS

S.B., B.K.: Manuscript preparing, writing and editing, language translating. A.M.Ü., T.E., A.E.: Manuscript preparing and writing, data collection. M.E.İ.: Manuscript preparing and writing. B.D.: Manuscript editing.

CONFLICTS OF INTEREST

Disclosure of benefit is a declaration that the authors have no conflicting interests, not supported or funded by any drug company.

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