Original Article
Clinics in Orthopedic Surgery 2023;15:793-799 • https://doi.org/10.4055/cios22331

A Beginner's Perspective on Biportal Endoscopic Spine Surgery in Single-Level Lumbar Decompression: A Comparative Study with a Microscopic Surgery

Jeongik Lee, MD, Dae-Woong Ham, MD*, Kwang-Sup Song, MD*

Department of Orthopaedic Surgery, Chung-Ang University Gwangmyeong Hospital, Chung-Ang University College of Medicine, Gwangmyeong,
**Department of Orthopaedic Surgery, Chung-Ang University Hospital, Chung-Ang University College of Medicine, Seoul, Korea*

Background: The application of biportal endoscopic spinal surgery (BESS) in spine surgery is increasing. However, the clinical results of related studies have been inconsistent. In this study, the perioperative and clinical outcomes of two techniques in single-level lumbar decompression surgery were compared using the perspective of a spine surgeon experienced in microscopic surgery but inexperienced in BESS.

Methods: This is a retrospective study performed with prospectively collected data. From April 2019, 50 consecutive patients who underwent a single-level lumbar decompression surgery with BESS were evaluated. Additionally, the data of 150 consecutive patients who underwent the same microscopic surgery before April 2019 were collected. We performed 1 : 1 ratio propensity score matching for these two groups to adjust for baseline variables. The postoperative patient-reported outcome measures included the Oswestry Disability Index (ODI) and numeric rating scale for the back and leg preoperatively and at 6 months after surgery. The laboratory data (C-reactive protein [CRP, mg/L] and hemoglobin [Hb, g/dL]) were measured preoperatively and 3 times (1, 2, and 3 or 4 days) postoperatively. In these periods, the peak and lowest CRP and Hb concentrations were evaluated. The perioperative outcomes, operation time (from skin incision to dressing), length of hospital stay, drainage (for 24 hours after surgery), and surgery-related complications were also evaluated.

Results: Forty-seven patients (27 men and 20 women) were included in each group. The postoperative 6-month ODI was significantly lower in the BESS group than in the microscope group (6.90 ± 5.98 vs. 11.54 ± 9.70). The peak CRP concentration (16.63 ± 19.41 vs. 42.40 ± 37.73, $p < 0.001$) and CRP increment (peak CRP minus preoperative CRP, 14.69 ± 19.47 vs. 40.71 ± 37.32, $p < 0.001$) were significantly higher in the microscope group. Operation time (83.72 ± 35.71 vs. 70.27 ± 23.24, $p = 0.047$) was significantly longer in the BESS group. Surgery-related complications were found in 6 and 3 cases in the BESS group (3 revisions, 2 dural tears, and 1 conversion to open surgery) and microscope group (2 revisions and 1 hematoma), respectively.

Conclusions: BESS as a new technique resulted in satisfying short-term outcomes. It was a well-tolerated option for surgical treatment of single-level lumbar degenerative disease. The relatively high incidence of recurrence at the index level and incidental dural tears should be considered for surgeons new to BESS; however, these were manageable complications.

Keywords: *Minimally invasive surgical procedures, Endoscopy, Decompression, Lumbosacral region, Microscopy*

Received October 13, 2022; Revised January 29, 2023; Accepted March 1, 2023
Correspondence to: Kwang-Sup Song, MD
Department of Orthopaedic Surgery, Chung-Ang University Hospital, Chung- Ang University College of Medicine, 102 Heukseok-ro, Dongjak-gu, Seoul 06973, Korea
Tel: +82-2-6299-1589, Fax: +82-2-822-2017, E-mail: ksong70@cau.ac.kr

Enhanced recovery after surgery has been attracting attention in all surgical fields to promote an early discharge, minimize disruptions to patient homeostasis due to the operation, and improve patient experiences.[1-4] Therefore, the demand for the application of minimally invasive surgery is increasing.[5-7] In spine surgery, endoscopic surgeries meet this trend; it is predicted that the demand from patients and surgeons who promote its application will increase.

Endoscopic spine surgery has been rapidly improving in the last 2 decades. Recently, the application of techniques using 2 separate portals (1 viewing channel and 1 working channel) is increasing. The so-called biportal endoscopic spinal surgery (BESS) has several advantages when compared with the uniportal endoscopic technique. First, handling of surgical instruments is easier using 2 separate portals. Second, there is no need for additional equipment by using an endoscopy system used for other joints or laparoscopic surgeries.[5-9]

As endoscopic spine surgery becomes more popular, the number of related studies has increased. Additionally, comparative studies with microscopic spine surgery, which has already been widely performed, have been reported. However, the results of the clinical effects, complications, and learning curves of surgery reported in each study are inconsistent. In addition, most studies were conducted by experienced surgeons in endoscopic spine surgery; therefore, few studies have considered the perspective of surgeons new to the technique.

In this study, we compared the perioperative and clinical outcomes of BESS with those of microscopic surgery in single-level lumbar decompression surgery performed by an experienced microscopic spinal surgeon who was inexperienced in BESS. Based on our findings, we would like to share our experience with spinal surgeons who are yet to use BESS.

METHODS

This is a retrospective study performed using prospectively collected data. Ethical approval and waiver of consent were obtained from the Institutional Review Board (No. 2305-001-19468). From April 2019 to October 2020, 50 consecutive patients who underwent single-level lumbar decompression surgery with BESS were evaluated. Additionally, we collected data of 150 consecutive patients who underwent the same surgery using microscopy from January 2016 to April 2019. We performed 1 : 1 ratio propensity score matching for these two groups to adjust for baseline variables. Forty-seven patients (27 men and 20 women) were included in each group (Table 1). All the patients aged between 18 and 80 years with single-level lumbar degenerative disease and over 6 months of follow-up were enrolled. Patients with a history of previous lumbar surgery at the same level, suspicious infection, tumor, or psychological disorders were excluded.

Surgical Methods

All operations were performed by a surgeon (KSS) who had 17 years of experience in spinal surgery but was a beginner in BESS. Both BESS and microscopic surgeries were performed with the unilateral interlaminar approach. In cases where patients with stenosis required bilateral decompression, unilateral laminotomy and bilateral decompression was used.

The BESS technique in this study has been described previously.[6-8,10,11] First, under fluoroscopic guidance, the interlaminar space of the index level was checked. The caudal portal was positioned at the lower margin of interlaminar space, and the cranial portal was created at 1 to 2 cm proximal to the caudal portal. The 2 portals were located 0.5 to 1 cm laterally from the midline. When the surgery was performed on the patient's left side, the caudal portal was used as a working portal (for handling instru-

Table 1. Propensity Score Matching with Age, Sex, and Preoperative ODI

Variable	Unmatched group		*p*-value	Standardized difference	Propensity-matched group		*p*-value	Standardized difference
	BESS	Microscope			BESS	Microscope		
Number of cases	50	150	-	-	47	47	-	-
Age (yr)	61.6 ± 12.5	60.9 ± 15.9	0.771	–0.046	60.1 ± 15.8	60.8 ± 12.4	0.823	–0.049
Preoperative ODI	21.74 ± 8.28	23.75 ± 8.53	0.144	0.249	49.60 ± 17.41	49.46 ± 17.72	0.969	0
Sex (male : female)	30 : 20	81 : 69	0.438	0.142	27 : 20	27 : 20	> 0.990	0

Values are presented as as mean ± standard deviation.
ODI: Oswestry Disability Index, BESS: biportal endoscopic spinal surgery.

ments) and the cranial portal was used as a viewing portal. In the right-side surgery, the 2 portals were conversely used. The location of the working and viewing portals was changed intraoperatively based on the target location. After incising the 2 portals, paraspinal muscles were detached from the lamina using a narrow Cobb elevator to obtain an adequate working space. Following the creation of the working space, the surgical technique replicated the microscopic surgery except using natural irrigating systems, bipolar radiofrequency cautery, and a shaver.

The microscopic surgery procedure used in this study is similar to what has been described in previous studies.[6-8,11] We made a 3-cm midline incision after fluoroscopic confirmation of the surgical level. After a skin incision, the multifidus muscle was dissected unilaterally from the spinous process and lamina using a Cobb elevator and retracted by a retractor. After detachment of paraspinal muscles, ipsilateral laminotomy was performed using a burr and Kerrison punches, followed by flavectomy using a microscope.

Outcome Measurements

All preoperative and postoperative patient-reported outcome measures data were collected prospectively. These included the Oswestry Disability Index (ODI; highest score = 45, expressed as a percentage), numeric rating scale (NRS, 0 = no pain, 10 = worst pain imaginable) for the back and leg (or gluteal) preoperatively and at 6 months after surgery. Laboratory data (C-reactive protein [CRP], mg/L and hemoglobin [Hb], g/dL) were measured preoperatively and 3 times (1, 2, 3 or 4 days) postoperatively. In these periods, the peak and lowest concentrations of CRP and Hb, respectively, were evaluated. The perioperative outcomes, operation time (from skin incision to dressing), length of hospital stay (LOS), drainage (for 24 hours after surgery), and surgery-related complications were evaluated. On complications, we defined recurrent disc herniation as "lesion recurrence with a pain-free period and confirmed new space occupying lesion" and incomplete decompression or incomplete disc removal as "having remnant symptoms with radiologically unreleased neural elements".

Statistical Analysis

All statistical analyses were performed using IBM SPSS ver. 25.0.0.2 (IBM Corp., Armonk, NY, USA) and "matchit" and "optmatch" R-packages (ver. 3.5.1; R Foundation, Vienna, Austria). The propensity score with a greedy matching algorithm and 1 : 1 ratio was calculated by binary logistic regression using R-packages with the covariates (age, sex, and preoperative ODI) specified in Table 1. The standardized difference was used as a balance diagnostic. A < 10% difference in the mean or prevalence of covariates between groups was considered acceptable. The differences between groups were examined using independent t-tests for continuous variables. Categorical variables were compared using the chi-square test. A p-value < 0.05 was considered statistically significant.

RESULTS

Demographic Data

Table 2 shows the demographic data of the enrolled patients in each group. There were no statistically significant differences in preoperative clinical scores between groups. Thirty-five and 40 patients underwent discectomy with decompression in the BESS and microscope groups each. In both groups, L4–5 was the most frequent level of surgery.

Outcomes Analysis

The evaluation of clinical scores at postoperative 6 months revealed that the ODI was significantly lower in the BESS group than in the microscope group (6.90 ± 5.98 vs. 11.54 ± 9.70). There were no significant differences in back and leg NRS between the groups. There was no difference in the preoperative CRP concentration of the two groups; however, the peak CRP concentration (16.63 ± 19.41 vs.

Table 2. Demographic Data of Patients

Variable	BESS group	Microscope group	*p*-value
Age (yr)	60.1 ± 15.8	60.8 ± 12.4	0.823
Sex (male : female)	27 : 20	27 : 20	> 0.990
Preoperative ODI (%)	49.60 ± 17.41	49.46 ± 17.72	0.969
Preoperative NRS (back)	4.23 ± 2.81	4.96 ± 2.90	0.223
Preoperative NRS (leg)	7.64 ± 1.74	7.79 ± 2.21	0.717
Discectomy	35	40	0.199
L1–2	0	2	-
L2–3	0	4	-
L3–4	6	8	-
L4–5	29	24	-
L5–S1	12	9	-

Values are presented as mean ± standard deviation.
BESS: biportal endoscopic spinal surgery, ODI: Oswestry Disability Index, NRS: numerical rating scale.

Table 3. Perioperative and Postoperative Clinical Outcomes

Variable	BESS group	Microscope group	p-value
ODI (%)			
Preoperative	49.60 ± 17.41	49.46 ± 17.72	0.969
Postoperative 6 months	6.90 ± 5.98	11.54 ± 9.70	0.006
Decrement	42.70 ± 17.69	37.92 ± 18.20	0.200
NRS (back)			
Preoperative	4.23 ± 2.81	4.96 ± 2.90	0.223
Postoperative 6 months	1.50 ± 1.11	2.04 ± 1.92	0.100
Decrement	2.77 ± 2.57	2.96 ± 3.18	0.749
NRS (leg)			
Preoperative	7.64 ± 1.74	7.79 ± 2.21	0.717
Postoperative 6 months	2.26 ± 1.75	1.85 ± 1.46	0.226
Decrement	5.38 ± 2.31	5.98 ± 2.32	0.215
CRP (mg/L)			
Preoperative	1.93 ± 2.89	1.68 ± 1.40	0.602
Peak	16.63 ± 19.41	42.40 ± 37.73	< 0.001
Increment	14.69 ± 19.47	40.71 ± 37.32	< 0.001
Hemoglobin (g/dL)			
Preoperative	14.21 ± 1.39	13.99 ± 1.87	0.533
Lowest	12.16 ± 1.46	11.89 ± 1.89	0.454
Operation time (min)	83.72 ± 35.71	70.27 ± 23.24	0.047
Postoperative drainage (mL)	61.30 ± 64.66	35.56 ± 42.65	0.095
Postoperative length of stay (day)	3.79 ± 2.53	4.43 ± 2.04	0.181

Values are presented as mean ± standard deviation.
BESS: biportal endoscopic spinal surgery, ODI: Oswestry Disability Index, NRS: numerical rating scale, CRP: C-reactive protein.

42.40 ± 37.73, $p < 0.001$) and CRP increment (peak CRP minus preoperative CRP, 14.69 ± 19.47 vs. 40.71 ± 37.32, $p < 0.001$) were significantly higher in the microscope group. There was no difference in the lowest preoperative and postoperative serum Hb concentrations between the groups. Total postoperative drainage and LOS were not different between groups; however, operation time was significantly longer in the BESS group (83.72 ± 35.71 vs. 70.27 ± 23.24, $p = 0.047$) (Table 3).

Surgery-Related Complications

The surgery-related complications were reported in 6 and 3 cases in the BESS group and microscope group, respectively. In the BESS group, there were 3 revision discectomy cases due to recurrent disc herniation. These were performed at 3, 4, and 10 weeks after surgery. In the microscope group, there was 1 case of revision decompression surgery (at postoperative 20 weeks) for a recurrent facet cyst and 1 case of revision discectomy (at postoperative 18 weeks). Intraoperative complications included 3 cases in the BESS group: 2 cases of an incidental dural tear and 1 case of conversion to open surgery because of a vague surgical view caused by bleeding. In the microscope group, there was 1 case of symptomatic hematoma; its evacuation was performed on the fifth day after the primary surgery (Table 4).

Table 4. Surgery-Related Complications

Variable	BESS group (n = 47)	Microscope group (n = 47)
Revision surgery		
Decompression only (case)	0/12	1/7
Discectomy (case)	3/35	1/40
Intraoperative complications (case)	Dural tear: 2 Conversion to open surgery: 1	0
Symptomatic hematoma	0	1
Neurologic deficit	0	0
Wound problem	0	0
Total (case)	6	3

BESS: biportal endoscopic spinal surgery.

DISCUSSION

Previous studies on BESS have inconsistent clinical results, which may cause confusion for surgeons who wish to learn this technique. In this study, the perioperative and clinical outcomes of the two techniques in single-level lumbar decompression surgery performed by an experienced microscopic spinal surgeon who was a beginner in BESS were compared. Interestingly, the BESS group had a lower ODI at 6 months after surgery than the microscope group. However, the average operation time was longer and there was a higher frequency of early recurrences after discectomy.

The ODI at postoperative 6 months was significantly lower in the BESS group. This is consistent with some previous studies. However, most studies reported that there was no difference between groups. Furthermore, as the follow-up period after surgery increased, the final ODI scores of the two groups converged to similar values.[6,12-15] We did not evaluate back pain immediately after surgery in the current study; other studies have reported that patients showed significantly less postoperative back pain following BESS when compared with microscopic surgery.[14-17] The ODI is a tool used to evaluate functional outcomes related to low back pain; therefore, the time to reach the final ODI is expected to be faster in the BESS group because less back pain is predicted immediately after surgery with this technique.[18] Similarly, there was no difference in postoperative hospital stay between groups in the current study. Previous studies have reported shorter stays in the BESS group. This indicates that patients in the BESS group recover faster.[7,11-13]

In this study, the concentration of peak CRP and CRP increment were significantly lower in the BESS group. This is consistent with the results of previous studies.[13,17,19] CRP is an acute inflammatory serum marker; however, it is not a specific marker of tissue damage caused by surgery. Nonetheless, the lower rise in patients who underwent BESS indicates lower tissue destruction during the procedure. Moreover, the serially measured trend data indirectly support this. In other studies, additional inflammatory markers, such as interleukin-6, tumor necrosis factor alpha, creatine phosphokinase, malondialdehyde, myeloperoxidase, superoxide dismutase, and total antioxidant capacity, have been measured.[13,17] All studies reported reduced elevation of these factors in the endoscopic surgery group. Choi and Kim[19] have suggested the possibility that the irrigation water used during BESS surgery removes inflammatory debris, thereby lowering the rise of these markers.

The BESS was conducted for the initial 50 cases by a spinal surgeon who had no experience with this technique. Our study showed that the mean operation time for these patients was longer than microscopic surgery. Park et al.[20] have conducted a study on the learning curve of BESS. They found that a trainee with no experience with BESS reached an adequate performance level within 58 cases. One of the biggest problems facing surgeons new to BESS is the lack of access to an adequate surgical field of view due to bleeding control failure. In our study, there was 1 case of conversion to open surgery due to a failure of bleeding control during BESS. The failure to secure an adequate field of view prolonged the operation time. In other studies, published by experienced surgeons, the operation time of BESS was similar to or shorter than that of microscopic surgery.[6,7,11,12] This is thought to be because the time required for the surgical approach can be reduced if the surgeon becomes skillful at BESS and learns the best practice in securing the field of view.

More surgical complications occurred in the BESS group. In particular, the frequency of revision surgery for recurrence was higher; all revision surgeries were within 10 weeks of the index discectomy. The high incidence of early recurrence suggests that the primary discectomy was insufficient. Operating through a magnified view during BESS has the advantage of being able to see the surgical field in detail; however, the crowding of instruments could be 1 of the factors of incomplete discectomy, especially when retracting nerve roots for discectomy for a beginner. There were 2 cases (5.7%) of incidental durotomy in the BESS group in our series. A meta-analysis revealed there was no difference in the occurrence of durotomy between groups. Interestingly, there have been reports of an increase in dural tears in microscopic surgery.[13] Park et al.[21] have reported that the incidence of dural tears in patients who underwent BESS was 4.5% (29 out of 643 cases). Lin et al.[22] have reported an overall complication rate of BESS as 6.7% (range, 0%–13.8%) in a systemic review. Kim et al.[8] have described that the unsuccessful outcome of BESS was 10.29%; they cited hematoma, lesion recurrence, incomplete decompression, and dural tears as the causes. In addition, complications such as instability, ascites, and infection have been suggested as the causes of poor surgical outcomes in patients.

This study has several limitations. First, there was a selection bias associated with the retrospective design; however, we believe that the propensity score matching analysis and prospectively collected data minimized the bias. Single-surgeon data, small population, and short-term follow-up period are weaknesses of this study. In addition, the patients' diagnoses were diverse, including ligamentum flavum hypertrophy, facet hypertrophy, facet cyst, osteophyte, and spondylolisthesis, and most patients had a combination of these diagnoses, making it difficult to classify by diagnosis. Due to these factors, it is difficult to have a strong validity to compare the results of the 2 surgeries. However, the purpose of this study was to share the clinical results while a surgeon was learning the BESS technique for the first time. Therefore, it is meaningful despite these limitations.

The evolution of arthroscopy has dramatically changed the landscape of orthopedic surgery. Arthroscopic procedures are now among the most commonly performed elective interventions worldwide. Likewise, spinal surgery using an endoscope is likely to have a bigger market in the future; some spine surgeons are already performing fusion surgery using an endoscope.[22-30] Spinal surgeons who are not yet trained in endoscopic surgery need to prepare in advance, so they do not fall behind the trend.

In summary, performing BESS as a beginner resulted in satisfying short-term outcomes. It was a well-tolerated option for the surgical treatment of single-level lumbar degenerative disease. The relatively high incidence of recurrence at the index level and incidental dural tears should be considered when learning BESS; however, these appeared to be manageable complications.

CONFLICT OF INTEREST

No potential conflict of interest relevant to this article was reported.

ORCID

Jeongik Lee https://orcid.org/0000-0002-3071-259X
Dae-Woong Ham https://orcid.org/0000-0003-4278-2701
Kwang-Sup Song https://orcid.org/0000-0002-9238-8908

REFERENCES

1. Debono B, Wainwright TW, Wang MY, et al. Consensus statement for perioperative care in lumbar spinal fusion: Enhanced Recovery After Surgery (ERAS®) Society recommendations. Spine J. 2021;21(5):729-52.
2. Elsarrag M, Soldozy S, Patel P, et al. Enhanced recovery after spine surgery: a systematic review. Neurosurg Focus. 2019;46(4):E3.
3. Dietz N, Sharma M, Adams S, et al. Enhanced recovery after surgery (ERAS) for spine surgery: a systematic review. World Neurosurg. 2019;130:415-26.
4. Ljungqvist O, Scott M, Fearon KC. Enhanced recovery after surgery: a review. JAMA Surg. 2017;152(3):292-8.
5. Simpson AK, Lightsey HM 4th, Xiong GX, Crawford AM, Minamide A, Schoenfeld AJ. Spinal endoscopy: evidence, techniques, global trends, and future projections. Spine J. 2022;22(1):64-74.
6. Park SM, Park J, Jang HS, et al. Biportal endoscopic versus microscopic lumbar decompressive laminectomy in patients with spinal stenosis: a randomized controlled trial. Spine J. 2020;20(2):156-65.
7. Min WK, Kim JE, Choi DJ, Park EJ, Heo J. Clinical and radiological outcomes between biportal endoscopic decompression and microscopic decompression in lumbar spinal stenosis. J Orthop Sci. 2020;25(3):371-8.
8. Kim W, Kim SK, Kang SS, Park HJ, Han S, Lee SC. Pooled analysis of unsuccessful percutaneous biportal endoscopic surgery outcomes from a multi-institutional retrospective cohort of 797 cases. Acta Neurochir (Wien). 2020;162(2):279-87.
9. Yoon JW, Wang MY. The evolution of minimally invasive spine surgery: JNSPG 75th anniversary invited review article. J Neurosurg Spine. 2019;30(2):149-58.
10. Kim JE, Choi DJ, Park EJ, et al. Biportal endoscopic spinal surgery for lumbar spinal stenosis. Asian Spine J. 2019;13(2):334-42.
11. Kang T, Park SY, Kang CH, Lee SH, Park JH, Suh SW. Is biportal technique/endoscopic spinal surgery satisfactory for lumbar spinal stenosis patients?: a prospective randomized comparative study. Medicine (Baltimore). 2019;98(18):e15451.
12. Pranata R, Lim MA, Vania R, July J. Biportal endoscopic spinal surgery versus microscopic decompression for lumbar spinal stenosis: a systematic review and meta-analysis. World Neurosurg. 2020;138:e450-8.
13. Barber SM, Nakhla J, Konakondla S, et al. Outcomes of endoscopic discectomy compared with open microdiscectomy and tubular microdiscectomy for lumbar disc herniations: a meta-analysis. J Neurosurg Spine. 2019;31(6):802-15.
14. Heo DH, Lee DC, Park CK. Comparative analysis of three types of minimally invasive decompressive surgery for lumbar central stenosis: biportal endoscopy, uniportal endoscopy, and microsurgery. Neurosurg Focus. 2019;46(5):E9.
15. Kim SK, Kang SS, Hong YH, Park SW, Lee SC. Clinical comparison of unilateral biportal endoscopic technique versus open microdiscectomy for single-level lumbar discectomy: a multicenter, retrospective analysis. J Orthop Surg Res. 2018;13(1):22.
16. Heo DH, Quillo-Olvera J, Park CK. Can percutaneous biportal endoscopic surgery achieve enough canal decompression for degenerative lumbar stenosis?: prospective case-control study. World Neurosurg. 2018;120:e684-9.
17. Choi KC, Shim HK, Hwang JS, et al. Comparison of surgical invasiveness between microdiscectomy and 3 different endoscopic discectomy techniques for lumbar disc herniation. World Neurosurg. 2018;116:e750-8.
18. Park SM, Kim GU, Kim HJ, et al. Is the use of a unilateral biportal endoscopic approach associated with rapid recovery after lumbar decompressive laminectomy?: a preliminary analysis of a prospective randomized controlled trial. World Neurosurg. 2019;128:e709-18.

19. Choi DJ, Kim JE. Efficacy of biportal endoscopic spine surgery for lumbar spinal stenosis. Clin Orthop Surg. 2019; 11(1):82-8.

20. Park SM, Kim HJ, Kim GU, et al. Learning curve for lumbar decompressive laminectomy in biportal endoscopic spinal surgery using the cumulative summation test for learning curve. World Neurosurg. 2019;122:e1007-13.

21. Park HJ, Kim SK, Lee SC, Kim W, Han S, Kang SS. Dural tears in percutaneous biportal endoscopic spine surgery: anatomical location and management. World Neurosurg. 2020;136:e578-85.

22. Lin GX, Huang P, Kotheeranurak V, et al. A systematic review of unilateral biportal endoscopic spinal surgery: preliminary clinical results and complications. World Neurosurg. 2019;125:425-32.

23. Heo DH, Hong YH, Lee DC, Chung HJ, Park CK. Technique of biportal endoscopic transforaminal lumbar interbody fusion. Neurospine. 2020;17(Suppl 1):S129-37.

24. Park MK, Park SA, Son SK, Park WW, Choi SH. Clinical and radiological outcomes of unilateral biportal endoscopic lumbar interbody fusion (ULIF) compared with conventional posterior lumbar interbody fusion (PLIF): 1-year follow-up. Neurosurg Rev. 2019;42(3):753-61.

25. Heo DH, Park CK. Clinical results of percutaneous biportal endoscopic lumbar interbody fusion with application of enhanced recovery after surgery. Neurosurg Focus. 2019;46(4):E18.

26. Kim JE, Choi DJ. Biportal endoscopic transforaminal lumbar interbody fusion with arthroscopy. Clin Orthop Surg. 2018;10(2):248-52.

27. Junjie L, Jiheng Y, Jun L, haixiong L, Haifeng Y. Comparison of unilateral biportal endoscopy decompression and microscopic decompression effectiveness in lumbar spinal stenosis treatment: a systematic review and meta-analysis. Asian Spine J. 2023;17(2):418-30.

28. Wu PH, Kim HS, An JW, et al. Prospective cohort study with a 2-year follow-up of clinical results, fusion rate, and muscle bulk for uniportal full endoscopic posterolateral transforaminal lumbar interbody fusion. Asian Spine J. 2023;17(2):373-81.

29. Choi JY, Park SM, Kim HJ, Yeom JS. Recent updates on minimally invasive spine surgery: techniques, technologies, and indications. Asian Spine J. 2022;16(6):1013-21.

30. Yeung YK, Park CW, Jun SG, Park JH, Tse AC. Comparative cohort study for expansion of lateral recess and facet joint injury after biportal endoscopic ipsilateral decompression and contralateral decompression. Asian Spine J. 2022; 16(4):560-6.