Journal of Pain Research

Dovepress
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ORIGINAL RESEARCH

# Mid-to-Long Term Radiological and Clinical Outcomes of Oblique Lateral Interbody Fusion versus Posterior Lumbar Interbody Fusion for Severe Lumbar Spinal Stenosis: A Retrospective Comparative Study

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**Purpose:** To explore and compare the clinical efficacy and radiological changes of oblique lateral interbody fusion (OLIF) and posterior lumbar interbody fusion (PLIF) in patients with severe lumbar spinal stenosis (LSS).

**Patients and Methods:** We retrospectively collected data from 34 patients with severe LSS (Schizas grade C or D) who underwent either OLIF or PLIF at our institution between June 2014 and June 2020. Imaging evaluation included the cross-sectional area (CSA) of the spinal canal and ligamentum flavum on MRI. Clinical evaluation included Visual Analogue Scale (VAS) scores and Oswestry Disability Index (ODI). Statistical analysis was performed using independent sample *t*-tests and analysis of variance for repeated measures.

**Results:** The cross-sectional area of the spinal canal in the OLIF group was gradually expanded from 47.6 ± 16.5 $mm^2$ preoperatively to 67.0 ± 17.8 $mm^2$ at 3 weeks and further to 97.5 ± 22.3 $mm^2$ at 1 year ($P < 0.05$), while the area of ligamentum flavum was decreased from 119.9 ± 49.7 $mm^2$ to 107.0 ± 38.9 $mm^2$ and to 87.8 ± 25.3 $mm^2$, respectively ($P < 0.05$). At 3 weeks after the operation, the improvement of VAS score (Low back: 1.3 vs 3.8; Leg: 1.6 vs 3.6) and ODI (12.24 vs 35.21) of low back and leg pain in the PLIF group was better than that in the OLIF group ($P < 0.05$). There was no significant difference in VAS score and ODI between the two groups 1 year after operation ($P > 0.05$).

**Conclusion:** OLIF technology provides significant mid-term (1-year) spinal canal dilatation and clinical improvement in severe LSS, achieving outcomes comparable to PLIF. Therefore, OLIF can be considered a viable and effective surgical option for severe LSS.

**Keywords:** oblique lateral interbody fusion, indirect decompression, lumbar spinal stenosis, MRI, clinical features

## Introduction

Lumbar spinal stenosis (LSS) is a debilitating condition in spinal surgery, which is caused by various pathological conditions such as lumbar spinal degeneration. Clinically, LSS is manifested as the pain in hip muscles and lower limb muscles, often accompanied by lumbar pain. Symptomatic LSS is characterized by neurogenic intermittent claudication, which can be relieved by lumbar flexion, sitting, or lying position.[1] For patients with chronic low back pain or accompanied by nerve damage, surgery is recommended when conservative treatment is ineffective. Posterior lumbar decompression and fusion, such as posterior lumbar interbody fusion (PLIF), is a direct posterior decompression technique, which is widely applied in lumbar degenerative diseases including LSS, lumbar spondylolisthesis, post-operative adjacent segment degeneration, and spinal deformity.[2] As a classic surgical method for the treatment of LSS, PLIF can obtain satisfactory clinical efficacy, but it also has the risk of causing significant trauma and potential nerve root

https://doi.org/10.2147/JPR.S552131
Received: 4 August 2025
Accepted: 30 December 2025
Published: 13 January 2026

injury, which is not conducive to the tolerance of middle-aged and elderly patients. With the continuous improvement of spinal surgery and the gradual popularization of the concept of minimally invasive surgery, it becomes increasingly important to select the personalized surgical method for LSS patients.[3]

In recent years, oblique lateral interbody fusion (OLIF), as a relatively new type of indirect retroperitoneal decompression and fusion, has been widely used in the treatment of LSS due to the short duration of surgery, less bleeding, rapid postoperative recovery, and favorable indirect spinal decompression effect. Moreover, OLIF has shown considerable efficacy in treating adjacent lumbar segment degeneration and scoliosis. Recent studies have emphasized the importance of biomechanical factors in decompression, suggesting that indirect decompression via OLIF may be as effective as direct decompression in improving spinal canal dimensions and clinical outcomes.[4,5] Since OLIF achieves the purpose of spinal canal decompression indirectly, there are many disputes about its application in severe LSS. Especially in the case of severe LSS with posterior articular process cohesion and osteophyte formation, most doctors tend to choose direct decompression rather than indirect decompression.[6,7] Recent studies have confirmed that even severe LSS can be treated by indirect decompression that benefits from the continuous dilatation of the spinal canal after operation.[8–10] OLIF effectively avoids causing damage to the psoas major muscle and lumbar plexus and bears the advantages of simple and convenient operation, high surgical safety, fast postoperative recovery, and low incidence of postoperative complications.[11,12] However, these studies lack a controlled setting. The safety of OLIF in the treatment of LSS needs to be evaluated by comparing it with the traditional direct posterior decompression.

Through retrospective analysis, this study aimed to compare the efficacy of indirect decompression via the OLIF with direct decompression via the PLIF in patients with severe LSS, by evaluating postoperative changes in both radiological parameters—specifically the cross-sectional area of the spinal canal and ligamentum flavum on MRI[13]—and clinical outcomes, thereby providing evidence for summarizing the indications of OLIF in the treatment of LSS.

# Materials and Methods

## General Information

The study protocol was reviewed and approved by the Medical Ethics Committee of the 900th Hospital of the Joint Logistic Support Force (Approval Number: 2025–089). This study confirmed that informed consent was obtained from the participants, and also confirmed that the guidelines outlined in the Declaration of Helsinki were followed.

34 LSS patients who underwent OLIF and posterior lumbar interbody fusion (PLIF) in the 900th Hospital of the Joint Logistic Support Force, located in Fuzhou, Fujian Province, China, from June 2014 to June 2020 were collected retrospectively. The inclusion criteria were based on the Participant, Intervention, Comparison, Outcome Study (PICOS) strategy:[14] 1. The data of patients with severe LSS diagnosed according to clinical symptoms, signs, and imaging examination were collected retrospectively (according to Schizas classification, the severity degree of LSS was judged by the shape of the dural sac, belonging to grade C or D; Figure 1), and all these patients had failed to conservative treatment. 2. The surgical segment was L3/4 with/or L4/5. 3. The postoperative follow-up time was >

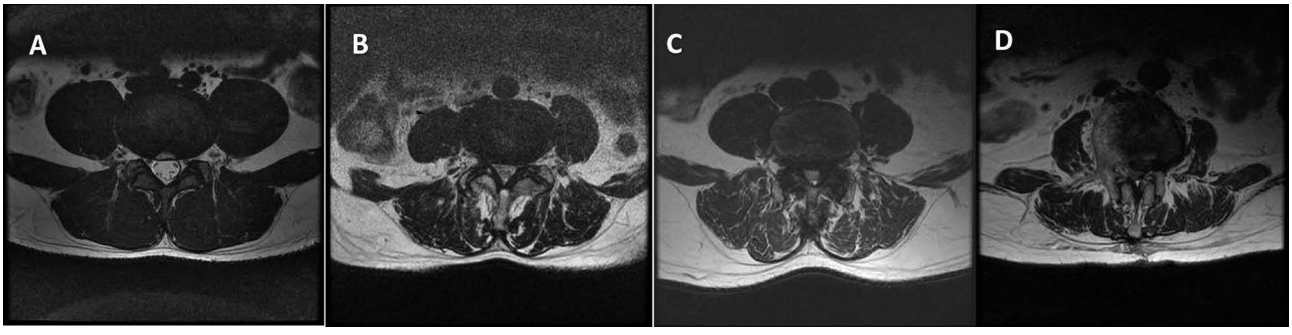


**Figure 1** Severity classification of LSS on MRI ((**A**), cerebrospinal fluid is clearly visible in the dural sac; (**B**), the nerve root occupies the whole dural sac, but the shape of the nerve root can still be seen; (**C**), unclear nerve roots due to posterior epidural fat and invisible cerebrospinal fluid; (**D**), no posterior epidural fat and unclear nerve root).

1 year. 4. LSS patients receiving OLIF or PLIF treatment. 5. Patients undergoing anterior and lateral radiography of the lumbar spine, lumbar computed tomography (CT), and MRI examination. 6. Patients with the records of Visual Analogue Scale (VAS) and Oswestry Disability Index (ODI) of low back and leg pain. The exclusion criteria were as follows: 1. prolapse of the lumbar intervertebral disc; 2. lumbar spondylolisthesis II° or above; 3. lumbar Cobb angle > 10°; 4. postoperative fusion cage subsidence, displacement, and pseudojoint formation.

## Surgical Methods

### OLIF

The OLIF procedure was performed in accordance with established techniques.[2,3] In brief, with the patient in the right lateral decubitus position, a standard oblique retroperitoneal approach was utilized to access the target disc space. After discectomy and endplate preparation, an appropriately sized interbody cage filled with allogeneic bone was implanted. Subsequently, the patient was repositioned prone for percutaneous pedicle screw fixation, which was performed under fluoroscopic guidance. The specific steps of our surgical protocol, consistent with the cited standard techniques, are illustrated in Figure 2A–C (original schematic diagram created for this study).

### PLIF

The PLIF procedure was performed as previously described.[6,7] In summary, via a standard posterior midline approach, a wide laminectomy and facetectomy were performed to achieve direct neural decompression. Following discectomy and endplate preparation, an interbody cage was placed. Posterior instrumentation was completed with pedicle screw fixation. The key steps of this procedure are demonstrated in Figure 3A–C (original schematic diagram created for this study).

## Clinical Efficacy Evaluation

The VAS score of low back and leg pain before the operation, 3 weeks after the operation, and 1 year after the operation was recorded. The VAS score ranged from 0–10 points, with the higher score indicating the graver pain.[15] The ODI was used to evaluate lumbar disorders, with a score range of 0–50 points. The lower the score, the better the recovery of lumbar function.[16]

## Imaging Evaluation of Curative Efficacy

All patients underwent lumbar spine radiography (anteroposterior and lateral views), CT, and MRI preoperatively, at 3 weeks postoperatively, and at 1 year postoperatively. The CSA of the spinal canal and ligamentum flavum were measured on axial T2-weighted MRI sequences at the level of the central intervertebral disc. The spinal canal CSA was defined as the area enclosed by the dural sac. The ligamentum flavum CSA was measured by outlining the bilateral

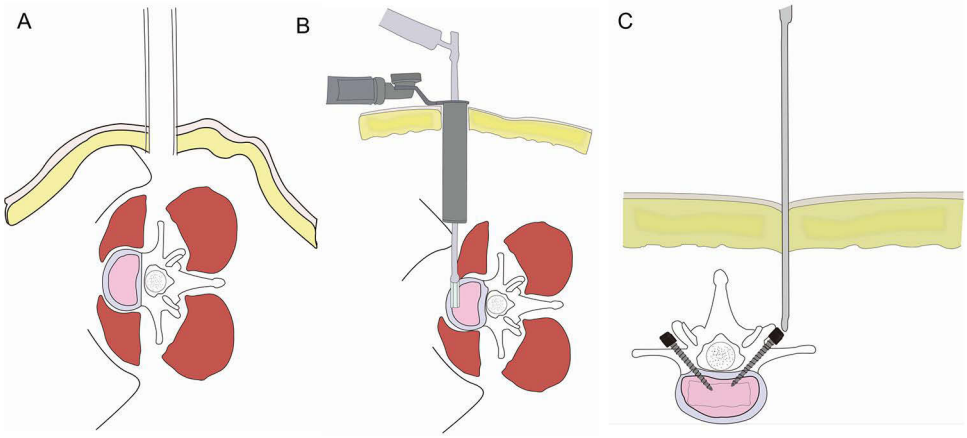


**Figure 2** Schematic diagram of key operations of OLIF. (**A**) The patient was in a standard right arm recumbent, and the target intervertebral space was exposed through the left ventrolateral intermuscular approach. (**B**) Lumbar discectomy, cartilage endplate cleaning, intervertebral distraction, and fusion cage implantation were performed under the spinal canal channel. (**C**) Afterward, the patient was in the prone position and pedicle screws were inserted percutaneously.


https://doi.org/10.2147/JPR.S552131

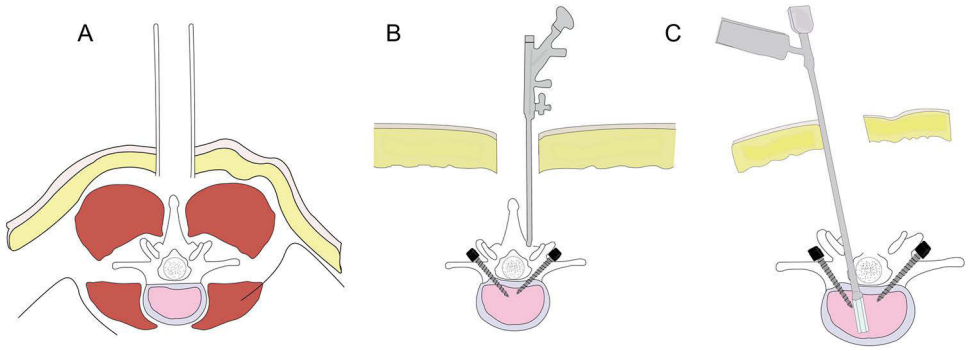


**Figure 3** Schematic diagram of key operations of PLIF. (**A**) The patient was in the prone position and kept his abdomen suspended. (**A**) longitudinal incision was made with the diseased segment as the center. (**B**) The paravertebral muscles were stripped to both sides and pedicle screws were placed on both sides. (**C**) Total laminectomy, lumbar discectomy, cartilage endplate cleaning, and fusion cage implantation were performed.

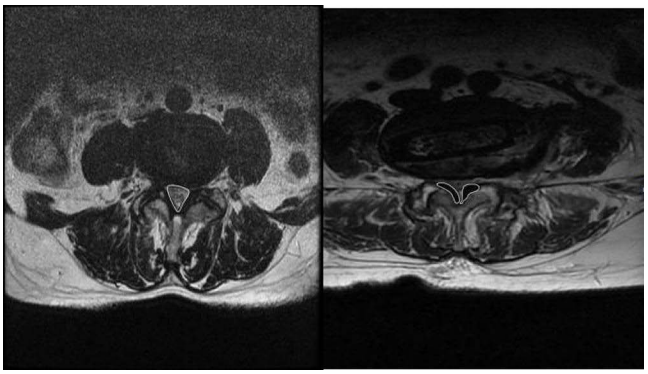

**Figure 4** The cross-sectional areas of the spinal canal and ligamentum flavum were measured on T2-weighted MRI.

ligamenta flava at their thickest point. All measurements were performed independently by three experienced spine surgeons using standardized PACS imaging software, and the average values were used for analysis. Intervertebral foramen height and area were also calculated. A detailed schematic of the measurement methodology is provided in Figure 4.

## Complications

The related complications of patients in the two groups were recorded, including nerve injury, incision infection, cerebrospinal fluid leakage, hip flexion weakness, lower limb numbness or pain, fusion cage displacement or subsidence, and pseudojoint formation.

## Statistical Analysis

SPSS 20.0 (SPSS, USA) statistical software was used for data processing. The cross-sectional areas of the spinal canal and ligamentum flavum, and the VAS and ODI scores of low back and leg pain in the two groups were compared by using the independent sample *t*-test. The measurement parameters of the same group at different time points before and after operation were compared by analysis of the variance of repeated measurement data. The significant level was set as $\alpha = 0.05$.

# Results

## General Information

This study enrolled 46 LSS patients undergoing OLIF or PLIF in our department from June 2014 to June 2020. According to the inclusion and exclusion criteria, 34 patients were finally included, including 16 males and 18 females,

with an average of (65.7 ± 6.85) years old (ranging from 42–81 years old). There were 18 cases in the OLIF group and 16 cases in the PLIF group. By comparing and analyzing the basic conditions of patients in the OLIF and PLIF groups, it was found that there was no significant difference in preoperative data (Table 1).

## Comparison of Clinical Indexes Between the Two Groups

There was no significant difference in the VAS score of low back pain before operation between the two groups ($P > 0.05$). The VAS score of low back pain after operation was better than that before operation in the two groups ($P < 0.05$). The VAS score of low back pain at three weeks after operation in the OLIF group was higher than that in the PLIF group, and the difference was statistically significant ($P < 0.05$). There was no significant difference in the VAS score of low back pain between the two groups one year after the operation ($P > 0.05$) (Table 2).

There was no significant difference in the VAS score of leg pain before operation between the two groups ($P > 0.05$). The VAS score of leg pain after the operation was better than that before the operation in the two groups ($P < 0.05$). The VAS score of leg pain at three weeks after operation in the OLIF group was higher than that in the PLIF group, and the difference was statistically significant ($P < 0.05$). There was no significant difference in the VAS score of leg pain between the two groups one year after the operation ($P > 0.05$) (Table 2).

There was no significant difference in ODI between the two groups before the operation ($P > 0.05$). The ODI after the operation was better than that before the operation in the two groups ($P < 0.05$). The ODI in the OLIF group was

**Table 1** Comparison of Preoperative General Data Between the OLIF Group and PLIF Group

| | OLIF (N=18) | PLIF (N=16) | p |
|---|---|---|---|
| Gender | | | 0.22 |
| Male, % | 7 (38.9) | 9 (56.3) | |
| Female, % | 11 (61.1) | 7 (43.8) | |
| Age (years) | 64.9 ± 7.5 | 63.7 ± 8.1 | 0.34 |
| Operative segment | | | 0.68 |
| L3/4, % | 4 (22.2) | 4 (25.0) | |
| L4/5, % | 10 (55.6) | 8 (50.0) | |
| L3/4, L4/5, % | 3 (16.7) | 4 (25.0) | |
| Preoperative diagnosis | | | 0.54 |
| Lumbar spinal stenosis, % | 12 (66.7) | 10 (62.5) | |
| Lumbar spondylolisthesis, % | 7 (38.9) | 5 (31.3) | |
| Preoperative articular process degeneration grade | | | 0.71 |
| Grade C, % | 7 (38.9) | 6 (37.5) | |
| Grade D, % | 15 (83.3) | 12 (75.0) | |

**Table 2** Comparison of Clinical and MRI Indexes Before and After Operation Between OLIF and PLIF Groups

| Parameter | OLIF Group | | | | PLIF Group | | | |
|---|---|---|---|---|---|---|---|---|
| | Before Operation | 3 Weeks After Operation | 1 Year After Operation | P | Before Operation | 3 Weeks After Operation | 1 Year After Operation | P |
| VAS score of low back pain | 7.4 ± 0.8 | 3.8 ± 0.7* | 1.4 ± 0.5* | 0.00072 | 7.3 ± 0.8 | 1.3 ± 0.9* | 1.2 ± 0.7* | 0.00031 |
| VAS score of leg pain | 7.9 ± 0.9 | 3.6 ± 0.9* | 1.5 ± 0.5* | 0.00083 | 8.0 ± 0.9 | 1.6 ± 0.7* | 1.4 ± 0.5* | 0.00027 |
| ODI index | 60.12 ± 12.10 | 35.21 ± 4.35* | 15.21 ± 3.46* | 0.0088 | 65.34 ± 14.61 | 12.24 ± 2.23* | 10.24 ± 3.32* | 0.00056 |
| Cross-sectional area of spinal canal | 47.6 ± 16.5 | 67.0 ± 17.8* | 97.5 ± 22.3* | 0.0234 | 45.6 ± 12.7 | - | - | - |
| Cross-sectional area of ligamentum flavum | 119.9 ± 49.7 | 107.0 ± 38.9* | 87.8 ± 25.3* | 0.0341 | 120.1 ± 49.7 | - | - | - |

**Note**: *P < 0.05 vs Before operation. VAS, visual analogue scale; ODI, Oswestry disability index.


https://doi.org/10.2147/JPR.S552131

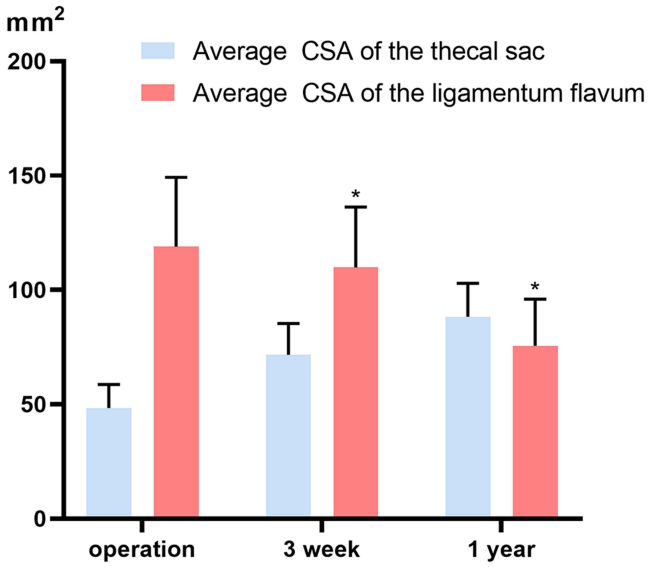


**Figure 5** The average cross-sectional area of dural sac and ligamentum flavum before OLIF operation, 3 weeks, and 1 year after OLIF operation. The area of the spinal canal 3 weeks and 1 year after OLIF operation was significantly larger than that before OLIF operation (*P < 0.05), while the thickness of ligamentum flavum 3 weeks and 1 year after operation was significantly thinner than that before operation (*P < 0.05).

significantly higher than that in the PLIF group three weeks after the operation ($P < 0.05$). There was no significant difference in ODI between the two groups one year after operation ($P > 0.05$) (Table 2).

## Comparison of MRI Indexes Between the Two Groups

There was no significant difference in the cross-sectional area of the spinal canal between the two groups before the operation (P > 0.05). The cross-sectional area of the spinal canal three weeks after the operation was larger than that before the operation in the OLIF group (P < 0.05), and the cross-sectional area of the spinal canal one year after the operation was larger than that three weeks after the operation (P < 0.05), with an improvement rate of 45.2 (33.0–61.8)%. Since patients in the PLIF group underwent total laminectomy during the operation, no comparison was made (Table 2 and Figure 5).

There was no significant difference in the cross-sectional area of ligamentum flavum before the operation between the two groups (P > 0.05). The cross-sectional area of ligamentum flavum three weeks after the operation was smaller than that before the operation in the OLIF group (P < 0.05), and the cross-sectional area of ligamentum flavum one year after the operation was larger than that three weeks after the operation (P < 0.05), with an improvement rate of 21.3 (14.0–32.9)%. Since patients in the PLIF group underwent excision of ligamentum flavum during operation, no comparison was made (Table 2 and Figure 5).

## Comparison of Complications Between the Two Groups

In the OLIF group, 3 patients (16.7%) developed postoperative complications. One patient had hip flexion weakness, and two patients had elevated lower limb skin temperature accompanied by nocturnal burning pain. All patients did not have fusion cage subsidence, displacement, or pseudojoint formation.

In the PLIF group, 4 patients (25%) had postoperative complications. One patient had an incision infection, and three patients had intraoperative nerve traction injury and postoperative discomfort such as numbness and pain of the lower limbs on the decompression side. All patients did not have fusion cage subsidence, displacement, or pseudojoint formation.

# Discussion

The main principle of OLIF technology for the treatment of LSS is to tighten and retract the fibrous ring, posterior longitudinal ligament, and ligamentum flavum through effective adjacent intervertebral space dilatation and height

recovery, then expand the lumbar spinal canal, lateral recess, nerve root canal, and intervertebral foramen, eliminate the stress symptoms caused by stenosis, and finally reconstruct the stability of spine through intervertebral fusion. In this study, we analyzed the clinical effect of OLIF on indirect decompression in patients with severe LSS and compared the efficacy of indirect decompression via the oblique lateral approach and direct decompression via the posterior approach. The results showed that the cross-sectional area of the spinal canal was gradually expanded while the area of ligamentum flavum was decreased in patients receiving OLIF; the improvement of VAS and ODI scores of low back and leg pain in the PLIF group was better than that in the OLIF group three weeks after operation; there was no significant difference in VAS and ODI between the two groups one year after the operation. These findings suggest that the clinical effect of OLIF on the middle and long-term spinal canal dilatation of severe LSS is worthy of affirmation. These findings suggest that the clinical effect of OLIF on the mid-to-long-term spinal canal dilatation of severe LSS is worthy of affirmation. Given its minimally invasive nature and the achievement of outcomes comparable to PLIF at one year, OLIF can be considered a valuable choice for the surgical treatment of severe LSS.

The intervertebral disc forms the anterior wall and the ligamentum flavum forms the posterior wall of the lumbar spinal canal, and the posterolateral wall is the intervertebral facet joint. During intervertebral disc degeneration, the stress makes the intervertebral disc collapse, decreases the height, and relaxes the ligaments around the vertebral body, increasing the local load of the lumbar facet joint. Such repeated action in a non-physiological state destroys facet cartilage, as well as the formation, hypertrophy, and cohesion of osteophytes at the edge of the joint, leading to spinal canal stenosis.[17] When degeneration occurs, the biomechanical properties of the ligamentum flavum also change, which is characterized by increased stress, reduced strain, and inward folding and bulging of the ligamentum flavum. Meanwhile, stress stimulation or stress injury leads to cytokine alternations, inflammatory reactions, collagen synthesis increase, and elastic fiber degradation, thus eventually resulting in ligamentum flavum hypertrophy and compression.[18] Limthongkul et al[19] proposed that the tension of the ligamentum flavum affects the cross-sectional area of the spinal canal, and the relaxation of the ligamentum flavum after indirect decompression can increase the area of the spinal canal by about one-third. Although there is no exact quantitative relationship, it is enough to explain the relief of symptoms in clinical patients. However, the area changes of ligamentum flavum and dural sac during the follow-up after the OLIF operation are still unclear. Shimizu et al[9] found that in the case of severe stenosis, the cross-sectional area of the spinal canal was improved from 54.5 ± 19.2 $mm^2$ before the operation to 84.7 ± 31.8 $mm^2$ three weeks after the operation, and 132.6 ± 37.5 $mm^2$ at the last follow-up, with an average improvement time of 28.3 months. Takahashi et al[10] observed that in patients with spondylolisthesis complicated by severe spinal stenosis (CSA ≤ 50 $mm^2$), the average CSA of the spinal canal was increased from 35.8 $mm^2$ before the operation to 81.4 $mm^2$ immediately after the operation, and to 105.7 $mm^2$ two years after the operation. Nakashima et al[8] reported the follow-up results of 6 months, 1 year, and 2 years after lateral lumbar interbody fusion (LLIF) operation, and found that the cross-sectional area of ligamentum flavum was decreased significantly while the area of the spinal canal was increased, and the reduction degree of intervertebral disc bulging was increased with the extension of time. The decrease of the cross-sectional area of the ligamentum flavum caused by the relaxation of the ligamentum flavum is the immediate change after operation, and the remodeling of the ligamentum flavum is the reason for its continuous decrease.

The mechanism of ligamentum flavum remodeling after OLIF has not been determined. Some scholars speculate that the reason for ligamentum flavum remodeling may be related to the reduction of stress stimulation to ligamentum flavum by fusion and assisted posterior internal fixation. Ligamentum flavum remodeling can further enlarge the spinal canal.[20] In this study, we found that in patients with severe LSS (grade D) diagnosed by preoperative MRI, OLIF without posterior decompression did not significantly improve the ligamentum flavum area and dural sac area three weeks after the operation, nor obviously improved the VAS score and ODI of low back and leg pain; however, the VAS score and ODI of low back and leg pain in patients with severe LSS of the same grade were significantly improved after PLIF operation. Notably, the VAS score and ODI of low back and leg pain one year after OLIF operation were significantly improved compared with three weeks after operation in patients with spinal canal stenosis. While indirect decompression did not show an immediate clinical superiority, the radiological parameters improved progressively. With the passage of time, the cross-sectional area of ligamentum flavum and intervertebral disc bulging decreased significantly. At the same time, the spinal canal continued to expand, suggesting the promising long-term therapeutic effect of OLIF. With the

passage of time, the cross-sectional area of ligamentum flavum and intervertebral disc bulging decreased significantly, while the spinal canal continued to expand, suggesting the promising long-term therapeutic effect of OLIF.

At present, some documents have recorded the adaptive range of OLIF in the treatment of LSS. Through the 5-year follow-up of 557 LSS patients undergoing indirect decompression, Li et al[21] found that the secondary posterior decompression rate of LSS patients accompanied by severe degeneration of posterior articular process can reach 70.88–82.61%. Lang et al[6] also proposed that LSS patients accompanied by posterior articular process degeneration are not suitable for indirect decompression because the height of intervertebral space fails to be opened and the volume of the spinal canal can not be expanded effectively in an indirect way. At present, it is still uncertain whether severe articular process degeneration is a contraindication of OLIF operation and whether the articular process degeneration is aggravated or alleviated after OLIF. Goel et al[22] believed that LSS can be relieved by simple posterior arthrodesis to eliminate pathological spinal instability. In this study, we also found that the percentage improvement in the area of spinal canal dilatation was greater than the percentage reduction in the area of the ligamentum flavum [45.2% vs 21.3%], suggesting that other factors causing spinal stenosis were also improved, such as the reversal of posterior joint degeneration due to the restoration of spinal stability. Undoubtedly, this standpoint needs to be validated by further clinical research. According to the severity of spinal stenosis evaluated by Schizas classification, LSS patients with grades C and D were included in this study. The operative segment was the lumbar 3/4 or 4/5 intervertebral space, a common segment with degenerative changes. This paper analyzed the efficacy of OLIF-assisted posterior pedicle screw in the treatment of severe LSS. It was found that even severe LSS could be treated by indirect decompression, achieving a similar effect to direct decompression and fusion.

In the current study, there were no complications such as fusion cage subsidence, displacement, and pseudojoint formation in patients receiving OLIF or PLIF operation. Bocahut et al[23] reported that the fusion cage subsidence rate of simple OLIF (Stand alone operation) was 32%, with average subsidence of (5.5 ± 1.5) mm, but there was no significant correlation between fusion cage subsidence and clinical symptom improvement. Through meta-analysis, AlviMA et al[24] pointed out that the displacement rate of fusion cage after simple OLIF was 18%, while the displacement rate after combined internal fixation was 3%. The auxiliary pedicle screw can provide stronger stability, which contributes to avoiding the subsidence of the fusion cage. Shimizu et al[25] suggested the use of auxiliary posterior pedicle screws to provide strong stability during OLIF operation, thereby minimizing the symptoms related to instability. In this study, all cases underwent auxiliary posterior pedicle screws to prevent the above complications, showing a certain preventive effect.

Our study demonstrates that OLIF provides significant mid-term radiographic and clinical improvements in severe LSS, comparable to PLIF. However, we acknowledge that the surgical learning curve may influence early outcomes, particularly the higher postoperative complication rates observed during initial case implementations.[26] Additionally, when comparing OLIF to other techniques, our findings align with literature suggesting comparable efficacy between OLIF and TLIF/XLIF in select cases. For instance, OLIF exhibits advantages in restoring disc height and segmental lordosis but may be inferior to direct posterior approaches in achieving immediate canal expansion.[27] Additionally, OLIF with anterior fixation (OLIF-AF) reduces blood loss and operation time compared to OLIF with posterior fixation (OLIF-PF), yet fails to show superior patient-reported outcomes.[28] These nuances highlight that indirect decompression via OLIF is highly dependent on patient-specific anatomy, such as ligamentum flavum elasticity and the absence of severe facet joint arthropathy.

This study has several limitations that should be considered when interpreting the results. Firstly, its retrospective nature introduces the potential for selection bias, as the choice of surgical procedure was based on surgeon preference and patient-specific factors at the time, rather than randomization. Secondly, the follow-up period was limited to a mid-term duration of up to 2 years; longer-term follow-up is necessary to validate the durability of these outcomes and to assess the risk of adjacent segment disease. Thirdly, while the size and position of the interbody cage are critical determinants of the indirect decompression effect, we did not analyze their specific impact on the degree of spinal canal dilatation. Furthermore, we did not perform a comprehensive analysis correlating the extent of radiological improvement with the magnitude of clinical improvement. Future prospective, randomized controlled trials with larger sample sizes are

required to mitigate selection bias, confirm our findings, and precisely investigate the influence of technical factors such as cage specifications on clinical and radiological outcomes.

In conclusion, the findings of this study suggest that OLIF is a safe and effective alternative for achieving significant mid-term radiological and clinical improvement in severe LSS, with outcomes comparable to PLIF at one year. Future large-scale, prospective trials are warranted to confirm these findings and further refine patient selection criteria.

## Data Sharing Statement

Data will be made available available from the corresponding author on request.

## Ethics Approval and Informed Consent

The study protocol was reviewed and approved by the Medical Ethics Committee of the 900th Hospital of the Joint Logistic Support Force (Approval Number: 2025-089). This study confirmed that informed consent was obtained from the participants, and also confirmed that the guidelines outlined in the Declaration of Helsinki were followed.

## Author Contributions

All authors made a significant contribution to the work reported, whether that is in the conception, study design, execution, acquisition of data, analysis and interpretation, or in all these areas; took part in drafting, revising or critically reviewing the article; gave final approval of the version to be published; have agreed on the journal to which the article has been submitted; and agree to be accountable for all aspects of the work.

## Funding

There is no funding to report.

## Disclosure

The author(s) report no conflicts of interest in this work.

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