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Research Article

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Comparison of Oblique Lateral Interbody Fusion Combined with Minimally Invasive Transforaminal Lumbar Interbody Fusion versus Posterior Lumbar Interbody Fusion for Long-Segment (L2-S1) Degenerative Lumbar Spinal Stenosis

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Availability of data and materials
The datasets generated and/or analyzed during the current study are not publicly available because they contain patient-level clinical information, but de-identified data may be available from the corresponding author on reasonable request, subject to approval by the relevant ethics committees and applicable data-protection regulations.
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Not Applicable

Abstract

Objective: Oblique lateral interbody fusion (OLIF) is widely used to treat degenerative lumbar disorders but is generally unsuitable for the L5-S1 level. We therefore combined OLIF at L2-L5 with minimally invasive transforaminal lumbar interbody fusion (MIS-TLIF) at L5-S1 (hereafter referred to as OMAT) to treat long-segment (L2-S1) degenerative lumbar spinal stenosis (LDLS). This study compared the clinical and radiographic outcomes of OMAT and posterior lumbar interbody fusion (PLIF), with particular emphasis on perioperative recovery, surgical characteristics, and spinal alignment.

Methods: From May 2020 to May 2023, 27 patients with LDLS underwent either OMAT (n = 12) or PLIF (n = 15) at the Affiliated Hospital of Nantong University or the Affiliated Haian Hospital of Nantong University. We evaluated intraoperative blood loss, transfusion requirements, operative time, complications, and preoperative and postoperative Oswestry Disability Index (ODI) and visual analog scale (VAS) scores. Radiographic parameters, including anterior disc height (ADH), posterior disc height (PDH), lumbar lordosis (LL), and fused-segment lordosis (FSL), were also measured and compared between groups.

Results: No significant between-group differences were observed in postoperative LL or Cobb angle, indicating comparable deformity-correction efficacy. ADH and PDH were restored to a significantly greater extent in the OMAT group than in the PLIF group ($P < 0.05$). VAS and ODI scores improved significantly after surgery in both groups, with no significant between-group difference in postoperative improvement ($P > 0.05$).

Conclusion: Both OMAT and PLIF produced significant clinical improvement and satisfactory radiographic outcomes in patients with long-segment (L2-S1) degenerative lumbar disease. OMAT provided greater restoration of intervertebral height while achieving comparable correction of lumbar alignment and symptoms. Its less invasive approach may reduce tissue injury and facilitate postoperative recovery. Larger prospective studies with longer follow-up are required to confirm these findings.

Keywords: oblique lateral interbody fusion (OLIF); minimally invasive transforaminal lumbar interbody fusion (MIS-TLIF); posterior lumbar interbody fusion (PLIF); long-segment (L2-S1) degenerative lumbar spinal stenosis (LDLS)

Introduction

With the global population aging, degenerative lumbar spondylolisthesis (DLS) has become increasingly prevalent, affecting approximately 5%-7% of individuals. It commonly presents with chronic low back pain in middle-aged and older adults and may be accompanied by neurogenic intermittent claudication or cauda equina symptoms. These manifestations substantially impair physical function and quality of life. The pathogenesis of DLS is multifactorial and involves intervertebral disc degeneration, facet-joint osteoarthritis, hormonal factors, and spinal canal stenosis. Surgery is generally considered when adequate conservative treatment fails. In clinical practice, an increasing number of patients present with multilevel lumbar spinal stenosis (L2-S1), severe symptoms, and marked walking impairment, making surgical treatment necessary.

Spinal fusion is an effective treatment for pain caused by degenerative lumbar disease and can improve patients' quality of life. Posterior lumbar interbody fusion (PLIF), the conventional open technique, stabilizes the posterior spinal elements, including the interspinous ligaments, facet joints, and their capsules. However, extensive posterior exposure can cause substantial iatrogenic injury to the paraspinal muscles and posterior ligamentous complex. Potential consequences

include adjacent-segment degeneration, facet arthropathy, nerve-root injury, facet violation or fracture, stress shielding, and osteolysis. Minimizing injury to the paraspinal musculature while preserving posterior biomechanics is therefore important for long-term outcomes. Minimally invasive transforaminal lumbar interbody fusion (MIS-TLIF), first described in 2002, reduces blood loss, soft-tissue injury, infection, and length of hospital stay. Oblique lateral interbody fusion (OLIF) has also gained popularity. It uses a retroperitoneal corridor between the great vessels and the psoas major muscle to access the disc space, thereby enabling indirect neural decompression while preserving the posterior ligamentous complex.

Because the great vessels obstruct access to L5-S1, OLIF cannot generally be used at that level. For minimally invasive treatment of long-segment (L2-S1) stenosis, we therefore used OLIF at L2-L5 and MIS-TLIF at L5-S1, followed by posterior percutaneous pedicle-screw fixation in a single-stage procedure. This study evaluated the clinical and radiographic outcomes of this combined procedure (OMAT) versus PLIF for long-segment (L2-S1) degenerative lumbar spinal stenosis.

Methods

Ethics approval and consent to participate

This retrospective study was conducted in accordance with the principles of the Declaration of Helsinki. The study protocol was reviewed and approved by the Institutional Review Board and Ethics Committee of the Affiliated Hospital of Nantong University (2025-K003-01 2025.2.6) and by the Institutional Review Board and Ethics Committee of Affiliated Haian Hospital of Nantong University (2025-HaiAn-LL3 2025.3.5). Written informed consent was obtained from all participants before surgery.

Inclusion and exclusion criteria

The inclusion criteria were as follows:

Patients with low back pain and unilateral or bilateral radicular leg pain at rest, or neurogenic claudication defined by the absence of leg symptoms at rest; bilateral lower-extremity pain, paresthesia, dysesthesia, or fatigue after walking 50-100 m; inability to continue walking; and symptom relief with rest.

Magnetic resonance imaging, computed tomography, and radiographs showing long-segment (L2-S1) spinal stenosis.

Failure of comprehensive conservative treatment for at least 3 months, with clinically significant impairment of work and basic daily activities.

A stable general condition, well-controlled comorbidities (e.g., cardiovascular disease, hypertension, or diabetes), and no clinically significant psychiatric or cognitive impairment.

1) Complete perioperative records and longitudinal radiographic follow-up data.

The exclusion criteria were as follows:

1) Previous lumbar spine surgery.
2) Adjacent-segment disc herniation or dynamic instability with unclear biomechanical significance.
3) Concomitant infection, tumor, scoliosis, or fracture.

4) Symptoms of cauda equina syndrome.
5) Therapeutic or prophylactic anticoagulant or antiplatelet therapy within 6 months before evaluation.

Surgical techniques (Schematic diagrams of the two surgical procedures are shown in Fig 1)

OMAT procedure (Fig 2)

1) After induction of general anesthesia, the patient was placed in the right lateral decubitus position. The target disc level was localized with C-arm fluoroscopy. A 4-10 cm oblique incision was made on the left flank, approximately 3-4 cm anterior to the center of the disc. The external oblique, internal oblique, and transversus abdominis muscles were sequentially dissected through a retroperitoneal approach to expose the disc space anterior to the psoas muscle.
2) A working channel was established, and complete discectomy and meticulous endplate preparation were performed while preserving the anterior and posterior annulus fibrosus. After contralateral annular release, trial spacers were used to achieve adequate distraction. The OLIF cage was inserted vertically and then rotated to a horizontal position within the disc space. This approach was used at L2-L5.
3) The patient was then repositioned prone. The L5-S1 disc space was localized with real-time C-arm fluoroscopy. Two 3-cm longitudinal incisions were made approximately 1 cm lateral to the projected pedicles. Percutaneous pedicle cannulation was performed with Jamshidi needles, followed by insertion of Kirschner guidewires under continuous fluoroscopic guidance.
4) A paramedian incision was made at the target disc level to accommodate an expandable working channel. Under microscopic visualization, complete discectomy and neural decompression were performed. The endplates were prepared with curettes while preserving the bony endplates, and an interbody cage was inserted under fluoroscopy. Percutaneous pedicle screws were then placed from L2 to S1 over the guidewires, and their position was confirmed with intraoperative imaging.

PLIF procedure (Fig 3)

1) After induction of general anesthesia, the patient was placed prone on a radiolucent operating table. The surgical field was prepared and draped in the usual sterile manner.
2) A standard posterior midline approach was used. A longitudinal incision approximately 20 cm long was made, and the skin and deep fascia were incised sequentially. The paraspinal muscles were dissected bilaterally along the spinous processes to expose the laminae from L2 to S1, the superior and inferior articular processes, and the transverse processes. The pedicle entry point was identified at the intersection of the lateral border of the superior articular process and the transverse-process axis. Pedicle probes and screws were inserted, and their trajectories and depths were confirmed by intraoperative navigation.
3) Adequate spinal-canal decompression
    a. Exposure and decompression
        a) The spinous processes were resected to expose the intervertebral spaces and adjacent vertebral endplates.

b) Partial facetectomy and endplate resection were performed, including removal of the inferior two-thirds of the superior endplate, the superior one-third of the inferior endplate, and the medial one-third of the superior articular process.
c) The ligamentum flavum was identified, carefully dissected, and completely removed.

b. Neural decompression and discectomy
a) The dura mater and bilateral nerve roots were exposed and gently retracted medially.
b) The herniated nucleus pulposus was removed, followed by complete discectomy and thorough debridement of the cartilaginous endplates.

c. Interbody fusion
a) The intervertebral space was filled with an adequate quantity of autologous bone graft.
b) An interbody fusion cage was inserted under fluoroscopic guidance.

d. Final assessment and instrumentation
a) The distal nerve-root canals were explored. No residual stenosis was observed, and the nerve roots were mobile.
b) The surgical field was irrigated, and meticulous hemostasis was achieved.
c) The bilateral pedicle screws were connected with precontoured rods, and the locking caps were tightened.

4) Adequate fixation and implant position were confirmed by C-arm fluoroscopy. After wound irrigation and hemostasis, the transverse processes were decorticated bilaterally and a mixture of autologous and allogeneic bone graft was placed. Two silicone drains were inserted before layered wound closure.
5) The operation was completed without incident. A sterile dressing was applied, and the patient was transferred to the ward in stable condition.

Patient data

Between May 2020 and May 2023, 27 patients who met the inclusion criteria were enrolled: 12 in the OMAT group and 15 in the PLIF group.

Data collection and clinical evaluation

Prophylactic antibiotics were routinely administered for less than 48 h after surgery. Anteroposterior and lateral lumbar radiographs were obtained. Supervised ambulation with a lumbar brace began on postoperative day 1, and the brace was worn for 3 months. Follow-up assessments were scheduled at 1, 3, and 6 months and at 1 year after surgery. Operative time, intraoperative blood loss, and complications were recorded. Pain was assessed using the visual analog scale (VAS), and disability related to low back pain was assessed using the Oswestry Disability Index (ODI) before and after surgery. Lumbar lordosis (LL) was measured as the angle between lines along the superior endplates of L1 and S1 on a midsagittal image. Fused-segment lordosis (FSL) was measured by the Cobb method between the superior endplates of the most cranial and caudal fused vertebrae on standing lateral radiographs; for L2-S1 fusion, this was the angle between the superior endplates of L2 and S1. ADH and PDH were measured as the vertical distances between the corresponding anterior and posterior points of the inferior and superior endplates at the fused level. All radiographic parameters were measured digitally with ImageJ software.

Statistical analysis

Analyses were performed with SPSS for Windows, version 22.0 (SPSS Inc., Chicago, IL, USA). Continuous variables, including operative time, intraoperative blood loss, VAS scores, and ODI scores, were compared between groups using the independent-samples t-test or Mann-Whitney U test, as appropriate. Categorical variables, including age, sex, body mass index (BMI), symptom duration, conversion rate, and complications, were analyzed using the chi-square test or Fisher exact test. Paired t-tests or Wilcoxon signed-rank tests were used for within-group comparisons of preoperative and postoperative measurements. All tests were two-sided, and $P < 0.05$ was considered statistically significant.

Results

Baseline characteristics

During follow-up (range, 2-18 months; mean, 10.4 months), demographic and anthropometric characteristics, including sex, age, and BMI, were comparable between groups. No significant between-group differences were found in age (OMAT, 50.53 ± 6.5 years; PLIF, 57.42 ± 5.4 years), BMI (OMAT, 24.33 ± 3.14 kg/m²; PLIF, 24.85 ± 2.68 kg/m² kg/m²), or symptom duration (OMAT, 40.16 ± 17.22 months; PLIF, 38.92 ± 16.43 months), confirming similar baseline characteristics (Table 1).

Comparison of operative time, intraoperative blood loss, postoperative hospital stay, and complications between the OMAT and PLIF groups

Operative time was significantly shorter in the PLIF group than in the OMAT group (242 ± 20.34 vs. 312.46 ± 31.33 min). Intraoperative blood loss was significantly lower in the OMAT group (62.74 ± 10.78 mL) than in the PLIF group (125.55 ± 11.48 mL). The OMAT group also had a shorter hospital stay (4.23 ± 0.37 days vs. 7.32 ± 1.05 days). One patient in the OMAT group (8.33%) developed reduced left hip-flexion strength postoperatively, probably because of intraoperative genitofemoral-nerve irritation; the symptoms improved after 1 month of targeted rehabilitation. One patient in the PLIF group (6.67%) experienced transient lower-limb numbness, likely related to multilevel decompression and ischemia-reperfusion injury. The symptoms improved after corticosteroid and oral neurotrophic treatment (Table 2).

Comparison of preoperative and postoperative parameters in the OMAT and PLIF groups

Patients in the OAMT group experienced achieved significant postoperative improvements. The VAS scores reduced by 4.5 points on average, from 6.34 ± 1.56 to 1.48 ± 0.92 points. The ODI scores reduced about 15 points, respectively dropping from 53.18 ± 11.25 to 18.32 ± 10.02. The lumbar lordosis (LL) angle increased from 39.87° ± 8.48 to 44.21° ± 9.12. The anterior disc height (ADH) and posterior disc height saw a average gains of 2.85 mm and 2.97mm, significantly, rising from 7.62 mm ± 0.63 to 10.47 mm ± 1.23 for ADH, and from 6.83mm ± 0.73 to 9.81mm ± 1.45. In addition, the Cobb angle, revealed a substantial average correction of 18.49° , from 20.23° ± 5.84 to 1.74° ± 1.96, which indicates spinal curvature. At the last, the Clinically Satisfactory was 11 (91.67%) (Fig 4).

In the PLIF group, the postoperative results were particularly striking. The VAS scores reduced from 6.73 ± 1.21 to 1.74 ± 0.87 points. And Then, the ODI scores dropped from 57.96 ± 10.46 to 21.22 ± 7.54. The LL angle improved by about 5.01°, from 40.15° ± 7.33 to 45.16°

± 8.11. ADH increased by an average of 1.70 mm, from 7.11mm ± 0.84 to 8.81 mm ± 0.38, and PDH rose by 1.37 mm, from 6.86 mm ± 0.78 to 8.23 mm ± 0.75. The Cobb angle corrected by about 18.08°, from 21.55° ± 7.41 to 3.47° ± 2.98. The Clinically Satisfactory was 14 (93.34%) (Table 3).

Overall comparison

No significant between-group differences were observed in postoperative LL or Cobb angle, indicating comparable deformity-correction efficacy. ADH and PDH were restored significantly more in the OMAT group than in the PLIF group ($P < 0.05$), suggesting superior disc-space reconstruction with OMAT. VAS and ODI scores improved significantly after surgery in both groups, with no significant between-group difference in postoperative improvement ($P > 0.05$).

Discussion

Lumbar spinal stenosis is a common degenerative disorder in middle-aged and older adults. Typical manifestations include lower-extremity paresthesia, pain, fatigue, neurogenic claudication, recurrent low back pain, and radicular symptoms, all of which can substantially impair quality of life. Because conservative treatment is often insufficient in advanced disease, surgery may be required.

Minimally invasive techniques have attracted increasing attention because they reduce surgical trauma and may accelerate functional recovery. PLIF, introduced by Briggs and Milligan in 1944, has become a standard procedure for degenerative disc disease, spondylolisthesis, and scoliosis. It provides direct access for neural decompression and pedicle-screw placement but requires extensive dissection of the paraspinal muscles. This may cause muscle injury, postoperative pain, prolonged recovery, substantial blood loss, and iatrogenic instability.

Preserving the posterior soft-tissue envelope is a core principle of minimally invasive spine surgery. MIS-TLIF and OLIF have therefore been widely used for degenerative lumbar stenosis. OLIF accesses the disc through the natural retroperitoneal plane between the great vessels and the psoas major muscle while preserving the posterior structures. The lower blood loss and drainage reported with OLIF may reflect reduced vascular and muscular injury, avoidance of laminectomy, and preservation of bony structures. These factors may also explain the shorter hospital stay observed after OLIF, although previous studies have reported inconsistent results. In contrast, paraspinal-muscle and facet-joint injury during PLIF may delay recovery.

OLIF may require more frequent fluoroscopy than PLIF because repeated imaging is needed for disc-level localization and cage positioning, particularly during the learning curve. In our study, operative time was also longer in the OLIF-based group, partly because it included patient repositioning and re-preparation of the surgical field. Single-position OLIF with simultaneous posterior fixation may reduce this inefficiency. Previous studies have reported shorter operative times with single-position procedures than with dual-position procedures, suggesting that greater familiarity with single-position fixation may improve operative efficiency.

Because OLIF cannot generally be performed at L5-S1, we combined OLIF at L2-L5 with MIS-TLIF at L5-S1 (OMAT). Both groups showed marked reductions in VAS and ODI scores during follow-up. The less invasive approach may preserve the paraspinal musculature and

posterior nerve branches, thereby reducing denervation, fatty infiltration, and postoperative pain. However, transient hip-flexion weakness may occur because of genitofemoral-nerve irritation. These symptoms are usually self-limiting. Surgical outcomes are also influenced by psychosocial factors, early ambulation, and drainage management; reduced blood loss, tissue disruption, and hospital stay may contribute to improved early recovery.

Both OMAT and PLIF achieved spinal stabilization and deformity correction in the coronal and sagittal planes. OMAT provided greater restoration of intervertebral height, particularly in multilevel degenerative disease. This advantage may be attributable to the larger footprint of OLIF cages, which provides greater endplate coverage and structural support than the relatively smaller PLIF implants.

This study has several limitations. Its retrospective design and small sample may have introduced selection bias and limited statistical power. Differences in expectations and understanding between surgical teams and participants may also have caused assessment bias. Although OMAT provided satisfactory indirect decompression through ligamentotaxis, longer follow-up is needed to determine the durability of postoperative canal remodeling and clinical improvement. Prospective, multicenter studies with larger cohorts and at least 5 years of follow-up are needed to establish the relative clinical and radiographic merits of OMAT and PLIF.

Conclusion

This study compared OMAT and PLIF using clinical follow-up and radiographic assessment. Both procedures significantly improved symptoms and produced satisfactory clinical outcomes in patients with long-segment (L2-S1) degenerative lumbar disease.

For multilevel (L2-S1) deformity correction, OMAT achieved greater restoration of intervertebral height while providing clinical and radiographic outcomes comparable to those of PLIF. Its minimally invasive design may reduce tissue injury and perioperative morbidity.

The findings should be interpreted in light of the small cohort, relatively short follow-up, and limited radiographic parameters. Future studies should include larger samples, longer follow-up, and more comprehensive biomechanical and radiographic assessments.

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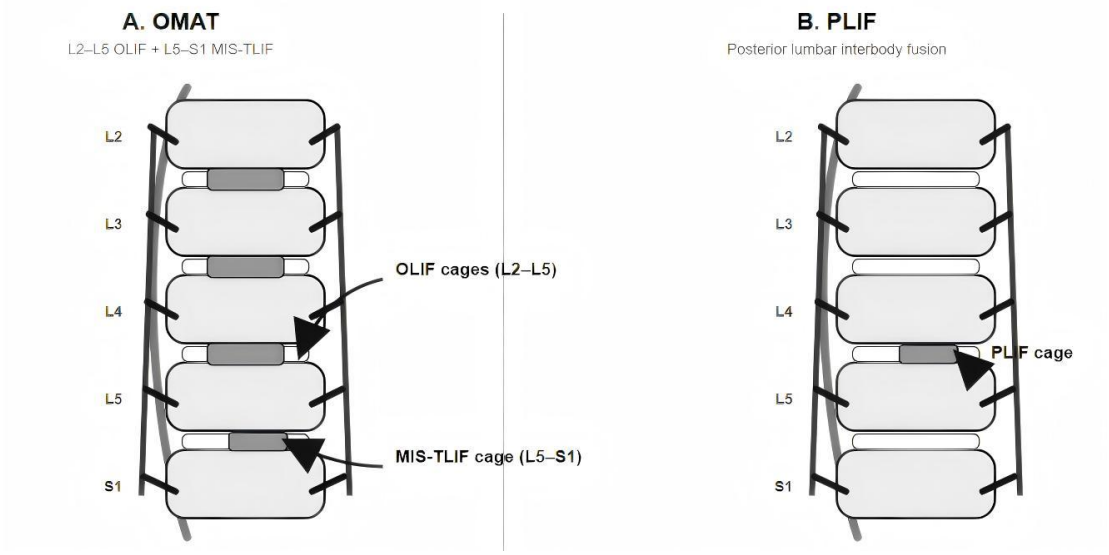
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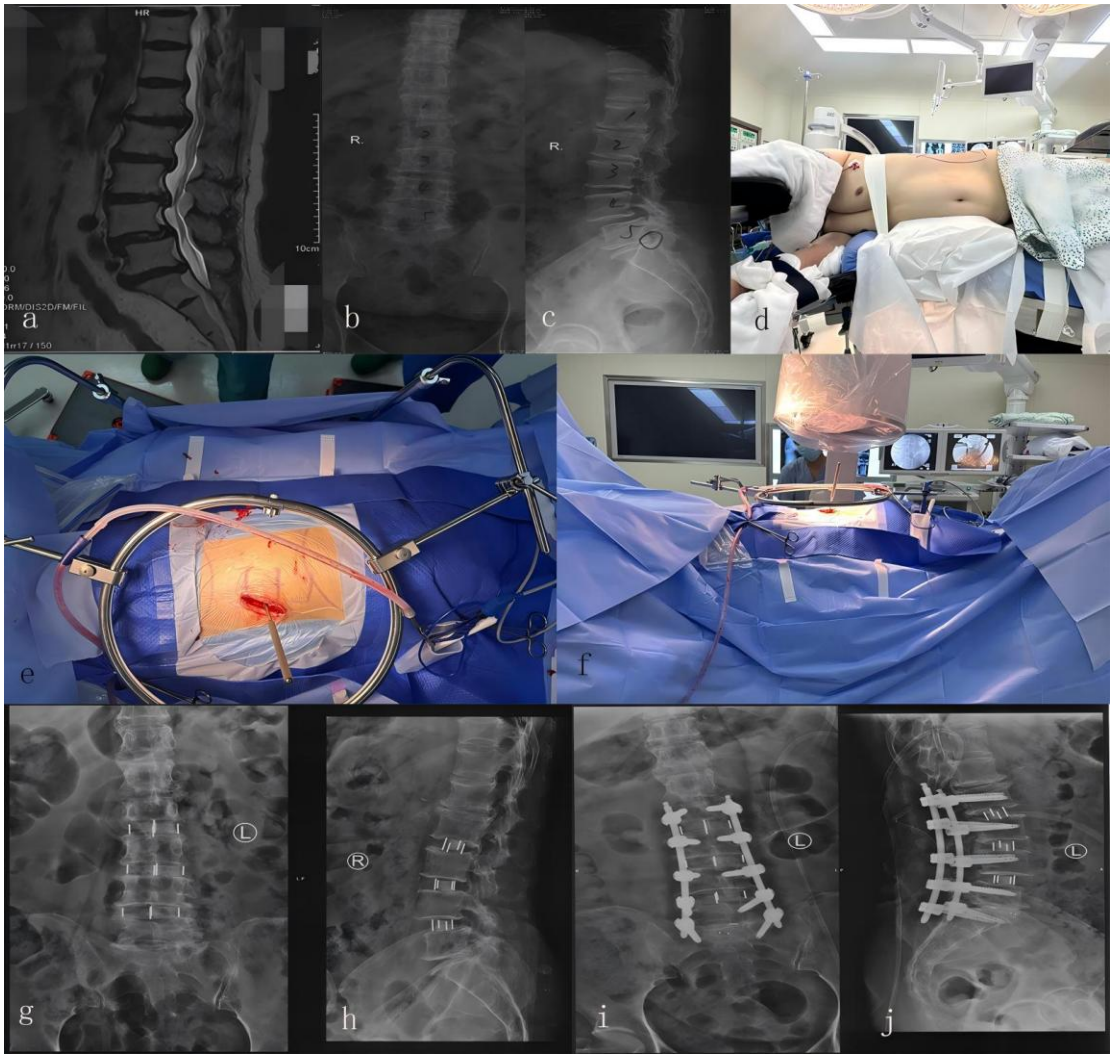
Figure 1: Schematic comparison of OMAT anf PLIF (A and B).

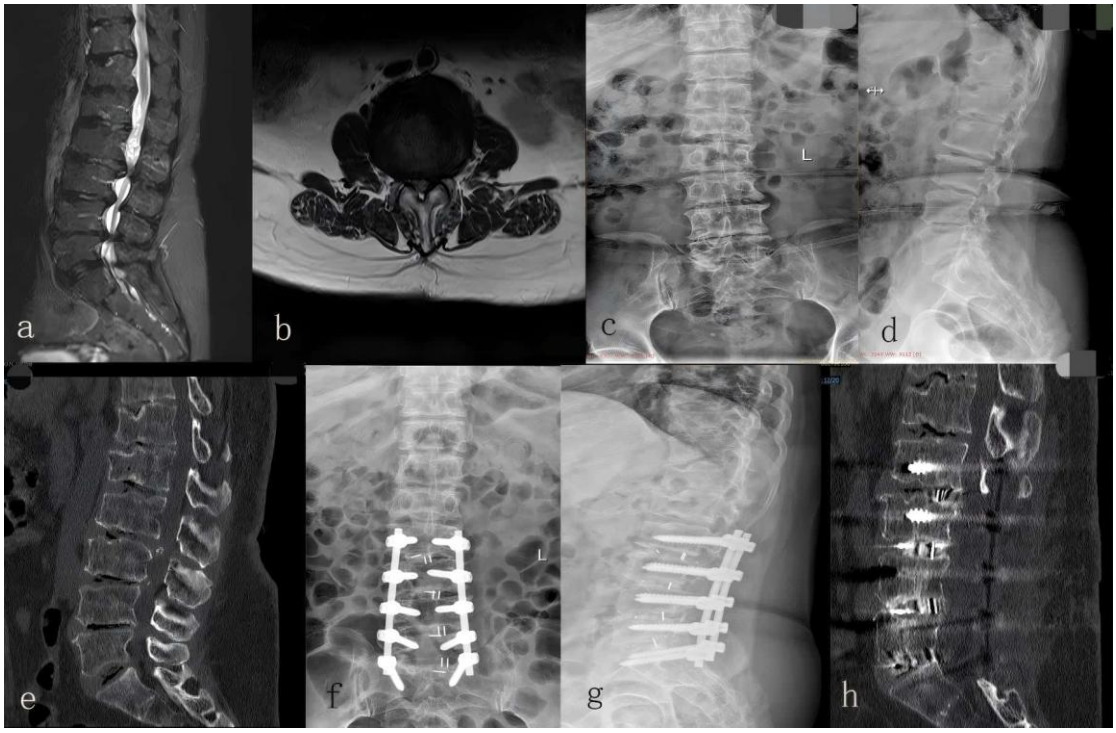
Figure 2: Intraoperative imaging of a patient with back and leg pain during OAMT. The MRI indicates long-segment lumbar spinal canal stenosis (L2-S1) (a). Frontal and lateral X-ray reveals lumbar spine sequence (b and c).The patient was placed in the left lateral decubitus position preoperatively, with the lumbar spine flexed to maximize the distance between the ribs and the iliac bone (d). OLIF intraoperative procedure (e and f). Postoperative X-ray of the lumbar spine (AP and lateral views) was performed after OLIF (g and h). Postoperative X-ray of the lumbar spine (AP and lateral views) was performed after Mis-tlif and PPS (i and j).

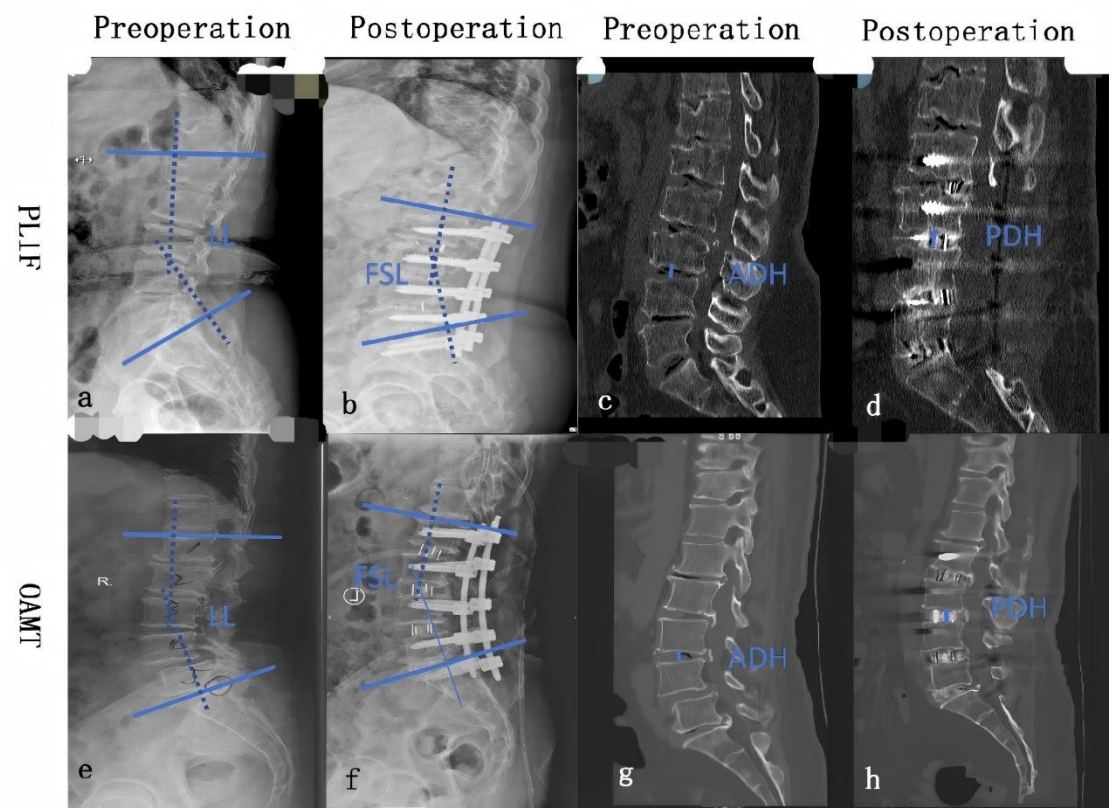
Figure 3: Intraoperative imaging of a patient with back and leg pain during PLIF. The MRI and CT indicates long-segment lumbar spinal canal stenosis (L2-S1) (a, b, e). Frontal and lateral X-ray reveals lumbar spine sequence (c and d). Postoperative X-ray of the lumbar spine (AP and lateral views) was performed after PLIF (g and h).

Figure 4: Diagram illustrating the measurement of imaging parameters before and after surgery. PLIF group: Preoperation and Postoperation LL and FSL(a and b). Preoperation and Postoperation ADH and PDH (c and d). OAMT group: Preoperation and Postoperation LL and FSLe and f). Preoperation and Postoperation ADH and PDH (g and h).




a
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Preoperation
Postoperation
Preoperation
Postoperation
PLIF
OAMT
LL
FSL
ADH
PDH
a
b
c
d
e
f
g
h

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- Table1.docx
- Table2.docx
- Table3.docx