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Unilateral biportal endoscopic lumbar interbody fusion (ULIF) versus minimally invasive transforaminal lumbar interbody fusion (MI-TLIF) for the treatment of degenerative lumbar spondylolisthesis: a retrospective analysis

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Abstract

Objective This study retrospectively compared the early clinical and imaging outcomes of the single-level Meyerding Grade I degenerative lumbar spondylolisthesis (DLS) between unilateral biportal endoscopic lumbar interbody fusion (ULIF) and minimally invasive transforaminal lumbar interbody fusion (MI-TLIF) using an expandable tubular retractor system under a surgical loupe.

Methods This was a retrospective study. This study included fifty-five patients, with twenty-eight underwent ULIF and twenty-seven who underwent MI-TLIF at the Affiliated Hospital of Jiangsu University from June 2020 to July 2021. Demographic characteristic, surgical parameters, laboratory results, and clinical and imaging outcomes were collected and compared between the two groups.

Results In our retrospective study, the ULIF group was superior in terms of the mean total blood loss, intraoperative blood loss than MI-TLIF ($P<0.05$). However, there was no statistically significant difference in hidden blood loss between the two groups ($P>0.05$). Moreover, the mean operative time was significantly longer than in the ULIF group in the MI-TLIF group ($P<0.05$). The mean CK and CRP levels on the first postoperative day were significantly lower in the ULIF group ($P<0.001$). All clinical scores improved significantly after the operation in both groups. The VAS back score for pain at two weeks and 1 month postoperatively was significantly lower in the ULIF group ($P<0.05$). There was no significant difference between the two groups in the change in the dural sac cross-sectional area preoperatively or at the final postoperative follow-up. The fusion rate was significantly greater in ULIF at 6 months after the operation ($P<0.05$).

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Conclusion Compared to MI-TLIF, the ULIF technique has the advantages of less hemorrhage, less inflammation, and earlier fusion. However, this approach has a limited operation time. However, further clinical outcomes need to be followed up in the longer term.

Keywords Degenerative lumbar spondylolisthesis, Minimally invasive surgery, Unilateral biportal endoscopy, Transforaminal lumbar interbody fusion

Introduction

Degenerative lumbar spondylolisthesis (DLS) is a prevalent condition that causes low back pain [1]. If patients do not tolerate back pain and radiating leg pain or do not respond to conservative treatment, surgery becomes a more aggressive option. Surgical intervention aims to decompress the spinal canal and stabilize the involved segments [2]. Lumbar interbody fusion is used to treat degenerative lumbar spondylolisthesis [3, 4]. Since Foley et al. first introduced minimally invasive transforaminal lumbar interbody fusion (MI-TLIF) surgery, this technique has been widely developed as a prevalent surgical method for DLS. Studies have reported that MI-TLIF has several advantages such as improvements to surgical injury, postoperative pain and postoperative hospital stays [5–7]. Recently, unilateral biportal endoscopic lumbar interbody (ULIF) has attracted particular attention because of its ability to achieve its adequate decompression of the spine and nerve root under clear and magnified conditions in water media [8–10]. Therefore, the main aim of the present research was to compare early clinical and imaging outcomes between ULIF and MI-TLIF. The results of this research will provide a reference for the treatment of DLS.

Methods

Patients

This was a retrospective study. Twenty-eight patients who underwent ULIF and twenty-seven who underwent MI-TLIF from June 2020 and July 2021 at the Affiliated Hospital of Jiangsu University were included. The study was approved by the Ethics Committee of the Affiliated Hospital of Jiangsu University (KY2024K0204). The inclusion criteria were (1) patients diagnosed with one-level Meyerding grade I DLS (defined as a subluxation of the vertebral body above the vertebral body below less than 25% on X-ray); (2) patients who had back pain with radiation leg pain in the lower limb and with or without neurogenic claudication; (3) patients whose symptoms persisted for at least 3 months despite conservative treatment; (4) patients who underwent a follow-up period of a minimum of 1 year after the operation. Patients who had a history of other spinal surgeries, infection, severe coagulopathy, or ankylosing spondylitis were excluded.

Surgical technique for ULIF

After general anesthesia, the patient was placed prone on a radiolucent table. The lesion spine segment was confirmed under anteroposterior and lateral fluoroscopic imaging. Two transverse skin incisions were made on the affected side. Taking the left-sided approach as an example, the endoscopic incision is located at the outer edge of the upper pedicle, and the working incision is located at the level of the target segment's intervertebral space. the observation port measures 0.5 cm, and the operating port measures 1.5 cm. Depending on the patient's physique and the surgical segment, the two incisions are spaced 1.5–2.5 cm apart (Fig. 2A). Sequential dilators were inserted to establish two tubular operative portals. A 30° endoscope was inserted through the viewing portal to observe surgical fields (Fig. 2B). Continuous saline is placed at a height of 70–100 cm from the incision and relies on gravity to flow from the endoscope portal to the working portal. A radiofrequency probe was inserted from the working portal to remove soft tissues and to coagulate the vessel. Until the ipsilateral lamina and facet joint were identified via endoscopic view, diamond drills, osteotomes and curettes were used to perform ipsilateral laminectomy and facetectomy. After the ligamentum flavum was removed, the exiting and traversing neural roots were exposed and Kambin's triangle was identified (Fig. 1A). If patients were also symptomatic on the contralateral side, contralateral spinal canal and nerve root decompression were performed (Fig. 1BCD). Then, suitable ring curettes, endplate curettes, and pituitary forceps were used for the preparation of the endplate (Fig. 1F). Autologous bone fragments and allogenic bone dowel were filled into the target intervertebral space with the help of a specialized funnel. After a retractor was used to protect the exiting root, a suitable interbody fusion cage (PEEK, WEGO ORTHO) was inserted under fluoroscope guidance (Fig. 1GH). After hemostasis was achieved using a radiofrequency probe, the endoscope was removed. Then, bilateral pedicle screws were placed into the adjacent upper and lower vertebral bodies and the titanium rods were connected under C-arm fluoroscopic guidance. Finally, to prevent postoperative epidural hematoma, the incisions were closed after the insertion of a small drainage catheter.

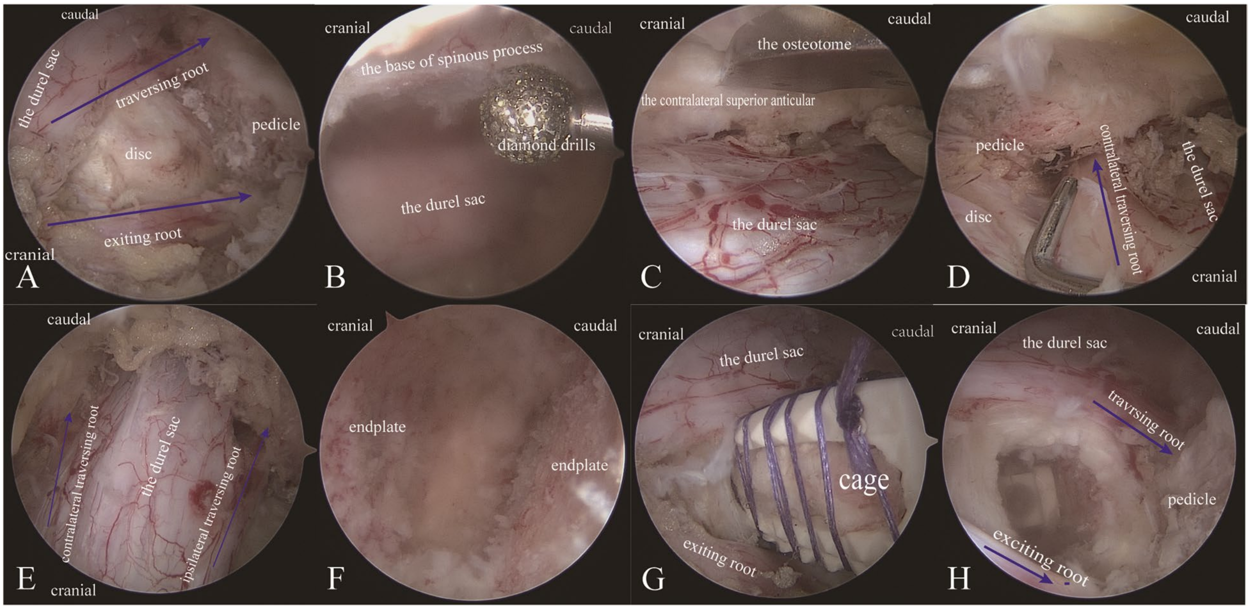

Fig. 1 Intraoperative endoscopic images: (**A**) the Kambin triangle; (**B**) the partial base of the spinous process was ground with a diamond drill to expose the contralateral field of view; (**C**) the inner margin of the contralateral superior anticular was removed to compress the contralateral lateral recess with a curved osteotome; (**D**) the contralateral traversing root was exposed and depressed; (**E**) the bilateral depression including the bilateral traversing root; (**F**) the cartilaginous endplate was removed completely; (**G**) the cage with tied autologous bone fragments was inserted; (**H**) the position of the inserted cage

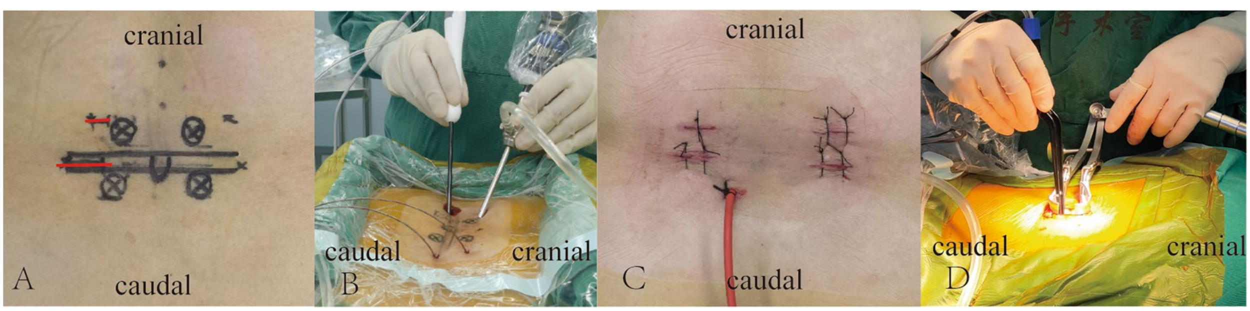

Fig. 2 **A** The incision design for ULIF surgery involves a left-sided approach, with a short red line segment representing the endoscopic channel and a longer red line segment representing the working channel; (**B**) Intraoperative overview in ULIF; (**C**) Post-ULIF surgery incision image. **D** MI-TLIF Intraoperative overview in MI-TLIF

Surgical technique for MI-TLIF

The patient was placed in a prone position, under general anesthesia (Fig. 2). All procedures were performed under surgical loupe magnification. The involved lumbar segment was identified through a C-arm fluoroscope. Then, the locations of the incisions and surface projections of the bilateral pedicles on the skin were marked. A longitudinal incision was made at the affected ipsilateral pedicle line. Then the skin was incised and the soft tissue between the longissimus and multifidus muscles was dissected. An expandable tubular retractor was inserted to obtain sufficient view. Then ipsilateral laminectomy and facetectomy were performed using conventional surgical devices. If patients were also symptomatic on the contralateral side, contralateral exploration and decompression of the spinal canal and nerve root were performed. After discectomy was performed, the endplate was prepared. Autologous and allografts bone fragments were inserted into the intervertebral space using a specialized funnel. A suitable interbody fusion cage (PEEK, WEGO ORTHO) was inserted under fluoroscope guidance Bilateral percutaneous instrumentation of the pedicle screws and rods was applied under C-arm fluoroscope guidance. Finally, the incisions were closed after the bleeding was controlled and a small drainage catheter was inserted (Fig. 2C).

Clinical and imaging evaluations

Patient demographic dates such as age, sex, BMI, smoking status and levels involved were collected. Moreover, indicators including total blood loss (TBL), intraoperative blood loss (IBL), hidden blood loss (HBL), operation time, length of postoperative hospital stay, and drainage volume at two days after surgery were evaluated. The calculation of total blood loss is performed using the Gross formula [11]. Total blood loss = PBV × (Hct_{pre}—Hct_{post})/Hct_{ave}. The patient's blood volume (PBV) was determined utilizing the formula as outlined by Nadler et al. [12]: PBV = k1 × height (m)3 + k2 × weight (kg) + k3; where k1 = 0.3669, k2 = 0.03219, and k3 = 0.6041 for men, and k1 = 0.3561, k2 = 0.03308, and k3 = 0.1833 for women. The Hctpre denoted the initial preoperative hematocrit (Hct) level, while Hctave represented the mean of the Hctpre and the Hctpost values. The postoperative hematocrit was measured on postoperative day 1. Due to the presence of physiological saline during ULIF, which complicated the calculation of intraoperative blood loss (IBL), the IBL associated with ULIF was assessed exclusively based on the weight of gauzes employed during the percutaneous pedicle screw insertion. IBL of MI-TLIF was estimated by the anesthetist and included the blood in the suction bottles (deducting the lavage fluid) and in the weighed gauzes that were used during the surgery. HBL was calculated using the method of Sehat et al. [13]. No blood transfusions were performed, thus HBL = TBL – (IBL + postoperative drainage volume). The following laboratory parameters were evaluated: creatine kinase (CK), and C-reaction protein (CRP) levels before and one day after surgery. Clinical outcomes were assessed using visual analog scale (VAS) scores for leg and back pain and Oswestry Disability Index (ODI) scores preoperatively and at each follow-up after surgery. For the imaging outcomes, the expansion of the dural sac cross-sectional area (DSCSA) on T2-weighted magnetic resonance images was measured preoperatively and at the final postoperative follow-up. The intervertebral disc height (IDH), slip percentage (SP), segmental lordosis angle (SLA), and lumbar lordosis angle (LLA) on X-ray images were compared between the two groups preoperatively and at the final postoperative follow-up. The IDH was determined by averaging the heights of the anterior and posterior edges of the vertebrae at the level of the disc. The SP was determined by calculating the ratio between the overhang distance of the superior vertebral body and the diameter of the inferior vertebral body. Using the Cobb method, SLA was measured between the superior endplate line of the upper vertebra and the inferior endplate line of the lower vertebra. The LLA was defined as the angle subtended by the upper plane of the L1 lumbar vertebra and the upper plane of the S1 sacral vertebra. The fusion rate assessment was conducted by two independent experienced radiologists on postoperative CT scans at 6 months and 1 year after surgery, using the Bridwell interbody fusion grading system. Bridwell interbody fusion grading system: Grade I is defined as a reconstruction with remodeling and the presence of trabeculae; Grade II is an intact graft with incomplete remodeling; Grade III is an intact graft with lucency present at either the cranial or caudal end; Grade IV is the absence of fusion with collapse or resorption of the graft. We define Bridwell Grades I and II as indicative of a successful fusion.

Statistical analysis

Statistical analysis was performed by using SPSS software version 25 (SPSS Inc, IBM). The measurement data are presented as means ± standard deviations. If the continuous data met the assumptions of normality and homogeneity of variance, Student's t test was used; otherwise, the Mann–Whitney U test was employed. Repeated measures analysis of variance was utilized to compare two groups across multiple time points. The enumeration data are shown by percentages and ratios, and group comparisons were performed using the chi-square test or Fisher's exact test. P-values less than 0.05 were considered to indicate a statistically significant difference.

Results

Demographic characteristics

All fifty-five patients who met the recruitment criteria were enrolled with 28 at ULIF and 27 at MI-TLIF. A typical case is shown in Fig. 3. All patients were regularly followed up for at least 1 year after surgery in the ULIF group (14.1 ± 1.4 months) and MI-TLIF group (14.7 ± 1.6 months), without loss to follow-up in either group. There was no significant difference in age, sex ratio, BMI, smoking status, degree of osteoporosis or levels involved between the two groups (Table 1).

Operation parameters

Postoperative analysis revealed significantly greater total blood loss in the minimally invasive transforaminal lumbar interbody fusion (MI-TLIF) group, with an average of 349.37 ± 55.87 ml, compared to the unilateral biportal endoscopic lumbar interbody fusion (ULIF) group, which had an average of 237.19 ± 63.47 ml ($p < 0.001$). Similarly, intraoperative blood loss (IBL) was markedly higher in the MI-TLIF group, averaging 84.22 ± 49.37 ml, than in the ULIF group, with an average of 18.29 ± 26.53 ml ($p < 0.001$). However, there was

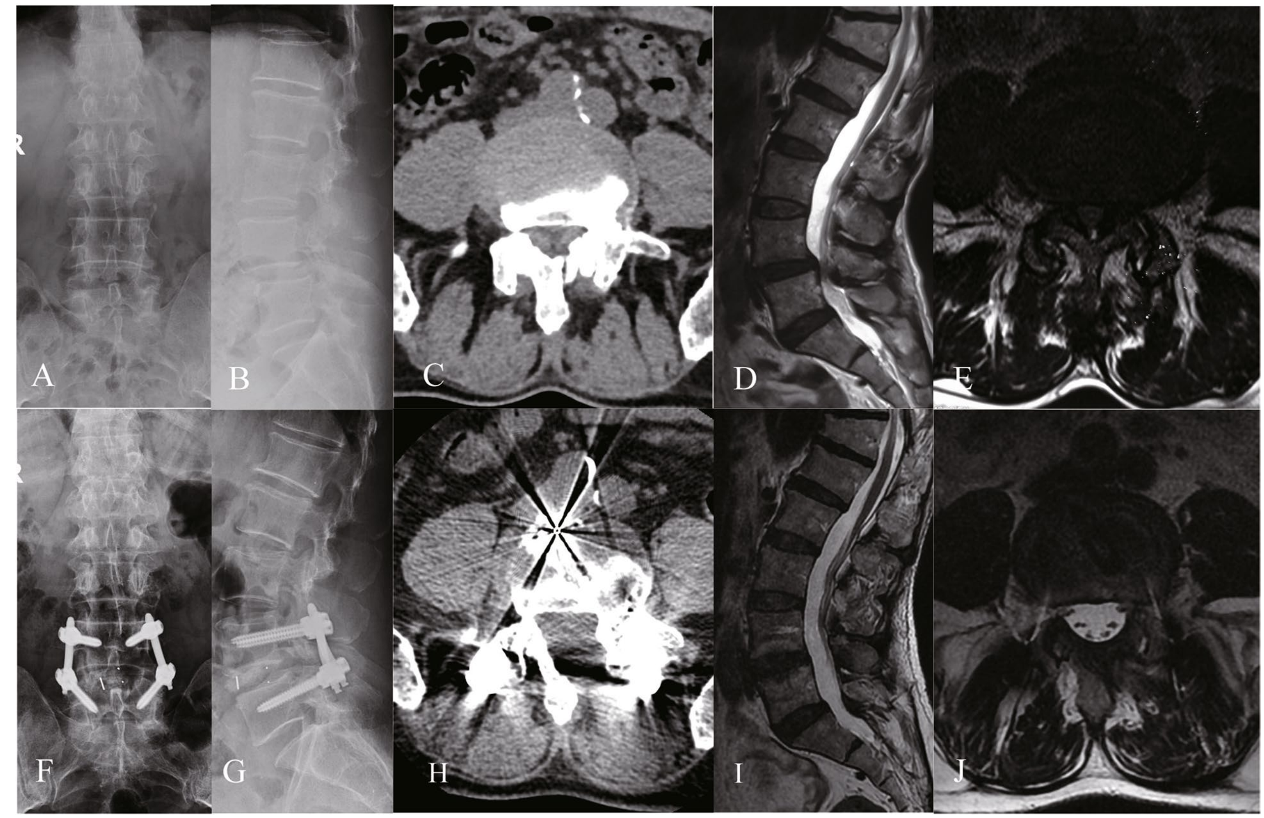

Fig. 3 A 60-year-old female patient who underwent ULIF surgery. **A**, **B** Preoperative antero-posterior and lateral radiographs. **C** Preoperative transverse CT scan. **D**, **E** Preoperative sagittal and axial axial T2-weighted MR image; (**F**, **G**) Postoperative antero-posterior and lateral radiographs; (**H**) Postoperative CT scan. (**I**, **J**) Postoperative sagittal and axial T2-weighted MR images

Table 1 Demographic characteristics of the two groups

	ULIF group (28)	MI-TLIF group (27)	*P* value
Age (years)	64.2 ± 5.4	65.7 ± 4.8	0.284
Sex (Male/Female)	(12/16)	(13/14)	0.789
BMI (kg/m^2)	24.89 ± 2.08	24.86 ± 1.63	0.964
Level involves			
L3/4	2	1	
L4/5	14	13	0.822
L5/S1	12	13	
Smoking(yes/no)	(16/12)	(20/7)	0.187
degree of osteoporosis (DXA)			
T > -1	12	9	
-2.5 < T≦-1	10	13	0.640
T≦-2.5	6	5	
Course of disease (months)	12.3 ± 3.5	11.3 ± 1.9	0.180
Follow-up time (months)	14.1 ± 1.4	14.7 ± 1.6	0.144

BMI Body mass index

no statistically significant difference in postoperative drainage volumes between the MI-TLIF group, averaging 110.36 ± 46.20 ml, and the ULIF group, averaging 92.36 ± 49.23 ml ($p > 0.05$). Furthermore, there was no statistically significant difference in hidden blood loss between the MI-TLIF group, averaging 154.78 ± 76.24 ml, and the ULIF group, averaging 126.55 ± 59.29 ml ($p > 0.05$). However, the operation time in the ULIF group (135.91 ± 23.03 min) was significantly longer than that in the MI-TLIF group (119.22 ± 20.26 min). The CK level at 1 day postoperatively in the MI-TLIF group (307.97 ± 29.83U/L) was significantly higher than that in the ULIF group (251.21 ± 18.53 U/L) ($p < 0.05$). The MI-TLIF group (24.15 ± 6.70 mg/l) had significantly higher CRP levels at 1 postoperative day than did the ULIF group (18.90 ± 4.49 mg/l) ($p < 0.05$). There was no significant difference in the length of postoperative hospital stay between the MI-TLIF group (8.48 ± 3.00 days) and the ULIF group (8.04 ± 2.49 days) ($p > 0.05$). In our study, there was only one case of dural tear in the ULIF group, with no occurrences of complications such as epidural hematoma, postoperative radiating leg pain, or infection. There was only one dural tear occurred in the ULIF group, and that in this case, endoscopic manipulation was quickly terminated within 20 min as per our protocol. Since the tears were less than 4 mm and there was no herniation of the cauda equina, we did not perform suturing or other special treatments. The patients did not exhibit symptoms such as postoperative headache or nausea, which are indicative of high spinal pressure. The drainage tube was retained for 2 days after surgery, with no obvious cerebrospinal fluid leakage (Table 2).

Clinical outcomes

Compared with those in the preoperative period, all clinical outcome scores at the both groups improved at all postoperative follow-up points. The ULIF group had significantly lower VAS back pain scores than the MI-TLIF group at 2 weeks and 1 month postoperatively ($P < 0.05$, $P < 0.05$). However, there was no significant difference between both the two groups in terms of the VAS score for back pain at 3 months or 1 year postoperatively, and there was no significant difference between the two groups in terms of the VAS score for leg pain or the ODI at any postoperative follow-up (Table 3).

Imaging outcomes

There was no significant difference in the mean expansion of the DSCSA between the ULIF group (69.70 ± 14.66 mm^2) and MI-TLIF group (72.10 ± 13.71 mm^2). All the parameters of the SP, SLA, and LLA in both groups at postoperative follow-up were significantly different from those at preoperative follow-up ($P < 0.05$). No significant difference between the two groups was found in the IDH, SP, SLA, or LLA ($P > 0.05$). Lumbar fusion was evaluated by the Bridwell anterior interbody fusion grading system. Lumbar fusion was defined as the Bridwell grade I and II. The fusion rates were 85.7%, and 96.4% in ULIF patients and 59.3%, and 92.3% in MI-TLIF patients at 6 months and 1 year postoperatively, respectively. The fusion rate was statistically greater in ULIF group than in the MI-TLIF group at 6 months postoperatively ($p < 0.05$), but there was no significant difference between the two groups at 1 year postoperatively (Table 4) (Figs. 3 and 4).

Table 2 Comparison of surgical data and laboratory results between the two groups

	ULIF group (28)	MI-TLIF group (27)	P value
Operative time(mins)	135.91 ± 23.03	119.22 ± 20.26	< 0.05*
Hospital stay (days)	8.04 ± 2.49	8.48 ± 3.00	0.232
TBL (ml)	237.19 ± 63.47	349.37 ± 55.87	< 0.001*
IBL (ml)	18.29 ± 26.53	84.22 ± 49.37	< 0.001*
Drainage volume(ml)	92.36 ± 49.23	110.36 ± 46.20	0.168
HBL (ml)	126.55 ± 59.29	154.78 ± 76.24	0.130
Preop CK level (IU/l)	80.24 ± 29.53	83.74 ± 34.23	0.687
Postop 24h CK level	251.21 ± 18.53	307.97 ± 29.83	< 0.001*
Preop CRP level(mg/l)	3.17 ± 1.71	3.69 ± 2.10	0.311
Postop 24h CRP level	18.90 ± 4.49	24.15 ± 6.70	0.001*

CK Creatine kinase, *CRP* C-reactive protein, *TBL* Total blood loss, *IBL* Intraoperative blood loss, *HBL* Hidden blood loss

Table 3 Comparison of clinical outcomes between the two groups

	ULIF group (28)	MI-TLIF group (27)	P value
VAS for leg pain			
preop	6.97 ± 1.21	7.01 ± 1.24	0.897
Postop 2 weeks	3.84 ± 0.85	4.16 ± 0.69	0.143
Postop 1 month	3.03 ± 0.65	3.00 ± 0.71	0.877
Postop 3 months	2.09 ± 0.45	2.29 ± 0.71	0.266
Final leg VAS	1.61 ± 0.65	1.77 ± 0.76	0.409
VAS for back pain			
Preop	6.73 ± 0.95	6.77 ± 1.00	0.885
Postop 2 weeks	3.09 ± 0.97	4.06 ± 1.20	< 0.05*
Postop 1 month	2.90 ± 0.96	3.48 ± 0.70	< 0.05*
Postop 3 months	1.97 ± 0.85	2.21 ± 0.44	0.233
Final back VAS	1.61 ± 0.36	1.76 ± 0.56	0.226
ODI			
Preop	64.54 ± 3.40	64.85 ± 2.92	0.653
Postop 2 weeks	34.00 ± 2.61	32.59 ± 2.86	0.070
Postop 1month	27.75 ± 2.22	28.52 ± 1.91	0.160
Postop 3months	19.86 ± 2.48	20.89 ± 2.14	0.125
Final ODI	8.04 ± 2.53	9.00 ± 2.24	0.202

VAS Visual analog scale, *ODI* Oswestry Disability Index

Discussion

Degenerative lumbar spondylolisthesis (DLS) is a common and frequently-occurring disease in elderly individuals. For patients with DLS, the most common symptom is low back pain with radiating pain or intermittent claudication [1]. Lumbar decompression and fusion have been proven to be the most effective methods for treating DLS. According to the surgical approach, methods such as posterior lumbar interbody fusion (PLIF), transforaminal lumbar interbody fusion (TLIF), oblique lumbar interbody fusion (OLIF), anterior lumbar interbody fusion (ALIF), and lateral lumbar interbody fusion (LLIF) have been widely applied [4]. In recent years, lumbar surgery has developed from conventional open surgery to minimally invasive surgery [14]. The MI-TLIF technique using a tubular retractor has been widely applied to prevalent surgical methods since Foley was first introduced [5, 6]. A few studies have reported that MI-TLIF offers benefits such as lower blood loss, earlier recovery, and fewer deep wound infections compared to conventional TLIF [15,

Table 4 Comparison of imaging outcomes between the two groups

	ULIF group (28)	MI-TLIF group (27)	*P* value
Preop DSCSA (mm^2)	69.70 ± 14.66	72.10 ± 13.71	0.534
Postop DSCSA (mm^2)	175.83 ± 58.76	166.87 ± 37.93	0.506
Expansion of DSCSA	106.87 ± 37.93	94.77 ± 32.09	0.341
Preop IDH (mm)	7.12 ± 1.37	7.84 ± 1.83	0.108
Postop 1 year IDH (mm)	10.47 ± 0.69	10.33 ± 2.21	0.751
Preop SP (%)	11.07 ± 3.70	10.17 ± 4.16	0.399
Postop 1 year SP (%)	3.67 ± 1.45	3.58 ± 1.34	0.818
Preop SLA (°)	7.09 ± 2.93	8.57 ± 2.81	0.063
Postop 1 year SLA (°)	10.32 ± 2.34	11.01 ± 3.58	0.405
Preop LLA (°)	31.15 ± 9.55	31.13 ± 8.78	0.995
Postop 1 year LLA (°)	35.80 ± 4.11	34.67 ± 6.47	0.442
Fusion rate (%)			
Postop 6 months	85.7% (24/28)	59.3% (16/27)	0.037*
Postop 1 year	96.4% (27/28)	92.3% (26/27)	0.979

Preop Preoperative, *Postop 1 year* Postoperative 1 year, *DSCSA* Dural sac cross-sectional area, *IDH* Intervertebral disc height, *SP* Slip percentage, *SLA* Segmental lordosis angle, *LLA* Lumbar lordosis angle

16]. However, the operation is restricted by the use of a long tubular retractor in the limited field of view and space available for the MI-TLIF technique [17]. Soliman introduced the biportal endoscopy technique with two independent channels for operation and viewing and with continuous fluid irrigation [18]. A few studies have reported that the biportal endoscopy technique can be used to treat DLS [10, 17]. ULIF surgery offers less bleeding and earlier postoperative recovery [13, 19–22]. Early clinical and imaging outcomes were compared between ULIF surgery and MI-TLIF surgery in this study.

In our retrospective study, the ULIF technique was superior in terms of total blood, intraoperative blood loss. This finding was similar with that of Huang et al. [21]. To our knowledge, the reasons for this can be explained as follows. Under a magnified endoscopic view, blood vessels become visible, and hemostasis became effective using the radiofrequency electrotome, especially for both the epidural and the vertebral venous plexus. Then, the ULIF technique was performed under continuous irrigation saline, which could keep the endoscopic views clear. However, hidden blood loss during ULIF surgery is a complication that cannot be ignored. Hidden blood loss (HBL) can be attributed to several factors, including extravasation of blood into tissue compartments, and oxidative damage to red blood cells (RBCs) and hemoglobin mediated by free fatty acids [23, 24]. Peng et al. reported that the mean hidden blood loss was 227.86 ± 221.75 mL in ULIF surgery [22]. In our study, the hidden blood loss for ULIF and MI-TLIF surgeries were 126.55 ± 59.29 ml and 154.78 ± 76.24 ml, respectively. There was no significant difference in hidden blood loss between the two groups. This result differs from the study by Huang et al. [21]. These differences can be explained by the following reasons: 1) The continuous drainage during ULIF surgery may have led to the neglect of blood loss in the surgical suction device. 2) During the exposure of the surgical field under endoscopy, it is necessary to continuously use radiofrequency, and bleeding under endoscopy can severely affect the field of view, thus requiring continuous radiofrequency coagulation during surgery. In our study, postoperative hematocrit was measured uniformly on postoperative day 1. While measuring hematocrit too

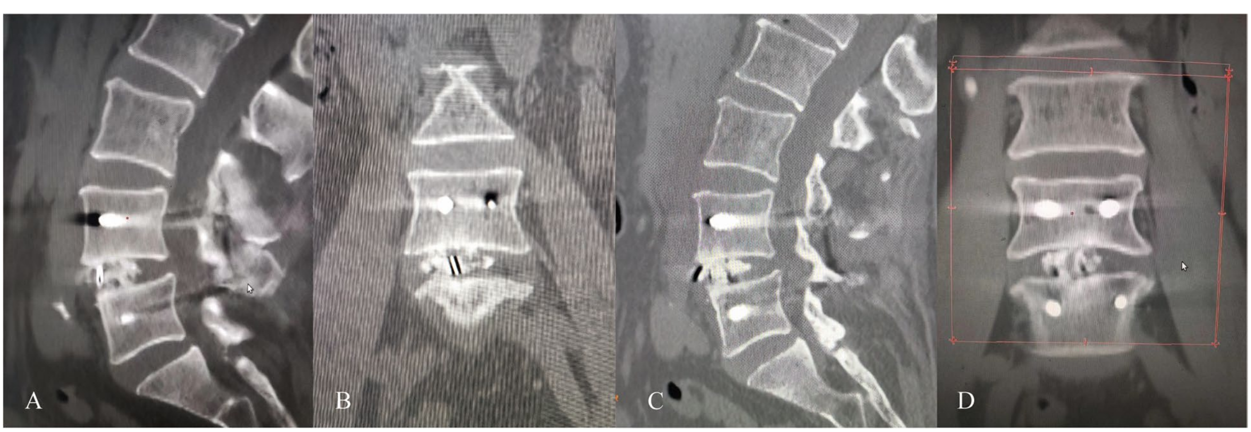

Fig. 4 **A**, **B** At six months postoperatively, the CT scans in the sagittal and coronal planes showed an intact graft with incomplete remodeling, classified as a Grade II fusion; (**C**, **D**) at one year postoperatively, the CT scans in the sagittal and coronal planes demonstrated reconstruction of the trabeculae between the upper and lower endplates, classified as a Grade I fusion

early-before fluid balance is fully restored and hemodilution occurs-can lead to relatively higher hematocrit values and thus underestimate true and hidden blood loss, the standardized perioperative fluid replacement and consistent timing of hematocrit measurement across both groups ensure that the comparison of blood loss between them remains reliable.

In the present study, the mean postoperative drainage volume was 92.36 ± 49.23 mL in the ULIF group which was not significantly different from that in the MI-TLIF group. This outcome is contrary to that of Kang et al. [19]. In contrast with MI-TLIF, due to the extensive use of irrigation fluid during ULIF surgery, postoperative drainage primarily consists of residual fluid and small tissue fragments from the flushing process, rather than predominantly blood-tinged irrigation fluid. Therefore, the actual blood drainage volume was less than the postoperative wound drainage volume we described in the ULIF group.

In our study, the levesl of CK and CRP after surgery were significantly lower in ULIF patients than MI-TLIF group at 24 h after surgery. The serum enzyme level has been shown to be significantly related to the duration and intensity of paraspinal muscle contractions [25]. Some studies have suggested that this increase in muscle damage commonly observed when tubular retractors are used in MI-TLIF may cause excessive traction [26]. However, the ULIF technique, whichuses two different portals, allows the paravertebral muscles are stripped from the posterior vertebral body structure without excessive stretching. Additionally, the UBE technique can cause less iatrogenic muscle injury. Due to the use of endoscopic technology in ULIF surgery, it is only necessary to create an incision to facilitate the entry of instruments, and there is no need for extensive cutting and stripping of paraspinal muscles such as the multifidus muscle to provide a surgical view, because ULIF surgery causes less damage to the paraspinal muscles. In addition, continuous fluid irrigation can wash the released inflammatory mediators in the vertebral interbody space which may produce an inevitable systemic inflammatory response [27].

However, the operation time in the ULIF group was longer in this study. The factors that prolong the operation time may be that bleeding from small blood vessels and the bone surface during surgery affects the surgical visual field. Careful intraoperative hemostasis using the radiofrequency electrotome to ensure a clear surgical field becomes important. Moreover, many studies have reported that the UBE technique requires a longer fluoroscopy time [28]. O-arm total navigation assistive ULIF technology can help reduce fluoroscopy time [29] A long learning curve in ULIF may be another reason for the longer operation time when the surgeon is not familiar with the anatomical structure marks under the endoscope. Kim et al. reported that the operation time leveled off until the surgeon performed the 34th operation [30]. The ULIF technique has advantages for the surgeons with endoscopic experience.

The clinical outcomes of the two groups improved postoperatively compared to those in the preoperative period in this study. The results demonstrate that both surgeries can improve symptoms. However, the VAS score for back pain in the early postoperative period was significantly lower in the ULIF group than in the MI-TLIF. These findings are similar to those of previous studies [19, 31, 32]. The ULIF technique can minimize damage to the soft and bone tissue of the back after sufficient decompression. This approach is beneficial for early postoperative recovery.

In this study, the expansion of the DSCSA on MRI preoperatively and postoperatively at two weeks is improved after surgery in both groups. However, there was no significant difference between the two groups. This finding might be explained by the fact that the two surgical methods could achieve sufficient decompression of the central spinal canal. Moreover, to our knowledge, the ULIF technique uses two different portals and obtains a wider surgical field, especially on the contralateral side of the spinal canal and the contralateral nerve root. The ULIF has important strengths of the contralateral lateral recess.

The results of this study indicated that the sagittal parameters, such as the SLA, LL and SP improved in both groups postoperatively compared with preoperatively. Previous studies have indicated that effective reduction of slip can improve postoperative sagittal spinal balance [33] The maintenance of sagittal spinal balance is crucial for ensuring postural stability and minimizing energy consumption [34]. According to these findings, we can infer that ULIF surgery can improve local and regional sagittal balance.

Previous studies reported that the final fusion rate was 80%–100% in ULIF surgery which is consistent with our findings [31, 35]. In our study, the fusion rate was greater in ULIF (85.7%) than in MI-TLIF (59.3%) at 6 months post-surgery. At 1 year postoperatively, the fusion rates between the two groups were not statistically significant. During the 1-year follow-up after surgery, neither group experienced pedicle screw loosening, graft dislodgement, or implant failure. Most studies report that there is no difference in the fusion rates between ULIF and MI-TLIF at 1 year postoperatively [31], which is consistent with our research. At present, there is a limited amount of literature studying the fusion rates at six months postoperatively for ULIF and MIS-TLIF surgeries. There have been reports that the radiographic fusion rate at 6 months post-MI-TLIF is 83% [36], but in this study, the proportion of patients with L5/S1 involvement was relatively low, suggesting that the fusion rate for the L5-S1 segment may be lower than that for other lumbar segments [37]. The preparation of the endplate is sufficient and safe in the endoscopic visualization view without damaging the endplate in the ULIF technique. Research has shown that during the preparation of the endplate, complete removal of the cartilaginous endplate while preserving the bony endplate can lead to a higher rate of postoperative fusion. In ULIF surgery, the endoscope is inserted into the intervertebral space, allowing for careful observation of the endplate preparation, as depicted in Fig. 1F. However, in MI-TLIF surgery, the surgeon is required to work on the endplate in an air medium. Although assisted by head-mounted magnifying glasses or a microscope, intraoperative bleeding can easily obscure the view, leading to potential issues such as incomplete removal of the cartilaginous endplate or damage to the bony endplate. Moreover, continuous liquid flushing prevents thermal burns to the vertebrae and endplates caused by thermal energy. Adequate preparation of the endplate is achieved until bleeding pot of the bone appears under endoscopic view. An advantage of ULIF is that a favorable fusion environment can be provided by completely removing the cartilage portion.

However, there are several limitations in this study. First, this was a retrospective study. This study is limited by the short follow-up period and the small sample size. Thus, a further studies including larger sample sizes and long-term follow-up are needed. The fact that we did not assess the inter- and intra-examiner measurement error of the images is another limitation of our study.

Conclusion

Compared to MI-TLIF, the ULIF technique has the advantages of less hemorrhage, less inflammation, and earlier fusion. However, this approach is associated with a longer operation time. However, further clinical outcomes need to be followed up in the longer term.

Abbreviations

ULIF	Unilateral biportal endoscopic lumbar interbody fusion
MI-TLIF	Minimally invasive transforaminal lumbar interbody fusion
DLS	Degenerative lumbar spondylolisthesis
ODI	Oswestry Disability Index
VAS	Visual analog scale
BMI	Body mass index
TBL	Total blood loss
IBL	Intraoperative blood loss
HBL	Hidden blood loss
CK	Creatine kinase
CRP	C-reactive protein
Preop	Preoperative
Postop	Postoperative
DSCSA	Dural sac cross-sectional area
SP	Slip percentage
SLA	Segmental lordosis angle
LLA	Lumbar lordosis angle
CT	Computed tomography
MRI	Magnetic resonance imaging

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Authors' contributions

All the authors contributed to the study conception and design. Zhicheng Zhu, Conceptualization, Data curation, Formal analysis, Investigation, Validation; Jifu Sun, Conceptualization, Resources, Validation, Writing – original draft, Writing – review & editing; Banglin He, Methodology, Software, Validation, Writing – review & editing; Yonghui Huang, Resources; Chen Meng, Project administration; Chao Jiang, Supervision; Liqun Lin, Software, Visualization. All authors reviewed the manuscript.

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Data availability

The datasets used and/or analysed during the current study are available from the corresponding author upon reasonable request.

Declarations

Ethics approval and consent to participate

This study was conducted in accordance with the principles of the Helsinki Declaration. The study was approved by the Ethics Committee of the Affiliated Hospital of Jiangsu University (KY2024K0204). Written informed consent was obtained from all participants.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

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References

1. Kalichman L, Kim DH, Li L, Guermazi A, Berkin V, Hunter DJ. Spondylolysis and spondylolisthesis. prevalence and association with low back pain in the adult community-based population. Spine. 2009;34(2):199–205.
2. Qin R, Liu B, Zhou P, Yao Y, Hao J, Yang K, Xu TL, Zhang F, Chen X. Minimally invasive versus traditional open transforaminal lumbar interbody fusion for the treatment of single-level spondylolisthesis grades 1 and 2: a systematic review and meta-analysis. World neurosurgery. 2019;122:180–9.
3. Ghogawala Z, Dziura J, Butler WE, Dai F, Terrin N, Magge SN, Coumans JV, Harrington JF, Amin-Hanjani S, Schwartz JS, Sonntag VK, Barker FG, Benzel EC. Laminectomy plus fusion versus laminectomy alone for lumbar spondylolisthesis. New Engl J Med. 2016;374(15):1424–34.
4. Mobbs RJ, Phan K, Malham G, Seex K, Rao PJ. Lumbar interbody fusion: techniques, indications and comparison of interbody fusion options including PLIF, TLIF, MI-TLIF, OLIF/ATP. LLIF and ALIF J Spine Surg (Hong Kong). 2015;1(1):2–18.
5. Foley KT, Holly LT, Schwender JD. Minimally invasive lumbar fusion. Spine. 2003;28(15 Suppl):S26–35.

6. Foley KT, Lefkowitz MA. Advances in minimally invasive spine surgery. Clin Neurosurg. 2002;49:499–517.
7. Schwender JD, Holly LT, Rouben DP, Foley KT. Minimally invasive transforaminal lumbar interbody fusion (TLIF): technical feasibility and initial results. J Spinal Disord Techniques. 2005;18 Suppl:S1–6.
8. Eun SS, Eum JH, Lee SH, Sabal LA. Biportal endoscopic lumbar decompression for lumbar disk herniation and spinal canal stenosis: a technical note. J Neurol Surg. Part A, Central European neurosurgery,. 2017;78(4):390–6.
9. Hwa EJ, Hwa HD, Son SK, Park CK. Percutaneous biportal endoscopic decompression for lumbar spinal stenosis: a technical note and preliminary clinical results. J Neurosurg Spine. 2016;24(4):602–7.
10. Heo DH, Son SK, Eum JH, Park CK. Fully endoscopic lumbar interbody fusion using a percutaneous unilateral biportal endoscopic technique: technical note and preliminary clinical results. Neurosurgical focus. 2017;43(2):E8.
11. Gross JB. Estimating allowable blood loss: corrected for dilution. Anesthesiology. 1983;58(3):277–80.
12. Nadler SB, Hidalgo JH, Bloch T. Prediction of blood volume in normal human adults. Surgery. 1962;51(2):224–32.
13. Sehat KR, Evans RL, Newman JH. Hidden blood loss following hip and knee arthroplasty. Correct management of blood loss should take hidden loss into account. J Bone Joint Surg Br. 2004;86(4):561–5.
14. Zhang Y, Chen J, Xie H, Li K, Wang Y, Chen Q, Jiang C, He J, Fu N. Comparison of the application value of two commonly used minimally invasive spinal surgery in the treatment of lumbar disc herniation. Exp Ther Med. 2021;21(4):299.
15. Price JP, Dawson JM, Schwender JD, Schellhas KP. Clinical and radiologic comparison of minimally invasive surgery with traditional open transforaminal lumbar interbody fusion: a review of 452 patients from a single center. Clin Spine Surg. 2018;31(2):E121–6.
16. Parker SL, Mendenhall SK, Shau DN, Zuckerman SL, Godil SS, Cheng JS, McGirt MJ. Minimally invasive versus open transforaminal lumbar interbody fusion for degenerative spondylolisthesis: comparative effectiveness and cost-utility analysis. World Neurosurg. 2014;82(1–2):230–8.
17. Kim JE, Choi DJ. Biportal endoscopic transforaminal lumbar interbody fusion with arthroscopy. Clin Orthop Surg. 2018;10(2):248–52. https://doi.org/10.4055/cios.2018.10.2.248.
18. Soliman HM. Irrigation endoscopic decompressive laminotomy. A new endoscopic approach for spinal stenosis decompression. Spine J: official journal of the North American Spine Society. 2015;15(10):2282–9.
19. Kang MS, You KH, Choi JY, Heo DH, Chung HJ, Park HJ. Minimally invasive transforaminal lumbar interbody fusion using the biportal endoscopic techniques versus microscopic tubular technique. The spine journal: official journal of the North American Spine Society. 2021;21(12):2066–77.
20. Kim JE, Yoo HS, Choi DJ, Park EJ, Jee SM. Comparison of minimal invasive versus biportal endoscopic transforaminal lumbar interbody fusion for single-level lumbar disease. Clin Spine Surg. 2021;34(2):E64–71.
21. Huang X, Wang W, Chen G, Guan X, Zhou Y, Tang Y. Comparison of surgical invasiveness, hidden blood loss, and clinical outcome between unilateral biportal endoscopic and minimally invasive transforaminal lumbar interbody fusion for lumbar degenerative disease: a retrospective cohort study. BMC Musculoskelet Disord. 2023;24(1):274. Published 2023 Apr 10.
22. Peng YJ, Fan ZY, Wang QL, Dai J, Zhang QZ, Cao JY, Liu XF, Yan J. Comparison of the total and hidden blood loss in patients undergoing single-level open and unilateral biportal endoscopic transforaminal lumbar interbody fusion: a retrospective case control study. BMC Musculoskelet Disord. 2023;24(1):295.
23. Erskine JG, Fraser C, Simpson R, Protheroe K, Walker ID. Blood loss with knee joint replacement. J R Coll Surg Edinb. 1981;26(5):295–7.
24. Bao N, Zhou L, Cong Y, et al. Free fatty acids are responsible for the hidden blood loss in total hip and knee arthroplasty. Med Hypotheses. 2013;81(1):104–7.
25. Choi KC, Shim HK, Hwang JS, Shin SH, Lee DC, Jung HH, Park HA, Park CK. Comparison of surgical invasiveness between microdiscectomy and 3 different endoscopic discectomy techniques for lumbar disc herniation. World neurosurgery. 2018;116:e750–8.
26. Kim CW. Scientific basis of minimally invasive spine surgery: prevention of multifidus muscle injury during posterior lumbar surgery. Spine. 2010;35(26 Suppl):S281–6.
27. Zhang J, Liang D, Xu M, Yan K, Zhang D, Qian W. Comparison of the short-term effects of lumbar endoscopic and microscopic tubular unilateral laminotomy with bilateral decompression in the treatment of elderly patients with lumbar spinal stenosis. Eur J Med Res. 2022;27(1):222.
28. Merter A, Karaeminogullari O, Shibayama M. Comparison of radiation exposure among 3 different endoscopic diskectomy techniques for lumbar disk herniation. World neurosurgery. 2020;139:e572–9.
29. Huang X, Gong J, Liu H, Shi Z, Wang W, Chen S, Shi X, Li C, Tang Y, Zhou Y. Unilateral biportal endoscopic lumbar interbody fusion assisted by intraoperative O-arm total navigation for lumbar degenerative disease: A retrospective study. Frontiers in surgery. 2022;9:1026952.
30. Kim JE, Yoo HS, Choi DJ, Hwang JH, Park EJ, Chung S. Learning curve and clinical outcome of biportal endoscopic-assisted lumbar interbody fusion. Biomed Res Int. 2020;2020:8815432.
31. Gatam AR, Gatam L, Mahadhipta H, Ajiantoro A, Luthfi O, Aprilya D. Unilateral biportal endoscopic lumbar interbody fusion: a technical note and an outcome comparison with the conventional minimally invasive fusion. Orthop Res Rev. 2021;13:229–39.
32. Lin GX, Yao ZK, Zhang X, Chen CM, Rui G, Hu BS. Evaluation of the outcomes of biportal endoscopic lumbar interbody fusion compared with conventional fusion operations: a systematic review and meta-analysis. World neurosurgery. 2022;160:55–66.
33. Thomas D, Bachy M, Courvoisier A, Dubory A, Bouloussa H, Vialle R. Progressive restoration of spinal sagittal balance after surgical correction of lumbosacral spondylolisthesis before skeletal maturity. J Neurosurg Spine. 2015;22(3):294–300.
34. Abelin-Genevois K. Sagittal balance of the spine. Orthop Traumatol Surg Res. 2021;107(1S):102769.
35. Kim JE, Choi DJ, Park EJJ, Lee HJ, Hwang JH, Kim MC, Oh JS. Biportal endoscopic spinal surgery for lumbar spinal stenosis. Asian Spine J. 2019;13(2):334–42.
36. Ma HH, Wu PH, Yao YC, et al. Postoperative spinal orthosis may not be necessary for minimally invasive lumbar spine fusion surgery: a prospective randomized controlled trial. BMC Musculoskelet Disord. 2021;22(1):619.
37. Lee YS, Kim YB, Park SW. Survival rates and risk factors for cephalad and L5–s1 adjacent segment degeneration after L5 floating lumbar fusion : a minimum 2-year follow-up. J Korean Neurosurg Soc. 2015;57(2):108–13.

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