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Comparative Analysis of Biportal Endoscopic L5–S1 Foraminotomy Versus L5–S1 Fusion

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Objective: With advances in endoscopic surgery, L5–S1 foraminotomy has become a readily accessible surgical technique. However, symptom relief is often short-lived, and recurrence is common. As an alternative, biportal endoscopic fusion at L5–S1 can improve symptoms. However, it can be challenging and may lead to fusion-related complications. Therefore, we aimed to compare 2 procedures for L5–S1 foraminal stenosis.

Methods: A total of 37 patients diagnosed with L5–S1 foraminal stenosis were divided into 2 groups for this study. Group 1, comprising 18 patients, underwent L5–S1 foraminotomy via a paraspinal approach from 2017 to 2019. Group 2, comprising 19 patients, underwent biportal endoscopic L5–S1 fusion with the facet-sacrificing approach from January 2021 to August 2023. A comprehensive evaluation of both groups was conducted using various metrics, including image findings, operation time, hospital stay, visual analogue score (VAS) back, VAS leg, Oswestry Disability Index (ODI), and the MacNab criteria. Postsurgical complications were meticulously recorded. The statistical analysis was performed using the Wilcoxon signed-rank test, and differences between the 2 surgical approaches were assessed using the Mann-Whitney U-test.

Results: No statistically significant difference was found in VAS back or ODI improvement between the 2 groups. However, the foraminotomy group exhibited a statistically significant advantage in terms of operation time and hospital stay. Conversely, the fusion group demonstrated statistically significant improvements in VAS leg and McNab criteria in comparison to the foraminotomy group. The most prevalent complication observed in the foraminotomy group was early symptom recurrence, while the fusion group experienced complications related to screw-related issues and infections.

Conclusion: Leg symptoms recurred more frequently in the foraminotomy group. Biportal endoscopic facet-sacrificing transforaminal lumbar interbody fusion surgery has been demonstrated to be a valuable technique for L5–S1 fusion with lower recurrence of leg symptoms; however, it is associated with complications specific to fusion.

Keywords: L5–S1 fusion, Foraminotomy, Biportal endoscopic surgery

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INTRODUCTION

The L5–S1 segment, located at the lumbosacral transition, presents distinct anatomical and biomechanical challenges. Because of its load-bearing function and steep inclination, it is subject to significant mechanical stress, making it susceptible to degeneration, herniation, and injury [1]. Instability can easily arise if the facet is severely compromised during a foraminotomy, leading to subsidence of the L5–S1 disc space. Consequently, it is hypothesized that decompression procedures may be less effective at L5–S1 compared to other lumbar segments. Short-term outcomes of L5–S1 foraminotomy using endoscopy have shown favorable results [2], but the recurrence of symptoms after simple decompression remains a concern. For patients diagnosed with foraminal stenosis at L5–S1, 2 surgical options are available: a simple foraminotomy or L5–S1 fusion. With advancements in endoscopic surgical techniques, biportal endoscopic L5–S1 foraminotomy has now become a widely accessible procedure. Alternatively, biportal endoscopic fusion at the L5–S1 level can also be considered. Despite these advancements, however, the lack of direct comparative studies between L5–S1 foraminotomy and L5–S1 fusion currently prevents a comprehensive understanding of the challenges associated with each procedure. Therefore, the objective of this study is to compare the efficacy of these 2 surgical approaches.

MATERIALS AND METHODS

This study was approved by the Institutional Review Board (IRB) of Wonkwang University Sanbon Hospital (IRB No. WMCSB 202504-31-250403).

The study comprised 37 patients who underwent biportal endoscopic surgery for L5–S1 disc herniation or foraminal stenosis between 2017 and 2023. The patients were divided into 2 groups: group A, comprising 18 patients who underwent biportal endoscopic foraminotomy between 2017 and 2022, and group B, comprising 19 patients who underwent biportal endoscopic fusion between 2021 and 2023. The study then compared the 2 groups using various metrics, including radiologic and magnetic resonance imaging (MRI) findings, operation time, hospital stay, and clinical outcomes (Table 1).

The division of patients into 2 groups was naturally determined by time period, reflecting the surgeons' evolving preferences. Biportal endoscopic foraminotomy used to be the technique performed most frequently. More recently, however, biportal endoscopic fusion has become the procedure of choice. This shift was prompted by an increased rate of leg pain recurrence that was observed after biportal endoscopic foraminotomies. Both groups were evaluated using the VAS back, VAS leg, ODI, and MacNab criteria pre- and postoperatively, and instances of symptom recurrence and postoperative complications were recorded.

Radiologic measurements of L5–S1 foraminal stenosis included posterior disc height, lysis, and spondylolisthesis slip percentage. The spondylolisthesis slip percentage was calculated by dividing the posterior slip amount by the length of the superior endplate of the S1 vertebra. MRI findings related to foraminal stenosis were also analyzed. To further explore potential confounding factors, the presence or absence of spondylolysis and the results of the MacNab criteria were examined specifically in group A.

Operative time and hospital stay were compared between

Table 1. Demographic data of the 2 groups (N=37)

Variable	Group A (n = 18)	Group B (n = 19)	p-value
Sex			0.875
Male	9	10	
Female	9	9	
Age (yr)	69.17 ± 11.30	65.26 ± 11.42	0.465
Body mass index (kg/m^2)	24.62 ± 3.23	24.04 ± 3.75	0.553
Bone mineral density (T score)	-1.18 ± 0.6	-1.14 ± 0.5	0.653
Before operation			
VAS back score	2.40 ± 2.50	4.16 ± 3.06	0.076
VAS leg score	7.20 ± 1.52	7.89 ± 1.45	0.176
ODI (%)	28.33 ± 5.33	30.68 ± 6.93	0.475
Follow-up (mo)	55.14 ± 18.09	22.68 ± 10.65	< 0.001*

Values are presented as number or mean±standard deviation.
Group A, patients who underwent biportal endoscopic foraminotomy; group B, patients who underwent biportal endoscopic fusion; VAS, visual analogue scale; ODI, Oswestry Disability Index.
*p<0.05, statistically significant differences (Mann-Whitney U-test).

the 2 groups. The collected data was analyzed using IBM SPSS Statistics ver. 23.0 (IBM Co., USA), while the Wilcoxon signed-ranked test was used to verify the effects of each surgical approach. The average follow-up period was 4 years and 7 months for group A and 1 year and 10 months for group B.

1. Surgical Techniques

1) Biportal endoscopic foraminotomy

The patient was positioned in the prone position on a spinal frame, and a general anesthetic was administered. Routine draping was then performed, and 2 portals were created under C-arm guidance, positioned 2 cm laterally to the L5–S1 facet area. Typically, the surgeon used the left portal for viewing and the right portal for instrumentation. Each portal required an approximately 1-cm skin incision. The fascia and deep muscles were retracted with Mosquito forceps to create sufficient space for both the viewing and instrument portals.

A metal rod was then inserted through the viewing portal, and a cannula was then advanced over the rod, directed toward the lateral aspect of the superior facet of S1. Upon identifying the S1 facet, the lateral portion or tip of the facet was excised using an osteotome or burr to expose the L5 nerve root. This approach exposed the L5 root on the deep side. The approach was aimed at preserving as much of the superior facet as possible. Decompression of the L5 root was confirmed from the medial side of the pedicle to the junction of the L5 transverse process and the ala (Figure 1). A discectomy was performed if herniation was present.

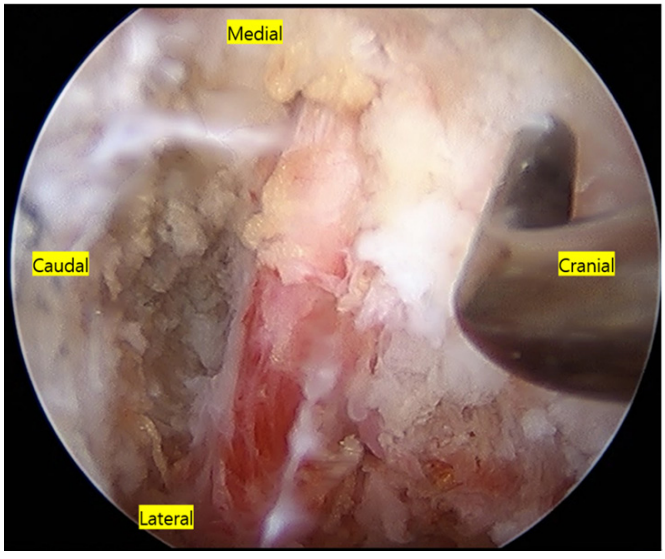

Figure 1. Intraoperative photograph illustrating the decompression of the L5 root from the pedicle to the ala, which was compressed within the L5–S1 foraminal space.

The surgery was concluded after checking for bleeding, followed by meticulous closure of the surgical area. A small, soft Hemovac drain was placed, and the 2 portals were closed using subcutaneous sutures. Finally, the skin was closed with nylon sutures.

2) Biportal endoscopic L5-S1 fusion

The patient was positioned prone on a spine frame, and two 1.5-cm incisions were made over the facet joints. The portals were typically positioned over the facet joints, with the left portal used for visualization and the right portal for instrumentation. Through the viewing portal, the L5–S1 facet was examined, and the inferior articular process of the L5 vertebra was removed with an osteotome to expose the superior facet of S1. The osteotome was also used to obtain bone for grafting into the cage. If the osteotomy proved challenging, any remaining bone was carefully excised using a burr.

Following the exposure of the superior facet, the osteotome was used to remove it, taking care to avoid damaging the L5 root beneath. Additional burring was performed to achieve further exposure. Once the disk was visible, the annular portion was removed to expose the interior area, which was then curetted to prepare for cage insertion.

After the endplates were adequately prepared, a third portal was created at an optimal angle and direction to provide external access to the disc space. The primary purpose of this third portal was to facilitate the insertion of a large cage, as trying to insert it through the 2 existing portals proved challenging.

An L5 nerve root protection guide was used during the procedure to ensure safe cage insertion without injuring the root. The cage was then rotated into its intended anterior center position and carefully impacted within the disc space. If further decompression was required, the procedure could be extended to achieve the desired decompression. Finally, posterior pedicle screws were inserted under C-arm guidance, and the wound was closed and dressed.

RESULTS

Radiological measurements of changes in posterior disc height differed between groups A and B. Group B patients had increased posterior disc height after the operation because of the inserted cage. Although a trend toward reduced spondylolisthesis was observed in group B, the difference was not statistically significant (Table 2).

Statistical analysis showed no statistically significant dif-

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Table 2. Disc height and spondylolisthesis in groups A (n=18) and B (n=19)

Variable	Group	Preoperative	Postoperative	Z	p-value	Difference	Z	p-value
Disc height	A	7.60±1.80	7.05±1.54	-1.40	0.162	-0.55±1.43	-4.50	<0.001
	B	6.37±1.93	9.27±1.68	-3.67	<0.001	2.90±1.99		
Spondylolisthesis	A	3.77±6.45	5.33±9.05	-2.02	0.043	1.56±3.39	-2.56	0.011
	B	0.49±2.13	0.44±1.90	-1.00	0.317	-0.05±.23		

Values are presented as mean±standard deviation.
Group A, patients who underwent biportal endoscopic foraminotomy; group B, patients who underwent biportal endoscopic fusion.

ferences in preoperative VAS back, VAS leg, and ODI scores between group A (foraminotomy group) and group B (fusion group) (Table 1). After surgical intervention for L5–S1 foraminal stenosis, both groups exhibited a statistically significant reduction in postoperative back and leg pain, as well as improvement in the ODI when compared to their respective preoperative values. This finding suggests that both groups A and B procedures were effective in reducing patient-reported pain and disability, as measured by the VAS and ODI (Table 3).

Postoperative outcomes, including final VAS back score, final VAS leg pain score, ODI, MacNab criteria, operation time, hospital stay, and follow-up period, were compared between both groups (Table 4). While no statistically significant differences were found in the final VAS back score and final ODI, significant differences were observed in the final VAS leg pain, MacNab criteria, operation time, hospital stay, and follow-up period between the groups (Table 4). Both operation time and hospital stay were significantly shorter in group A (foraminotomy).

An additional confounding factor was identified: the discrepancy in MacNab criteria results between the non-lysis and lysis subgroups within group A. On the MacNab scale (excellent = 4, good = 3, fair = 2, and poor = 1), the nonlysis subgroup reported significantly higher satisfaction levels than the lysis subgroup (Table 5).

In the foraminotomy group, a high incidence of symptom recurrence was observed, with 2 patients requiring L5–S1 fusion. In the fusion group, complications included one case of nerve injury due to malposition of the S1 screw and one case of delayed infection.

1. Case 1: Foraminotomy

A 48-year-old female patient presented with back pain and radiating lateral pain in the right thigh. Physical examination did not reveal any specific findings, but the patient-reported difficulty walking. Preoperative clinical scores were VAS back 4, VAS leg 7, and ODI 28. Radiographs revealed spondylolytic spondylolisthesis at L5–S1. MRI showed compression of the L5

Table 3. Comparison of the variable before and after surgery (N=37)

Variable	Before	After	p-value
Group A (n=18)			
VAS back score	2.40±2.50	1.07±1.53	0.024*
VAS leg score	7.20±1.52	4.33±2.55	0.005*
ODI (%)	28.33±5.33	13.27±11.68	0.003*
Group B (n=19)			
VAS back score	4.16±3.06	2.32±2.63	0.012*
VAS leg score	7.89±1.45	1.84±1.39	<0.001*
ODI (%)	30.68±6.93	16.95±13.07	0.001*

Values are presented as mean±standard deviation.
Group A, patients who underwent biportal endoscopic foraminotomy; group B, patients who underwent biportal endoscopic fusion; VAS, visual analogue scale; ODI, Oswestry Disability Index.
*p<0.05, statistically significant differences (Wilcoxon signed-rank test).

Table 4. Comparison of the variables between Group A and Group B (N=37)

Variable	Group A (n=18)	Group B (n=19)	p
VAS back score	1.07±1.53	2.32±2.63	.124
VAS leg score	4.33±2.55	1.84±1.39	.013*
ODI (%)	13.27±11.68	16.95±13.07	.600
MacNab criteria†	2.39±1.15	3.16±1.02	.040
Operating time	97.50±21.02	150.53±44.03	<.001*
Hospital stay (day)	6.50±3.17	11.95±5.34	<.001*
Follow-up (mo)	55.14±18.09	22.68±10.65	<.001*

Values are presented as mean±standard deviation.
Group A, patients who underwent biportal endoscopic foraminotomy; group B, patients who underwent biportal endoscopic fusion; VAS, visual analogue scale; ODI, Oswestry Disability Index.
*p<0.05, statistically significant differences (Mann-Whitney U-test). †On a scale of excellent 4, good 3, fair 2, and poor 1.

Table 5. Subanalysis of endoscopic foraminototomy (group A) according to lysis

	Nonlysis (n=13)	Lysis (n=5)	p-value
Satisfaction	3.00±1.00	1.40±.55	0.008*

Values are presented as mean±standard deviation.
On a scale of excellent 4, good 3, fair 2, and poor 1.
The nonlysis group had significantly higher satisfaction than the lysis group.
*p<0.05, statistically significant differences (Mann-Whitney U-test).

nerve by a right L5–S1 foraminal disc herniation. Decompression of the right L5–S1 foraminal area was performed, with the patient showing improvement in VAS back, VAS leg, and ODI scores after one month. However, 2 months after surgery, the patient experienced a recurrence of back pain, limping, and numbness in the legs. After four-and-a-half years, radiographs showed progression of spondylolisthesis at L5–S1. The final follow-up showed scores of VAS back 3, VAS leg 7, and ODI 28, which were similar to the preoperative symptoms (Figure 2).

2. Case 2: Fusion

A 53-year-old male patient presented with pain in the posterior aspect of both thighs, with the left being more severe. Physical examination revealed a left great toe dorsiflexion strength of 4, but no other abnormalities were noted. The patient complained of difficulty walking due to posterior thigh radiating pain. His preoperative clinical scores were: VAS back 0, VAS leg 7, and ODI 30. Radiographs showed L5–S1 foraminal stenosis, while MRI showed compression of both L5 nerves due to L5–S1 foraminal stenosis. Decompression of the left L5–S1 foraminal stenosis was performed, and fusion was achieved by placing a large cage through the left L5–S1 foramen. L5–S1 screws were then inserted percutaneously. One year after surgery, the patient's follow-up results showed VAS back 0, VAS leg 2, and ODI 2. The patient was satisfied with the outcome of the surgery (Figure 3).

DISCUSSION

Foraminotomy is a straightforward approach to addressing L5–S1 foraminal issues without the need for fusion surgery. With the current advancements in endoscopic techniques, foraminotomies can now be performed efficiently using either uniportal or biportal spinal surgery [2,3]. Recent studies indicate favorable outcomes for foraminotomy in cases of L5–S1 low-grade spondylolisthesis [2]. However, there is considerable heterogeneity in the results [4]. Kim et al. [2] reported positive outcomes with biportal endoscopic surgery, with no statistically significant differences shown in follow-up radiological images. However, the study did not distinguish between patients with L5–S1 issues and those with problems at other levels. The anatomy of the facet joints in the upper lumbar levels (L3–4) differs from that at L5–S1, and facet joint injury at the upper lumbar

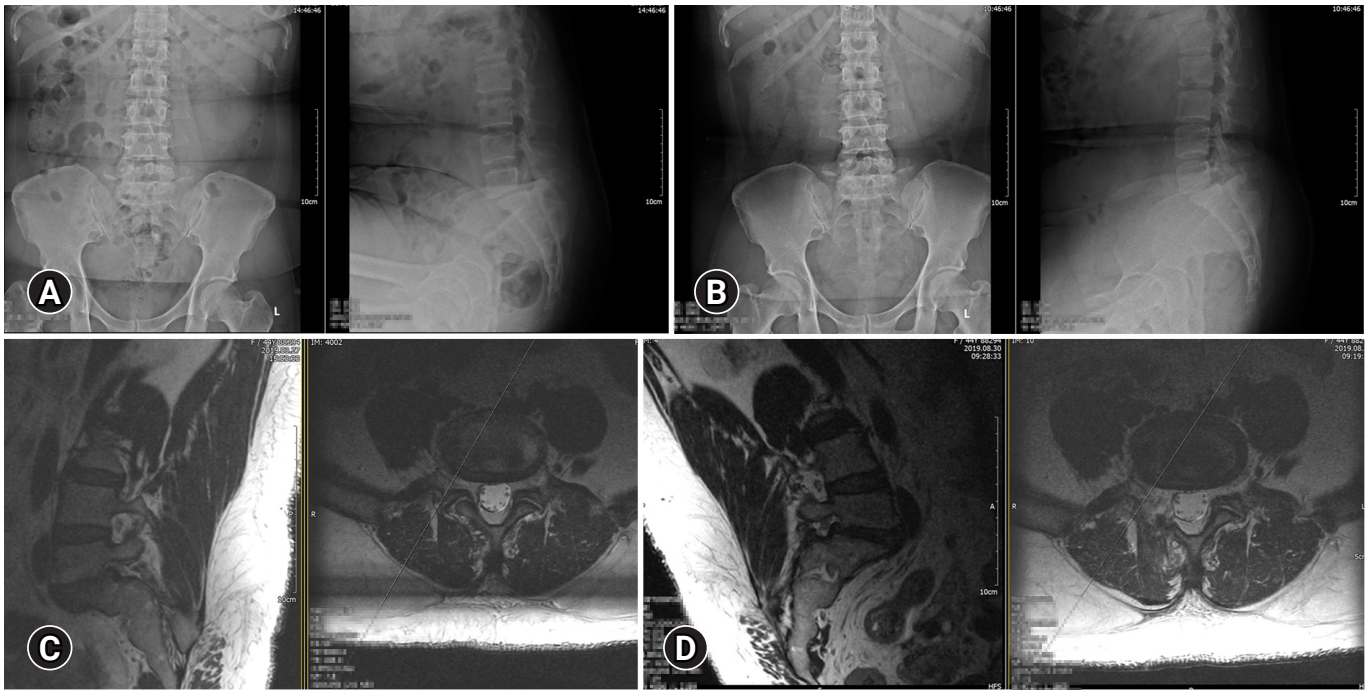

Figure 2. The following images show L5–S1 foraminotomy (preoperative and postoperative views). (A) A preoperative x-ray of the L5–S1 foraminotomy case reveals the presence of slippage at L5–S1 and narrowing of the disc space. (B) Postoperative x-rays reveal exacerbated L5–S1 slipping following posterior foraminal decompression. (C) Preoperative magnetic resonance imaging reveals that the L5–S1 disc exhibited compression in the superior direction of the L5 root ganglion. (D) The L5–S1 right foramen was fully decompressed, and the right L5 root was released from foraminal stenosis.

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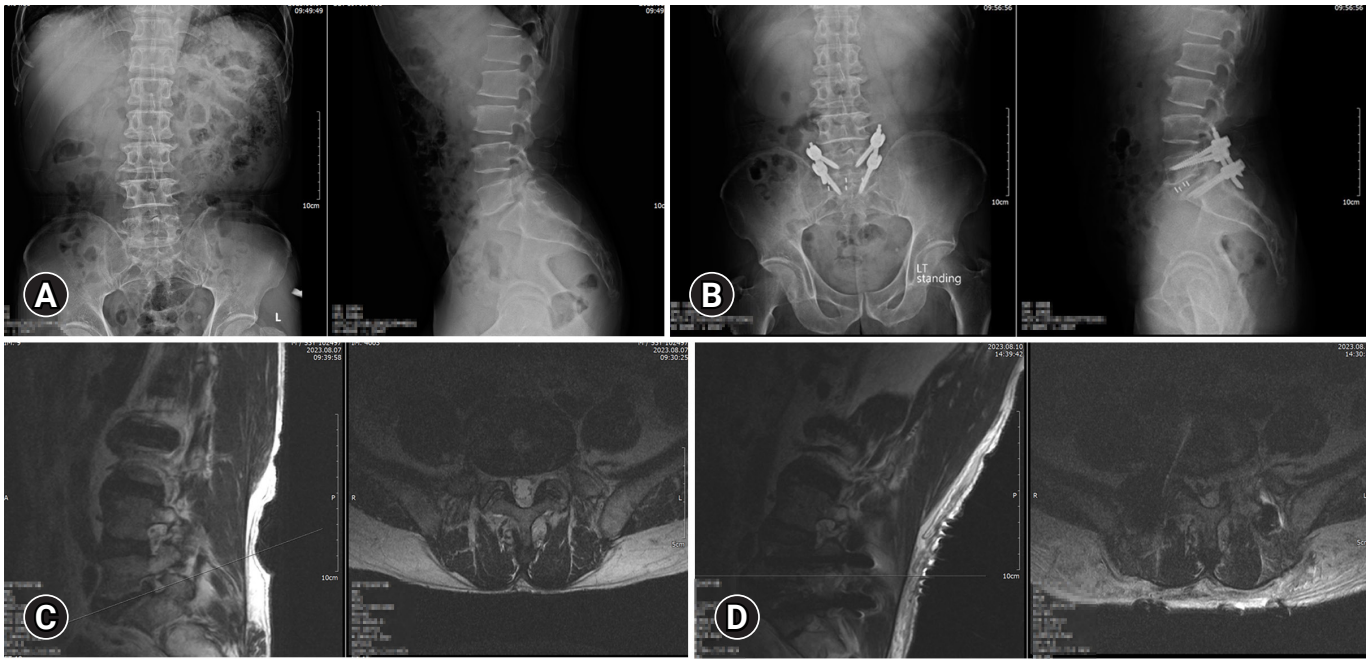

Figure 3. A case study illustrating the surgical intervention for L5–S1 fusion, including preoperative, postoperative, and postoperative x-rays and magnetic resonance imaging (MRI) scans. (A) A preliminary radiographic analysis of the L5–S1 fusion case reveals the presence of slippage at the L5–S1 level, accompanied by narrowing of the disc space. (B) Postoperative x-rays demonstrate that the L5–S1 disc space was restored and fused by the biportal endoscopic fusion technique, with posterior foraminal decompression. (C) Preoperative, MRI revealed that the L5–S1 disc compressed upward the right L5 root ganglion. (D) The left foramen was fully decompressed, and the L5–S1 vertebrae were fused. Additionally, the right L5 root was released from foraminal stenosis.

levels tends to be less severe, making postoperative instability less likely. However, if extensive foraminal decompression is required at L5–S1, the risk of postoperative instability increases, particularly at the L5–S1 level. Recurrence or worsening of radicular symptoms could indicate instability contributing to nerve root compression [5]. A 21.2% rate of poor outcomes following biportal foraminotomy has been linked to factors such as lower lumbar levels and a narrow cranial-vertebral angle [6].

In our study, we observed progression in 3 out of 5 cases of L5–S1 spondylolysis in group A. In 2 cases of extraforaminal herniation, which did not require the extensive removal of the superior S1 facet, the results were categorized as excellent and good (in MacNab criteria).

The surgical technique for biportal endoscopic fusion has evolved, meaning that biportal endoscopic fusion of L5–S1 is now feasible. This approach is now used to prevent disc height loss, restenosis, and instability in patients with foraminal issues at L5–S1 [7,8]. However, fusion surgery is not without its drawbacks, which include high costs, extended operation times, prolonged hospitalization, screw malposition, dura tear, nerve root injury, and varying degrees of adjacent segment syndrome. Consequently, it is difficult to decide whether to perform foraminotomy alone, accepting the risk of a recurrence of neurological symptoms, or to opt for fusion surgery, despite its inherent drawbacks. The aim of this study was to evaluate whether simple foraminotomy using a biportal endoscope is superior to biportal endoscopic fusion of L5–S1. In cases with pre-existing instability or spondylolisthesis, foraminotomy alone may not be sufficient, and fusion surgery may be necessary [9]. Fusion requires more surgical effort and time than foraminotomy and involves longer hospital stays and higher costs. However, fusion surgery does reduce the recurrence of lower limb symptoms. When comparing the VAS leg scores, and MacNab criteria, the fusion group demonstrated superior outcomes.

In our study, the fusion group did experience complications, including root injury due to screw malpositioning and delayed infection. Disadvantages of fusion surgery included longer operation times, prolonged hospital stays, screw-related complications, high costs, and junctional problems.

Although our study was retrospective and conducted over different surgical periods, it showed that the recurrence of lower limb symptoms was higher in the foraminotomy group. The fusion group, however, had complications associated with the surgical procedure itself and junctional problems. Since this was not a double-blind study, with the 2 groups not being

compared concurrently, there might have been differences in surgical experience and technique over time. For example, foraminotomy decompressions were performed during the first half of the study period, and fusion surgeries were performed in the second half, potentially reflecting advancements in surgical technique. Therefore, the results should be interpreted with caution. Even though the groups were operated on at different times, the foraminotomy group showed a higher rate of lower extremity pain recurrence, while the fusion group demonstrated excellent results in VAS leg scores and MacNab criteria.

CONCLUSION

In the treatment of L5–S1 foraminal stenosis, the fusion group showed better outcomes in terms of recurrence of lower limb symptoms.

NOTES

Conflicts of interest

DHH, is member of the Editorial Board of *Journal of Minimally Invasive Spine Surgery & Technique*, is the author of this article. However, he played no role whatsoever in the editorial evaluation of this article or the decision to publish it. Except for that, no potential conflict of interest relevant to this article was reported.

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