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# Comparative Outcomes of Biportal Endoscopic Decompression, Conventional Subtotal Laminectomy, and Minimally Invasive Transforaminal Lumbar Interbody Fusion for Lumbar Central Stenosis

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**Objective:** Spinal stenosis is a prevalent condition; however, the optimal surgical treatment for central lumbar stenosis remains controversial. This study compared the clinical outcomes and radiological parameters of 3 surgical methods: unilateral laminectomy bilateral decompression with unilateral biportal endoscopy (ULBD-UBE), conventional subtotal laminectomy (STL), and minimally invasive transforaminal lumbar interbody fusion (MIS-TLIF).
**Methods:** This retrospective study included 86 patients, divided into ULBD-UBE (n = 34), STL (n = 24), and MIS-TLIF (n = 28) groups. We evaluated demographics and perioperative factors and assessed clinical outcomes using the visual analogue scale (VAS), Oswestry Disability Index (ODI), and neurogenic intermittent claudication (NIC). Radiological parameters assessed included lumbar lordosis, L4S1 Cobb angle (L4S1), T12S1 Cobb angle (T12S1), increased cross-sectional dural area (CSA), dynamic angulation (DA), dynamic slip (DS), and development of postoperative instability.
**Results:** The ULBD-UBE group showed a significantly shorter hospital stay duration and operation time and reduced blood loss than the other groups ($p < 0.001$). ULBD-UBE group showed a trend towards greater VAS and ODI improvement at 1 month and postoperative NIC symptom relief. Radiologically, MIS-TLIF group exhibited lower postoperative DA and DS ($p < 0.001$), indicating higher postoperative stability. Postoperative instability was lower in the ULBD-UBE group (2.9%) than in the STL group (16.7%) and similar to the MIS-TLIF group (0.0%) ($p = 0.028$). The CSA was highest in the MIS-TLIF group (295.5%) compared to that in the other groups (ULBD-UBE, 216.3%; STL, 245.2%) ($p < 0.001$).
**Conclusion:** Compared to other procedures, ULBD-UBE is a safe, effective, and viable surgical procedure for treating lumbar central stenosis.

**Keywords:** Spinal stenosis, Endoscopic spine surgery, Decompression, Biportal endoscopy

## INTRODUCTION

Central lumbar stenosis is a prevalent cause of chronic back pain and radiating leg pain. As the population ages, degenerative disorders such as spinal stenosis are becoming increasingly prevalent.[1] Although various treatment options are available, including medication and nerve blocks, surgical intervention is often required.[2,3] Surgical options typically involve decompression or fusion surgery. Decompression surgery can be performed via open surgery or minimally invasive surgery. However, there is currently no consensus on the most effective surgical approach for treating central lumbar stenosis.[4-11]

Several studies indicate that decompression alone may be sufficient for treating lumbar stenosis.[5,6] However, some study shows that patients without deformity or instability who undergo wide decompression or facetectomy could develop iatrogenic lumbar instability.[7] Biomechanical studies have linked the extent of decompression to postoperative instability.[12,13] While some authors advocate that adding fusion is more effective than decompression alone for improving overall physical health[8] and pain relief,[9] others argue that fusion offers a modest decrease in long-term reoperation rates.[10] Nonetheless, fusion surgery can lead to muscle damage and adjacent segment disease.[11]

With advancing technology, there is a growing trend towards endoscopic spine surgery, particularly the use of unilateral biportal endoscopy (UBE).[14] UBE has demonstrated effectiveness for lumbar disc herniation.[15,16] However, its efficacy for endoscopic decompression of lumbar spinal stenosis remains debated because several studies have reported that possibility of complications and insufficient decompression is not lower compared to other surgeries, and in some studies, the complication rate is slightly higher.[17-23] This study aimed to compare the clinical outcomes and radiological parameters of 3 different surgical methods: unilateral laminectomy bilateral decompression with UBE (ULBD-UBE), conventional subtotal laminectomy (STL), and minimally invasive transforaminal lumbar interbody fusion (MIS-TLIF).

## MATERIALS AND METHODS

### 1. Patients and Study Design

This retrospective study analyzed data from patients who underwent surgery for single-level central lumbar stenosis at a single institution between 2018 and 2022. A total of 86 patients were included and categorized into 3 groups based on the surgical procedure: ULBD-UBE (n = 34), STL (n = 24), and MIS-TLIF (n = 28). All patients had single-level central stenosis with Schizas grade C or D[24] and presented with symptoms, such as radiculopathy and neurogenic intermittent claudication (NIC), which persisted despite adequate conservative treatment. All patients were followed up for at least 6 months. Exclusion criteria included a history of prior spinal surgery, foraminal stenosis, spondylolisthesis classified as Meyerding grade 2 or higher, and any signs of lumbar instability which is defined as angular rotation of > 15° at the L1–2 to L3–4 segments, > 20° at the L4–5 segment, and > 25° at the L5–S1 segment and/or sagittal translation of > 4.5 mm or 15% of vertebral body width.[25] This study was approved by the Institutional Review Board (IRB) of Yonsei College of Medicine, Gangnam Severance Hospital (IRB No. 3-2024-0215).

### 2. Surgical Methods

All surgeries were performed under general anesthesia. The end point of each surgery was to achieve decompression to the bilateral pedicles. STL procedure followed previously described protocols.[26,27] Central laminectomy was performed with preservation of the upper part of the spinous process and lamina and both facet joints. ULBD-UBE was conducted according to previously described methods.[27-29] A 1-cm skin incision was independently performed above and below the lesion and a dilator was inserted to separate and dissect the muscle unilaterally. Two skin incisions were made on one side, as follows: one for the endoscope (viewing portal) and one for the instruments (working portal). A partial hemilaminectomy was performed to decompress the ipsilateral and contralateral sides using saline irrigation. This procedure was performed on the left side owing to the preference of right-handed surgeons.

MIS-TLIF was performed on the symptomatic side as previously described.[30] A 3-cm incision was made along the lateral pedicle line on the disc space, and a working channel was created using a tubular retractor (METRx, Medtronic, Memphis, TN, USA). The procedure involved total facetectomy, partial laminectomy, ipsilateral and contralateral decompressions, discectomy, and preparation of the disc space for fusion. The interbody cage and percutaneous pedicle screws were inserted under fluoroscopic guidance.

### 3. Outcome Measures

Demographic and perioperative parameters, including age, sex, American Society of Anesthesiologists (ASA) physical status classification, level of operation, length of stay, operation time, and estimated blood loss, were collected and analyzed. Clinical outcomes assessed included the visual analogue scale (VAS) score, Oswestry Disability Index (ODI), severity and improvement of NIC, and incidence of complications. VAS and ODI scores were evaluated preoperatively, 1 month postoperatively, and at the final follow-up visit.

Radiological parameters, including lumbar lordosis (LL), L4S1 Cobb angle (L4S1), T12S1 Cobb angle (T12S1), dynamic angulation (DA), and dynamic slip (DS), were assessed preop-

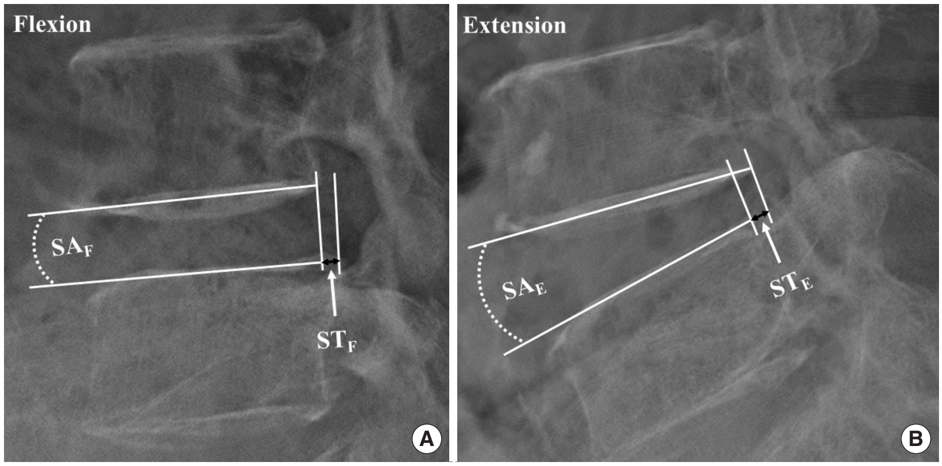


Fig. 1. (A, B) Measurement of dynamic angulation (DA) and dynamic slip (DS). DA is defined as the difference in sagittal angulation change between flexion ($SA_F$) and extension ($SA_E$) ($DA = SA_F - SA_E$); DS is the difference in segmental translation between flexion ($ST_F$) and extension ($ST_E$) ($DS = ST_F - ST_E$). To measure the segmental angle (SA), tangent lines are drawn along the lower endplate of the superior vertebra and upper endplate of the inferior vertebra. For segmental translation (ST), a perpendicular line is drawn from the posterior margin of the lower endplate of the superior vertebra to the line of the upper endplate of the inferior vertebra.

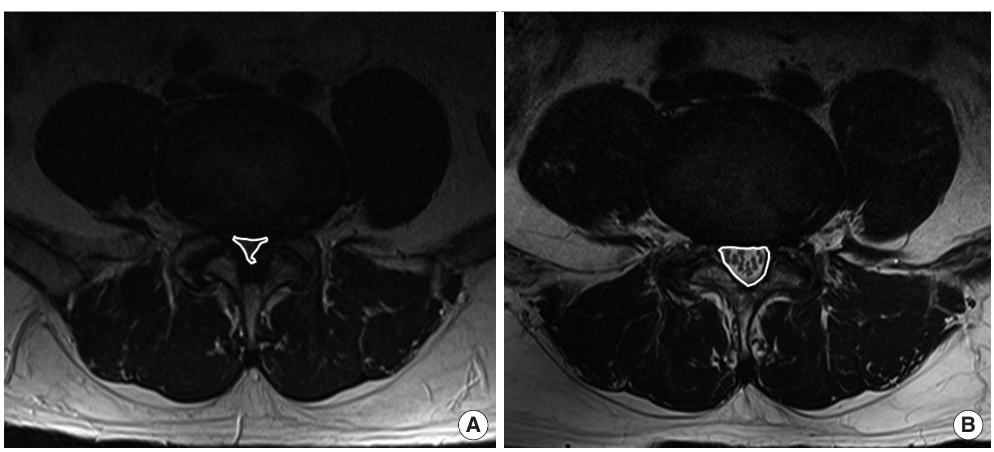


Fig. 2. Measurement of dural sac cross-sectional area (DCSA) ($mm^2$) on preoperative (A) and postoperative (B) magnetic resonance imaging. Increase in cross-sectional area (CSA) = postoperative DCSA/preoperative DCSA × 100 (%). DCSA, dural sac cross-sectional area.

eratively, 1 month postoperatively, and at the final follow-up. The differences in these parameters were evaluated. DA refers to the difference in segmental angulation during flexion and extension observed on lateral radiographs, while DS represents the difference in segmental translation during these movements (Fig. 1).[31] The dural sac cross-sectional area (DCSA) was measured on the most stenotic axial magnetic resonance images preoperatively and postoperatively to assess decompression. DCSA was measured by a spine fellowship-trained surgeon 3 times, and the average value was used to minimize error. The increase in the cross-sectional dural area (CSA) was also calculated (Figs. 2 and 3). Postoperative instability was evaluated at the final follow-up visit, with instability defined as angular rotation of > 15° at the L1–2 to L3–4 segments, > 20° at the L4–5 segment, and > 25° at the L5–S1 segment and/or sagittal translation of > 4.5 mm or 15% of vertebral body width.[25]

### 4. Statistical Analysis

Statistical analyses were performed using R ver. 4.2.3 (R Foundation for Statistical Computing, Vienna, Austria). Patient data were analyzed using analysis of variance and chi-square tests. Statistical significance was set at $p < 0.05$.

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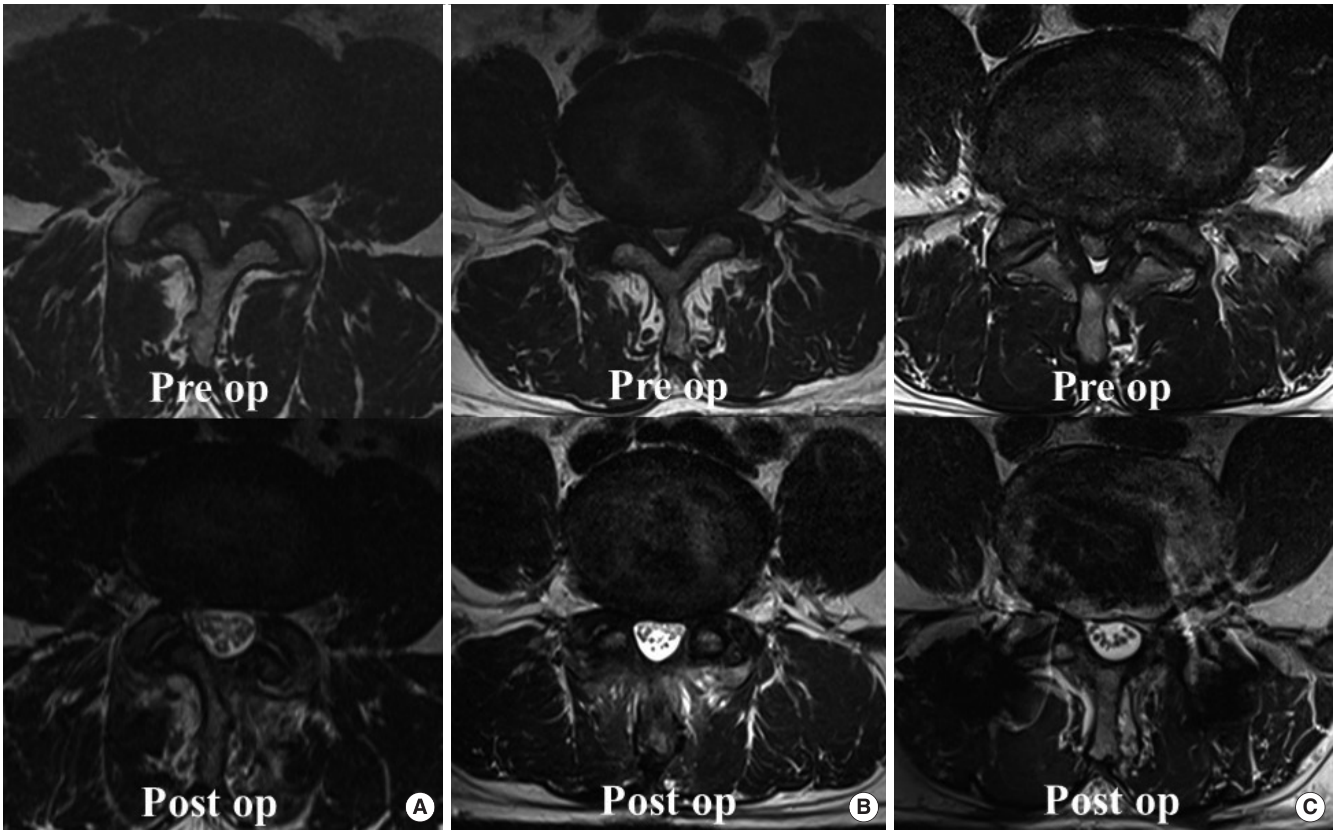


Fig. 3. Comparison of preoperative and postoperative magnetic resonance imaging in 3 different surgeries: unilateral biportal endoscopy (A), conventional subtotal laminectomy (B), and minimally invasive transforaminal lumbar interbody fusion (C).

## RESULTS

### 1. Demographics

Of the 86 patients enrolled in this study, 34, 24, and 28 patients underwent ULBD-UBE, STL, and MIS-TLIF, respectively. The mean follow-up period was 14.1 ± 7.2, 11.1 ± 8.1, and 12.4 ± 3.1 months for the ULBD-UBE, STL, and MIS-TLIF groups, respectively. The ULBD-UBE group had the shortest length of hospital stay (6.8 ± 3.0 days), followed by the STL (10.4 ± 7.6 days) and MIS-TLIF (11.2 ± 3.3 days) groups, with significant differences ($p < 0.001$). Operation times were significantly shorter for ULBD-UBE (78.1 ± 15.2 minutes) than for STL (86.5 ± 28.5 minutes) and MIS-TLIF (102.3 ± 21.6 minutes) ($p < 0.001$). The ULBD-UBE group also experienced significantly less blood loss (65.6 ± 82.3 mL) than that in the STL (118.8 ± 73.4 mL) and MIS-TLIF (192.9 ± 145.8 mL) ($p < 0.001$) groups. No significant differences were observed in sex, age, ASA physical status classification, or Schizas grade among the groups (Table 1).

### 2. Clinical and Radiological Outcomes

Table 2 depicts the clinical outcomes of the patients. No significant differences were observed in these parameters; however, at 1 month postoperatively, the STL and MIS-TLIF groups reported higher VAS scores for back pain ($p = 0.116$) and lower ODI improvement scores ($p = 0.096$) than the ULBD-UBE group. Preoperatively, the ULBD-UBE and MIS-TLIF groups exhibited more severe NIC symptoms than the STL group ($p = 0.056$). Postoperatively, the ULBD-UBE and MIS-TLIF groups showed greater improvement than the STL group.

Radiological parameters, including DA and DS at 1 month postoperatively ($DA_{1\ month}$ and $DS_{1\ month}$, respectively) and at the last follow-up visit ($DA_{Last}$ and $DS_{Last}$, respectively), differed significantly. The MIS-TLIF group had lower DA and DS than those of the other groups ($p < 0.001$). The differences in DA between the preoperative and last follow-up visits ($\Delta DA_{Last-Preop}$, $p < 0.001$), in DS between the preoperative and postoperative 1 month ($\Delta DS_{1\ month-Preop}$, $p = 0.001$), and in DS between the preoperative and last follow-up visit ($\Delta DS_{Last-Preop}$, $p = 0.003$) were significantly greater in the MIS-TLIF group, indicating improved

**Table 1.** Demographics and perioperative data

| Variable | ULBD-UBE (U: n = 34) | STL (S: n = 24) | MIS-TLIF (M: n = 28) | p-value | U vs. S | S vs. M | U vs. M |
|---|---|---|---|---|---|---|---|
| Age (yr) | 65.7 ± 12.6 | 69.3 ± 10.1 | 64.8 ± 9.9 | 0.303 | | | |
| Sex | | | | 0.484 | | | |
| Male | 19 (55.9) | 16 (66.7) | 14 (50.0) | | | | |
| Female | 15 (44.1) | 8 (33.3) | 14 (50.0) | | | | |
| ASA PS classification grade | | | | 0.580 | | | |
| I | 3 (8.8) | 1 (4.2) | 2 (7.1) | | | | |
| II | 18 (52.9) | 11 (45.8) | 15 (53.6) | | | | |
| III | 13 (38.2) | 12 (50.0) | 11 (39.3) | | | | |
| Level | | | | 0.431 | | | |
| L2–3 | 4 (11.8) | 0 (0) | 1 (3.6) | | | | |
| L3–4 | 4 (11.8) | 5 (20.8) | 4 (14.3) | | | | |
| L4–5 | 26 (76.5) | 19 (79.2) | 23 (82.1) | | | | |
| Schizas grade | | | | 0.919 | | | |
| C | 27 (79.4) | 18 (75.0) | 22 (78.6) | | | | |
| D | 7 (20.6) | 6 (25.0) | 6 (21.4) | | | | |
| Length of stay (day) | 6.8 ± 3.0 | 10.4 ± 7.6 | 11.2 ± 3.3 | < 0.001* | 0.020* | 0.995 | 0.002* |
| Operation time (min) | 78.1 ± 15.2 | 86.5 ± 28.5 | 102.3 ± 21.6 | < 0.001* | 0.455 | 0.030* | < 0.001* |
| Estimated blood loss (mL) | 65.6 ± 82.3 | 118.8 ± 73.4 | 192.9 ± 145.8 | < 0.001* | 0.190 | 0.040* | < 0.001* |
| Follow-up (mo) | 14.1 ± 7.2 | 11.1 ± 8.1 | 12.4 ± 3.1 | 0.209 | | | |

Values are presented as mean ± standard deviation or number (%).
ULBD-UBE, unilateral laminectomy bilateral decompression with unilateral biportal endoscopy; STL, conventional subtotal laminectomy; MIS-TLIF, minimally invasive transforaminal lumbar interbody fusion; ASA PS, American Society of Anesthesiologists physical status.
Analysis of variance and chi-square test were used for statistical analysis. All the above group comparisons were confirmed by a *post hoc* test.
U vs. S, *post hoc* test between ULBD-UBE and STL; S vs. M, *post hoc* test between STL and MIS-TLIF; U vs. M, *post hoc* test between ULBD-UBE and MIS-TLIF.
*p < 0.05, statistically significant differences.

postoperative stability compared to the other groups (Table 3). Postoperative instability was significantly different among the 3 groups, with the ULBD-UBE group having a lower incidence (2.9%) than that in the STL group (16.7%) and similar to that in the MIS-TLIF group (0%) ($p = 0.028$). CSA was significantly higher in the MIS-TLIF (295.5% ± 104.9%) group than in the ULBD-UBE (216.3% ± 53.2%) group ($p < 0.001$, Table 3). No significant differences were found in the Cobb angles of LL, L4S1, and T12S1 pre- and postoperatively.

When analyzing patients who underwent surgery at the L4–5 level (ULBE-UBE, n = 26; STL, n = 19; MIS-TLIF, n = 23), significant differences were observed in LL ($LL_{preop}$, $p = 0.036$), Cobb angle L4S1 ($L4S1_{preop}$, $p = 0.033$; $L4S1_{Last}$, $p = 0.049$), and T12S1 ($T12S1_{preop}$, $p = 0.025$; $T12S1_{Last}$, $p = 0.044$) preoperatively and at the last follow-up. However, the LL, L4S1, and T12S1 Cobb angles preoperatively, 1 month postoperatively, and at the last follow-up visit did not differ significantly, likely due to preoperative individual differences (Table 4). At the L4–5 level, DA and DS at 1 month postoperatively ($DA_{1\ month}$ and $DS_{1\ month}$, respectively) and at the last follow-up visit ($DA_{Last}$ and $DS_{Last}$, respectively) were significantly different, with the MIS-TLIF group showing lower values than the other groups ($p < 0.001$). The MIS-TLIF group demonstrated significantly greater reductions in DA between preoperative and 1 month postoperative ($\Delta DA_{1\ month-Preop}$, $p = 0.012$), DA between preoperative and last follow-up ($\Delta DA_{Last-Preop}$, $p < 0.001$), DS between preoperative and 1 month postoperative ($\Delta DS_{1\ month-Preop}$, $p = 0.006$), and DS between preoperative and last follow-up ($\Delta DS_{Last-Preop}$, $p = 0.007$) at the L4–5 level. The incidence of postoperative instability was lower (3.8%) in the ULBD-UBE group than in the STL group (15.8%), and similar to that in the MIS-TLIF group (0.0%) ($p = 0.082$) at the L4–5 level. CSA was significantly higher in the MIS-TLIF group (304.7% ± 112.6%) than in the ULBD-UBE group (228.0% ± 51.1%) ($p = 0.011$, Table 4).


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**Table 2.** Clinical outcomes

| Variable | ULBD-UBE (n = 34) | STL (n = 24) | MIS-TLIF (n = 28) | p-value |
|---|---|---|---|---|
| VAS back | | | | |
| Preoperative | 6.1 ± 2.4 | 5.7 ± 2.5 | 5.8 ± 1.8 | 0.772 |
| 1 Month | 2.5 ± 1.7 | 2.8 ± 1.4 | 3.3 ± 1.5 | 0.116 |
| Last | 2.7 ± 2.1 | 3.5 ± 1.8 | 2.9 ± 1.9 | 0.363 |
| VAS leg | | | | |
| Preoperative | 6.8 ± 2.0 | 6.5 ± 2.4 | 6.6 ± 1.8 | 0.844 |
| 1 Month | 2.4 ± 1.3 | 2.8 ± 1.2 | 2.9 ± 0.9 | 0.145 |
| Last | 3.1 ± 2.3 | 3.4 ± 1.9 | 2.7 ± 2.5 | 0.536 |
| ODI | | | | |
| Preoperative | 48.2 ± 15.3 | 44.3 ± 16.2 | 43.2 ± 14.8 | 0.752 |
| 1 Month | 23.6 ± 15.3 | 25.1 ± 13.8 | 29.6 ± 17.8 | 0.340 |
| Last | 23.8 ± 14.7 | 22.5 ± 13.9 | 24.8 ± 12.5 | 0.843 |
| ΔVAS back | | | | |
| 1 Month–preoperative | -3.6 ± 2.5 | -2.9 ± 3.2 | -2.5 ± 2.3 | 0.263 |
| Last–preoperative | -3.4 ± 2.7 | -2.2 ± 2.9 | -2.9 ± 2.3 | 0.261 |
| ΔVAS leg | | | | |
| 1 Month–preoperative | -4.4 ± 2.3 | -3.6 ± 2.5 | -3.6 ± 2.1 | 0.335 |
| Last–preoperative | -3.7 ± 2.8 | -3.0 ± 3.0 | -3.9 ± 3.3 | 0.595 |
| ΔODI | | | | |
| 1 Month–preoperative | -23.3 ± 12.5 | -19.2 ± 12.9 | -15.0 ± 18.3 | 0.096 |
| Last–preoperative | -23.1 ± 12.1 | -21.8 ± 14.9 | -19.9 ± 15.4 | 0.663 |
| Preop NIC | | | | 0.056 |
| < 5 Min | 19 (55.9) | 7 (29.2) | 18 (64.3) | |
| 5–10 Min | 9 (26.5) | 6 (25.0) | 5 (17.9) | |
| > 10 Min | 6 (17.6) | 11 (45.8) | 5 (17.9) | |
| Postoperative NIC | | | | 0.103 |
| Improved | 31 (91.2) | 17 (70.8) | 25 (89.3) | |
| Not improved | 3 (8.8) | 7 (29.2) | 3 (10.7) | |
| Complication* | | | | 0.653 |
| Yes | 2 (5.9) | 3 (12.5) | 2 (7.1) | |
| No | 32 (94.1) | 21 (87.5) | 26 (92.9) | |

Values are presented as mean ± standard deviation or number (%).
ULBD-UBE, unilateral laminectomy bilateral decompression with unilateral biportal endoscopy; STL, conventional subtotal laminectomy; MIS-TLIF, minimally invasive transforaminal lumbar interbody fusion; VAS, visual analogue scale; ODI, Oswestry Disability Index; NIC, neurogenic intermittent claudication.
*In ULBD-UBE group, 2 cases of dura tear had occurred. In STL group, 2 cases of dura tear and 1 case of infection had occurred. And in MIS-TLIF group, 2 case of dura tear had occurred. Only 1 case of which infection had happened in STL group needed reoperation.
Analysis of variance and chi-square test were used for statistical analysis.

## DISCUSSION

As the population ages, the prevalence of degenerative conditions such as lumbar spinal stenosis has increased.[1] The SPORT trial, which compared non-surgical and surgical treatments over 4 years, found that surgical intervention led to better outcomes in bodily pain, physical functioning, and ODI values.[32] The main goal of lumbar spinal stenosis surgery is to decompress and relieve pressure on the dural sac and nerve, but this often compromises spinal stability. Consequently, decompression combined

**Table 3.** Radiologic parameters

| Variable | ULBD-UBE (U: n = 34) | STL (S: n = 24) | MIS-TLIF (M: n = 28) | p-value | U vs. S | S vs. M | U vs. M |
|---|---|---|---|---|---|---|---|
| Lumbar lordosis | | | | | | | |
| Preoperative (°) | 43.7 ± 10.7 | 41.7 ± 11.5 | 37.9 ± 11.5 | 0.130 | | | |
| 1 Month (°) | 39.5 ± 9.9 | 38.6 ± 11.4 | 33.2 ± 11.7 | 0.062 | | | |
| Last (°) | 45.8 ± 9.1 | 42.1 ± 8.5 | 40.5 ± 10.5 | 0.096 | | | |
| Cobb angle L4S1 | | | | | | | |
| Preoperative (°) | 30.7 ± 7.9 | 31.3 ± 7.4 | 27.0 ± 8.9 | 0.109 | | | |
| 1 Month (°) | 29.8 ± 7.5 | 29.9 ± 9.4 | 26.0 ± 8.5 | 0.152 | | | |
| Last (°) | 31.5 ± 8.2 | 31.5 ± 8.7 | 28.2 ± 8.6 | 0.247 | | | |
| Cobb angle T12S1 | | | | | | | |
| Preoperative (°) | 42.8 ± 10.0 | 39.7 ± 12.3 | 37.0 ± 11.8 | 0.145 | | | |
| 1 Month (°) | 38.2 ± 9.1 | 36.2 ± 12.3 | 31.8 ± 11.9 | 0.078 | | | |
| Last (°) | 44.3 ± 8.9 | 39.2 ± 9.5 | 39.2 ± 11.0 | 0.086 | | | |
| Dynamic angulation | | | | | | | |
| Preoperative (°) | 2.7 ± 2.0 | 3.9 ± 2.1 | 3.0 ± 1.8 | 0.084 | | | |
| 1 Month (°) | 8.0 ± 4.0 | 6.1 ± 3.5 | 2.8 ± 2.7 | < 0.001* | 0.134 | 0.003* | < 0.001* |
| Last (°) | 4.5 ± 3.4 | 6.6 ± 3.5 | 0.9 ± 1.3 | < 0.001* | 0.023* | < 0.001 | < 0.001* |
| Dynamic slip | | | | | | | |
| Preoperative (mm) | 0.4 ± 0.5 | 0.6 ± 0.6 | 0.3 ± 0.4 | 0.130 | | | |
| 1 Month (mm) | 0.5 ± 0.5 | 0.9 ± 1.1 | -0.1 ± 0.4 | < 0.001* | 0.096 | < 0.001* | 0.004* |
| Last (mm) | 0.7 ± 0.7 | 0.8 ± 1.0 | -0.0 ± 0.2 | < 0.001* | 1.000 | < 0.001* | 0.001* |
| ΔLumbar lordosis | | | | | | | |
| 1 Month–preoperative (°) | -4.2 ± 7.8 | -3.1 ± 9.5 | -4.8 ± 10.7 | 0.821 | | | |
| Last–preoperative (°) | 0.4 ± 11.8 | 0.4 ± 6.4 | 2.6 ± 6.2 | 0.574 | | | |
| ΔCobb angle L4S1 | | | | | | | |
| 1 Month–preoperative (°) | -0.9 ± 5.7 | -1.4 ± 7.0 | -1.0 ± 7.3 | 0.945 | | | |
| Last–preoperative (°) | 0.3 ± 6.4 | 0.2 ± 5.4 | 1.2 ± 5.0 | 0.773 | | | |
| ΔCobb angle T12S1 | | | | | | | |
| 1 Month–preoperative (°) | -3.2 ± 11.1 | -3.5 ± 10.1 | -5.2 ± 10.5 | 0.746 | | | |
| Last–preoperative (°) | 3.1 ± 14.6 | -0.5 ± 6.7 | 2.2 ± 6.6 | 0.448 | | | |
| ΔDynamic angulation | | | | | | | |
| 1 Month–preoperative (°) | -2.2 ± 2.0 | -2.9 ± 2.0 | -3.1 ± 1.8 | 0.139 | | | |
| Last–preoperative (°) | 2.0 ± 4.5 | 1.3 ± 3.9 | -2.2 ± 2.0 | < 0.001* | 1.000 | 0.003* | < 0.001* |
| ΔDynamic slip | | | | | | | |
| 1 Month–preoperative (°) | 0.1 ± 0.5 | 0.3 ± 1.0 | -0.4 ± 0.5 | 0.001* | 0.723 | 0.001* | 0.022* |
| Last–preoperative (°) | 0.2 ± 0.6 | 0.2 ± 1.0 | -0.4 ± 0.4 | 0.003* | 1.000 | 0.018* | 0.006* |
| Instability | | | | 0.028* | | | |
| Yes | 1 (2.9) | 4 (16.7) | 0 (0.0) | | | | |
| No | 33 (97.1) | 20 (83.3) | 28 (100.0) | | | | |
| CSA (Postop DCSA/preop DCSA × 100) (%) | 216.3 ± 53.2 | 245.2 ± 80.8 | 295.5 ± 104.9 | < 0.001* | 1.000 | 0.373 | < 0.001* |
| MRI follow-up period (mo) | 8.6 ± 9.1 | 10.1 ± 8.8 | 12.3 ± 3.0 | 0.152 | | | |

Values are presented as mean ± standard deviation or number (%).
ULBD-UBE, unilateral laminectomy bilateral decompression with unilateral biportal endoscopy; STL, conventional subtotal laminectomy; MIS-TLIF, minimally invasive transforaminal lumbar interbody fusion; CSA, increase of dural sac cross-sectional area (DCSA); MRI, magnetic resonance imaging.
Analysis of variance and chi-square test were used for statistical analysis. All the above group comparisons were confirmed by a *post hoc* test.
U vs. S, *post hoc* test between ULBD-UBE and STL; S vs. M, *post hoc* test between STL and MIS-TLIF; U vs. M, *post hoc* test between ULBD-UBE and MIS-TLIF.
*$p < 0.05$, statistically significant differences.


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**Table 4.** Radiologic parameters (L4–5)

| Variable | ULBD-UBE (U: n = 26) | STL (S: n = 19) | MIS-TLIF (M: n = 23) | p-value | U vs. S | S vs. M | U vs. M |
|---|---|---|---|---|---|---|---|
| Lumbar lordosis | | | | | | | |
| Preoperative (°) | 46.3 ± 8.7 | 41.8 ± 12.4 | 38.0 ± 12.1 | 0.036* | 0.538 | 0.810 | 0.031* |
| 1 Month (°) | 40.4 ± 10.4 | 39.3 ± 11.3 | 33.7 ± 12.5 | 0.108 | | | |
| Last (°) | 47.9 ± 8.5 | 42.4 ± 9.2 | 41.3 ± 11.1 | 0.056 | | | |
| Cobb angle L4S1 | | | | | | | |
| Preoperative (°) | 33.2 ± 6.4 | 31.1 ± 8.2 | 27.3 ± 8.6 | 0.033* | 1.000 | 0.353 | 0.029* |
| 1 Month (°) | 32.3 ± 6.4 | 30.1 ± 10.4 | 27.0 ± 8.2 | 0.092 | | | |
| Last (°) | 34.5 ± 5.9 | 31.5 ± 9.3 | 29.0 ± 7.2 | 0.049* | 0.606 | 0.829 | 0.044* |
| Cobb angle T12S1 | | | | | | | |
| Preoperative (°) | 45.5 ± 7.8 | 39.7 ± 13.2 | 36.5 ± 12.3 | 0.025* | 0.287 | 1.000 | 0.023* |
| 1 Month (°) | 39.2 ± 9.3 | 36.7 ± 11.8 | 32.3 ± 12.5 | 0.106 | | | |
| Last (°) | 46.3 ± 8.7 | 39.4 ± 10.3 | 39.8 ± 11.4 | 0.044* | 0.091 | 1.000 | 0.099 |
| Dynamic angulation | | | | | | | |
| Preoperative (°) | 2.3 ± 1.8 | 3.6 ± 1.8 | 3.2 ± 1.9 | 0.054 | | | |
| 1 Month (°) | 8.7 ± 4.0 | 6.3 ± 3.0 | 2.9 ± 3.0 | < 0.001* | 0.065 | 0.005* | < 0.001* |
| Last (°) | 4.5 ± 3.2 | 6.9 ± 3.5 | 0.9 ± 1.3 | < 0.001* | 0.025* | < 0.001* | < 0.001* |
| Dynamic slip | | | | | | | |
| Preoperative (mm) | 0.5 ± 0.5 | 0.5 ± 0.6 | 0.3 ± 0.4 | 0.381 | | | |
| 1 Month (mm) | 0.6 ± 0.5 | 0.7 ± 0.6 | -0.1 ± 0.4 | < 0.001* | 1.000 | < 0.001* | < 0.001* |
| Last (mm) | 0.8 ± 0.7 | 0.7 ± 0.9 | -0.0 ± 0.2 | < 0.001* | 1.000 | 0.002* | < 0.001* |
| ΔLumbar lordosis | | | | | | | |
| 1 Month–preoperative (°) | -5.9 ± 6.0 | -2.5 ± 10.0 | -4.2 ± 11.3 | 0.481 | | | |
| Last–preoperative (°) | -1.1 ± 12.1 | 0.6 ± 6.6 | 3.3 ± 6.2 | 0.248 | | | |
| ΔCobb angle L4S1 | | | | | | | |
| 1 Month–preoperative (°) | -0.9 ± 5.7 | -1.0 ± 7.8 | -0.3 ± 7.8 | 0.934 | | | |
| Last–preoperative (°) | 0.5 ± 6.8 | 0.5 ± 5.8 | 1.7 ± 4.8 | 0.728 | | | |
| ΔCobb angle T12S1 | | | | | | | |
| 1 Month–preoperative (°) | -4.3 ± 10.7 | -2.9 ± 10.7 | -4.2 ± 10.9 | 0.900 | | | |
| Last–preoperative (°) | 2.6 ± 15.9 | -0.3 ± 7.0 | 3.3 ± 6.5 | 0.549 | | | |
| ΔDynamic angulation | | | | | | | |
| 1 Month–preoperative (°) | -1.8 ± 1.8 | -3.0 ± 1.7 | -3.2 ± 1.9 | 0.012* | 0.082 | 1.000 | 0.016* |
| Last–preoperative (°) | 2.5 ± 4.3 | 1.3 ± 4.3 | -2.2 ± 2.2 | < 0.001* | 0.897 | 0.009* | < 0.001* |
| ΔDynamic slip | | | | | | | |
| 1 Month–preoperative (°) | 0.1 ± 0.6 | 0.1 ± 0.7 | -0.4 ± 0.6 | 0.006* | 1.000 | 0.017* | 0.014* |
| Last–preoperative (°) | 0.2 ± 0.6 | 0.2 ± 0.9 | -0.4 ± 0.5 | 0.007* | 1.000 | 0.036* | 0.011* |
| Instability | | | | 0.082 | | | |
| Yes | 1 (3.8) | 3 (15.8) | 0 (0.0) | | | | |
| No | 25 (96.2) | 16 (84.2) | 23 (100.0) | | | | |
| CSA (Postop DCSA/preop DCSA × 100) (%) | 228.0 ± 51.1 | 264.4 ± 85.6 | 304.7 ± 112.6 | 0.011* | 1.000 | 0.931 | 0.009* |

Values are presented as mean ± standard deviation or number (%).
ULBD-UBE, unilateral laminectomy bilateral decompression with unilateral biportal endoscopy; STL, conventional subtotal laminectomy; MIS-TLIF, minimally invasive transforaminal lumbar interbody fusion; CSA, increase of dural sac cross-sectional area (DCSA).
Analysis of variance and chi-square test were used for statistical analysis. All the above group comparisons were confirmed by a *post hoc* test.
U vs. S, *post hoc* test between ULBD-UBE and STL; S vs. M, *post hoc* test between STL and MIS-TLIF; U vs. M, *post hoc* test between ULBD-UBE and MIS-TLIF.
*$p < 0.05$, statistically significant differences.

with fusion is a widely used approach.[33]

The debate over choosing decompression alone versus decompression with fusion for lumbar spinal stenosis is ongoing.[4-10] Decompression alone is less invasive and has lower complication rates; however, its efficacy may be lower than that of decompression with fusion.[8,9] Postoperative instability could develop after decompression.[7,12,22] Fusion surgeries, while often effective and associated with lower reoperation rates, come with higher complication rates, reduced spinal mobility, and potential degeneration of adjacent segments at the fusion site.[33] A meta-analysis by Yang et al.[4] found that decompression alone resulted in shorter operative times, less blood loss, and lower overall VAS scores. Försth et al.[5] reported no significant differences in patient satisfaction or subsequent lumbar surgeries between decompression and decompression with fusion groups after 2 years. Recently, MIS-TLIF has gained popularity over conventional posterior lumbar interbody fusion owing to less damage to paraspinal muscles, reduced bleeding during surgery, and faster recovery times.[34-37]

Conventional decompression has a success rate of 64%[38]; however, can cause substantial damage to posterior bony and muscular structures, paraspinal muscle weakness, atrophy that could lead to scar formation,[39-41] and instability. This has prompted a shift towards minimally invasive surgery.[42] Minimally invasive unilateral laminectomy for bilateral decompression has a reported success rate of 67%–81%[39] and offers significant improvements in ODIs and VAS scores, along with shorter recovery times and reduced opioid use compared to conventional methods.[43]

Advancements in technology have expanded the use of endoscopic spinal surgery.[14-16,36,37,44-48] Unilateral biportal endoscopic surgery has become more common because of its familiarity among surgeons and its lower learning curve compared to that of the uniportal approach.[49] A study comparing ULBD-UBE and minimally invasive decompression reported that both surgeries preserved spinal structure without causing instability in the short term, with ULBD-UBE offering advantages such as less postoperative back pain and fewer hospital days, enabling early ambulation.[19] A meta-analysis of endoscopic spinal decompression reported less back pain, fewer hospitalization days, and reduced blood loss in the endoscopic surgery group.[44] However, some studies suggest that extensive decompression in endoscopic surgery could lead to instability, and caution should be taken regarding the potential for postoperative instability.[22]

In our study, we compared MIS-TLIF to decompression surgery. MIS-TLIF is known to be as effective as open fusion for spinal stenosis, but with significantly less muscle damage.[35-37,48] We believed that by reducing muscle and structural damage, the bias between the outcomes of MIS-TLIF and decompression alone could be minimized. When comparing ULBD-UBE, STL, and MIS-TLIF, we found no significant differences in age, sex, ASA physical status classification, or clinical outcomes among the groups. However, consistent with other studies,[20,50] the ULBD-UBE group had shorter length of hospital stays, shorter operative times, and less blood loss compared to the STL and MIS-TLIF groups. Preoperatively, the ULBD-UBE and MIS-TLIF groups exhibited more severe NIC symptoms than the STL group. Although the p-value is not statistically significant, this bias may be due to the small sample size in retrospective study. But postoperatively, they showed greater improvements, although not significantly different. The STL and MIS-TLIF groups reported higher VAS scores and lower ODI improvement 1 month postoperatively compared to the ULBD-UBE group. This may be due to less tissue damage in the ULBD-UBE group compared to the STL and MIS-TLIF groups. However, there were no significant differences in clinical outcomes. The mean follow-up periods were $14.1 \pm 7.2$, $11.1 \pm 8.1$, and $12.4 \pm 3.1$ months, respectively, which is approximately one year. We believe this is sufficient time to provide valuable insight into the short-term effectiveness of the surgery.

Radiologically, compared to other surgeries, the MIS-TLIF group showed greater postoperative stability with significant differences because DA and DS at 1 month postoperatively and at the last follow-up showed little difference compared to preoperative values. These differences were also significant when comparing preoperative values to last follow-up measurements, indicating that the MIS-TLIF group achieved greater reductions in instability parameters. Similar trends were observed in patients who underwent surgery at the L4–5 level, with the MIS-TLIF group showing superior postoperative stability. The incidence of postoperative instability was lower in the ULBD-UBE group than that in the STL group and similar to that in the MIS-TLIF group, with a similar trend observed at the L4–5 level. There were no significant differences in LL, L4S1, or T12S1 among the 3 groups. However, LL decreased more in the MIS-TLIF at 1 month postoperatively compared to other surgeries. This finding may be due to the longer duration of postoperative back pain in MIS-TLIF. By last follow-up, LL recovered more in the MIS-TLIF. When analyzing patients who underwent surgery at the L4–5 level, LL, L4S1, and T12S1 preoperatively and at the last follow-up were significantly different owing to preoperative individual differences. Cobb angles of LL, L4S1, and T12S1 pre-

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operatively, 1 month postoperatively, and at the last follow-up visit were not significantly different. The CSA increased significantly in the MIS-TLIF group compared to that in the other groups, owing to wider decompression with facetectomy, and this trend was also observed at the L4/5 level. Adequate widening of the DCSA appears to correlate with improved clinical symptoms.[51]

This study has some limitations. We could not use the initially planned data from surgery for tubular retractor because the rapid shift in preference among MIS surgeons in South Korea from tubular retractors to endoscopic surgery limited the recruitment of enough patients for tubular decompression. As a result, we had to revise the study plan. In MIS-TLIF, 3-dimensonal-printed titanium cage and polyetheretherketone cage were used which were filled with mixture of demineralized bone matrix and small autologous local bone, and there is a limitation that all patients did not used the same type of cage. Additionally, this was a retrospective study, and selection bias may have occurred based on surgeon preference. The study also had a short-term follow-up period with a small sample size. Future prospective studies with larger sample sizes and longer follow-up period are required to validate our findings.

## CONCLUSION

Our findings suggest that compared with other procedures, UBE is a safe and effective surgical approach for central lumbar stenosis. While MIS-TLIF demonstrated higher postoperative stability, ULBD-UBE did not cause instability and effectively preserved LL. Therefore, UBE represents a promising treatment option for central lumbar stenosis.

## NOTES

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