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Retrospective Evaluation of Radiological and Clinical Postoperative Findings of Patients Who Had Endoscopic Lumbar Discectomy

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ABSTRACT

AIM: Minimally-invasive spinal surgery is increasingly being adopted worldwide. In this study, we evaluated the postoperative magnetic resonance imaging (MRI) findings and clinical outcomes of patients who underwent monoportal endoscopic lumbar disc surgery.

MATERIAL and METHODS: Preoperative and postoperative 3rd and 6th month MRI features, visual analog scale (VAS) score, Oswestry Disability Index (ODI), and clinical features of patients who underwent percutaneous endoscopic lumbar discectomy between August 2009 and January 2012 were retrospectively analyzed.

RESULTS: 65 patients (37 women, 28 men) were included in the study. VAS and ODI scores showed significant improvement postoperatively ($p<0.001$). Intervertebral disc height loss was observed only in two patients. In 31 (48%) out of the 64 levels treated, no significant anterior soft tissue mass developed. However, 33 patients (52%) showed anterior epidural edema and tissue formation postoperatively. Contrast enhancement of the nerve root was found in 20 levels (29.4%), nerve root edema in 3 levels (4.41%), and nerve root displacement in 3 levels (4.41%). None of the patients had all these 3 findings concomitantly. Of the 57 levels evaluated, 36 levels (63%) showed no or minimal changes in the posterior elements, and at the 3rd month, 9 levels (15.8%) demonstrated grade 1+ changes, 9 levels showed grade 2+ changes, and only 3 levels demonstrated grade 3+ changes; however, at 6-month follow-up, all vertebral levels showed improvements.

CONCLUSION: Endoscopic discectomy is a safe and effective minimally-invasive method. However, owing to the lack of definitive radiological criteria indicating success or failure, the radiological findings should always be interpreted in conjunction with clinical findings.

KEYWORDS: Lumbar disc herniation, Endoscopic lumbar discectomy, Interlaminar discectomy, Transforaminal discectomy, Postoperative magnetic resonance imaging, Surgical outcomes

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INTRODUCTION

Lumbar disc herniation (LDH) is the most common cause of low back pain and leg pain. Discectomy is often performed in patients who do not respond to medical treatments, lumbar injections, and physical therapies, or those who develop a neurological deficit. After the introduction of the surgical microscope, Caspar and Yaşargil described the laminectomy and microdiscectomy (MD) procedures (3,19). This technique has gradually evolved and has become a standard surgical procedure. It is currently one of the main surgical options for the treatment of LDH.

With the development of surgical endoscopes, minimally-invasive endoscopic procedures are now performed in various fields of medicine. However, the implementation of endoscopy in spinal surgery was slower compared to other fields, such as gastrointestinal or orthopedic surgery. Nevertheless, percutaneous endoscopic lumbar discectomy (PELD) for the treatment of LDH has rapidly gained popularity in recent years.

PELD offers many advantages over conventional microdiscectomy, such as less paravertebral muscle damage and faster postoperative recovery. Long-term case studies comparing PELD and microdiscectomy have demonstrated significantly better improvement in low back pain and fewer surgical complications with PELD (12,16).

Although there are many descriptions of endoscopic lumbar discectomy, minimally-invasive endoscopic approaches can be classified into two broad categories: transforaminal (TF) and interlaminar (IL). TF approaches can be divided into two subcategories, i.e., "monoportal endoscopic posterolateral techniques" and "monoportal endoscopic lateral techniques."

MRI is the most commonly used imaging modality for the evaluation of LDH because of its high tissue resolution. Over the past three decades, many studies have compared early and late postoperative MRI findings following conventional MD (2,7). Early postoperative MRI findings can be misleading and difficult to interpret because these often imply a soft tissue mass impinging on a nerve root, but this finding shows a weak correlation with clinical symptoms. However, no studies have investigated the early and late postoperative MRI changes and clinical evaluations in PELD cases.

In this study, we evaluated patients who underwent either monoportal endoscopic IL or lateral TF approach for LDH and who were evaluated clinically and with postoperative MRI on the 1st day, 3rd month, and at the end of the 6th month. The objective was to characterize the postoperative MRI and clinical findings following PELD, thereby presenting our experience of "monoportal endoscopic lumbar discectomy" from a safety and efficacy standpoint by assessing the correlation between MRI features and clinical outcomes.

MATERIAL and METHODS

The data in this study was obtained by scanning patient files. Patients who underwent PELD surgery between August 2009 and January 2012 and had MRIs taken on preoperatively andon 1st day and 3rd and 6th months postoperatively were included in the study. Patient age, gender, height, weight, operated levels, side findings, preoperative, postoperative 3rd and 6th-month Visual Analog Scale (VAS) scores, Oswestry Disability Index (ODI) scores, and clinical characteristics were recorded. All patients were operated on by the same surgeon.

Surgical Approach selection was based on the principles proposed by Ruetten and colleagues (14,16,17), and accordingly, the lateral transforaminal (TF) approach was preferred over the interlaminar (IL) approach. Despite TF being the initial choice, if there were well-known anatomical limitations, or if the sequestered disc fragment extended above the upper border of the cranial vertebra pedicle or below the lower border of the upper vertebra, and/or if the intended foramen appeared covered by the ilium shadow in lateral spinal X-rays, the IL approach was chosen instead (14,16,17). All surgical procedures were performed with patients under general anesthesia in the prone position.

Ethical approval was obtained from the local ethics committee (No:1188 Date:29.08.2013)

Neuroradiological Evaluation

Neuroradiological evaluations were conducted at the Neuroradiology Department. All MRI studies were performed using an MRI device equipped with a 1.5 Tesla-powered superconductive magnet (Siemens, Vision, Symphony, Erlangen, Germany). The imaging was performed with the patient in the supine position and with the spinal coils wrapped around the lumbar region. The imaging protocol involved the acquisition of 3–4 mm slices of T1A sequence (TR/TE/NEX/field of view (FOV): 1200 msm/600 msm/2/120 cm), T2A sequence (4000/800/2/120), and gadolinium contrast-enhanced images in sagittal and axial planes. During post-gadolinium injection image acquisitions, T1W fat-suppressed (FLAIR) axial images were also obtained. The MR images were transferred to an independent console for the elimination of artifacts resulting from breathing and/or tissue thickening by altering some parameters, and then the images were evaluated by an experienced neuroradiologist who was blinded to the clinical features.

After the surgery, if no complications occurred, the patients were ambulated three hours after the operation and discharged the following day. The day after the surgery, early postoperative lumbar MRIs were obtained, and physical examinations were performed. Lumbar MRIs and physical assessments were repeated at the 3rd and 6th months during follow-up visits. VAS score and ODI scores were recorded before and after surgery as clinical outcome measures. Follow-up examinations were performed by 3 doctors who were not involved in the surgeries.

Statistical Analysis

Data retrieved from the hospital records were entered in a Microsoft Excel 2010 worksheet. Preoperative and postoperative ODI Pain Assessment Scale and VAS scores in the 3rd and 6th months were compared using IBM SPSS 21.0 software (IBM Corp.). Friedman's test was used for variance measurements. Post-hoc analysis was conducted after Friedman's test for paired comparisons.

Table I: Age and Gender Ratios of Patients Who Underwent Surgery Due to Lumbar Disc Herniation

Age Group (in years of age)	Male	%	Female	%	Total	%
18 - 25	2	3.10	1	1.50	3	4.60
26 - 30	2	3.10	1	1.50	3	4.60
31 - 35	2	3.10	3	4.60	5	7.70
36 - 40	5	7.70	4	6.20	9	13.80
41 - 45	5	7.70	6	9.20	11	16.90
46 - 50	4	6.20	6	9.20	10	15.40
51 - 55	4	6.20	7	10.80	11	16.90
56 - 60	2	3.10	4	6.20	6	9.20
61 - 65	0	0.00	1	1.50	1	1.50
66 - 70	1	1.50	2	3.10	3	4.60
Over 71	1	1.50	2	3.10	3	4.60
Total	**28**	**43.10**	**37**	**56.90**	**65**	**100.00**

Table II: The Number of the Operated Spinal Levels Per Surgery and Their Overall Respective Frequencies

Number of levels	Number of patients	%
I	61	93.80
II	3	4.60
III	1	1.50
Total	**65**	**100.00**

RESULTS

Characteristics of the Study Population

A total of 65 patients with LDH (37 female and 28 male; mean age 46.7 ± 12.7 years [range, 18–81]) were included in this study (Table I). The mean height and weight of the patients were 168.4±9.9 cm (range, 190–150) and 81.3±15.9 NS (range, 46–130). Out of the 65 patients, 61 had single-level surgery, 3 had 2-level surgery, and 1 patient had 3-level surgery (Table II). A total of 31 levels were operated with the TF approach (1 level of L1-L2, 3 levels of L2-L3, 5 levels of L3-L4, 20 levels of L4-L5, and 2 levels of L5-S1). A total of 39 levels were operated with the IL approach (21 levels of L4-L5 and 18 levels of L5-S1).

Outcomes

One patient that was operated on with a left-sided L5-S1 IL approach presented with residual left leg pain during follow-up and was reoperated. Three patients experienced worsening of motor deficits after surgeries with a TF approach, one patient treated with the IL approach had CSF leakage that regressed with lumbar drainage, and one patient developed bladder distention (Table III). Patients were ambulated the same day after surgery, except for the patient with CSF leakage, and they were discharged in an average of 1 day (range, 1–7) after surgery.

On analysis of the ODI questionnaires filled by the patients, 29.2% of the patients were classified as grade V and 49.2% as grade IV in the preoperative period; however, in the 3rd month after surgery, none of the patients had grade V or IV disability. Twenty percent of the patients were grade III preoperatively, whereas this rate was 28.3% in the 3rd month, but it dropped down to 4.3% in the 6th month. Preoperatively, none of the patients were grade I, and only 1.5% of patients were grade II. In the 6th month after surgery, 60.9% of patients were rated as grade I, and 34.8% were rated as grade II.

The median preoperative VAS score was 8 (range, 5–10). The mean VAS scores in the postoperative 3rd month and 6th month were 2 (range, 0–7) and 1 (range, 0–6), respectively. ODI and VAS scores in the postoperative 3rd month and 6th month were available for 44 patients. There were significant differences between ODI scores during the preoperative period and in the postoperative 3rd month and 6th month (Friedman's test, $p<0.001$) (Table IV). For paired comparisons, post-hoc analysis was performed after Friedman's test. The results showed significant differences between preoperative and postoperative 3rd month ODI scores, between preoperative and postoperative 6th month ODI scores, and between postoperative 3rd and 6th month ODI scores (Table V). For paired comparisons, post-hoc analyses revealed significant differences between preoperative and postoperative 3rd month VAS scores, between 3rd and 6th months VAS scores, and between preoperative and postoperative 6th month VAS scores (Table VI). Moreover, there were significant differences between preoperative, postoperative 3rd month, and postoperative 6th month VAS scores (Friedman's test, $p<0.001$) (Table VII).

Table III: Surgical Method and Related Complications and Rates

		Surgical Method						
		TF		IL		TF&IL		Total
		Number of patients	%	Number of patients	%	Number of patients	%	
Compliatications	Worsening motor function	3	4.60	0	0.00	0	0.00	3
	CSF Fistula	0	0.00	1	1.50	0	0.00	1
	Urinary retention	0	0.00	1	1.50	0	0.00	1

Table IV: Paired Comparisons for Oswestry Disability Index Following Friedman's Test

OSWESTRY	p-value
Preop OSWESTRY – 3rd-month OSWESTRY	<0.001
Preop OSWESTRY – 6th-month OSWESTRY	<0.001
3rd-month OSWESTRY – 6th-month OSWESTRY	0.003

Table V: Comparison of Pre-Operative Oswestry Disability Index, 3rd Month Post-Operative and 6th Month Post-Operative Oswestry Disability Index

OSWESTRY	n	Median (min-max)	X^2	p-value
Preoperative OSWESTRY	44	38 (17-50)		
3rd month OSWESTRY	44	13.5 (2-35)	73.826	<0,001
6th month OSWESTRY	44	9 (2-23)		

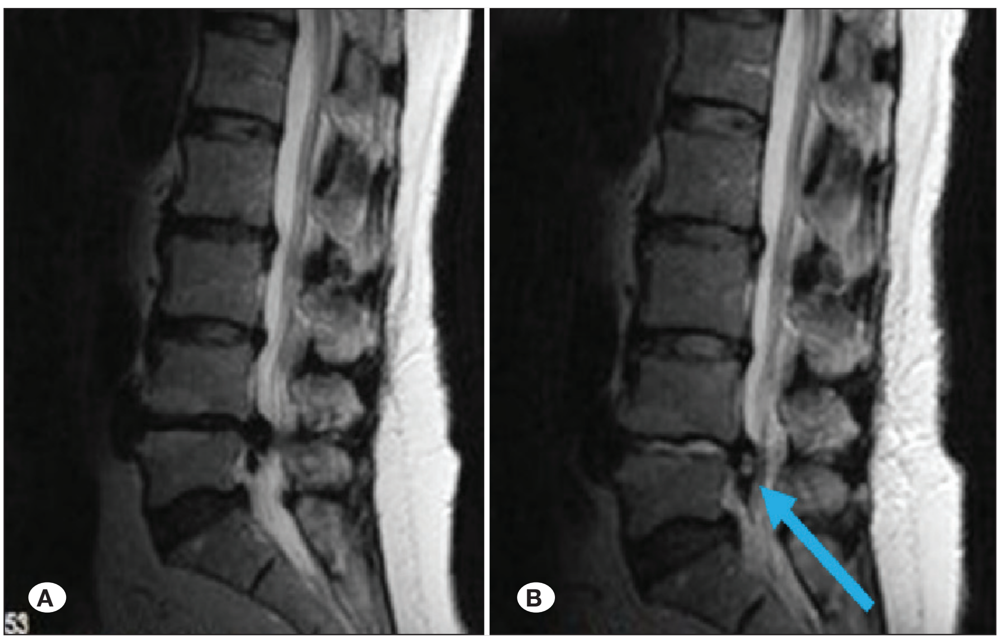

Figure 1: Peridiscal Changes **(A)** Pre-op Sagittal T2W image **(B)** Post-op 24th hour Sagittal T2A image.

In this study, 53 patients had undergone contrast-enhanced lumbar spinal MRI during routine follow-up at an average of 3 months after surgery and 46 patients at an average of 6 months after surgery. The MR images of these patients were evaluated for peridiscal changes (Figure 1A,B) (Modic-type changes), anterior epidural space changes (Figure 2A,B), root (edema, compression, and contrast uptake) (Figure 3), posterior elements (Figure 4) (muscle, facet, lamina, and ligament), disc (Figure 5A–C; 6A-F) (posterior contour and shape changes), and epidural contrast uptake (Figure 7) (fibrosis). One of the 65 patients evaluated in our study was excluded due to incomplete evaluation, and 8 patients were not evaluated due to the lack of mid and late-term evaluations of endplate changes and height loss. Only two patients had a loss of intervertebral disc height. In 13 (21%) of the 61 levels operated, Modic Type I inflammatory changes developed in the bone marrow. Of the total 64 levels, no significant anterior epidural soft tissue developed in 31 (48%) levels, while anterior epidural edema and postoperative scar tissue developed in 33 (52%) patients. Contrast uptake was observed in the root in 20 (29.4%) of the 68 operated levels, edema was observed in 3 levels (4.41%), and slight compression was observed in 3 levels (4.41%). None of the patients showed all three findings concomitantly. Changes in muscles, bones, ligaments, and soft tissues at the operated level were evaluated in the subacute and late stages and were evaluated using a visual subjective scale ranging from minimal or absent (–) to 5+. Of the 57 levels suitable for evaluation, in the 3rd month, there were no or minimal changes in the posterior elements and muscle tissues in 36 (63%) levels, 1+ in 9 (15.8%) levels, and 2+ in 9 levels; only 3 levels were evaluated as 3+. At the 6th month evaluation, regression was observed in all levels. The findings in the patients included in our study who were evaluated as positive in terms of changes in the posterior elements are different from the widespread changes reported in conventional discectomy and involve many anatomical layers, and are in the form of mild edema in and around the endoscopic entry line.

Table VI: Paired Comparisons for VAS Scores After Friedman's Test

VAS	p-value
Preop VAS – VAS at 3rd month	<0.001
Preop VAS – VAS at 6th month	<0.001

Table VII: Comparison of Pre-Operative VAS, 3rd month Post-Operative and 6th month Post-Operative VAS Variables

VAS	n	Median (min-max)	X^2	p-value
Preop VAS	44	8 (5-10)	73.049	<0.001
VAS in 3rd month	44	2 (0-7)		
VAS in 6th month	44	1 (0-6)		

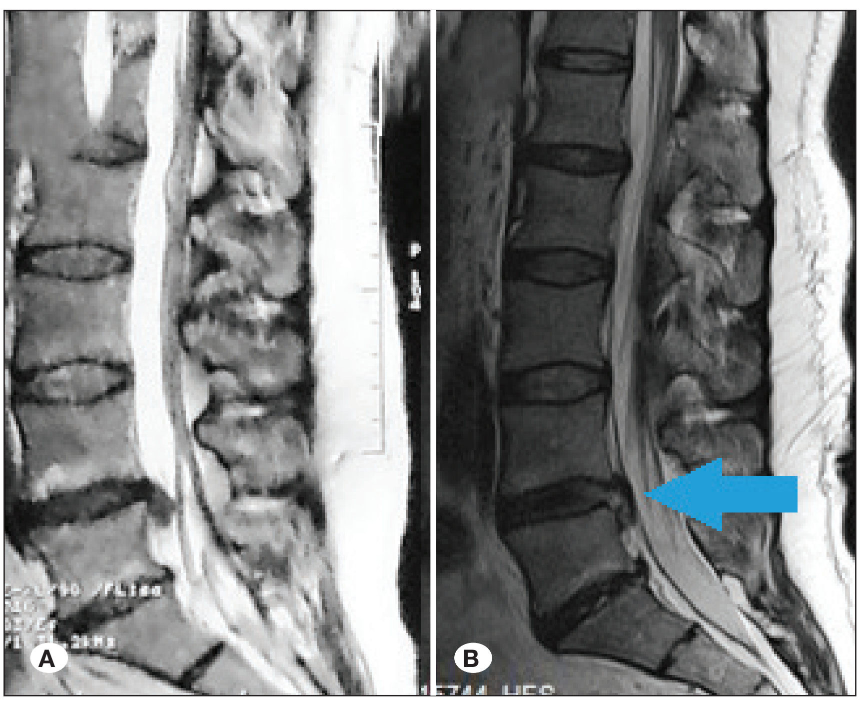

Figure 2: Anterior epidural space changes **(A)** Preoperative sagittal T2W (B) Post-op 24th hour Sagittal T2W Postop **(B)** Signal changes within the extruded disc herniation can be seen.

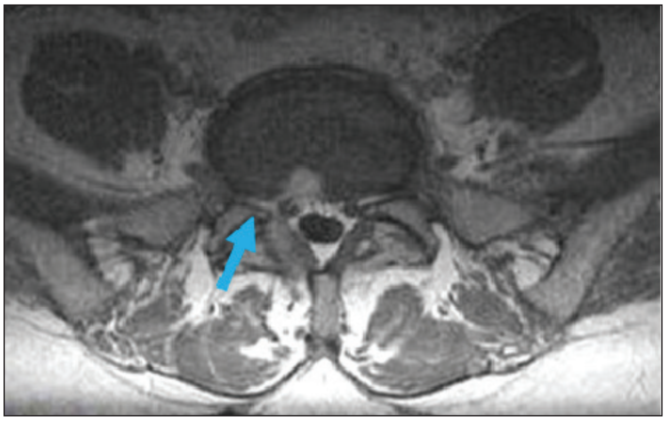

Figure 3: Nerve root changes (contrast-enhancement and mild displacement of the right S1 Root in in T1W axial images after IV contrast injection).

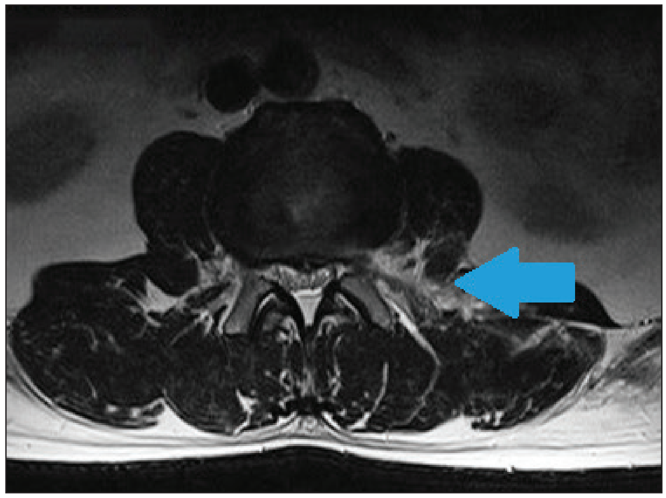

Figure 4: Bone, muscle, and ligament changes 2 postoperative appearance of endoscopy trajectory extending from subcutaneous tissue and muscle into left neural foramen in axial T2W image.

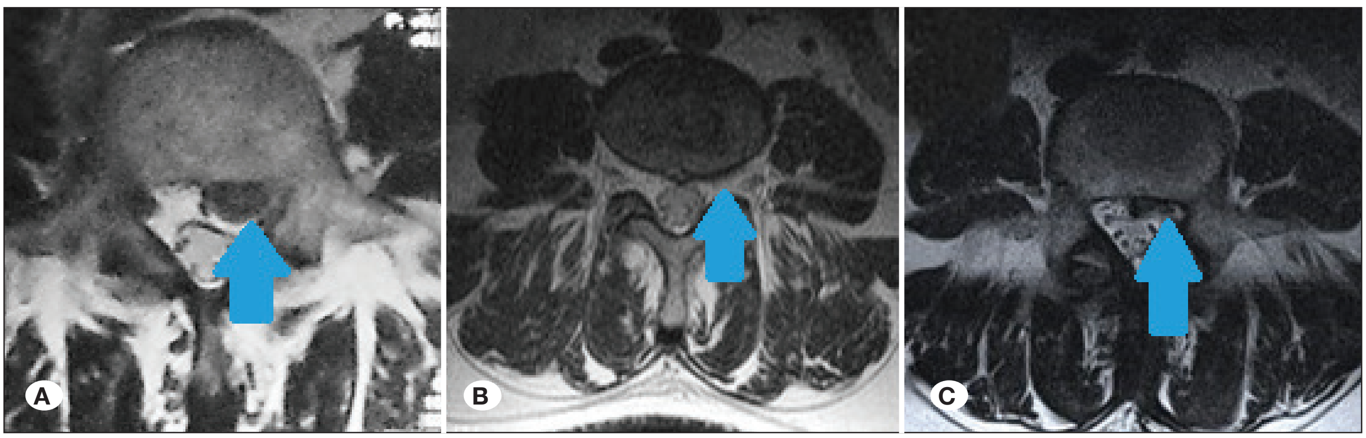

Figure 5: Posterior border of intervertebral disc Preoperative T2W axial images of a patient with an L4-L5 left paramedian extruded disc show extruded disc in the left lateral recess. In the 3rd month, this region appears to be normal, however, in the 6th month radiological recurrence was demonstrated. **A)** Preoperative axial T2W, **B)** postoperative 3rd month axial T2W, **C)** postoperative 6th month axial T2W.

The postoperative MRI appearance of the intervertebral disc at the relevant level was compared at postoperative 24 hours and 3rd and 6th months. The absence of any change in herniation amount and the general appearance of the disc was rated as 3; the success of herniectomy (complete disappearance of compression and herniation appearance) was rated as 1; any intermediate findings were rated as 2. Of the 64 levels evaluated in our study, 59 were evaluated as 2 or 1 (hernia disappeared well or moderately, mass effect decreased) in the first two evaluations, but 15 of these patients (23%) were found to have recurrence of disc herniation in the last examination. Radiological improvement was maintained in the remaining 44 patients. Contrast enhancement in the epidural space (lateral recess, dural sac proximity, and root circumference) was evaluated at 24 hours, 3rd month, and 6th month. Of the 66 levels evaluated in these examinations, the amount of contrast enhancement was evaluated subjectively on a scale ranging from no or minimal to 1+ (mild) to 5+ (severe). Minimal or 1+ epidural contrast enhancement was observed in 49 (74%) of the 66 levels, while 2 or 3+ enhancement was observed in 17 (26%) levels. None of the patients showed intense contrast enhancement that could be considered indicative of severe fibrosis (Figure 7).

DISCUSSION

The most obvious advantages of endoscopic spine surgery over microdiscectomies are small incisions, less tissue trauma, minimal blood loss, faster recovery, easier approach in obese patients, application under mild sedation or local or regional anesthesia, and less postoperative analgesic requirement (4,9,15-17).

The differences in VAS scores between preoperative, postoperative 3rd and postoperative 6th month were statistically significant (Table VI, VII). Similarly, Oswestry disability index also showed statistically significant changes between preoperative

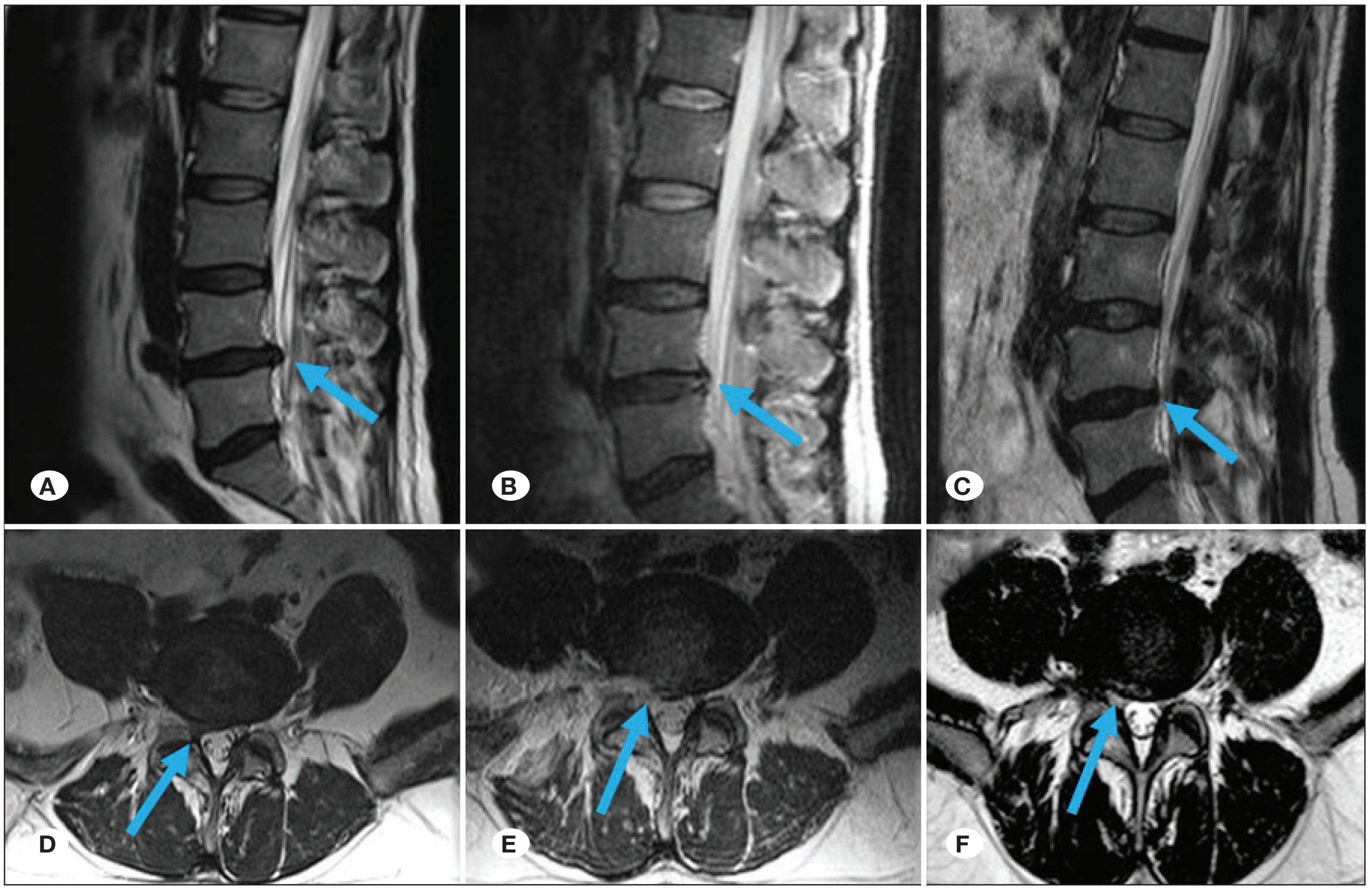

Figure 6: Posterior border of intervertebral disc- 2 Disappearance of the right paramedian disc herniation at L4-L5 level and recovered posterior contour of the disc, **A)** preoperative sagittal T2W, **B)** postoperative 24 hours sagittal T2W, **C)** postoperative 6th month sagittal T2W, **D)** preoperative axial T2W, **E)** postoperative 24 hours axial T2W, **F)** postoperative 6th month axial T2W.

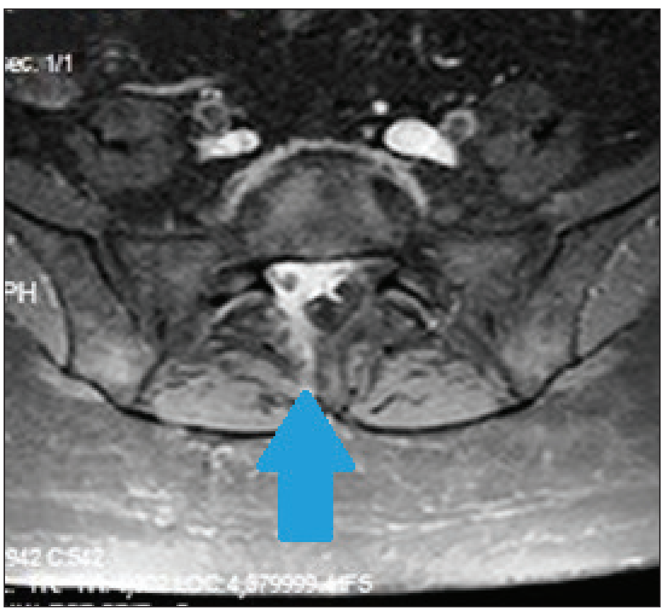

Figure 7: Epidural scar postoperative contrast enhancement in the right half of the epidural space, adjacent to right S1 root at the L5-S1 level and along the trajectory after iv contrast injection in 3rd month FS axial T1 imaging.

and postoperative 3rd and 6th months (Table IV, V). The result of these scores, which are comparable to VAS that is commonly used to assess the success of surgery, were found to be consistent with theliterature (1,16,17). The significant improvement in VAS and ODI scores showed the efficacy of PELD as a novel treatment method for LDH that provides a high level of patient satisfaction.

At our institution, the percutaneous monoportal endoscopic lumbar discectomy was initiated in 2009. Thus, the data collected in this study pertains to the "learning curve" period for this surgery.

Evaluation of postoperative imaging of the lumbar spine is not straightforward because several factors may affect the findings. These include anatomic features of the patient, age, the surgical method used, the underlying disease, biomechanical factors, time elapsed since surgery, and the postoperative clinical status of the patient (10). These elements are crucial during postoperative lumbar MR imaging, and it is also important to use the appropriate MR technique. Many studies have evaluated the postoperative MRI changes following standard microdiscectomy; however, no study has evaluated the correlation between radiologic and clinical findings during short-term and long-term follow-up after endoscopic discectomy. There is no standardized MR technique for evaluation of the lumbar spine following the discectomy procedure. Nevertheless, fast spin echo sagittal T1 and T2 weighted (W) are the main sequences used in many centers. For an in-depth investigation of bone marrow and corticomedullary junction, “short tau inversion recovery” and “fat suppression (FLAIR)” T1 sequences can be included. In patients whose sagittal investigations reveal herniation, bulging, or other pathologies, T1 and T2 W images parallel to the levels corresponding to pathological levels seen on sagittal views can be used.

Acquiring sagittal images and images from associated crossing intervals after intravenous contrast injection can be assumed as the standard procedure. Nevertheless, in some centers, FLAIR MRI techniques are added to contrast-enhanced imaging studies to increase the sensitivity, uncover the insidious radiological findings, or minimize the sensitivity to “susceptibility artifacts.” This technique especially increases the precision in the evaluation of root enhancement, epidural scar, and temporal changes in the findings. Owing to less scar formation with monoportal endoscopic techniques than with other techniques, FLAIR MRI techniques are useful in increasing the sensitivity of the investigations. Although double-dose application methods have been used in the literature, since there is a direct relation between increased gadolinium dose and renal toxicity in individuals with compromised kidney function, it was not used in our study (2,18).

Several papers have reported the early (0–8 weeks) radiological findings following discectomies. These findings must be interpreted carefully considering the clinical findings, the time elapsed since the surgery, and the surgical method used. The most frequently reported findings are inflammatory changes in vertebral endplates, enhancement in the annulus of the disc and endplates, enlarged soft tissue mass in anterior epidural space, compression of the dural sac, and changes in posterior elements, muscles, and ligaments depending on the surgical technique. The late postoperative period (8 weeks to 6 months or later) is the period in which the findings take their final forms and become prominent such as diminished anterior epidural space alterations, reduced disc height in some situations, lessening of posterior element changes, scar formations, and root findings, such as enhancement, edema, or displacement.

In our study, neuroradiological evaluations of the patients were performed by a single neuroradiologist who was not informed about clinical follow-up. Early and late postoperative findings of endplate changes (Modic type degeneration, loss of disc height), changes in anterior epidural space, nerve root findings (edema, displacement, and enhancement) at the operated levels, bony, muscular, and ligamentous changes, posterior borders of intervertebral discs, mass effect, recurrent herniations, and formation and severity of scar formations were evaluated. Following discectomies, T2A sequences commonly show a hyperintense zone extending from the nucleus pulposus to the site of loss of annular integrity (herniation), and this finding may normally last two months. Annular contrast enhancement may also be seen, and it is a normal finding (2,5,6,11,13,18). In a study 67% of the patients who underwent lumbar discectomy showed contrastenhancement lasting as long as 6 months postoperatively. Loss of intervertebral disc height was reported in 1/3rd of these patients, and this loss was found to be directly related to the width of the discectomy. Such reductions in height may eventually cause lateral recess stenosis or neural foraminal stenosis, leading to corresponding nerve root compression and associated findings (8).

Out of the 65 patients included, 1 patient was excluded due to insufficient radiological assessment, and in 8 patients, radiological comparisons could not be made due to the absence of mid- and late-term follow-up studies that would evaluate endplate and disc height changes.

Intervertebral disc height loss was found in only two patients in our study, and this ratio (2/61 levels) is extremely low compared to that in previous studies. We believe that the low incidence of disc height loss in our cohort is attributable to the atraumatic and herniectomy-based technique. Nevertheless, it is imperative to compare the incidence of postoperative disc height loss between monoportal endoscopic discectomies and non-monoportal endoscopic discectomies; in addition, future studies should compare the two methods in terms of lateral recess and foraminal stenosis formation.

Following discectomy, Modic Type I inflammatory changes have been reported to occur in the bone marrow in proximity to the intervertebral disc level. This change is characterized by the endplates showing hypointensity in T1W, hyperintensity in T2W images, and gadolinium contrast enhancement. In a study found this feature in only 1 out of 17 patients (5).

In our study, Modic type I changes were observed in 13 out of 61 operated levels, and this ratio was consistent with the literature. We believe that this radiological finding is an asymptomatic response irrespective of the discectomy technique used, and it should not be mistaken for infection (Figure1A, B).

Blurring of the posterior border of intervertebral disc annulus due to loss of integrity, development of edema and hemorrhage, and formation of muscle tissue that compresses the dural sac mimicking the preoperative appearance of the disc are commonly observed findings in MRI studies after discectomies (2,6,11,18).

Epidural tissue exhibits slight hyperintensity in T1W images similar to that in T2W images. Studies have shown that this epidural soft tissue mass can be seen in approximately 80% of the patients in the early period and that this ratio may drop to 50% in two months (2,4,18). In a study proposed that this tissue was epidural edema that would resolve with time (13). According to a study this tissue normally shrinks, and isreplaced by epidural fibrosis; moreover, the anterior epidural soft tissue was found to cause minimal or no symptoms, and epidural fibrosis was related to failed back surgery (5). In 31 out of the total 64 levels (48%), no significant anterior epidural stenosis developed, whereas anterior epidural edema and postoperative edema occurred in 33 patients (52%) in our study. No significant residual tissue formation was found in the subsequent evaluation in the 6^{th} month.

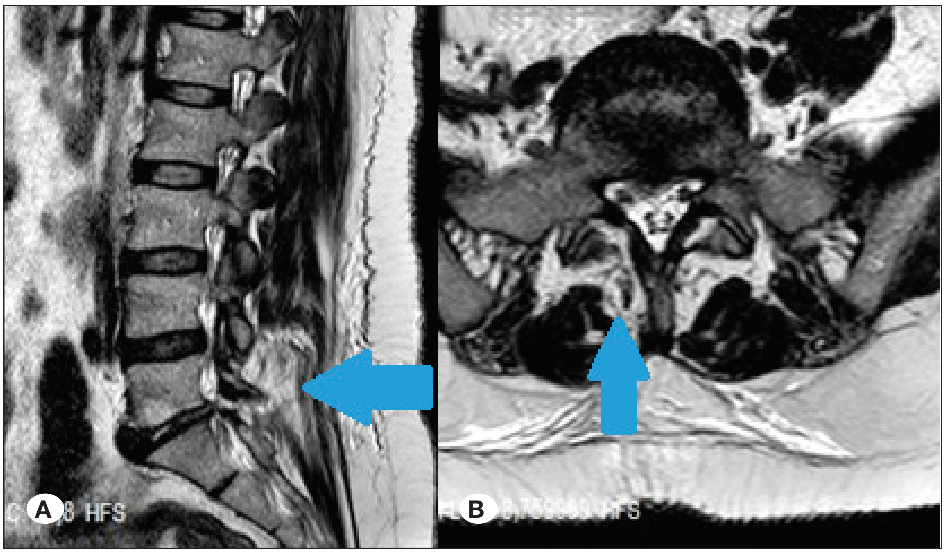

Figure 8: Bone, muscle, and ligament changes 1 postoperative appearance of the endoscopic trajectory passing through the subcutaneous tissues and muscles reaching the spinal canal during the interlaminar approach **(A)** sagittal T2W **(B)** axial T2W.

The low incidence of soft tissue generation and the higher rate of resolution in our cohort compared to previous studies can be attributed to the minimally-invasive nature of the technique (Figure 2A, B).

Studies have shown that in patients with residual or recurrent pain after lumbar discectomy, nerve root changes in MR images exhibit the strongest correlation with symptoms (2,11,13,18). In a study nerve root changes in 120 patients (140 discs) who had postoperative pain. They analyzed contrastenhancement, thickening, and displacement in nerve roots and found that nerve root thickening and edema showed the best association with clinical findings; moreover, this association was much stronger in patients who had a concomitant presence of all three findings. In that study, 65.7% of the nerve roots showed enhancement (11).

In our study, 20 (29.4%) of the 68 levels demonstrated nerve root enhancement, 3 (4.41%) levels showed edema, and 3 levels (4.41%) showed mild displacement in nerve roots. None of the patients in our study had all threefindings concomitantly. This result demonstrates that the low incidence of epidural fibrosis can be attributed to the minimally-invasive nature of the monoportal endoscopic discectomy technique. Most patients benefited from the surgery in terms of pain and neurological findings independent of the postoperative radiological findings related to decompression or residual discs, and the second surgery rate in our cohort was low (4.6%) (Figure 3).

Studies have shown that the evaluation of the loss of ligaments and/or laminae after standard microdiscectomy is best performed with T1W images (2,6,11,18). Asymmetry of the posterior paravertebral muscles and blurred/edematous muscle contours are the most prominent findings, especially in the early postoperative period. Depending on the surgical procedure and the size of the bony defect, asymmetric expansion of the dura toward the defective region may be observed (2,13,18) In our study, given the fact that bone, ligament, and muscle tissue changes are most prominent at subacute and late periods, these changes were evaluated at 3rd and 6th months and graded between “minimal or null (0)” and “5” using a subjective visual scale.

The aforementioned changes are seen as edema throughout the trajectory line, which is different from those seen in conventional microdiscectomies in which changes are diffuse and involve multiple anatomical layers.

We believe that minimal changes in the posterior elements are related to better clinical outcomes and recovery rates in our cohort. Postoperative diffuse muscle tissue and posterior element changes, anterior epidural edema, and epidural scar rates in our study were lower and more limited than described in previous studies investigating the conventional techniques (Figure 4; 8A, B).

The most common MRI findings in patients presenting with low back pain and leg pain are bulging, degenerative changes in discs and endplates, annular rupture, protrusion, and herniation. Especially in patients with low back pain only, these structural changes in MRI do not correlate well with clinical findings. Moreover, other parameters, such as workplace conditions, and genetic and psychological factors, showed a better correlation with symptoms (2,6,11,18).

In our study, we compared the MRI appearances of intervertebral discs at the 24 hour, 3rd month, and 6th month postoperatively. 59 out of 64 levels were initially graded 2 or 1 (good or moderate hernia evacuation and reduced mass effect); however, in 15 patients (23%), the final evaluation showed restoration of herniations to their preoperative states, indicating a recurrence (Figure 5A-C). The other 44 patients showed maintenance of the recovered state (Figure 6A-F).

None of the patients with radiologically recurred discs had a relevant clinical worsening that required reoperation; only one patient with grade 2 posterior border appearance underwent reoperation because of recurrent pain at an early phase. Another patient with a grade 2 posterior border appearance underwent reoperation at another center. Two of the five patients with initially graded 3 discs were reoperated in another hospital after 2 months; at the 6th-month follow-up, these two patients demonstrated improvement in posterior disc contours and appearance of the herniation, along with clinical improvement. For the remaining two patients, only the MRI performed at the 24th hour was available, and these patients are still in the follow-up process. In previous studies, the intervertebral discs were edematous in the first 24 hours after conventional surgeries and exhibited T2 hyperintensities, and generally, in the 2nd month, the impression of the swellings was diminished (2,13,18). More studies are required to assess the correlation between the radiological appearance of the discs and the clinical status after monoportal endoscopic disc surgery.

Epidural fibrosis or epidural scar formation refers to the replacement of the anterior epidural space by fibrotic tissue at the level of discectomy. Replacement of fat by an isointense tissue exhibiting homogenous contrast enhancement is consistent with fibrosis. It is important to distinguish this finding from recurrent disc herniation, as the former is present in various degrees in the early conventional postoperative imaging studies but diminishes in the first few months. Differential diagnosis between epidural scar and recurrent disc herniation is very important in terms of surgical indication in symptomatic patients (2,13,18).

A disc herniation is typically seen as a non-enhancing polypoid area in the epidural space, whereas epidural fibrosis shows homogenous enhancement. In the study the rates of recurrent/residual disc herniations and epidural scar formation after discectomies were 5–11% and 8–11%, respectively (2). Nevertheless, contrast enhancement can be a normal finding in the acute or subacute phase of discectomies, whichdoes not cause any symptoms. Therefore, in the absence of clinical deterioration, this should not be interpreted as an epidural scar (2,8,18).

As stated earlier, in patients with clinical complaints, epidural contrast enhancement exhibits a stronger correlation with symptoms in the presence of concomitant nerve root enhancement, edema, or displacement (2,8,18). There is a paucity of comparative analyses of epidural scar development after monoportal endoscopic surgery and conventional techniques.

In our study, contrast enhancement in epidural space (lateral recesses, area around dural sac, and nerve roots) was evaluated within the first 24 hours, and at the 3rd and 6th month. Sixty-six levels having at least one of those studies were evaluated, and the amount of enhancement was graded as follows using a subjective scale: – (none, or minimal), 1+ (mild) to 5+ (heavy). Forty-nine (74%) of the 66 levels exhibited minimal or 1+ enhancement, and 17 (26%) levels showed 2+ or 3+ enhancement. None of the patients showed a dense enhancement that could be attributed to severe fibrosis. Previous studies suggest that FLAIR MRI techniques are better at displaying the extent and density of enhancement compared to T1 and FS T1-contrast-enhanced techniques. In other studies, the rates of enhancement consistent with epidural fibrosis were between 80 to 90%, whereas, in our series, the rates of dense fibrosis and nerve root changes were low. This result, although being a subjective assessment, may be attributable to less tissue trauma caused during monoportal endoscopic discectomy compared to standard microdiscectomy (Figure 7).

Some limitations of this study should be considered while interpreting the findings. First, this was a single-center retrospective study with a small sample size. The retrospective study design constrained the number of parameters included in the analysis. The inclusion of a control group consisting of patients who had undergone standard microscopic surgery would have provided more robust results. Lastly, information as to why PLED surgery was chosen was not included in the study protocol.

CONCLUSION

This study demonstrates the safety and efficacy of endoscopic discectomy for LDH, as demonstrated by significant improvement in clinical outcomes. To the best of our knowledge, this is the first study assessing the correlation between the clinical outcomes and the short- and long-term radiological findings in this setting. Even though the radiological evaluation was based on subjective criteria and statistical analysis was not possible, the low incidence of postoperative epidural scar formation and nerve root edema support that monoportal endoscopic discectomy is a minimally-invasive method. Nevertheless, it must be emphasized that the radiological findings should always be interpreted in conjunction with clinical findings, and there is a lack of definitive objective radiological criteria indicatingsuccess or failure.

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Ethical Approval: All procedures performed were in accordance with the 1964 Helsinki Declaration. Written informed consent for scientific purposes and clinical data collection was obtained according to the institutional protocol. Ethical approval was obtained from the local ethics committee.

AUTHORSHIP CONTRIBUTION

Study conception and design: AS, OB

Data collection: OB, FD

Analysis and interpretation of results: SS, OB

Draft manuscript preparation: GBS, MC

Critical revision of the article: SK, EC

Other (study supervision, fundings, materials, etc...): ECS, EC

All authors (OB, GBS, FD, EC, MC, ECS, SK, EC, SS, AS) reviewed the results and approved the final version of the manuscript.

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