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Radiologic and Clinical Predictors of Reoperation Following Unilateral Biportal Endoscopic Spine Surgery: A Retrospective Cohort Study

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Purpose: Unilateral biportal endoscopic discectomy (UBE) is an effective and minimally invasive technique for the treatment of degenerative lumbar diseases. However, reoperation may be required, and evidence on how risk factors vary according to the timing of reoperation remains limited. This study aimed to identify the clinical and radiologic factors associated with short-term (<6 months) and long-term (≥6 months) reoperations following UBE.

Materials and Methods: This retrospective study included 80 patients who underwent reoperation after UBE between January 2016 and December 2023 with a minimum 24-month follow-up. The patients were classified into short-term and long-term reoperation groups. Clinical and radiologic parameters, including disc degeneration grade, facet joint osteoarthritis grade, and comorbidities, were compared between groups. Multivariable logistic regression was used to evaluate preoperative factors predicting postoperative functional improvement.

Results: Reoperations were performed for incomplete decompression (27.5%), facet cysts (10.0%), recurrent herniation (8.8%), restenosis (8.0%), and postoperative instability (43.7%). Long-term reoperation was associated with greater disc degeneration, a higher grade of facet joint osteoarthritis, and a higher prevalence of diabetes mellitus (DM). Short-term reoperation was mainly due to inadequate decompression, whereas long-term reoperation was largely attributable to postoperative instability. Multivariable analysis identified a higher preoperative grade of facet joint osteoarthritis as a predictor of postoperative functional improvement.

Conclusion: Short-term reoperation after UBE is primarily related to inadequate decompression, whereas long-term reoperation is linked to advanced disc degeneration, severe facet joint osteoarthritis, postoperative instability, and DM. These findings highlight the importance of thorough preoperative assessment of facet arthropathy and disc degeneration, ensuring adequate initial decompression, and careful postoperative management, particularly in patients with DM.

Key Words: Biportal endoscopic spine surgery, discectomy, recurrence, reoperation, facet degeneration

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INTRODUCTION

Endoscopic discectomy offers several advantages over conventional surgical techniques, including reduced muscle and bone injury, decreased postoperative pain, shorter recovery times, and a faster return to daily activities.[1,2] Unilateral biportal endoscopic discectomy (UBE) is a minimally invasive procedure with a short learning curve, and it provides an effective treatment for various degenerative spinal disorders.[2] This technique is increasingly used for elderly patients who are in poor general health and at a higher risk of complications.[3] The recurrence rate of disc herniation after conventional lumbar discectomy ranges from 5% to 15%, whereas endoscopic lumbar discectomy has been reported to have a lower recurrence rate of 3.2%–6.2%.[4-6] Furthermore, the reoperation rate following endoscopic discectomy ranges from 1.3% to 6.62%, which is lower than the 6%–13.2% reported for open discectomy.[7,8]

Reoperation following endoscopic lumbar discectomy may be required because of various factors including recurrent herniation, incomplete decompression with residual fragments, stenosis, infection, wound dehiscence, and postoperative instability.[1,9] Although advancements in endoscopic spine surgery have improved outcomes, recurrence and reoperation remain significant concerns. Several risk factors have been identified, including patient-related factors [e.g., age, sex, smoking, obesity, and diabetes mellitus (DM)] and radiologic factors [e.g., disc degeneration, facet joint degeneration, Modic changes, herniation type, and sagittal range of motion (ROM)].[10,11] Although some studies have investigated the causes of reoperation,[5,7,12,13] limited evidence exists regarding the influence of these factors on the timing of reoperation and on clinical and radiologic outcomes in patients undergoing endoscopic lumbar discectomy.

This retrospective study aimed to identify and compare radiologic and clinical factors that influence the need for reoperation after endoscopic discectomy. Patients were categorized into two groups based on the timing of reoperation: short-term (<6 months) and long-term (≥6 months). Understanding the risk factors associated with early and late reoperation is expected to enhance patient selection and surgical planning and to optimize clinical outcomes in endoscopic spine surgery.

MATERIALS AND METHODS

Patient population

This retrospective study included patients who underwent reoperation for lumbar disc protrusion, bony spurs, or stenosis after endoscopic spine surgery at affiliated hospitals between January 2016 and December 2023. The Institutional Review Board approved the study protocol (IRB number: 2024-0543-002). The inclusion criteria were recurrent symptoms with corresponding radiographic evidence on MRI or CT, refractory radiculopathy or neurological deficits unresponsive to conservative treatment after UBE, consent for further surgical intervention, and a minimum of 24 months of follow-up. Recurrent symptoms were classified as related to the primary index surgery if they met the following criteria: 1) new or worsening neurological symptoms localized to the initial surgical level; 2) radiographic evidence of pathology (MRI/CT) indicating disc herniation, restenosis, or instability at the same surgical level; and 3) failure of conservative management (e.g., physical therapy, medication, or epidural injection) prior to reoperation. Reoperation was defined as a secondary surgical procedure performed at the same level as the initial UBE. Cases in which surgery was performed at an adjacent or different spinal level (e.g., T12/L1) without prior surgery at that level were excluded to maintain specificity when evaluating the risk factors related to recurrence.

Patients with infections, vascular malformations, hematomas, trauma, tumors, or congenital anomalies were excluded. We also excluded patients lacking baseline imaging (X-ray, CT, or MRI), those with early surgery-related complications such as epidural hematoma or dural tear, and those lost to follow-up. Patients were categorized into short-term (<6 months) and long-term (≥6 months) reoperation groups based on the timing of reoperation.

Radiologic assessment

Degeneration of a herniated disc was evaluated using the Pfirrmann disc degeneration grade, which uses a scale from I to V (Supplementary Fig. 1, only online).[14] This categorization includes normal (Pfirrmann grade I), mild (grade II), moderate (grade III), advanced (grade IV), and severe (grade V) degeneration. High-intensity zones (HIZs) were identified on sagittal T2-weighted image (T2WI) MRI were also observed.[15] Disc morphology, including protrusions, extrusions, and free fragments, was assessed using axial and sagittal T2WI images. Vertebral endplate changes were evaluated using Modic changes observed on MRI.[15] Modic type 1 represents reactive or inflammatory changes, type 2 indicates lipid marrow replacement, and type 3 denotes calcification of the endplate and subchondral vertebral marrow. Facet joint osteoarthritis was graded using axial-view CT and T2W MRI. Grade 0 (normal) indicated a normal facet joint, and grades 1–3 indicated increasing signs of facet joint arthritis, with each grade including the signs of the lower grades. Grade 1 (mild) showed joint space narrowing, grade 2 (moderate) demonstrated sclerosis, and grade 3 (severe) revealed osteophytes (Supplementary Fig. 2, only online).[16] Segmental angular and translational motion was measured to assess segmental instability on dynamic flexion-extension radiographs. Segmental angle differences were calculated based on the lines along the upper margins of each vertebral body.[17] Segment translation was defined as the anterior displacement of the upper vertebral body relative to the lower, recorded in millimeters (mm).[17]

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Assessment of clinical outcomes

Clinical outcomes were evaluated using the visual analog scale (VAS) and Oswestry Disability Index (ODI) scores preoperatively and at least 24 months postoperatively. We defined a relative improvement in ODI of ≥66% as a good outcome.[18] Change in ODI was evaluated as an improvement and defined as follows:[18]

ODI change (%)=(preoperative ODI score–postoperative ODI score)/(preoperative ODI score)×100.

Operation technique

After general anesthesia, the patients were placed prone on a Jackson table for spine surgery. The UBE technique involved two portals chosen based on symptoms and radiologic findings. The upper and lower pedicles and transverse processes were identified using a C-arm by adjusting the angle parallel to the endplate. For central disc herniations and lateral recess stenosis, an interlaminar approach was used to optimize neural decompression,[2] in which a horizontal line was drawn at the intervertebral space, and the intersection point between the tangent line of the inner edge of the pedicle and the horizontal line above was located. A distance of 15 mm from the intersection point towards the cephalic side along the tangent line indicated the endoscopic portal position, while a distance of 1.5 cm towards the caudal side indicated the working portal position. For foraminal and extraforaminal disc herniation, a paraspinal approach was used to minimize disruption of the lamina and facet joints. In the paraspinal approach, portals were created 2–3 cm from the outer edge of each pedicle. Dilators were used to assist portal dilation and muscle detachment. The endoscope (upper portal) and working portal (lower portal) were introduced through separate incisions and docked onto the upper lamina.[19] For lesions on the left side, the scope portal was positioned on the left, and the working portal was on the right. Conversely, the positions of the scope and working portal were interchanged, as necessary, for right-sided lesions. A potential space was created using a shaver and radiofrequency ablation wand (ArthroCare, Austin, TX, USA). The water pump pressure was maintained at 30–50 mm Hg, with irrigation provided through the skin portal. A unilateral laminotomy was performed using a high-speed drill and a Kerrison rongeur to remove the ligamentum flavum and expose the dural sac. The nerve roots were identified and protected during discectomy for lumbar disc herniation. Finally, a drain was inserted, and the incision was closed.

Surgical reinterventions and causes

Surgical reinterventions were determined based on various factors, including affected levels, comorbidities, instability, and surgeon preference, with the aim of reducing the risk of reherniation due to disc fragments, restenosis, or instability and improving clinical outcomes. UBE, microdiscectomy, minimally invasive transforaminal lumbar interbody fusion (MIS TLIF), oblique lumbar interbody fusion (OLIF), and posterior lumbar interbody fusion (PLIF) were performed. Follow-up examinations were conducted 3–24 months postoperatively to assess the clinical outcomes.

The reasons for surgical reintervention were incomplete decompression, recurrent lumbar disc herniation, facet cysts, secondary stenosis, and postoperative instability. Incomplete decompression was defined as nerve root compression by residual disc material or stenosis with continuous symptoms observed on immediate postoperative MRI. Recurrent disc herniation was defined as the presence of herniated disc material at the same level, accompanied by the same symptoms, even after a symptom-free period of at least two weeks, with an immediate postoperative MRI confirming the complete removal of herniated disc fragments or the absence of nerve root compression observed.[13] A facet cyst was defined as a symptomatic synovial cyst following endoscopic decompression. Secondary lumbar stenosis was defined as restenosis resulting from lamina regrowth or facet hypertrophy at the same level after laminectomy or foraminotomy/facetectomy. Postoperative instability was defined as instability at the same segmental level following primary discectomy or laminectomy, regardless of the presence of definitive segmental instability during the initial surgery.

Statistical analysis

All values are expressed as mean±standard deviation or as percentages. Normally distributed continuous variables were compared using Student's t test, and non-normally distributed variables were analyzed using the Mann–Whitney U test. For categorical variables (e.g., sex, hypertension, DM, and cause of reoperation), frequency analyses were performed to summarize overall distributions, and cross-tabulation analyses were conducted to compare distributions between the short-term and long-term reoperation groups. The chi-square test was used to assess statistical significance, and Fisher's exact test was applied when the expected frequency for any category was less than five.

Pearson correlation analysis was used to evaluate the strength and direction of linear relationships between continuous preoperative clinical variables (leg and back VAS scores, ODI, and age) and radiologic parameters (Pfirrmann disc degeneration grade, facet joint osteoarthritis grade, segmental angulation, and segmental translation). These correlation analyses were exploratory and were not intended for primary inference. Multivariable logistic regression was performed to identify the preoperative predictors of significant postoperative functional improvement, defined as a ≥66% relative ODI change at 24 months. Independent variables included age, sex, hypertension, DM, Pfirrmann disc degeneration grade, and facet joint osteoarthritis grade. The Pfirrmann and facet osteoarthritis grades were incorporated as categorical variables using dummy coding to reflect their ordinal nature. The odds ratios (ORs) with 95% confidence intervals (CIs) were calculated. All analyses were conducted using MedCalc version 23.1.7 (MedCalc Software Ltd., Mariakerke, Belgium), with $p<0.05$ considered statistically significant.

RESULTS

During the study period (January 1, 2016, to December 31, 2023), 2221 patients underwent 2255 lumbar discectomies (single- or two-level procedures). Among them, 167 (109 male and 58 female) required reoperation for recurrent lumbar disc herniation, stenosis, or instability. After excluding 53 patients who initially underwent conventional open discectomy, 114 patients required reoperation after UBE, resulting in an overall UBE reoperation rate of 5.13% (114/2221). Eighty patients (42 male and 38 female) met the inclusion criteria (Fig. 1). The mean age at the time of surgery was 57.2±15.0 years (range, 23–84 years), and the mean duration of symptoms was 6.5±4.8 months (range, 2–24 months). The mean follow-up period was 53.8±30.8 months (range, 34–86 months).

The mean time to reoperation following primary endoscopic surgery was 6.3±6.1 months (range, 2–26 months). Eighty patients underwent the following reoperation procedures: UBE (n=2), microdiscectomy (n=19), MIS TLIF (n=5), MIS OLIF (n=2), or PLIF (n=52). The baseline demographic and clinical characteristics of the participants are shown in Table 1.

Radiologic findings according to reoperation timing

A total of 44 patients were assigned to the short-term reoperation group (<6 months) and 36 to the long-term reoperation group (≥6 months) (Table 2). The Pfirrmann disc degeneration grade was significantly different between the short- and long-term reoperation groups (p=0.006). Grade III Pfirrmann degeneration was more frequent in the short-term group (65.91%) than in the long-term group (44.44%), whereas grade IV degeneration was more prevalent in the long-term group (50.00%) than in the short-term group (15.91%). The average Pfirrmann disc degeneration grade differed significantly between the short- and long-term reoperation groups (3.25 vs. 3.61, p=0.008). Additionally,

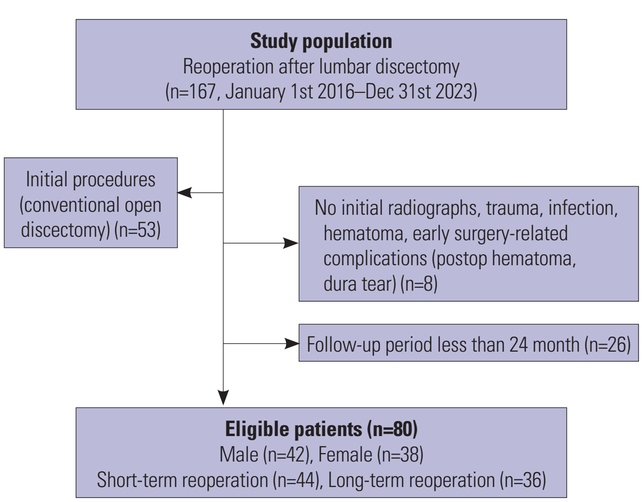

Fig. 1. Flowchart of patient selection.

Table 1. Patient Demographics (n=80)

Characteristic	Value
Age (yr)	57.20±15.00
Sex	
Male	42 (52.5)
Female	38 (47.5)
Symptom duration (months)	6.54±4.77
Reoperation period (months)	6.27±6.12
Preoperative clinical assessment	
Leg VAS	7.88±1.01
Back VAS	4.91±1.88
ODI	30.70±7.45
24-month postoperative clinical assessment	
Leg VAS	2.55±0.99
Back VAS	2.54±1.07
ODI	12.38±3.31
Primary surgical level	
L2/3	2 (2.50)
L3/4	6 (7.50)
L4/5	37 (46.25)
L5/S1	23 (28.75)
L2/3/4	1 (1.25)
L3/4/5	5 (6.25)
L4/5/S1	6 (7.50)
Reoperation level	
L2/3	2 (2.50)
L3/4	4 (5.00)
L4/5	30 (37.50)
L5/S1	23 (28.75)
L3/4/5	5 (6.25)
L4/5/S1	12 (15.00)
L2/3/4/5	1 (1.25)
L3/4/5/S1	3 (3.75)
Cause of reoperation	
Incomplete decompression	20 (25.0)
Facet cyst	8 (10.0)
Recurrent herniation	9 (11.25)
Secondary lumbar stenosis	7 (8.75)
Postoperative instability	36 (45.0)
Reoperation procedure	
UBE	2 (2.5)
Microdiscectomy	19 (23.75)
MIS TLIF	5 (6.25)
MIS OLIF	2 (2.5)
PLIF	52 (65.0)

MIS OLIF, minimally invasive oblique lumbar interbody fusion; MIS TLIF, minimally invasive transforaminal lumbar interbody fusion; ODI, Oswestry Disability Index score; PLIF, posterior lumbar interbody fusion; UBE, unilateral biportal endoscopic discectomy; VAS, visual analog scale.
Data are expressed as mean±standard deviation or n (%).

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Table 2. Comparison of Primary Radiologic Findings according to the Timing of Reoperation

	Short-term group (n=44)	Long-term group (n=36)	p
Disc degeneration			0.006*
II	4 (9.09)	0 (0)	
III	29 (65.91)	16 (44.44)	
IV	7 (15.91)	18 (50.00)	
V	4 (9.09)	2 (5.56)	
Disc morphology			0.758
Broad-based herniation	6 (13.64)	6 (16.67)	
Focal herniation	13 (29.54)	7 (19.44)	
Extruded	21 (47.73)	20 (55.56)	
Sequestered	4 (9.09)	3 (8.33)	
HIZ on T2WI in AF	13 (29.55)	11 (30.56)	0.922
Modic change			0.499
None	29 (65.91)	18 (50.00)	
Type I	12 (27.27)	13 (36.11)	
Type II	2 (4.55)	3 (8.33)	
Type III	1 (2.27)	2 (5.56)	
Facet osteoarthritis grade			0.001*
0	4 (9.09)	0 (0)	
1	16 (36.36)	3 (8.33)	
2	15 (34.09)	12 (33.33)	
3	9 (20.46)	21 (58.33)	
Segmental angulation (°)	7.96±4.60	7.09±4.33	0.436
Segmental translation (mm)	2.75±1.92	2.70±1.25	0.959
Operation side			0.216
Right side	22 (50.00)	13 (36.11)	
Left side	22 (50.00)	23 (63.89)	

AF, annulus fibrosus; Disc degeneration, Pfirrmann disc degeneration grade; HIZ, high-intensity zone; Long-term group, long-term reoperation group; Short-term group, short-term reoperation group; T2WI, T2-weighted imaging.
Data are expressed as mean±standard deviation or n (%).
*$p<0.05$.

the mean facet joint osteoarthritis grade differed significantly between the short- and long-term reoperation groups (1.66 vs. 2.50, respectively; $p<0.001$). Segmental angulation and translation, measured using initial dynamic flexion-extension X-rays, showed no significant differences between the short- and long-term reoperation groups. Other radiologic findings, including HIZs and Modic changes, did not differ significantly between groups. All surgeons performing the primary endoscopic discectomies were right-handed. Twenty-two patients (50.00%) in the short-term reoperation group and 13 patients (36.11%) in the long-term group underwent surgery on the right side, whereas 22 patients (50.00%) in the short-term group and 23 patients (63.89%) in the long-term group underwent surgery on the left side, with no significant differences in the lesion side ($p=0.216$) (Table 2). The total mean operation time was 75.5±19.2 min (range: 40–126 min). The mean operation times for right-sided (71.3±21.6 min) and left-sided lesions (78.7±16.7 min) did not differ significantly ($p=0.087$).

Table 3. Comparison of Clinical Findings according to the Timing of Reoperation

	Short-term group (n=44)	Long-term group (n=36)	p
Age (yr)	55.45±16.09	59.33±13.46	0.253
Sex			0.396
Male	25 (56.82)	17 (47.22)	
Female	19 (43.18)	19 (52.78)	
Reoperation duration (months)	3.15±1.26 (1.16–5.84)	10.08±7.44 (7.59–35.74)	<0.001*
Hypertension	17 (38.64)	22 (61.11)	0.107
DM	25 (56.82)	29 (80.56)	0.025*
Smoking	19 (43.18)	10 (27.78)	0.157
Leg VAS			
Preoperative	8.00±0.96	7.72±1.03	0.218
24-month postoperative	2.59±1.04	2.50±0.94	0.686
Back VAS			
Preoperative	4.84±1.89	5.00±1.89	0.709
24-month postoperative	2.57±1.21	2.50±0.88	0.778
ODI			
Preoperative	31.11±7.63	30.19±7.28	0.586
24-month postoperative	12.86±3.74	11.78±2.62	0.132
Change (%)	58.03±8.03	60.12±8.11	0.358
Causes of reoperation			0.001*
Incomplete decompression	18 (40.91)	1 (2.78)	
Recurrent herniation	6 (13.64)	3 (8.33)	
Facet cyst	4 (9.09)	4 (11.11)	
Secondary lumbar stenosis	6 (13.64)	2 (5.56)	
Postoperative instability	10 (22.72)	26 (72.22)	
Reoperation procedure			0.323
UBE	2 (4.55)	0 (0)	
Microdiscectomy	14 (31.81)	6 (16.67)	
MIS TLIF	2 (4.55)	3 (8.33)	
MIS OLIF	1 (2.27)	1 (2.78)	
PLIF	25 (56.82)	26 (72.22)	

DM, diabetes mellitus; Long-term group, long-term reoperation; MIS OLIF, minimally invasive oblique lumbar interbody fusion; MIS TLIF, minimally invasive transforaminal lumbar interbody fusion; ODI, Oswestry Disability Index score; PLIF, posterior lumbar interbody fusion; Short-term group, short-term reoperation; UBE, unilateral biportal endoscopic discectomy; VAS, visual analog scale.
Data are expressed as mean±standard deviation or n (%).
*$p<0.05$.

Clinical findings according to reoperation period

The mean interval to reoperation was 3.2±1.3 months (range, 1.2–5.8 months) in the short-term group and 10.1±7.4 months (range, 7.6–35.7 months) in the long-term group. The prevalence of DM was higher in the long-term reoperation group than in the short-term reoperation group. The cause of reoperation differed significantly depending on the reoperation period. In the short-term group, 40.9% of reoperations were due to incomplete decompression after primary endoscopic discectomy, whereas in the long-term group, most were attributable to instability (72.2%). No significant differences were observed between the two groups in postoperative outcomes or reoperation procedures (Table 3).

The Pfirrmann disc degeneration grade (p=0.045), facet joint osteoarthritis grade (p=0.003), and cause of reoperation (p<0.001) were correlated with the surgical technique used. Higher Pfirrmann degeneration grades (III and IV) were associated with surgical fusion (p=0.034). Similarly, higher facet joint osteoarthritis grades (2 and 3) were associated with the use of interbody fusion technique (p=0.001). Postoperative instability as a cause of reoperation was associated with the surgical fusion technique (p<0.001). The representative cases are shown in Figs. 2 and 3.

Preoperative predictors of ODI improvement

In the multivariable logistic regression analysis, a good functional outcome—defined as ≥66% ODI improvement at 24 months—was significantly associated with a lower facet joint osteoarthritis grade (grades 0–1 vs. 2–3; OR=18.27, 95% CI=1.95–171.58, β=2.91, p=0.011) after adjustment for preoperative variables (age, sex, hypertension, DM, and Pfirrmann disc degeneration grade) (Table 4). The wide confidence interval likely reflects variability related to sample size and category distribution.

Pearson correlation analyses between preoperative clinical and radiologic variables are summarized in Supplementary Table 1 (only online). Briefly, the facet osteoarthritis grade showed positive correlations with both the preoperative and 24-month postoperative back VAS scores (r=0.321 and r=0.241, respectively) and age (r=0.564). Greater segmental translation was negatively correlated with ODI improvement (r=-0.280).

DISCUSSION

Multiple risk factors contribute to reoperation following endo-

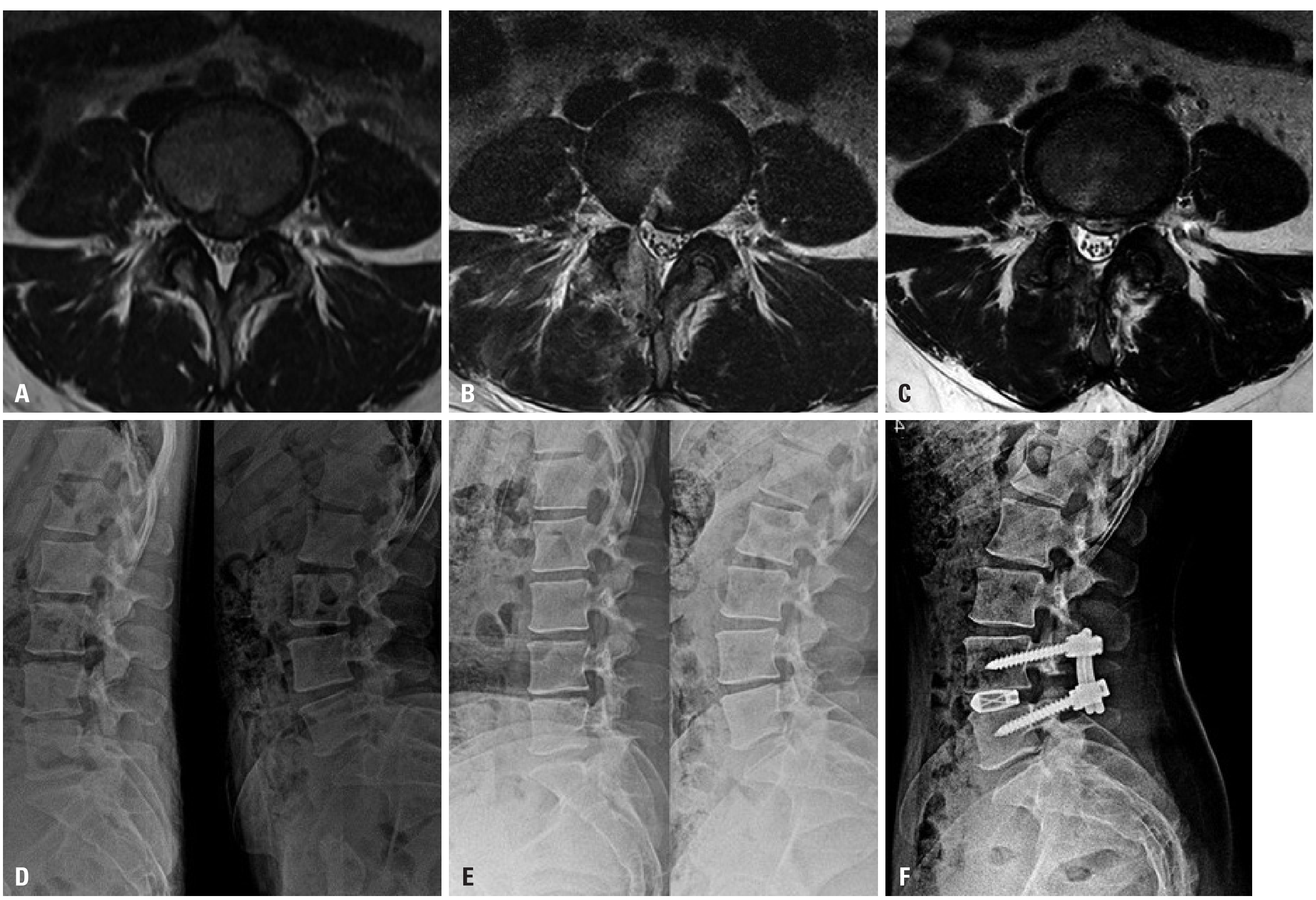

Fig. 2. Postoperative instability and facet damage. A 33-year-old female patient experienced pain and numbness in her right leg due to a herniated lumbar disc at the L4–5 level. (A) Axial T2W MRI showed significant disc protrusion and subligamentous rupture at the L4–L5 level. (B) Axial T2W MRI obtained the day after UBE surgery showed decompression of the thecal sac. (C) Eight months after undergoing UBE, the patient complained of intense pain radiating to both legs and severe back pain when transitioning from sitting to standing, making walking difficult. MRI revealed re-herniation. (D) Initial lumbar spine flexion–extension radiographs. (E) The L4–5 space shows slight anterior collapse of the lumbar spine on a lateral flexion X-ray taken 8 months after surgery. (F) PLIF was performed at the L4–5 level, resulting in improvement of the patient's leg pain after surgery. PLIF, posterior lumbar interbody fusion; T2W, T2-weighted; UBE, unilateral biportal endoscopic discectomy.

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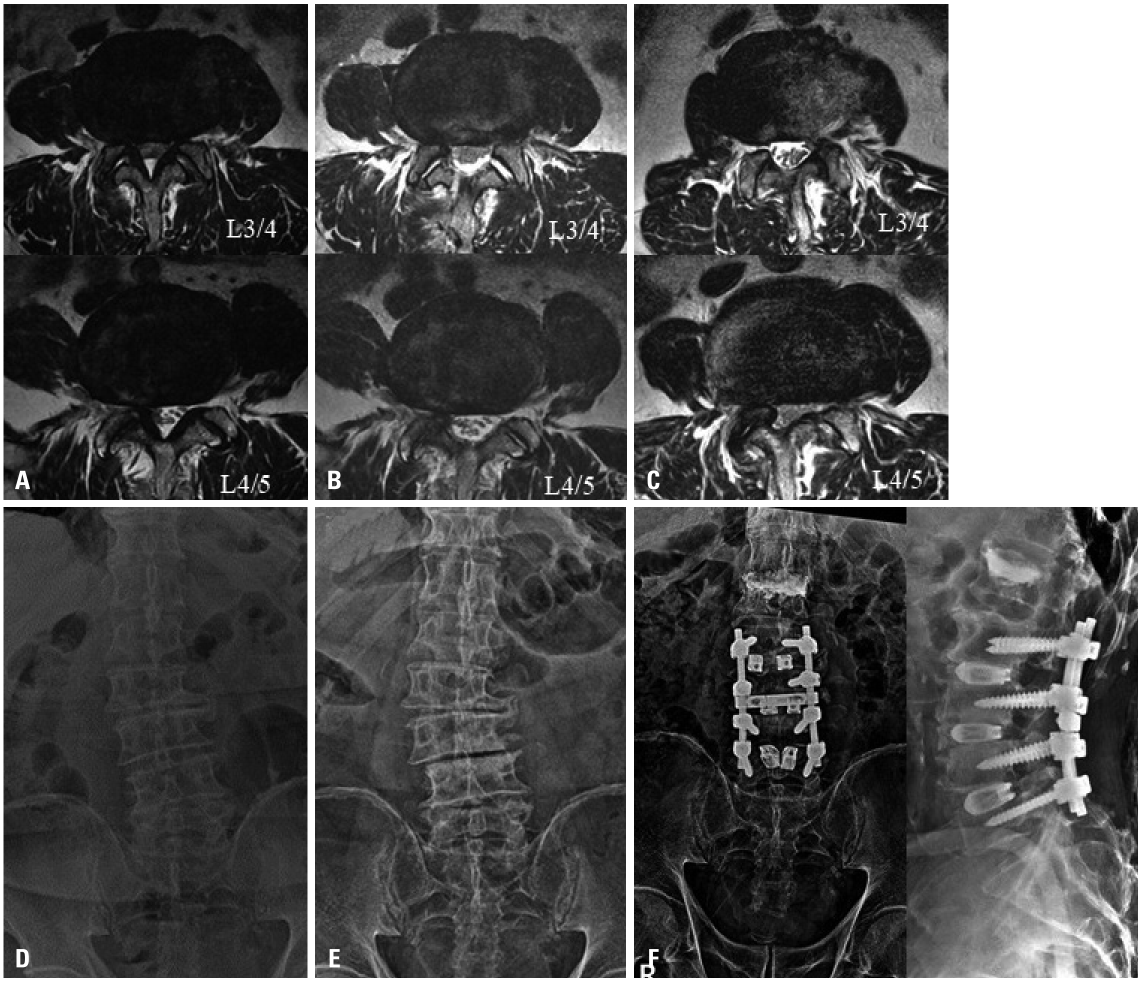

Fig. 3. Restenosis and lateral slippage of the vertebral body following UBE with two levels of decompression. A 74-year-old male patient presented with lower back pain, bilateral leg pain, and numbness that were more pronounced on the right side. (A) Axial T2W MRI revealed a bony spur, facet hypertrophy, foraminal stenosis, and herniated disc protrusion at levels L3–4–5. (B) Axial T2W MRI obtained the day after UBE showing thecal sac decompression at L3–4–5. (C) The patient complained of severe pain in the right leg and back 12 months after surgery. MRI revealed restenosis, foraminal stenosis, and severe L5 nerve compression. (D) Initial lumbar spine anteroposterior radiograph. (E) Lateral slippage of the vertebral body is observed. The patient had no history of osteoporosis or falls within the previous 12 months. (F) PLIF was performed at levels L2–L5, and vertebroplasty at was performed at L1 due to a slight compression fracture of the superior endplate of L1. The right leg and lower back pain improved postoperatively. PLIF, posterior lumbar interbody fusion; T2W, T2-weighted; UBE, unilateral biportal endoscopic discectomy.

Table 4. Multivariable Logistic Regression Analysis of Preoperative Factors Associated with ODI Improvement

Variables	OR (95% CI)	*p*
Age (per year)	0.922 (0.835–1.017)	0.104
Sex (male vs. female)	0.973 (0.237–4.002)	0.969
Hypertension (yes vs. no)	0.399 (0.071–2.244)	0.298
DM (yes vs. no)	4.052 (0.358–45.823)	0.258
Pfirrmann grade II (vs. V)	0.158 (0.014–1.838)	0.140
Pfirrmann grade III (vs. V)	0.093 (0.006–1.382)	0.085
Pfirrmann grade IV (vs. V)	2.682 (0.127–56.708)	0.526
Facet OA grade 0–1 (vs. 2–3)	18.271 (1.946–171.577)	0.011*

CI, confidence interval; DM, diabetes mellitus; OA, osteoarthritis; ODI, Oswestry Disability Index; OR, odds ratio.
*$p<0.05$.

scopic lumbar discectomy, including radiologic parameters such as disc degeneration, facet joint osteoarthritis, disc height, and ROM, as well as clinical factors such as age, sex, smoking, and obesity.[6,20] This study aimed to identify the predictors of unplanned reoperation and assess whether these risk factors vary based on reoperation timing. Our findings suggest that long-term reoperation (≥6 months) is associated with advanced disc degeneration and severe facet osteoarthritis, whereas short-term reoperation (<6 months) is predominantly associated with incomplete decompression. Furthermore, DM was more prevalent in the long-term reoperation group, indicating its potential contribution to increased reoperation risk.

The Pfirrmann disc degeneration grade was found to be associated with reoperation due to recurrent disc herniation, with recurrence rates varying according to the severity of degeneration.[21,22] As intervertebral disc degeneration progresses, the distinction between the nucleus and annulus fibrosus becomes unclear, leading to significant disc height loss, which may reduce the likelihood of re-herniation. Abdallah and Güler Abdallah[21] reported that incomplete decompression in patients with mild-to-moderate degeneration and preserved disc height increases the risk of re-herniation. In contrast, Hwang, et al.[22] identified advanced degeneration (Pfirrmann grade IV) as a risk factor for recurrent herniation following discectomy. Our study demonstrates a difference in reoperation timing based on disc degeneration. A higher prevalence of advanced degeneration (Pfirrmann grade IV) was observed in the long-term reoperation group, whereas a greater proportion of moderate degeneration (Pfirrmann grade III) was observed in the short-term reoperation group. Patients who underwent long-term reoperation demonstrated a higher average Pfirrmann disc degeneration grade than those who underwent short-term reoperation, indicating more advanced degeneration and significant initial disc height loss.

Radiologic evidence of facet joint osteoarthritis was observed in 89% of patients following lumbar discectomy.[23,24] The degree of preoperative facet joint osteoarthritis correlated with the risk of postoperative reoperation.[23] Wang, et al.[25] found that advanced facet joint degeneration predicts early reoperation after endoscopy. However, in this study, a high percentage of mild-grade facet osteoarthritis was observed in patients in the short-term reoperation group, while those in the long-term reoperation group showed a high percentage of severe-grade osteophyte formation. Facet joint hypertrophy and osteoarthritis can cause severe bony foraminal or lateral recess stenosis, which complicates the establishment of a working channel. It is assumed that the risk of facet damage increases with worsening facet osteoarthritis, which can lead to increased postoperative instability. When dealing with severe facet osteoarthritis and hypertrophy, it is crucial to accurately position the endoscope and take steps to minimize facet damage during laminectomy and facetectomy using a shaver or drill.

Reoperation has been recognized as a significant complication following discectomy, with a reported frequency of up to 21%.[26] The most frequent site of reoperation following primary discectomy was the previous operation site.[26] Reoperation after endoscopic lumbar discectomy results from several factors, including recurrent disc herniation, incomplete decompression with residual fragments, stenosis, instability, and postoperative complications such as hematoma, infection, and nerve injury.[6,13] The timing of reoperation varied with different causes of reoperation in this study. Incomplete decompression was the primary cause of short-term reoperation, whereas postoperative instability was more prevalent in the long-term reoperation group. In this study, the reoperation rate after UBE was 5.13%. Tang, et al.[6] documented a 2-year reoperation rate of 6.2%. Other studies reported reoperation rates between 6.7% and 9.6% for endoscopic decompression[5,13] The literature indicates that the UBE reoperation rate, especially below 10%, supports its role as an effective surgical option for treating lumbar degenerative diseases.

Incomplete decompression refers to failure to completely remove the herniated disc material, which can lead to reoperation. Choi, et al.[13] reported that improper positioning of the working channel, types of herniated discs, and the migration characteristics of herniated discs may lead to incomplete decompression and affect surgical outcomes. Axillary-type disc herniation and high-grade migration of discs can lead to incomplete removal of herniated disc material, as fragments located in the epidural space may persist and compress the traversing nerve root.[13] In this study, six patients were identified as having incomplete decompression in foraminal or extraforaminal disc protrusion at the time of the initial endoscopic surgery. We retrospectively assessed immediate postoperative MRI scans in all cases to determine whether there was remnant root compression in the upper, lower, or foraminal regions of the disc space. Most patients recovered without radicular pain due to postoperative fluid collection, hematoma, or small disc herniation fragments. Some patients with radiating postoperative pain show improvement with pain blocks or physical therapy. The remaining patients reported radiating pain and required reoperation. In this study, 40.91% of the patients who underwent short-term reoperation within 6 months had incomplete decompression as the main cause. Some researchers have reported that endoscopic lumbar discectomy is more likely to fail when performed by less experienced spine surgeons.[9] However, endoscopic surgical techniques have become more popular owing to the development of video teaching materials. Additionally, because an endoscopic technique, such as UBE, has a short learning curve, a more thorough examination of all areas during surgery is needed to ensure accurate decompression, rather than solely depending on the surgeon's expertise and experience.

Some researchers have reported that incomplete decompression is associated with certain types of disc herniation.[13,15] Ziegler, et al.[15] investigated the association between recurrent disc herniation and disc morphological types. Our findings demonstrated that disc morphological types, such as extrusion or sequestration, were similar in both reoperation timing groups (short- and long-term).

Postoperative spondylolisthesis and instability have been reported as causes of reoperation, with an incidence of 2.28% after endoscopic discectomy and decompression.[27] Furthermore, excessive decompression during the initial procedure may exacerbate instability. Endoscopic surgery has advantages, including reduced iatrogenic injury to the paraspinal muscles and facet joints, and better preservation of back muscle function than open lumbar discectomy.[1,28] Patients who underwent endoscopic discectomy had lower serum creatine kinase levels than those who underwent open microdiscectomy.[29] Nevertheless, to achieve optimal neural decompression during spinal surgery, facet joint violation is sometimes unavoidable. If optimal decompression is not achieved, surgical

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outcomes may be poor because of incomplete canal decompression, development of dynamic stenosis, or early restenosis. Approximately 30% ipsilateral facet joint resection is required for successful central canal and lateral recess decompression.[30] In contrast, resecting more than 50% of the unilateral facet joint results in iatrogenic biomechanical issues and instability.[31] When degenerative changes are severe, accurately determining the extent of facet joint resection is challenging. This study demonstrated that patients who underwent long-term reoperation exhibited more severe facet osteoarthritis and disc degeneration at the time of initial endoscopic surgery than those who underwent short-term reoperation. Boden and Wiesel[32] defined sagittal plane instability as greater than 3 mm of translational motion or 8% of the adjacent vertebral width displacement. A translation greater than 3 mm and angular motion exceeding 10° were defined as unstable, necessitating surgical treatment.[33] Preoperative segmental instability may be exacerbated by surgical intervention, requiring lumbar fusion. In this study, segmental instability was not observed at the time of the primary surgery. However, patients undergoing long-term reoperation exhibit significant degenerative changes at the initial operation site and postoperative instability as a primary cause of reoperation, which may have been aggravated by facet joint resection for neural decompression.

Clinical factors such as DM, smoking, and obesity may also contribute to the risk of reoperation.[34] Diabetic patients often have reduced proteoglycan content in intervertebral discs, leading to a weakened collagen matrix and increased susceptibility to recurrent herniation.[35] Mobbs, et al.[36] reported a reoperation rate in diabetic patients of 28%, compared to 3.5% in controls. In this study, the percentage of diabetic patients was higher in the long-term reoperation group than in the short-term reoperation group. Strict blood glucose control after endoscopic decompression may help reduce reoperation rates. Several studies have identified a correlation between smoking and recurrent disc herniation.[20] Nicotine induces intervertebral disc degeneration through vasoconstriction and may hinder healing after discectomy.[37] However, this study found no significant difference in smoking prevalence between the short- and long-term reoperation groups.

In the multivariable logistic regression analysis, a higher preoperative facet osteoarthritis grade was significantly associated with reduced odds of achieving good functional improvement. This negative predictive relationship is consistent with previous reports indicating that advanced facet degeneration can limit postoperative recovery through residual foraminal stenosis, facet hypertrophy, and altered spinal biomechanics.[23,25] Such degenerative changes may restrict the extent of achievable neural decompression without compromising segmental stability, leading to persistent symptoms or delayed deterioration. While these findings do not establish causation, we emphasize the importance of a detailed preoperative evaluation of the facet joint pathology. In cases of advanced facet degeneration, tailored surgical strategies, such as preserving stabilizing structures or considering fusion, may be necessary to optimize postoperative functional outcomes.

Although the facet osteoarthritis grade emerged as a significant predictor of favorable ODI improvement, the confidence interval demonstrated substantial dispersion. This finding indicates that while the direction of the association is consistent, the precision of the effect estimate is limited, most likely due to sample size constraints and uneven category distribution. Therefore, the observed association should be interpreted with caution and validated in larger prospective studies. Although not used as the primary basis for statistical inference, exploratory correlation analyses supported the negative prognostic implications of facet degeneration and instability. Specifically, a higher facet osteoarthritis grade was correlated with increased back pain and older age, whereas greater segmental translation was inversely associated with functional recovery. These trends reinforce the biomechanical implications of facet degeneration and segmental instability in endoscopic spinal surgery.

The positioning of portals in biportal endoscopic surgery is important for achieving favorable outcomes and is influenced by the surgeon's preferences and the proximity of the anatomical lesion to the portal sites.[38] Incomplete decompression or complications may occur when right-handed surgeons choose a right-sided approach in early reoperation following endoscopic surgery, as the working portal is in the non-dominant hand, potentially leading to discomfort and affecting postoperative outcomes. Some right-handed surgeons recommend a contralateral approach if the lesion is on the right side.[39] In this study, no significant differences were found when dominant-handed surgeons performed procedures on either the dominant or non-dominant side, regardless of reoperation timing. Surgeons should flexibly and adaptively select the surgical portal position within a designated range, considering the patient's condition and the precise location of the lesion.

Endoscopic disc surgery causes less bone destruction than traditional techniques, and the magnified operative field can help prevent excessive facet joint resection.[40] Nonetheless, it is important to note that in endoscopic spine surgery, wide decompression can potentially lead to facet damage. Consequently, endoscopic decompression cannot completely eliminate concerns regarding instability, facet joint damage, or degeneration of adjacent segments. Preoperative evaluation of facet joint arthropathy is essential to minimize the risk of reoperation due to postoperative instability and facet damage following endoscopic discectomy. Adequate decompression in cases with less severe degeneration might reduce the risk of short-term reoperation, whereas in cases of severe degeneration and disc height loss, endoscopic techniques such as biportal endoscopic transforaminal lumbar interbody fusion may help mitigate the likelihood of long-term postoperative instability and the need for reoperation.[3] Based on our results, minimizing facet injury is crucial to reduce the need for reoperation following endoscopic surgery. This study identified variations in the factors influencing short- and long-term reoperations following endoscopic spine surgery. These findings provide valuable insights for spinal surgeons and endoscopy practitioners in guiding patient selection, surgical techniques, and postoperative care to reduce the need for reoperation and improve patient outcomes.

This study has several limitations. First, this was a retrospective study with a relatively small number of patients, and inherent differences between groups were unavoidable. This heterogeneity in the patient population, which included differences in age, comorbidities, and preoperative spinal conditions, may have introduced variability in the reasons for reoperation. Although efforts have been made to control confounding factors, further subgroup analyses and prospective multicenter studies are needed to validate these findings in more homogeneous cohorts. Second, there was selection bias due to the study design, as reoperation cases included patients who underwent surgery at our hospital and those transferred from other hospitals. Third, only patients who underwent UBE were analyzed, which may have introduced a bias. Fourth, the management strategies were determined by the treating surgeons, and differences in institutional and surgeon preferences may have affected the clinical outcomes of the surgical treatment, including whether UBE, microdiscectomy, MIS TLIF, MIS OLIF, or PLIF were performed. In the future, prospective and multicenter studies are needed to identify the radiologic and clinical factors affecting the risk of reoperation following uni- or biportal endoscopic spine surgery for lumbar disc herniation.

In conclusion, UBE is an effective treatment for degenerative lumbar diseases; however, the risk of reoperation remains high. In this cohort of patients who underwent reoperation after UBE, the primary cause of short-term reoperation was incomplete decompression, whereas advanced disc degeneration, severe facet osteoarthritis, postoperative instability, and DM were more commonly associated with long-term reoperation. Multivariable analysis identified a higher preoperative facet osteoarthritis grade as a significant negative predictor of postoperative functional improvement. These observations, derived from a reoperation-only population, may help guide preoperative assessment and surgical planning. However, these findings should not be generalized to all patients undergoing UBE. Further prospective studies with larger patient populations are warranted to determine whether addressing these factors through comprehensive preoperative evaluation, precise surgical technique, and targeted postoperative care can help reduce reoperation rates and improve long-term outcomes after endoscopic spine surgery.

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