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A retrospective cohort study comparing perioperative clinical outcomes and radiographic results between patients undergoing TLIF and OLIF surgeries

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Abstract

Purpose To investigate the perioperative outcomes, clinical manifestations, and radiographic indicators in patients who underwent oblique lateral lumbar fusion (OLIF) and posterior instrumentation, compared with those who underwent posterior transforaminal lumbar interbody fusion (TLIF) and instrumentation.

Methods In this retrospective cohort analysis, elderly patients diagnosed with L4-5 lumbar spinal stenosis between July 2022 and July 2023 at our institution who underwent OLIF and posterior instrumentation (OLIF group), compared with those who underwent posterior TLIF and instrumentation (TLIF group). Enhanced Recovery After Surgery (ERAS) protocol was implemented for all patients. The perioperative data, patient-reported outcomes (PROs), radiographic assessments, and complications were gathered immediately after surgery and again at the 1-year follow-up. The perioperative outcomes and immediately postoperative and follow-up radiographic outcomes were compared between the two groups.

Results A total of 120 patients participated in this study, with 60 patients assigned to the OLIF group and 60 to the TLIF group. With respect to outcomes, the length of stay was notably shorter in the OLIF group compared to the TLIF group ($P<0.001$). Patients in the OLIF group exhibited significantly reduced postoperative drainage volume ($P<0.001$), first ambulation on the postoperative day (POD) ($P<0.001$), drain placement duration ($P<0.001$), and urinary catheter retention ($P=0.037$) compared to those in the TLIF group. Furthermore, there were statistically significant differences between the two groups in the incidence of postoperative deep venous thrombosis (DVT) (1 vs. 8, $P=0.015$), urinary tract infection (2 vs. 11, $P=0.008$), pulmonary infection (2 vs. 10, $P=0.015$), and nausea and vomiting (3 vs. 11, $P=0.023$). With respect to radiographic measurements, At the 1-year follow-up, the posterior disc height (PDH) and intervertebral disc angle (IDA) demonstrated statistically increase in the OLIF group. The sagittal vertical axis (SVA) was statistically decrease and Lumbosacral lordosis (LL) was statistically increase in the OLIF group.

Conclusion OLIF was demonstrated to have significant advantages in terms of perioperative, clinical outcomes and radiographic parameters for L4-5 lumbar spinal stenosis for elderly patients, comapred with TLIF.

Keywords ERAS, Oblique lateral lumbar fusion, Transforaminal lumbar interbody fusion, Perioperative outcomes, Local intervertebral disc parameters

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Introduction

Lumbar spinal stenosis (LSS) is a elderly condition caused by various forms of narrowing of the spinal canal, neural canal, and intervertebral foramina, as well as a series of altered spinal canal volumes caused by soft tissues and the narrowing of the dural sac itself [1]. As the aging population intensifies, the prevalence of lumbar spinal stenosis has reached 3.9%- 16% [2, 3]. It is one of the most common conditions that lead to low back pain or neurological manifestations such as intermittent claudication [4], which has a profound impact on a patient's quality of life [5].

Since the TLIF procedure was proposed and applied to lumbar spinal stenosis, it has become one of the most commonly used techniques for lumbar interbody fusion [6]. However, with the widespread application of TLIF in the treatment of various degenerative lumbar diseases, people have begun to worry about its limitations, such as severe iatrogenic injury, paraspinal muscle atrophy, and limitations in correcting coronal imbalance and restoring lordosis [7]. Previous multicenter studies have demonstrated that, in comparison to transforaminal lumbar interbody fusion (TLIF), ALIF/lateral lumbar interbody fusion achieves greater segmental lordosis [8] and more favorable improvements in spinopelvic parameters [9].

The oblique lateral lumbar fusion (OLIF) is mainly accessed from the natural corridor between the anterior obliquely lateral psoas muscle and the sheath of the abdominal great vessels [10, 11]. Mehren C et al. showed that OLIF has a significant advantage over TLIF in the treatment of lumbar degenerative disc disease [12]. The larger fusion cage of OLIF has a significant effect on vertebral balance. The Enhanced Recovery After Surgery (ERAS) protocol, as a nursing model that can effectively reduce surgical stress response, is particularly important for elderly spinal patients. However, previous studies have primarily concentrated on the alterations in sagittal balance following oblique lateral lumbar fusion (OLIF), with a notable scarcity of research examining the perioperative outcomes associated with this procedure for elderly patients with single-segment L4 - 5 lumbar spinal stenosis following the use of ERAS protocols [13]. Therefore, the objective of this study was to comprehensively evaluate the perioperative outcomes (including intraoperative blood loss, operation time, postoperative complications, length of stay, 1 st ambulation on POD, urinary catheter retention and drain placement), clinical outcomes, and radiographic outcomes immediately after surgery and at the 1-year follow-up in elderly patients undergoing oblique lateral lumbar fusion (OLIF).

Materials and methods

Study design

This retrospective controlled study was granted approval by the Institutional Review Board of Capital Medical University Xuanwu Hospital (IRB#2,018,086). Informed consent was obtained in accordance with institutional requirements. We retrospectively analyzed consecutive patients aged 65 and older with single-segment L4 - 5 lumbar spinal stenosis (LSS) admitted to our institution between July 2022 and July 2023. The ERAS protocol was utilized in all patients. Inclusion criteria comprised: 1) patients aged over 65 years; and 2) a diagnosis of LSS confirmed by radiography and previous medical records. Exclusion criteria were as follows: 1) LSS secondary to lumbar spinal trauma, infection, tuberculosis, tumors, or other causes; 2) patients with sagittal imbalance, spinal malformations, or space-occupying lesions in the spinal canal; 3) patients with previous surgical treatment of the relevant segment or who were medically unfit for surgery; and 4) patients with LSS lacking postoperative imaging data. 5) involving the types of pathology at L45 such as isthmic spondylolisthesis, degenerative spondylolisthesis, vacuum disc phenomena, or osteoporosis. Diagnostic criteria for LSS were based on the second edition of the guidelines for the diagnosis and treatment of degenerative lumbar spinal stenosis published by the North American Spine Society (NASS), where all patients exhibited neurogenic intermittent claudication and lower back pain relieved by sitting or bending forward. In this study, surgeons fully introduced the OLIF and TLIF surgical techniques to patients and their families based on the patients'anatomical characteristics, symptoms, and the presence of comorbidities, and the patients and their families voted together to choose the surgical approach. Ultimately, patients were divided into OLIF group and TLIF group. We confirm that all cases in the OLIF group underwent indirect decompression, all cases in the OLIF group underwent bilateral decompression.

Perioperative nursing care

In this study, all patients underwent the ERAS protocol. The ERAS interventions were divided into preoperative, intraoperative, and postoperative steps [14].

Preoperative steps:

(1) Education and counseling. A nurse explained the pre-and postoperative stages of the ERAS procedure, the discharge criteria, and the main scenarios that can occur early after discharge.
(2) Preoperative nutrition. ERAS protocol took the form of 2 h of water fasting and 8 h of fasting before

anesthesia. Timely nutritional supplementation if the nutritional level is low after the first operation.

(3) Fluid and carbohydrate loading. A carbohydrate drink was allowed up to 2 h before surgery.
(4) Preventable analgesia: 75 mg pregabalin given orally the day before surgery.

Intraoperative steps:

(1) Antibiotic prophylaxis within 1 h of the incision.
(2) Tranexamic acid within 30 min of incision.
(3) Maintenance of normothermia, which involved keeping the core body temperature at 36–37 °C.
(4) Local anesthesia was used before incision and after suturing.

Postoperative steps:

(1) Early oral feeding. This involved drinking water early after recovery from anesthesia, early feeding starting at 6 h, and protein powder supplement during the liquid phase.
(2) Early ambulation. This involved postoperative ambulation after 24 h.
(3) Early removal of bladder catheter after 24 h.
(4) Multimodal analgesia: including a combination of acetaminophen, non-steroidal anti-inflammatory drugs, steroids, and pregabalin. Data on nutritional levels, drainage, drain placement, the postoperative 1 st ambulance on POD, urinary catheter removal, and postoperative hospital stay after secondary surgery were collected.

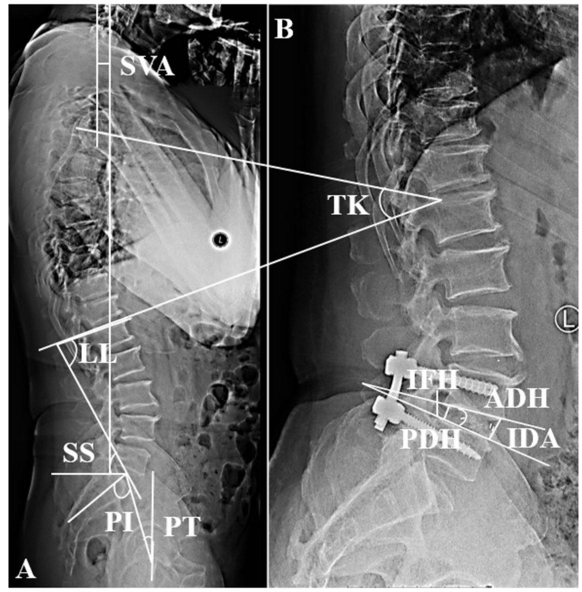

Fig. 1 Radiographic evaluation of the spinal sagittal parameters. A. SVA indicates sagittal vertical axis, TK indicates thoracic kyphosis, LL indicates lumbar lordosis, SS indicates sacral slope, PI indicates pelvic incidence, PT indicates pelvic tilt. B. PDH indicates posterior disc height, ADH indicates anterior disc height, IFH indicates intervertebral foramen height, IDA indicates intervertebral disc angle

Clinical indicators and imaging outcome

Demographic characteristics and surgery-related indicators, including age, body mass index (BMI), American Society of Anesthesiologists (ASA) score, Charlson Comorbidity Index (CCI), operative duration, and intraoperative estimated blood loss, were collected. The data reported reflect the total of both stages. Also, through the patient's laboratory examination, we collected preoperative albumin and total lymphocyte counts to estimate the preoperative nutritional status of patients. Postoperative outcomes, such as length of hospital stay, complications, nutritional status, and symptom improvement, were also documented. Preoperative, postoperative, and 1-year follow-up assessments were conducted using Visual Analog Scale (VAS) and Oswestry Disability Index (ODI) scores. The achievement of minimal clinically important difference (MCID) for patient-reported outcomes (PROs) (VAS, ODI) were collected in the 1-year follow-up. Sagittal parameters, including thoracic kyphosis (TK), lumbar lordosis (LL), pelvic incidence (PI), pelvic tilt (PT), sacral slope (SS), and sagittal vertical axis (SVA), as well as local intervertebral disc parameters, including intervertebral foramen height (IFH), intervertebral disc angle (IDA), anterior disc height (ADH), and posterior disc height (PDH), were measured on preoperative, postoperative, and 1-year follow-up full-length spine radiographs for both groups. All radiological measurements were independently performed by a radiologist and a spine surgeon, and the averages were calculated. The global sagittal parameters measured are illustrated in Fig. 1. The established MCID thresholds were as follows: a minimum improvement of 1.2 points from baseline for back pain VAS, 1.6 points for leg pain VAS, 12.8 points for ODI scores. Early ambulation was defined as getting out of bed within 1 day after surgery, early urinary catheter removal was defined as removal within 1 day postoperatively, and when the drainage volume is < 50 ml/day, the drainage tube should be removed, as previously described in our hospital's literature. All patients were evaluated for clinical signs of DVT, such as swelling, pain, and redness in the lower extremities. Patients with a high clinical suspicion of DVT or those who scored above a certain threshold on the [e.g., Wells score] were referred for ultrasound evaluation.

Surgical procedures

OLIF technique

The patient was placed in the right lateral position after general anesthesia. The deep internal oblique and transversus abdominis muscles were distinctly separated in the direction of the muscle fibers. The target disc is removed and then the cartilaginous endplate is removed. Put in the right fusion device. The surgical site was flushed with saline several times, and the incision was closed layer by layer after stopping the bleeding [15]. The second posterior approach was performed, the patient was kept in the prone position, the fascial layer was separated to find the muscle corridor, and the screws were fixed using a pedicle screw-rod internal fixation device after bluntly separating and propping up the muscle corridor in the lateral space of the multifidus muscle(Wiltse). An artificial bone or autogenous bone-filled fusion device of appropriate height and length is then selected and tapped into the intervertebral space. Finally, close layer by layer after stopping the bleeding [16].

TLIF technique

The patient was anesthetized and kept in a prone position. After the incision was opened to expose the transverse processes, bilateral pedicle screws were implanted. Subsequently, a partial Minor arthrodesis, laminectomy, and ligamentum flavum resection were performed on the symptomatic side. The fragmented bone obtained through access/decompression is then placed posterior to the implant block along with the interbody fusion at the feasible height. Multiaxial pedicle screws and a crescent-shaped interbody fusion device were used for internal fixation. Finally, close layer by layer after stopping the bleeding [17].

Statistical analysis

Histograms and Shapiro–Wilk test were used to evaluate the distribution of numerical variables.Continuous variables were expressed as mean ±standard deviation and analyzed using the Student's t test as appropriate. For variables with multiple comparisons, we used Friedman analysis with FDR adjustments. Categorical variables were expressed as frequencies with percentages and analyzed using chi-square tests. All statistical analyses were performed using SPSS Statistics 26 (SPSS, version 22.0, Inc. Chicago, IL, USA).

Results

Patient demographics

A total of 120 patients were enrolled in the study, with 60 patients assigned to each of the two groups. The results are presented in Table 1. Demographic analysis revealed no statistically significant differences between the two groups. However, a slightly higher proportion of Grade D patients was observed in the TLIF group compared to the OLIF group (30% vs. 23.3%), although this difference was not statistically significant ($P = 0.471$). Furthermore, no statistically significant differences were found in operative time (106.25 ±34.92 vs. 120.88 ±38.06, $P= 0.218$) or estimated blood loss (166.13 ±85.52 vs. 239.42 ±103.83, $P= 0.061$) between the two groups. Preoperative comorbidities were assessed using the CCI for both groups, as shown in Table 2.

Table 1 Demographics and surgical characteristics

	OLIF	TLIF	P
Age (years)	73.13 ±6.85	72.02 ±6.47	0.204
Male/Female	12/48	15/45	0.512
BMI (kg/m^2)	24.36 ±3.57	24.83 ±3.35	0.456
ASA	2.40 ±0.53	2.63 ±0.89	0.169
≤ 2	36(60.0%)	33 (55.0%)	
2 < n ≤ 4	24(40.0%)	27(45.0%)	
CCI	4.80 ±1.46	4.73 ±1.29	0.766
n ≤ 2	36(60.0%)	32(53.3%)	
> 2	24(40.0%)	28(46.7%)	
Hemoglobin (g/L)	127.21 ±15.04	126.48 ±13.89	0.491
Albumin (g/L)	38.74 ±3.61	38.28 ±3.49	0.297
Total lymphocyte counts(10^9/L)	1.77 ±0.78	1.92 ±0.73	0.631
Co-Morbidities, n (%)			
Osteoporosis	31(51.6%)	37(61.6%)	
Diabetes disease	9(15.0%)	18(30.0%)	
Hypertension	25(41.6%)	43(71.6%)	
Schizas Grade	2.85 ±0.92	2.98 ±0.98	
Grade A	6(10.0%)	8(13.3%)	0.471
Grade B	15(25.0%)	10(16.7%)	
Grade C	25(41.7%)	24(40.0%)	
Grade D	14(23.3%)	18(30.0%)	
Lee Grade			0.432
Grade 0/1	7(11.7%)	10(16.7%)	
Grade 2/3	53(88.3%)	50(83.3%)	
Operative time (min)	106.25 ±34.92	120.88 ±38.06	0.218
Estimated blood loss (ml)	166.13 ±85.52	239.42 ±103.83	0.061

BMI Body Mass Index; *ASA* American Society of Anesthesiologists; *CCI* Charlson Comorbidity Index

Postoperative outcomes

As shown in Table 3, the postoperative length of hospital stay in the OLIF group was significantly lower than that in the TLIF group (3.52 ±3.94 vs. 6.81 ±4.28, $P< 0.001$). The percentage of postoperative blood transfusion and albumin transfusion in the OLIF group was significantly lower than that in the TLIF group. The patients in the OLIF group had significantly lower postoperative drainage volume (109.11 ±35.13 vs. 225.92 ±43.64, $P< 0.001$),

Table 2 The detailed information and incidence of CCI (Chronic Comorbidity Index) in present study

Comorbidity	OLIF	TLIF
1 point		
Myocardial infarction	4	5
Congestive heart failure	1	1
Peripheral vascular disease	21	19
Cerebrovascular disease	2	4
Dementia	0	0
Chronic pulmonary disease	2	6
Connective tissue disease	3	4
Ulcer disease	2	5
Mild liver disease	1	1
Diabetes	11	10
2 points		
Hemiplegia	0	2
Moderate or severe renal disease	1	2
Diabetes with end organ damage	0	0
Any tumor	1	1
Leukemia	0	0
Lymphoma	0	0
3 points		
Moderate or severe liver disease	1	1
6 points		
Metastatic solid tumor	0	1
AIDS	0	0

the postoperative 1st ambulance on POD (1.79 ±1.70 vs 3.42 ±2.00, $P<$ 0.001), drain placement (3.40 ±1.35 vs 4.73 ±2.23, $P<$ 0.001) and urinary catheter retention (2.67 ±1.95 vs 3.86 ±2.79, $P=$ 0.037) was significantly lower than those in the TILF group. Meanwhile, There were notable differences in the incidence of postoperative DVT ($P = 0.015$), urinary tract infection ($P = 0.008$), pulmonary infection ($P = 0.015$), and nausea and vomiting ($P = 0.023$) between the two groups. In addition, the number of postoperative patients in the TLIF group who temporarily experienced lower extremity weakness ($P =$ 0.027) and numbness ($P = 0.018$) was significantly greater than that in the OLIF group.

Pain rating scale

The results are shown in Table 4. There were notable differences between preoperative and postoperative VAS scores of the lower leg and lower back between the two groups (P1 <0.05); but between postoperative and 1-year follow-up (P2 >0.05), there was no statistically significant difference. Also, the ANOVA found a statistically significant difference between the two groups in ODI scores within the group between preoperative and postoperative (P1 <0.05), and between postoperative and 1-year follow-up (P2 <0.05). The proportion of patients who achieved MCID in the 1-year follow-up ODI scores differed significantly ($p = 0.032$).

Local radiographic parameters

The local parameters are detailed in Table 5. The preoperative PDH, ADH, IFH, and IDA were no statistically significant differences between the two groups ($P > 0.05$). However, there are obvious differences after surgery($P <$ 0.05). The PDH and IDA have a statistically significant differences in 1-year follow-up between the two groups. Statistically significant differences were found in preoperative and postoperative PDH (P1 <0.001), ADH (P1 <0.001), IFH (P1 <0.001), and IDA (P1 =0.001) in patients in the OLIF group. There were notable differences between preoperative and postoperative patients in the TLIF group on PDH (P1 <0.001), ADH (P1 =0.044), IFH (P1 =0.029), and IDA (P1 =0.041). There were no statistically significant differences in postoperative and 1-year follow-up both groups.

Global sagittal parameters

Preoperative, postoperative, and follow-up periods TK, TLK, PT, PI, SS, and SVA in the OLIF group did not differ from those in the TLIF group ($P > 0.05$). For the preoperative and postoperative results within the two groups, there were statistically significant differences in all global sagittal parameters except for PI ($P = 0.128$), which were not significantly different in the TLIF group. At postoperative and 1-year follow-up, there also were no statistically significant differences between the two groups except for significant differences in LL and SVA(Table 6).

Discussion

With the current aging of the population, the proportion of elderly patients with lumbar spinal stenosis is gradually increasing [18]. Previous research has indicated that L4 -5 and L5-S1 are the prevalent segments affected by lumbar spinal stenosis. Nevertheless, in the context of spinal surgery, a relatively small proportion of these cases involve the L5-S1 level. Consequently, this study has centered its attention on the statistical analysis of patients specifically diagnosed with L4 -5 lumbar spinal stenosis. The high number of preoperative comorbidities accompanying elderly patients often leads to a slow recovery of physiologic function, resulting in a high incidence of postoperative complications [19]. OLIF, as a surgical approach from the patient's anterolateral natural space, has been widely used in the treatment of degenerative spinal pathology.

Lateral lumbar interbody fusion(LLIF), including extreme lateral interbody fusion(XLIF) and oblique lateral interbody fusion(OLIF), constitute a treatment

Table 3 Postoperative outcome

	OLIF	TLIF	P
Post-LOS (days)	3.52 ± 3.94	6.81 ± 4.28	**< 0.001**
Postoperative blood transfusion	6(10.0%)	22(37.7%)	**0.001**
Postoperative albumin transfusion	10(16.7%)	25(41.7%)	**0.003**
1 st Hemoglobin on Postoperative (g/L)	112.67 ± 17.60	111.23 ± 16.18	0.646
1 st Albumin on Postoperative (g/L)	30.17 ± 9.78	29.05 ± 3.60	0.469
Hemoglobin at discharge (g/L)	108.13 ± 16.65	110.67 ± 14.17	0.935
Albumin at discharge (g/L)	31.76 ± 2.89	32.39 ± 3.43	0.918
Drain placement (days)	3.40 ± 1.35	4.73 ± 2.23	**< 0.001**
Drainage volume (ml)	109.11 ± 35.13	225.92 ± 43.64	**< 0.001**
Urinary catheter retention (days)	2.67 ± 1.95	3.86 ± 2.79	**0.037**
1 st ambulation on POD (days)	1.79 ± 1.70	3.42 ± 2.00	**< 0.001**
90-day reoperation, n (%)	1(1.7%)	3(5.0%)	0.309
90-day readmission, n (%)	2(3.3%)	5(8.3%)	0.243
Complications, n (%)			
Wound infarction	2(3.3%)	6(10.0%)	0.143
DVT	1(1.7%)	8 (13.3%)	**0.015**
Cerebrovascular accident	0(0%)	1(1.7%)	0.315
Urinary Retention	2(3.3%)	4(6.6%)	0.402
Urinary tract infection	2(3.3%)	11(18.3%)	**0.008**
Delirium	1(1.7%)	5 (8.3%)	0.094
Pneumonia	2(3.3%)	10(16.6%)	**0.015**
Nausea/vomiting	3(5.0%)	11(18.3%)	**0.023**
Headache	3(5.0%)	9(15.0%)	0.068
Local hematoma	2(3.3%)	6(10.0%)	0.143
1-year follow-up outcomes			
Subsidence	2(3.3%)	6(10.0%)	0.143
Rreoperation, n (%)	3(5.0%)	5(8.3%)	0.593
Readmission, n (%)	1(1.7%)	6(10.0%)	0.055
Leg weakness			
Transient	2(3.3%)	9(15.0%)	**0.027**
Persistent	0(0.0%)	2(3.3%)	0.154
Leg numbness			
Transient	4(6.6%)	13(21.7%)	**0.018**
Persistent	0(0.0%)	3(5.0%)	0.079

Significant results with $P < 0.05$ in bold. Post-LOS, postoperative length of stay

option for many lumbar disorders that predominantly cause degenerative disc disease. LLIF is beneficial for managing conditions, such as lumbar spondylolisthesis, degenerative disc disease, and adult spinal deformities. It has been shown that OLIF and other lateral interbody fusion can effectively reduce surgical trauma to promote patients'postoperative physiological function recovery [20]. Compared with minimally invasive surgery (MIS)—transforaminal interbody fusion (TLIF), lateral interbody fusion has better results in patients with lumbar spinal stenosis, as demonstrated in a study by Hiyama A et al. [21]. In this study, the authors divided all patients into two groups according to the surgical method: were treated with MIS-TLIF (direct decompression group; DP), and were treated with XLIF (indirect decompression group; IDP). The authors found that although postoperative pain was improved in both groups, IDP surgery was superior in terms of reducing bleeding and preserving posterior supporting elements such as facet joints, lamina, and paraspinal muscles. These findings suggest that IDP surgery results in better postoperative outcomes compared with DP surgery. This conclusion was also confirmed in our study, where we found that indirect decompression with OLIF surgery resulted in

Table 4 Pain rating scale

	OLIF	TLIF	P
VAS of back			
Preoperative	6.48 ± 0.42	6.45 ± 0.64	0.804
Postoperative	2.63 ± 0.89	2.89 ± 1.05	0.116
Follow-up	1.53 ± 0.76	1.87 ± 1.11	0.135
P	**P1 < 0.001**, P2 = 0.423	**P1 < 0.001**, P2 = 0.573	
VAS of leg			
Preoperative	6.30 ± 0.73	6.29 ± 0.70	0.893
Postoperative	2.81 ± 0.69	2.81 ± 0.63	0.973
Follow-up	1.71 ± 0.54	1.97 ± 1.07	0.307
P	**P1 < 0.001**, P2 = 0.431	**P1 < 0.001**, P2 = 0.541	
ODI (%)			
Preoperative	53.37 ± 2.73	54.37 ± 3.71	0.068
Postoperative	21.10 ± 2.54	25.64 ± 2.88	**0.031**
Follow-up	17.10 ± 3.54	21.73 ± 3.07	**0.027**
P	**P1 < 0.001**, **P2 = 0.021**	**P1 < 0.001**, **P2 = 0.028**	
Achieved MCID at 1-year follow-up			
Achieved MCID for VAS-low back	54 (90.0%)	51 (85.0%)	0.408
Achieved MCID for VAS-leg	55 (91.7%)	52 (86.7%)	0.378
Achieved MCID for ODI	56 (93.3%)	48 (80.0%)	**0.032**

Significant results with $P < 0.05$ in bold; *VAS* Visual Analog Scale, *ODI* Oswestry Disability Index, *MCID* minimal clinically important difference

P1 represents preoperative v.s. postoperative; P2 represents postoperative v.s. follow-up

better perioperative outcomes than direct decompression with TLIF. Also, in a study by Du et al. [22], they compared the efficacy of OLIF and TLIF for the treatment of single-segment degenerative lumbar spondylolisthesis (DLS). In this study, the authors observed that the implementation of OLIF for the treatment of DLS resulted in shorter operative times, reduced bleeding, and decreased postoperative drainage. In alignment with the findings of this study, our research also demonstrated that, compared to TLIF, the application of OLIF for patients with LSS led to less surgical bleeding, a shorter hospital stay, decreased postoperative drainage and a decreased rate of postoperative complications. Furthermore, we noted that postoperative hemoglobin and albumin levels were significantly below the normal range in both groups, with lower levels observed in the TLIF group; however, these differences did not reach statistical significance between the two groups. This is consistent with the study by Chen et al. [23], which also found no significant difference in postoperative hemoglobin and albumin levels. However, our study revealed a higher percentage of postoperative blood and albumin transfusions in the TLIF group compared to the OLIF group. This may be due to blood loss was estimated using intraoperative suction and drainage output, which are the standard methods used in many studies. However, we acknowledge that this approach may not fully account for hidden blood loss, especially in OLIF, where blood loss may be underreported. Therefore, the hemoglobin level is higher after OLIF. Regarding postoperative transfusions, likely due to the greater surgical trauma, which contributed to higher blood loss.

Recovery of postoperative physiologic function is a major concern, especially for elderly patients [24]. Compared to younger patients, the prolonged postoperative lying down time in elderly patients is more likely to experience thromboembolism. Wang et al. [25], showed that early postoperative exercise aids recovery and reduces DVT incidence. However, in the case of elderly LSS patients, early postoperative exercise is still a major test, patients'poor postoperative physical functioning and low postoperative nutritional levels all contribute to patients getting off the floor late in the postoperative period [26]. The advantages of OLIF, which involves a two-stage procedure, include its relatively short duration and minimally invasive nature, effectively addressing this issue. Consistent with this study, our findings indicate a significant reduction in postoperative time to ambulation for patients in the OLIF group compared to those in the TLIF group, along with a lower incidence of DVT. The observed DVT rate of 13.3% in our cohort is higher than the typical rates reported in other studies [27], which may be attributed to our higher-risk patient population and more rigorous screening protocols. Additionally, the OLIF group exhibited significantly

Table 5 Local image-based parameters

L45	OLIF	TLIF	P
PDH(mm)			
Preoperative	8.91 ± 2.84	8.66 ± 2.33	0.623
Postoperative	13.24 ± 3.62	11.34 ± 4.39	**0.046**
Follow-up	17.46 ± 9.23	13.55 ± 4.23	**0.001**
P	**P1 < 0.001**, P2 = 0.052	**P1 < 0.001**, P2 = 0.106	
ADH(mm)			
Preoperative	12.30 ± 4.02	12.75 ± 4.35	0.585
Postoperative	17.99 ± 4.21	13.90 ± 4.89	**0.031**
Follow-up	17.10 ± 3.54	16.73 ± 6.07	0.607
P	**P1 < 0.001**, P2 = 0.247	**P1 = 0.044**, P2 = 0.121	
IFH(mm)			
Preoperative	18.58 ± 3.39	19.14 ± 3.90	0.428
Postoperative	24.92 ± 6.64	21.09 ± 4.99	**0.047**
Follow-up	23.74 ± 6.21	22.23 ± 5.88	0.137
P	**P1 < 0.001,** P2 = 0.535	**P1 = 0.039**, P2 = 0.897	
IDA(°)			
Preoperative	6.30 ± 4.72	6.50 ± 4.24	0.817
Postoperative	8.38 ± 5.61	7.02 ± 4.17	**0.027**
Follow-up	9.27 ± 4.61	7.80 ± 4.44	**0.025**
P	**P1 = 0.001**, P2 = 0.105	**P1 = 0.041**, P2 = 0.904	

PDH posterior disc height, *ADH* anterior disc height, *IFH* intervertebral foramen height, *IDA* intervertebral disc angle; Significant results with $P < 0.05$ in bold. P1 represents preoperative v.s. postoperative; P2 represents postoperative v.s. follow-up

Table 6 Sagittal parameter

	OLIF	TLIF	P
TK			
Preoperative	26.10 ± 16.46	23.52 ± 13.37	0.383
Postoperative	31.40 ± 14.47	27.73 ± 16.12	0.120
Follow-up	33.96 ± 16.39	29.78 ± 12.56	0.116
P	**P1 = 0.002**, P2 = 0.153	**P1 = 0.017**, P2 = 0.121	
TLK			
Preoperative	25.46 ± 12.72	22.70 ± 16.40	0.340
Postoperative	17.68 ± 11.96	18.86 ± 9.35	0.673
Follow-up	16.79 ± 12.61	13.80 ± 6.84	0.075
P	**P1 = 0.002**, P2 = 0.701	**P1 = 0.001**, P2 = 0.292	
LL			
Preoperative	27.45 ± 16.12	25.13 ± 18.11	0.427
Postoperative	33.08 ± 17.24	29.47 ± 12.07	**0.045**
Follow-up	37.21 ± 15.87	33.73 ± 14.12	**0.002**
P	**P1 = 0.009**, **P2 < 0.001**	**P1 = 0.007**, **P2 = 0.032**	
PT			
Preoperative	33.08 ± 9.44	31.29 ± 15.49	0.477
Postoperative	27.96 ± 15.24	29.30 ± 10.54	0.211
Follow-up	23.86 ± 15.00	26.52 ± 11.55	0.052
P	**P1 < 0.001**, P2 = 0.115	**P1 = 0.023**, P2 = 0.508	
PI			
Preoperative	50.05 ± 13.35	52.05 ± 13.36	0.437
Postoperative	55.57 ± 15.77	55.47 ± 8.91	0.931
Follow-up	58.83 ± 14.09	56.59 ± 11.19	0.365
P	**P1 = 0.039**, P2 = 0.077	P1 = 0.128, P2 = 0.687	
SS			
Preoperative	26.94 ± 9.64	31.43 ± 13.81	0.058
Postoperative	21.31 ± 13.06	25.30 ± 11.00	0.097
Follow-up	17.18 ± 12.54	21.84 ± 10.26	0.051
P	**P1 = 0.014**, P2 = 0.084	**P1 = 0.039**, P2 = 0.205	
SVA			
Preoperative	12.02 ± 7.36	11.77 ± 5.06	0.838
Postoperative	7.65 ± 4.64	9.71 ± 5.38	0.169
Follow-up	4.80 ± 4.76	6.27 ± 4.33	0.345
P	**P1 < 0.001**, **P2 = 0.020**	**P1 = 0.047**, **P2 < 0.001**	

TK toracic kyphosis, *TLK* thoracolumbar Kyphosis, *LL* lumbar lordosis, *PI* pelvic incidence, *PT* pelvic tilt, *SS* sacral slope, *SVA* sagittal vertical axis; Significant results with $P < 0.05$ in bold. P1 represents preoperative v.s. postoperative; P2 represents postoperative v.s. follow-up

decreased postoperative urinary catheter retention time, drain retention time, and drainage volume compared to the TLIF group ($P < 0.05$). Furthermore, the incidence of postoperative wound infections and urinary tract infections was also lower in the OLIF group. These conclusions are supported by a study conducted by Long Zhao, MD, et al. [28].

In this study, we compared ADH, PDH, IFH, and IDA parameters preoperatively, postoperatively, and at follow-up. Both groups showed significant improvement postoperatively, with the OLIF group showing stronger improvement than the TLIF group. The clinical cases of the three groups are shown in Fig. 2.This is consistent with the results of a retrospective study of patients with lumbar degenerative disease undergoing OLIF at L5-S1 by Nam-Su Chung et al. [29]. To evaluate the long-term effects of OLIF after surgery, we analyzed the parameters at the 1-year postoperative follow-up. It was found that there was still a significant improvement in these parameters relative to the preoperative period. This suggests that disc parameters were effectively maintained at follow-up after both OLIF and TLIF. Also, in this study, we investigated the overall sagittal parameters. Consistent with the results of the previous study, postoperative sagittal parameters were significantly improved and statistically different in both groups. However, we discovered the postoperative LL and PI results were slightly smaller

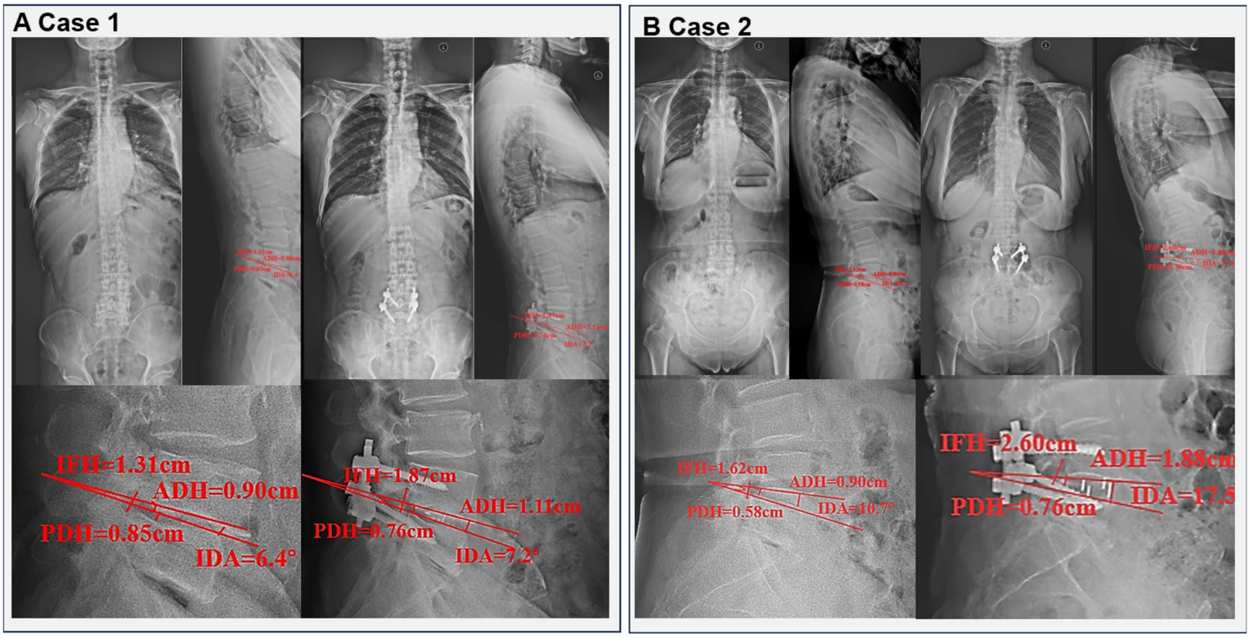

Fig. 2 A (case 1): A 71-year-old male patient underwent L4-L5 TLIF with a 1-year follow-up. Preoperative IFH, PDH, and ADH was 1.31 cm, 0.85 cm and 0.90 cm, respectively. At the 1-year follow-up, the IFH, PDH, and ADH was 1.87 cm, 0.76 cm and 1.11 cm, respectively, ISA increased from 6.4° to 7.2°. B (case 2): A 75-year-old female patient underwent L4-L5 two-stage OLIF with a 1-year follow-up. Preoperative IFH, PDH, and ADH was 1.62 cm, 0.58 cm and 0.90 cm, respectively. At the 1-year follow-up, the IFH, PDH, and ADH was 2.60 cm, 0.76 cm and 1.88 cm, respectively, ISA increased from 10.7° to 17.5°

than those of the OLIF group. This is consistent with the study by Xu et al. [3]. In the 1-year follow-up results, we found that the degree of improvement in sagittal position was significantly stabilized while LL was significantly increased and SVA was significantly decreased in both groups. Compared to the TLIF group, the OLIF group improvement was better. However, due to factors such as psoas muscle anatomy, vascular structure, and degree of foraminal stenosis, not all patients with single-level spinal stenosis are anatomically or clinically suitable for OLIF. In some cases, TLIF remains a valuable surgical option, especially in the following situations: patients have severe foraminal stenosis that requires direct decompression, which is easier to achieve with TLIF; anatomical limitations, such as high iliac crests or abnormal vascular anatomy, make OLIF technically challenging or unsafe. We believe that both techniques have their own role in the management of single-level spinal stenosis, and the decision should be tailored to each patient's situation to optimize the outcome.

The present study is subject to several limitations. Firstly, only 60 patients met the inclusion criteria in each of the OLIF and TLIF groups, which inherently limits the statistical power and robustness of our conclusions due to the small sample size. Secondly, in our study, blood loss was estimated using intraoperative suction and drainage output, which are the standard methods used in many studies. However, this approach may not fully account for hidden blood loss, especially in OLIF, where blood loss may be underreported. Postoperative hemoglobin trends could offer a more complete picture of total blood loss, but due to inconsistent data availability, we did not include this in our analysis. We suggest that future studies incorporate serial hemoglobin measurements to better capture hidden blood loss in OLIF procedures. Additionally, the retrospective nature of the analysis may have introduced biases and further complicated the interpretation of our findings. Secondly, all patients were recruited from the same medical center, which may introduce additional limitations and biases. Therefore, further multicenter studies with larger cohorts are necessary to validate and generalize our current findings.

Conclusion

OLIF demonstrated greater perioperative benefits for elderly patients with L4 - 5 lumbar spinal stenosis. Additionally, OLIF effectively improved local intervertebral disc parameters and overall sagittal alignment parameters in the postoperative period, with these improvements being well-maintained at the 1-year follow-up.

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Authors' contributions
Qingyang Huang collected the data and wrote the article, Shuaikang Wang, Peng Cui and Di Han processed the data, and Weiguo Zhu and Shibao Lu revised the article. Qingyang Huang and Weiguo Zhu as the main person in charge, with the same task proportion is listed as a common work.

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Data availability
The datasets generated during and analyzed during the current study are available from the corresponding author upon reasonable request.

Declarations

Ethics approval and consent to participate
This study was performed in line with the principles of the Declaration of Helsinki. This retrospective controlled study was granted approval by the Institutional Review Board of Capital Medical University Xuanwu Hospital (IRB#2018086). Written informed consent was obtained from all the participants in this study.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

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