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RESEARCH

New ipsilateral full endoscopic interlaminar approach for L5-S1 foraminal and extraforaminal decompression: technique description and initial case series

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Abstract

Background The L5-S1 interlaminar access described in 2006 by Ruetten et al. represented a paradigm shift and a new perspective on endoscopic spinal approaches. Since then, the spinal community has shown that both the traditional ipsilateral and novel contralateral interlaminar approaches to the L5-S1 foramen are good alternatives to transforaminal access. This study aimed to provide a technical description and brief case series analysis of a new endoscopic foraminal and extraforaminal approach for pathologies at the lumbar L5-S1 level using a new ipsilateral interlaminar approach.

Methods Thirty patients with degenerative stenotic conditions at the L5-S1 disc level underwent the modified interlaminar approach. The surgical time, blood loss, occurrence of complications, and clinical outcomes were recorded. The data were compiled in Excel and analyzed using R software version 4.2. All continuous variables are presented as the mean, median, minimum, and maximal ranges. For categorical variables, data are described as counts and percentages.

Results Thirty patients were included in the study. The cohort showed significant improvements in all quality-of-life scores (ODI, visual analog scale of back pain, and visual analog scale of leg pain). Five cases of postoperative numbness and three cases of postoperative dysesthesia have been reported. No case of durotomy or leg weakness has been reported.

Conclusions The fundamental change proposed by this procedure, the new ipsilateral approach, presents potential advantages to surgeons by overcoming anatomical challenges at the L5-S1 level and by providing surgeon-friendly visualization and access. This approach allows for extensive foraminal and extraforaminal decompression, including the removal of hernias and osteophytosis, without causing neural retraction of the L5-S1 roots while maintaining the stability of the operated level.

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Introduction

Foraminal and central stenoses are among the most prevalent diseases of the lumbar spine, spanning all levels from T12-L1 to L5-S1 [1, 2]. Additionally, symptoms of lower back pain and leg pain/irradiation are often intense, preventing patients from performing daily activities [3, 4]. In cases where conservative treatments fail or are contraindicated, the patient must undergo surgery. However, decompression procedures have been performed in an open fashion for a long time, which leads to significant recovery time and a predisposition to complications such as infections [5, 6].

With a more profound understanding of the foraminal anatomy combined with the description of the safety triangle by Kambin´s, the transforaminal approach has since been an excellent gateway for discal approaches in various pathologies [7–9]. Initially, this involved percutaneous discectomy, and later the description of the lateral transforaminal endoscopic technique, especially for levels above L4-5 [10, 11]. Since then, with advancements in technology and endoscopic equipment, there has been a revolution in the indications for spinal surgery through an endoscopic approach, allowing for a minimally invasive approach with increased safety and visualization of all anatomical structures. In this way, not only lumbar disc herniation but also canal decompression can be used to treat facet cysts and discitis, and to conduct biopsies in a safe and minimally invasive fashion [10, 12].

However, despite advancements in both technology and surgery, the anatomical intricacies of L5-S1 still pose challenges to endoscopic transforaminal approaches. The uniqueness of the L5-S1 segment is evident in both its interlaminar and articular anatomy, featuring the largest interlaminar window, greater distance from the spinous process concerning articulation, and highly coronalized facets of the S1 segment [2, 13]. Moreover, studies have demonstrated that more caudal, mainly L5-S1, levels present a wider window but a smaller foramen and direct interference from the iliac crest in the transforaminal corridor. At this level, the small foraminal area is due to the proximity of neural structures to bony structures, leaving a minimally safe area for any approach, whether extraforaminal, discal, or intracanal [13, 14]. Given its complex anatomy, this level poses major limitations to the transforaminal approach, including dysesthesia, neurological deficits, insufficient discal resection, radicular avulsion, compressive trauma, and a high recurrence of hernias [15, 16].

The L5-S1 interlaminar access described in 2006 by Ruetten et al. brought about a paradigm shift and a new perspective on endoscopic spinal approaches. It provides the largest window, albeit with the smallest foramen of the lumbar spine [17, 18]. Since then, the spinal community has shown that both the traditional ipsilateral and novel contralateral interlaminar approaches to the L5-S1 foramen are good alternatives to transforaminal access [18–21].

However, established contralateral interlaminar techniques have several disadvantages, such as the same complication rate as transforaminal approaches (approximately 1.9–2.7%) [22]. Moreover, surgeons are usually uncomfortable with the contralateral view of the foramen, making the learning curve steeper, which increases the potential for unintended injuries during the process [23].

Therefore, this study aimed to provide a technical description and brief case series analysis of a new endoscopic foraminal and extraforaminal approach for pathologies at the lumbar L5-S1 level using a new ipsilateral interlaminar approach, which was intended to reduce the main complications associated with both the transforaminal and interlaminar approaches.

Methods

Retrospective case series and technical notes.

Ethical statements

All research was conducted in accordance with ethical guidelines. All patients consented to the collection of their images and surgical data.

Brief technical description

The ipsilateral L5-S1 interlaminar technique serves as a surgical intervention for foraminal and extraforaminal pathologies, including foraminal stenosis, cysts, and disc herniations.

Materials

Full-endoscopic instruments supplied by WOLF (RichardWolf GmbH, Knittlingen, Germany) were used. These instruments include rod-lens optics (6.9 mm outer diameter, 4.2 mm intraendoscopic canal diameter, 25-degree angle of vision) and working sheaths (7.9 mm outer diameter, beveled opening).

For bone resection, oval burs with lateral protection, spherical burs without protection, and diamond burs were utilized to ensure optimal bone hemostasis.

Hemostasis, dissection, and nucleoplasty were performed using a flexible and steerable bipolar tip control RF (4 MHz frequency). Submersion of the procedure in physiological saline requires a pump irrigation system under controlled

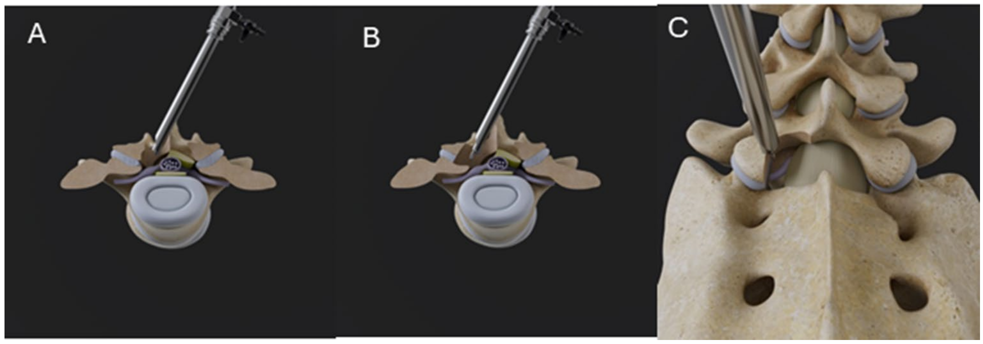

Fig. 1 Sequential resection at the L5-S1 level

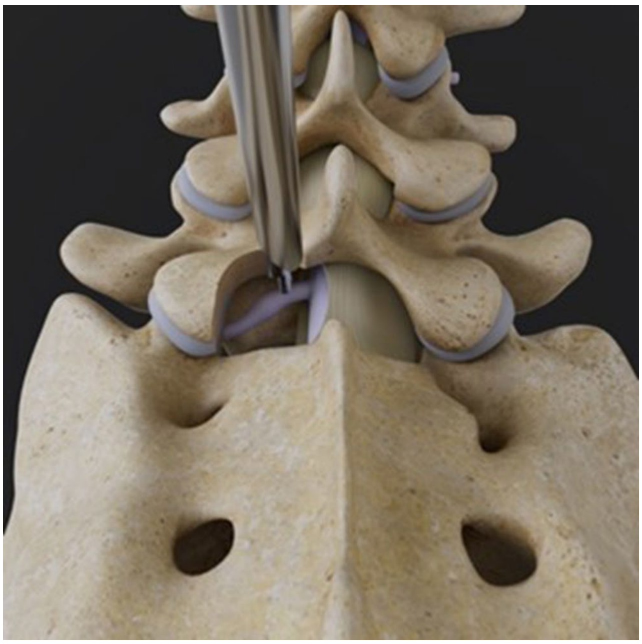

Fig. 2 Resection of the L5 lamina

pressure (60–150 mmHg) and flow (0.5–2) for enhanced safety.

Patient position and imaging

Patient positioning involves inducing lumbar flexion by adjusting the surgical table angle (30–40 degrees) and utilizing cushions in the thoracic and pelvic regions for optimal interlaminar window opening, distraction, and intervertebral foramen exposure.

Radiographic marking using fluoroscopy ensures precision in aligning the L5-S1 level at the center of the image. Notably, the initial marking is strategically located at the medial border of the inferior articular process (IAP), optimizing ergonomic handling of the endoscope and minimizing the need for significant medialization of the optics.

Operative steps

1. **Exposure of Articular Structures**: The procedure begins with the exposure of key structures, including the lamina, superior articular process of S1, and inferior articular process of L5, along with the ipsilateral yellow ligament.
2. **Resection of the Medial Capsular Border**: The medial border of the articular capsule, which is thinner at L5-S1 and rich in synovium, was carefully resected after detaching the superficial yellow ligament from the inferior articular process at L5.
3. **Bone Resection at L5-S1**: Sequential resection involves the tip and medial face of the inferior articular process (Fig. 1).

base of the L5 lamina (Fig. 2).

Detachment of the yellow ligament revealed epidural fat and exposed the medial face of the superior articular process of S1 to its cranial region (Fig. 3).

4. **Resection of the superior articular process of S1 and the ligamentum flavum**: The tip of the superior articular process of S1 was resected from the inside out, opening both the lateral recess and the ipsilateral L5-S1 foramen (Fig. 4).

This was followed by resection of the ligamentum flavum in this region (Fig. 5).

This step revealed the lateral aspect of the dural sac, axilla, shoulder, and S1 root, and fully decompressed the L5 root, which entered the free L5-S1 foramen (Fig. 6).

5. **Decompression**: Effective decompression was achieved by observing intraforaminal neural mobilization, visualizing the free movement of the L5 ganglion while preserving its cylindrical anatomy, and palpating the lateral edge of the disc during radiographic control, associated with decompression of the interlaminar recess and the S1 root being completely free (Fig. 7).

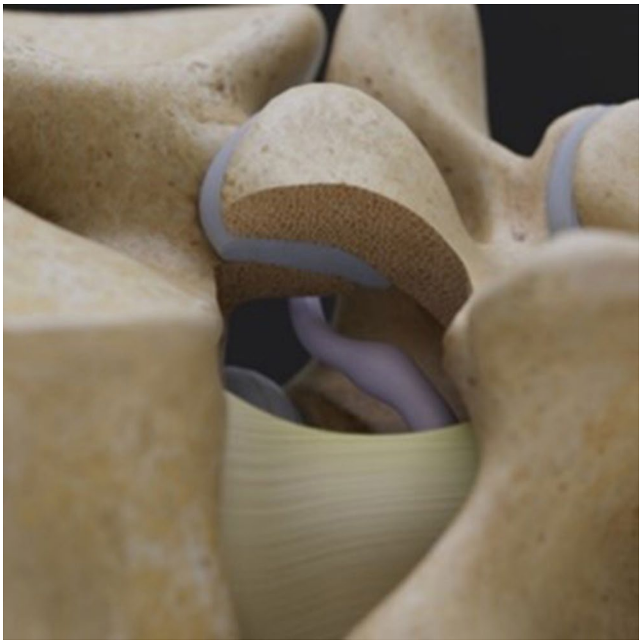

Fig. 3 Exposed medial face of the superior articular process of S1

Fig. 5 Resection of the ligamentum flavum

Statistical analysis

The data were compiled in Excel and analyzed using R software version 4.2. All continuous variables are presented as the mean, median, minimum, and maximal ranges. For categorical variables, data are described as counts and percentages. To estimate the change in pain scores over all follow-ups, the generalized linear mixed models (glmm) technique was applied, and all variables had their approximate distribution analyzed using the "UnivariateML" package; therefore, the appropriate distribution family and link could be used in the glmm. The estimated marginal means were used to estimate the differences between each follow-up period. The Benjamini–Yekutieli test was used to adjust the p-value for multiple comparisons. All variables of the model were reported after back transformation to the original scale.

Results

Thirty patients (16 male and 14 female patients) with a median age of 62 years were included in this study. The principal pathologies and other demographic data for each patient are presented in Table 1.

Destabilization of the operated segment was not observed in any of the patients. In 100% of patients, the technique was able to preserve at least 50% of the L5-S1 facet joint,

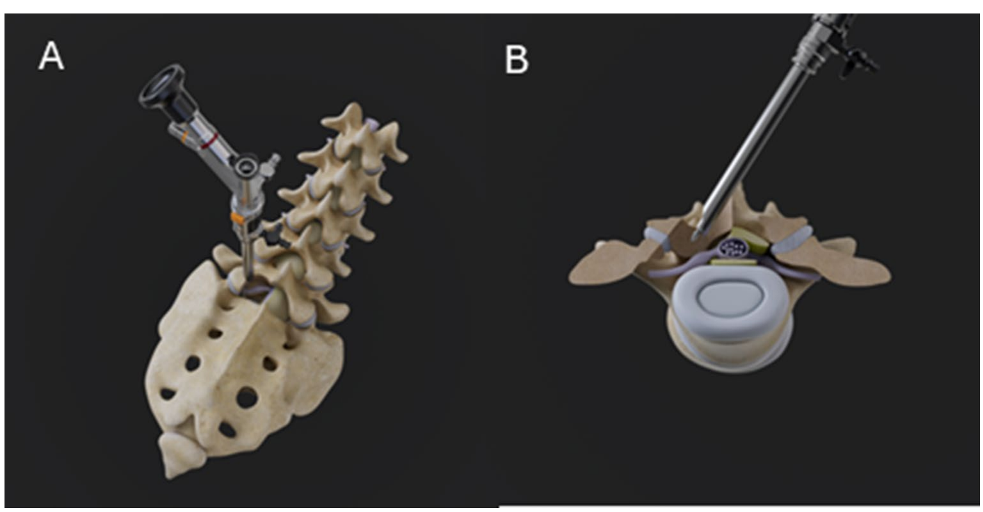

Fig. 4 Resection of the tip of the superior articular surface of the S1 process. **A**: Coronal view. **B**: Axial view

Fig. 6 Image showing the fully decompressed L5 root

as shown in the reconstruction below. None of the patients experienced intraoperative complications.

Furthermore, there was a significant reduction in pain scores (ODI, VAS Back and VAS Legs) after the procedure at the postoperative, three-month, and six-month follow-ups, as assessed using the generalized linear mixed model. The estimated marginal means and 95% confidence intervals are shown in Fig. 8.

The summary data of the postoperative scores are presented in Table 2.

Regarding postoperative complications, five patients complained of leg numbness after the procedure (16%), which resolved within 3 months of follow-up. Moreover, three patients presented with dysesthesia symptoms (10%) at the postoperative follow-up, all of which resolved within 3 months of follow-up. Finally, one patient underwent arthrodesis at the 5-month follow-up in another service due to no improvement in pain symptoms. No cases of durotomy or leg weakness were reported (Table 3).

Table 1 Demographic data and preoperative quality of life scores. IQR, Interquartile Range; ODI: Oswestry Disability Score; NA, Not applicable; std, Standard deviation; VAS, Visual Analog Scale

Label	Variables	Values
Gender	Female	14 (46.67%)
	Male	16 (53.33%)
Age	Min/Max	28.0/86.0
	Med [IQR]	62.5 [49.2;72.8]
	Mean (std)	61.1 (16.5)
	N (NA)	30 (0)
VAS Back Baseline	Min/Max	0/10.0
	Med [IQR]	3.0 [2.0;7.0]
	Mean (std)	4.2 (2.8)
	N (NA)	29 (1)
VAS Legs Baseline	Min/Max	5.0/10.0
	Med [IQR]	9.0 [7.0;9.0]
	Mean (std)	8.3 (1.4)
	N (NA)	29 (1)
ODI Baseline	Min/Max	30.0/92.0
	Med [IQR]	64.0 [53.5;74.0]
	Mean (std)	62.6 (15.5)
	N (NA)	28 (2)
Pathology	Stenosis	3 (10.0%)
	Stenosis + Listhesis	1 (3.33%)
	Foraminal Stenosis	15 (50.0%)
	Foraminal Stenosis + Lateral Recess Stenosis + Disc Herniation	1 (3.33%)
	Foraminal Stenosis + Disc Herniation	4 (13.33%)
	Foraminal Stenosis + Lateral Recess Stenosis	1 (3.33%)
	Disc Herniation	5 (16.67%)

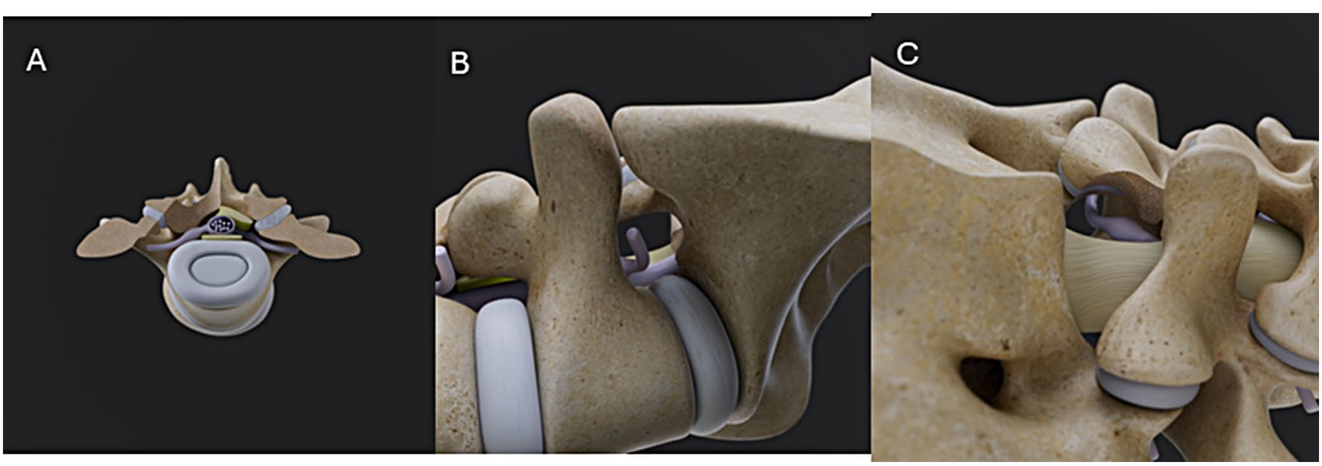

Fig. 7 Images showing decompression for the axial (**A**), lateral (**B**) and medial parameters (**C**)

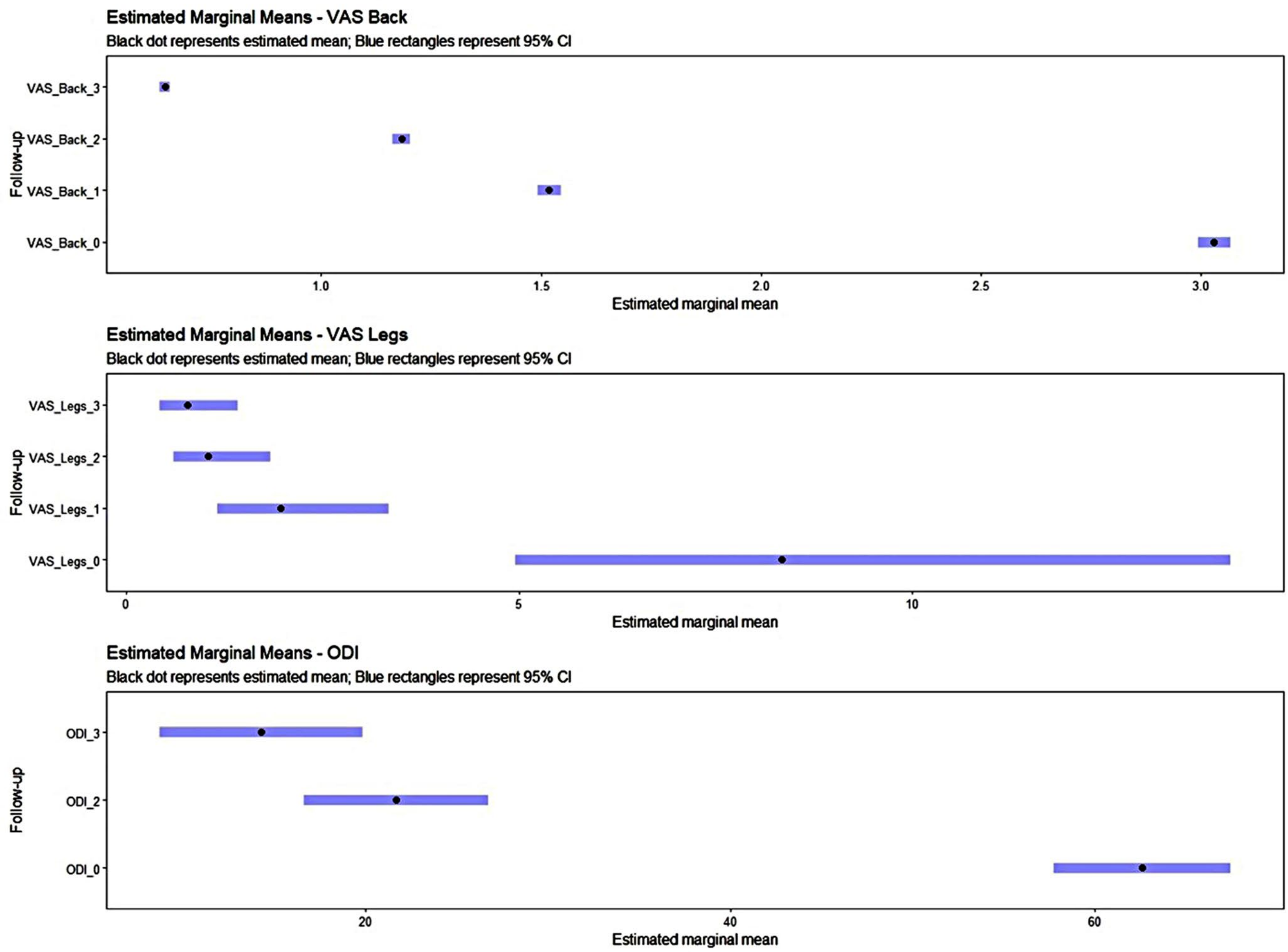

Fig. 8 Plots showing the estimated marginal means at each follow-up. Blue rectangle: 95% confidence intervals (CIs). Black dots: estimated marginal mean. Follow-ups: _0: Baseline; _1: Postoperative; _2:3 Month; _3:6 months

Patient 1

A 73-year-old female presented with intractable pain refractory to conservative treatment. She presented with radiculopathy symptoms that significantly affected her quality of life. Magnetic resonance imaging (MRI) revealed foraminal stenosis at the L5-S1 disc level (Fig. 9A-B). The authors opted to perform modified ipsilateral interlaminar endoscopic decompression to treat the foraminal stenosis (Fig. 9C). The procedure was successful with no complications, and sufficient decompression was achieved (Fig. 9D-E). The patient presented with substantial clinical improvement immediately after the procedure and maintained her quality-of-life score at the 3-month and 6-month follow-up.

Patient 2

A 70-year-old male patient presented with intractable pain that was refractory to conservative treatment. The patient presented with L5-S1 foraminal stenosis (Fig. 10A-B). The authors performed L5-S1-modified ipsilateral interlaminar decompression (Fig. 10C-D). The procedure was successful with no complications, and sufficient decompression was achieved (Fig. 10E-F).

Discussion

This technical report outlines a comprehensive and precise full-endoscopic ipsilateral interlaminar approach for L5-S1 pathologies, offering valuable insights into the intricacies of the procedure and materials employed for optimal outcomes. To the best of our knowledge, this is the first study to describe this approach.

Ruetten et al. (2006) published the first article regarding the use of interlaminar endoscopy for the treatment of lumbar spinal pathologies. The authors propose that the use of this new access to the ipsilateral interlaminar approach

Table 2 Postoperative quality of life scores. IQR, Interquartile Range; ODI: Oswestry Disability Score; NA, Not applicable; std, Standard deviation; VAS, Visual Analog Scale

label	variable	value
VAS Back Posop	Min / Max	0 / 7.0
	Med [IQR]	2.0 [1.0;4.0]
	Mean (std)	2.4 (2.0)
	N (NA)	29 (1)
VAS Back 3-months	Min / Max	0 / 5.0
	Med [IQR]	2.0 [0.5;3.0]
	Mean (std)	1.9 (1.5)
	N (NA)	27 (3)
VAS Back 6-months	Min / Max	0 / 6.0
	Med [IQR]	1.0 [0;2.2]
	Mean (std)	1.5 (1.7)
	N (NA)	24 (6)
VAS Legs Posop	Min / Max	0 / 5.0
	Med [IQR]	2.0 [1.0;3.0]
	Mean (std)	2.0 (1.5)
	N (NA)	28 (2)
VAS Legs 3-months	Min / Max	0 / 6.0
	Med [IQR]	1.0 [0;1.0]
	Mean (std)	1.0 (1.5)
	N (NA)	25 (5)
VAS Legs 6-months	Min / Max	0 / 6.0
	Med [IQR]	0 [0;0.8]
	Mean (std)	0.8 (1.6)
	N (NA)	22 (8)
ODI 3-months	Min / Max	6.0 / 48.0
	Med [IQR]	20.0 [16.0;30.0]
	Mean (std)	22.4 (11.3)
	N (NA)	25 (5)
ODI 6-months	Min / Max	0 / 36.0
	Med [IQR]	12.0 [6.5;17.0]
	Mean (std)	14.1 (9.8)
	N (NA)	19 (11)

Table 3 Detailed description of complications that occurred during follow-up

Complications	Variable	Count (%)
Leg weakness	No	30 (100.00%)
Numbness	No	25 (83.33%)
	Yes	5 (16.67%)
Dysesthesia	No	27 (90.00%)
	Yes	3 (10.00%)
Durotomy	No	30 (100.00%)
Evolution to arthrodesis	No	29 (96.67%)
	Yes	1 (3.33%)

could ease complications related to the complex anatomy of the L5-S1 foramen [18]. In a subsequent study, the same team compared the use of both the transforaminal and interlaminar endoscopic approaches to the traditional microsurgical approach for lumbar spine decompression. The group showed that endoscopic techniques yielded similar clinical outcomes with significantly reduced morbidity compared to microsurgical approaches [24, 25].

Given the success of the interlaminar approach compared to traditional decompression techniques, several groups have compared its efficacy with that of another established endoscopic technique, transforaminal endoscopic lumbar discectomy (TELD), mainly for L5-S1, because, as previously mentioned, it may pose a challenge owing to its narrow and complex foraminal anatomy [13, 14]. Additionally, in a study with both cadaveric specimens and intraoperative imaging analysis, Ozer et al. showed that in a sample of 34 patients, only six (17%) had a type 3 (normal) Kabin triangle, 17 (50%) had a type 2 (small) Kabin triangle, and 11 patients had a type 1 (practically nonexistent) triangle. Moreover, when focusing only on L5-S1, no type 3 triangles were found, with three patients presenting type 2 triangles and three presenting type 1 triangles [26].

Furthermore, several recent studies have shown that, although similar in efficacy, the use of an interlaminar approach might provide some advantages over the transforaminal technique. In their study, Cheng et al., 2022 showed that the interlaminar approach led to reduced operative and fluoroscopy times [16]. Similarly, Xu et al. (2023) reported that patients who underwent surgery using the interlaminar approach experienced significantly less postoperative back pain than those who underwent surgery using the transforaminal technique [27]. Finally, two recent studies have demonstrated that the use of contralateral interlaminar approaches can significantly improve clinical outcomes in patients [22, 28, 29].

Although contralateral interlaminar techniques have led to enormous improvements in the management of L5-S1 pathologies, they are not without limitations, such as a similar complication profile to that of transforaminal approaches and contralateral visualization (in the case of contralateral interlaminar), which might be tricky for inexperienced surgeons, leading to a steep learning curve [17, 22, 30].

Several authors have published derivations of previously described interlaminar techniques to address specific conditions or a more general pathology spectrum. Song et al., 2017 compared the use of full and intermittent interlaminar endoscopic techniques, showing that the use of an intermittent approach could lead to a significant reduction in surgical time and hospitalization costs [31].

Wu et al., 2020, reported the use of a laminoplasty-like technique to perform an endoscopic interlaminar approach to treat patients with a narrow interlaminar window [32]. Additionally, Cheng et al., 2020 reported that the use of a modified interlaminar approach through the inferior endplate pathway could lead to a reduction in the learning curve and complications compared to the traditional interlaminar approach [33]. Furthermore, Kim et al., 2020, presented a

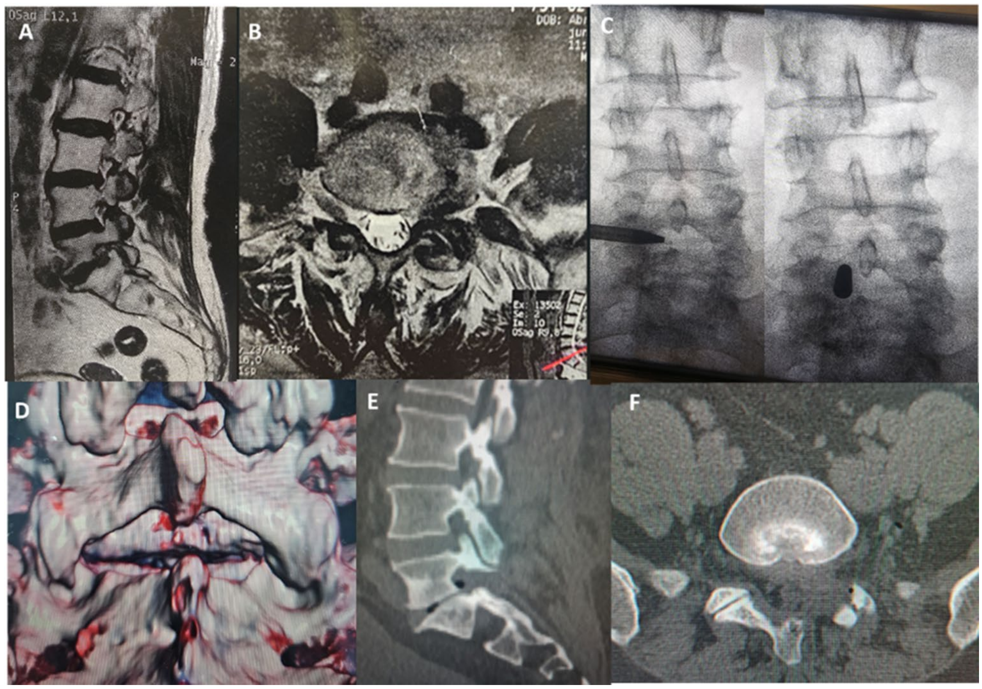

Fig. 9 Panel showing the Changes in perioperative images of the patients. **A**-**B**: T2-pondered magnetic resonance (MR) image showing foraminal stenosis. **C**: Fluoroscopic images showing the entry point for the ipsilateral interlaminar technique. **D**: 3D CT reconstruction image showing a small bone defect created using the modified endoscopic approach. **E**: Sagittal CT image showing decompression achieved using this technique. **F**: Axial tomography image showing partial laminotomy used to create the interlaminar approach and effective foraminal decompression

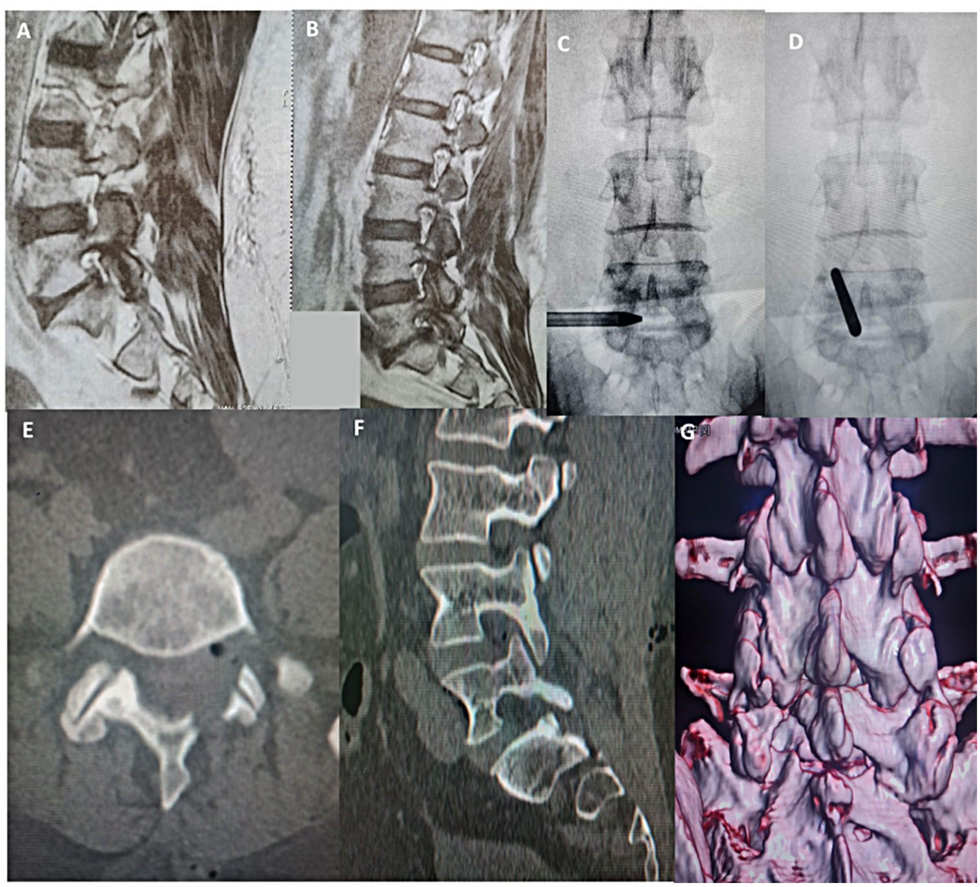

Fig. 10 Panel showing changes in perioperative images of patients. **A**-**B**: T2-pondered magnetic resonance (MR) image showing foraminal stenosis. **C**-**D**: Fluoroscopic images showing the entry point for the ipsilateral interlaminar technique. **E**-**F**: Sagittal and axial tomography images showing partial laminotomy used to create the interlaminar approach and effective foraminal decompression. **G**: 3D CT reconstruction showing reduced bone damage caused by the modified ipsilateral interlaminar approach

technical description focusing specifically on dealing with facet cysts as a derivation of the interlaminar approach reported by Komp et al., 2014 [34, 35]. Finally, Kim et al., 2021 reported a variation in the interlaminar technique to address cases of coexisting stenosis (lateral recess, foraminal, and extraforaminal), and showed that the technique yields a feasible, safe, and complex technique for treating coexisting stenosis [36].

Although several adaptations of the interlaminar technique have been reported, no study has used this new approach to widen the ipsilateral interlaminar pathway, as proposed in the present study.

This study describes an innovative and new technique, with a relevant initial case showing promising clinical and surgical outcomes. However, this study is not without limitations, including its retrospective nature and the lack of a control/comparative group. Therefore, future studies should truly understand the potential of this new technique for interlaminar decompression.

Conclusion

This study proposes a novel surgical method for addressing foraminal stenosis and hernia at the L5–L1 level considering the constraints of transforaminal endoscopic lumbar surgery (TELD). The fundamental change proposed by this procedure, the new ipsilateral approach, presents potential advantages to surgeons by overcoming anatomical challenges at the L5-S1 level and providing surgeon-friendly visualization and access.

This approach allows for extensive foraminal and extraforaminal decompression, including the removal of hernias and osteophytosis, without causing neural retraction of the L5-S1 roots while maintaining the stability of the operated level.

Further investigation is necessary to assess the long-term surgical and clinical outcomes of modified ipsilateral interlaminar endoscopic surgery in comparison with the established treatment for L5-S1 pathologies through a transforaminal endoscopic approach.

Author contributions MAM and GP: Writing the main manuscriptARV, MVL, MK, RBS, MOPC, JRS, SR: Revised the main manuscriptARV, MVL, RBS, MOPC, JRS: Data collectionMAM and GP: Figures and Statistical Analisys.

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Data availability No datasets were generated or analysed during the current study.

Declarations

Competing interests The authors declare no competing interests.

Conflict of interest The authors declare that they have received no financial support for the research, authorship, and/or publication of this article, and that there are no conflicts of interest.

Ethical approval Ethical committee approval was obtained from an independent ethics committee for the present study.

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