ORIGINAL RESEARCH

Comparison of Direct Pars Repair Techniques for Spondylolysis in Young Patients: Pedicle Screw Hook System versus Pedicle Screw Rod

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ABSTRACT

Background • Lumbar spondylolysis (LS) poses a potential threat, and there is a need to evaluate and compare the effectiveness of direct pars repair techniques.

Objective • To assess and compare the clinical and radiographic outcomes of direct pars repair techniques using the pedicle screw hook system (PSHS) and the pedicle screw rod system (PSRS) in young symptomatic patients with lumbar spondylolysis.

Methods • A retrospective study was conducted to compare clinical and radiological data in young symptomatic LS patients after surgery. Records of 45 post-surgery LS patients with a minimum 24-month follow-up (January 2014 to June 2019) were reviewed. A total of 26 patients underwent PSHS, and 19 had PSRS. Treatment outcomes were analyzed using the visual analog pain scale (VAS), Oswestry disability index (ODI), MacNab criteria, lumbar fusion status, and Pfirrmann grading standards. Patient baseline characteristics were also compared between the two groups.

Results • No disc degeneration was observed in either PSHS or PSRS groups at 24 months postoperatively, according to the Pfirrmann grading scale. The PSRS group outperformed the PSHS group in operative time, intraoperative blood loss, postoperative drainage, length of hospital stays, ODI, VAS values at 3 months postoperatively, and fusion status at 6 months postoperatively. No notable differences were observed in other parameters during the 24-month follow-up period, and no significant surgical complications were recorded.

Conclusions • Direct pars repair techniques using PSHS and PSRS yielded satisfactory clinical and radiographic results in young patients with symptomatic LS. PSRS, compared to PSHS, demonstrated greater effectiveness in young individuals with LS and promoted early recovery. (*Altern Ther Health Med.* 2024;30(10):472-477).

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INTRODUCTION

Lumbar spondylolysis (LS) manifests as a defect in the unilateral or bilateral pars interarticularis resulting from acute trauma or repetitive microtrauma[1] Primarily affecting the lower lumbar spine, articular processes are seldom implicated. LS predominantly occurs at the L5 level, constituting 85-95% of cases, and occasionally at the L3 and L4 levels.[2] The estimated incidence of spondylolysis in adults is 11%.[3] However, LS has the potential to induce severe and intolerable pain in some instances, with low back pain frequently attributed to LS in young individuals.[1] Despite initial conservative treatment, some patients continue to experience symptoms, necessitating surgical intervention.[4]

The primary surgical approaches include intersegmental fusion and intrasegmental vertebral fixation, also known as direct vertebral repair. While intersegmental fusion effectively immobilizes the vertebral body and halts further spinal slippage, it concurrently reduces the mobility of the involved moving segments and elevates mechanical stress at the adjacent level.[3-4] At the same time, intersegmental fusion represents a relatively more complex surgical procedure with a higher incidence of complications.[5] Conversely, intrasegmental pars fixation focuses on the direct repair of the pars without imposing motion restrictions on adjacent segments. This approach aims to maximize the preservation of spinal segmental motion and restore normal anatomy to the greatest extent possible.

Direct vertebral repair for LS has been reported to achieve a high fusion rate, sometimes surpassing that of intersegmental fusion for direct vertebral repair.[6]

Biomechanical studies have indicated that the direct repair and reconstruction of paravertebral defects contribute to reducing the load on adjacent segments.[7] The direct pars repair technique can potentially preserve lumbosacral mobility, mitigate the risk of subsequent disc degeneration, and enhance fusion outcomes through the compression operation applied across the bone-grafted defect.[8]

The pedicle screw hook system (PSHS) and the pedicle screw rod system (PSRS) represent the two primary surgical modalities for the direct repair of the vertebral body. Only one biomechanical study has compared the results of pars fixation procedures between PSHS and PSRS; the treatment outcomes for patients undergoing these two methods are scarcely reported in the literature. Therefore, in this study, we conducted a comparative analysis to assess the efficacy of these two surgical approaches for repairing LS. This study aims to provide valuable insights into the comparative effectiveness of the PSHS and the PSRS for the direct repair of lumbar spondylolysis, contributing to informed decision-making in surgical interventions.

METHODS AND MATERIALS

Study Design

This retrospective study involved the collection of patients' consultation records from January 2014 to June 2019 at Qilu Hospital, Shandong University. The clinical and radiographic outcomes of these patients were systematically reviewed. This study strictly adhered to ethical standards and research protocols. Written informed consent was obtained from all 45 young patients with LS who underwent either PSHS or PSRS. This study also received approval from the review committee of Qilu Hospital, Shandong University.

Inclusion and Exclusion Criteria

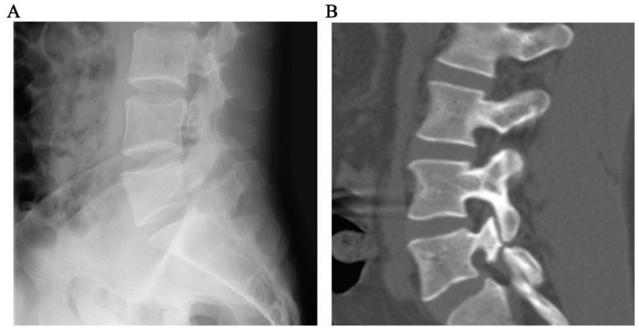
Inclusion criteria were as follows: (1) Patients aged between 14 and 40 years; (2) Single-segment lumbar spine slippage with bilateral vertebral defects confirmed by X-ray or computed tomography (CT) or classified as Meyerding grade I or below in the case of vertebral slippage. Figure 1 illustrates an example of pars defects in L5 on X-ray and CT images; (3) Patients with preoperative disc degeneration of grade I or II according to the Pfirrmann lumbar degeneration rating scale; (4) Patients presenting low back pain as the primary clinical symptom, having undergone conservative treatment for over 6 months without improvement; (5) Patients without abnormal neurological signs or nerve root compression; (6) Patients undergoing PSHS or PSRS surgery.

Exclusion criteria were as follows: (1) History of lumbar surgery; (2) Patients lacking complete clinical follow-up data post-surgery; (3) Patients deemed unfit for surgery; (4) X-ray and CT examinations indicated the absence of bilateral lumbar spondylolysis in L3, L4, and L5.

Preoperative Management

X-rays and CT scans of the lumbar spine in the anteroposterior, lateral, hyperextension, flexion, and oblique positions were conducted for all patients. Additionally, an MRI examination was employed to identify conditions such as spinal canal stenosis and disc herniation.

Figure 1. Paravertebral Defects in L5.The figure illustrates paravertebral defects in L5 through X-ray (A) and sagittal CT (B) X-ray



Surgical Procedure: Pedicle Screw Hook System (PSHS)

Under general anesthesia, a posterior midline longitudinal incision was made using anatomical landmarks and fluoroscopic guidance.

Exposure of Lesion Area. The S-shaped retractor was used to expose the outer edge of the facet joints, the spinous process of the vertebral segment, and the lamina of the lesion.

Identification of Isthmus Fracture. The spinous process was lifted with a towel clamp, revealing the location of the isthmus fracture, determined by the abnormal floating of the vertebral body's posterior arch at the lesion.

Bony Preparation and Grafting. Approximately 2 mm of sclerotic bone was removed at the broken end of the isthmus. Using a high-speed drill, the outer cortex of the lamina on both sides of the isthmus stump was burnished until bleeding occurred. A T-shaped planting bed was then precisely created around the isthmus stump. The periosteum of the attached muscle was dissected along the iliac crest. Two cancellous bone fragments were cut with a bone knife and pruned roughly to correspond to the size of the planting bed. Subsequently, the T-shaped bone graft was embedded in the isthmus and bone groove, firmly securing it in place.

Internal Fixation and Fluoroscopic Confirmation. Following the Weinstein positioning method, appropriately sized pedicle screws were individually placed on both sides of the vertebral body of the lesion. Laminar hooks of appropriate size were positioned at the lower edge of the corresponding lamina to compress the isthmus for bone grafting, and the location of the internal fixation was determined through fluoroscopy.

Finishing Steps and Postoperative Measures. After washing with normal saline, finely broken cancellous bone particles were implanted onto the isthmus surface, and two negative pressure drainage tubes (Figure 2A- 2B) were carefully positioned. Postoperative radiographs were then taken to confirm the correct screw and hook placement for the PSHS procedure; Refer to Figure 2C-D for a visual representation.

Figure 2. Laminar Hook and PSHS Surgery. (A) Physical picture of the laminar hook. (B) Intraoperative image after laminar hook installation. (C, D) Postoperative radiographs showing anteroposterior and lateral views of PSHS surgery.

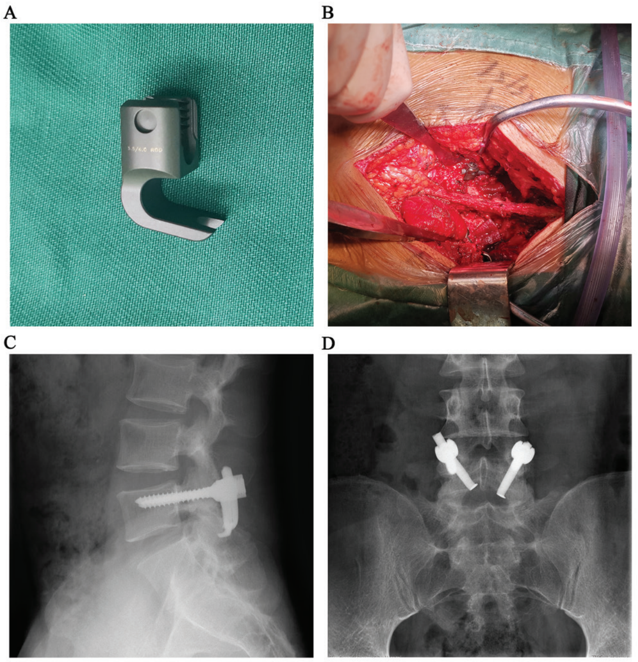
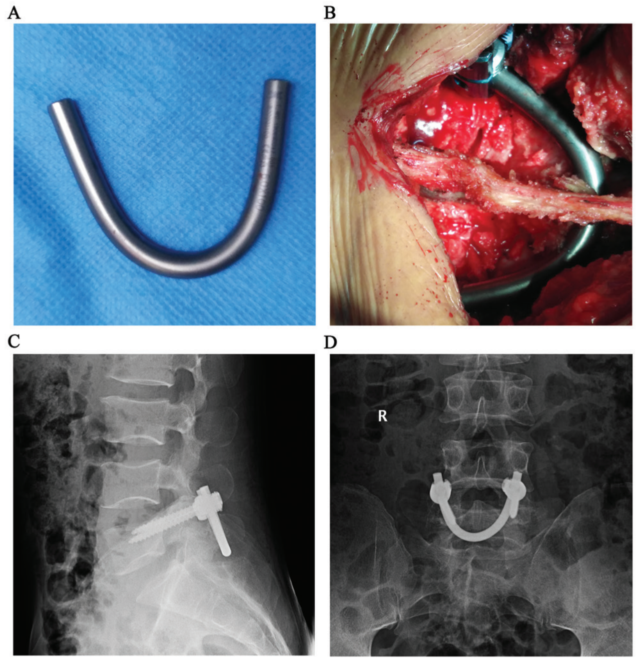


Figure 3. U-shaped Rod and PSRS Surgery. (A) Physical picture of the U-shaped rod. (B) Intraoperative image after U-shaped rod installation. (C, D) Postoperative radiographs showing anteroposterior and lateral views of PSRS surgery.



Surgical Procedure: Pedicle Screw Rod System (PSRD)

Under general anesthesia, the vertebral body of the lesion was identified and labeled using anatomical landmarks and fluoroscopic guidance. Utilizing it as the center, a midline longitudinal incision was made to expose the spinous process of the vertebral segment and the lamina of the lesion. Treatment for lumbar spondylolysis and bone grafting were performed in the same manner as in the PSHS group.

Implantation Method of U-shaped Rod. A rod of appropriate length was bent into a U shape (see Figure 3A) and placed under the spinous process of the vertebral body of the lesion. The U-shaped rod was pulled to the head, and constant pressure was applied to the stump of the isthmus, ensuring that the pull rod of the U-shaped titanium rod was close to the lower edge of the spinous process. Subsequently, the nut at the screw end was rotated for fixation, refer to Figure 3B. Postoperative radiographs confirmed the correct screw and rod placement for the PSRS procedure (see Figure 3C and 3D).

Postoperative Care

The drainage tube was removed 24 hours after surgery once the drainage flow was reduced to less than 50 mL. After removing the drainage tube, the patient was permitted to ambulate with the assistance of a brace. At the 6-week mark, patients engaged in suitable functional exercises. By the end of 3 months, patients gradually resumed normal motor activities.

Outcome Measurements

Clinical Outcomes Assessment. The assessment of clinical outcomes in both groups involved using the Visual Analogue Pain Scale (VAS) for lower back pain and the Oswestry Disability Index (ODI). Evaluations were conducted at pre-surgery and 3, 6, 12, 18, and 24 months post-surgery.

Subjective Assessment. A modified MacNab subjective assessment was carried out precisely at the 24-month post-surgery mark to provide a nuanced understanding of patient-reported outcomes.

Operative Parameters and Complications. Several critical operative parameters and potential complications were thoroughly analyzed, including operation time, intraoperative blood loss, postoperative drainage, and length of hospital stays.

Fusion Status Evaluation. The fusion status of LS was carefully observed by two experienced spine surgeons. Sagittal CT scans were conducted at 6, 12, 18, and 24 months post-operative follow-ups, with assessments continuing until significant bone fusion was visually confirmed. Bone fusion, defined as the passage of trabeculae through a cellular defect, was ascertained, refer to Figure 4.

Radiographic Assessment. At the 24-month follow-up, Pfirrmann's classification was employed to assess the vertebral disc signal, providing insights into the long-term impact of the surgical intervention on disc integrity.

Statistical Analysis

The data were presented as mean ± SD ($\bar{x} \pm s$) for quantitative variables, while qualitative data were expressed as numerical values. Differences between groups were assessed using Welch's two-sample *t* test or Mann-Whitney U test through SPSS 26.0. Qualitative data were analyzed using Pearson's chi-square test (χ^2) or Fisher's exact test. A

Figure 4. Sagittal CT in Lumbar Spine Follow-up. The figure displays sagittal CT images of the lumbar spine during the follow-up period.

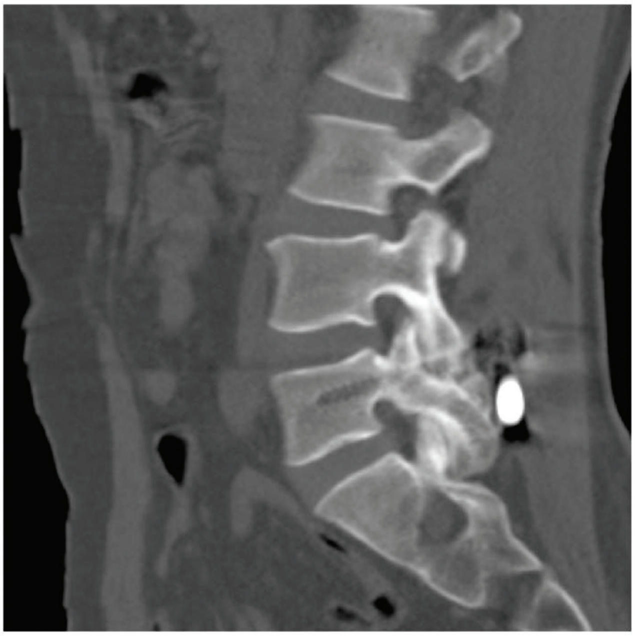


Table 1. Comparison of Patients Characteristics

Characteristics		PSHS	PSRS	*P* value
Gender[a]	Male[a]	19	15	.675
	Female[a]	7	4	.919
Restored lumbar segment[a]	L3	1	1	.970
	L4	3	2	
	L5	22	16	
Age (year)[b]		29.04±6.73	28.90±5.42	.675

[a]The number of patients
[b]Mean±SD

Note: Gender and restored lumbar segment are presented as counts, and age is presented as mean±standard deviation (SD). *P*-values were calculated using appropriate statistical tests.

Abbreviations: PSHS, Pedicle Screw Hook System; PSRS, Pedicle Screw Rod System.

Table 2. The Surgery-Related Indicators

Demographics	PSHS	PSRS	*P* value
Operation Time (min)[a]	175.2±54.1	146.9±31.1	.000
Intraoperative Blood Loss (mL)[a]	190.1±62.3	145.5±52.8	.000
Postoperative Drainage(mL)[a]	100.2±56.0	93.4±49.5	.001
Length of Hospital Stay (days)[a]	12.3±4.1	11.6±2.8	.021
Surgical Complications[b]	2	1	1.000

[a]Mean ± SD.
[b]The number of patients

Note: Surgical indicators, including operation time, intraoperative blood loss, postoperative drainage, length of hospital stay, and the occurrence of surgical complications, are presented for both PSHS and PSRS groups. Numerical values are expressed as mean±SD. *P* values were calculated using appropriate statistical tests.

Abbreviations: PSHS, Pedicle Screw Hook System; PSRS, Pedicle Screw Rod System.

Table 3. Efficacy Assessment (I)

Variables		PSHS	PSRS	*P* value
VAS				
Preoperative		7.19±0.90	7.11±0.88	.747
After surgery	3-month	3.12±1.11	2.32±0.82	.011
	6-month	2.08±1.06	1.95±0.78	.654
	12-month	1.58±1.07	1.53±0.96	.871
	18-month	1.15±1.12	1.11±1.05	.883
	24-month	0.69±1.05	0.74±1.10	.891
ODI				
Preoperative		73.00±8.00	72.00±8.20	.757
After Surgery	3-month	25.00±8.60	18.00±7.40	.009
	6-month	15.00±10.10	13.00±6.90	.536
	12-month	9.80±10.20	10.40±8.20	.840
	18-month	7.00±9.70	6.40±8.20	.836
	24-month	5.00±9.20	5.00±8.60	.987

Note: The table presents the Visual Analogue Scale (VAS) and Oswestry Disability Index (ODI) scores for both PSHS and PSRS groups at various time points. Values are expressed as mean±SD. *P* values indicate statistical significance.

Abbreviations: PSHS, Pedicle Screw Hook System; PSRS, Pedicle Screw Rod System.

significance level of $P < .05$ was applied to determine statistical significance.

RESULT

Patient Demographics

The study included 45 eligible patients, with 26 in the PSHS group and 19 in the PSRS group. The relatively small number of patients was attributed to strict inclusion criteria, limiting the pool of suitable candidates for this operation. Comparable studies investigating direct pars repair techniques included 16 and 17 patients, respectively.[9,10] Analysis of age, gender, and restored lumbar segment revealed no significant differences among the groups, refer to Table 1.

Surgery-Related Indicators

The operation time was (175.2±54.1) minutes in the PSHS group and (146.9±31.1) minutes in the PSRS group ($P = .000$). Intraoperative blood loss was (190.1±62.3) mL in the PSHS group and (145.5±52.8) mL in the PSRS group ($P = .000$). Postoperative drainage amounted to (100.2±56.0) mL in the PSHS group and (93.4±49.5) mL in the PSRS group ($P = .001$). The length of hospital stay was (12.3±4.1) days in the PSHS group and (11.6±2.8) days in the PSRS group ($P = .021$). Significantly lower intraoperative blood loss, postoperative drainage, and length of hospital stay were observed in the PSRS group compared to the PSHS group, and these differences were statistically significant. However, surgical complications in the PSRS group did not exhibit significant changes compared to the PSHS group ($P = 1.00$), refer to Table 2.

Assessment of Treatment Effectiveness

At the 3-month postoperative follow-up, VAS and ODI were significantly lower in the PSRS group than in the PSHS group ($P < .05$). However, no statistical difference was observed between the two groups in subsequent follow-ups (see Table 3). At the 6-month postoperative follow-up, the PSRS group exhibited a higher number of patients with bone fusion

Table 4. Efficacy Assessment (II)

		Bone Fusion Rate (%)		
	Time points	PSHS	PSRS	*P* value
After Surgery	6-month	7	11	.036
	12-month	16	14	.393
	18-month	20	16	.821
	24-month	23	17	1.000

Note: The table presents the bone fusion rates (%) for both PSHS and PSRS groups at different time points. *P* values indicate statistical significance.

Abbreviations: PSHS, Pedicle Screw Hook System; PSRS, Pedicle Screw Rod System.

Table 5. Efficacy Assessment (III)

MacNab evaluation	PSHS	PSRS	*P* value
Excellent	19	15	1.000
Good	5	3	1.000
Fair	2	1	1.000
Poor	0	0	1.000

Note: The table displays the MacNab evaluation results for both PSHS and PSRS groups. *P* values indicate statistical significance.

Abbreviations: PSHS, Pedicle Screw Hook System; PSRS, Pedicle Screw Rod System.

compared to the PSHS group ($P < .05$). More than 85% of patients in both groups achieved bone fusion at the 24-month follow-up, highlighting the effectiveness of the direct pars repair technique; refer to Table 4 for additional details.

MacNab evaluation of the PSHS and PSRS groups at the 24-month follow-up is presented in Table 5. More than 90% of patients in both groups experienced pain relief (categorized as excellent or good in MacNab evaluation), with no significant differences observed between the two groups at the four levels. Additionally, the PSHS and PSRS groups, evaluated according to the Pfirrmann grading standards at the 24-month follow-up, exhibited no intervertebral disc degeneration. Refer to Table 5 for more information.

DISCUSSION

Most of the early symptoms of LS can be improved by conservative treatment, especially in younger patients. However, LS can progress to more severe conditions such as lumbar instability, spondylolisthesis, narrowing of the vertebral space, and disc degeneration.[11] Typically, if conservative treatment fails to alleviate symptoms and spondylolisthesis worsens, surgical intervention is recommended.[7]

The primary surgical treatments for LS are intersegmental fusion and intrasegmental vertebral fixation (also known as direct vertebral repair). However, intersegmental fusion has been reported to alter kinematics at the adjacent level and significantly accelerate degenerative lesions, particularly in children.[12] In contrast, direct pars repair focuses solely on treating the defective pars, utilizing compression across the bone-grafted defect to achieve improved fusion. This approach involves less surgical dissection, preserves spinal motion, and restores the anatomy and stability of the spine.[6,7,13-15]

PSHS was employed to treat 15 patients with LS. None of the patients developed sciatica or motor disorders during the 24-month follow-up period, and both VAS and ODI scores showed significant improvement 24 months post-surgery compared to preoperative results.[16] PSRS was utilized in treating 20 LS patients, achieving a pain relief rate of 90% and a union rate of the pars defect of 80% after an average follow-up of four years.[17]

It is important to note that these were independent studies conducted at two different institutions, each with distinct patient enrollment criteria, and there was no direct comparison of the two surgical approaches. Four pars fixation procedures (Buck's, Scott's, PSHS, and PSRS) were compared in a biomechanical study. The spine model utilizing the PSRS technique demonstrated a superior improvement in flexion, extension, and range of motion.[18,19]

In this research, the PSHS group had a longer operative time, more intraoperative blood loss, greater postoperative drainage, and more extended hospital stay compared to the PSRS group. We believe it is not easy to assemble the pedicle screw, pedicle rod, and pedicle hook into a complete set in the PSHS technique and to fix this set by applying a compressive force.

In many cases, the PSHS technique demands significant effort for pressure application, necessitating more time and manipulation of soft tissue. This could account for the prolonged operation time, increased blood loss, and extended postoperative care observed in the PSHS group. Furthermore, the PSHS technique presents other challenges, including the high complexity involved in repositioning slipped vertebrae and the propensity for screws to loosen and break following surgery.

Additionally, we observed that no statistically significant differences were detected in clinical outcomes (including symptom improvement and radiological assessment) between the two groups during long-term follow-up (> 6 months). This implies that the long-term or overall outcomes of the two procedures are comparable. In comparison to PSHS, the PSRS technique involves simpler surgical steps, resulting in a notable reduction in operation time and soft tissue damage.

The insertion of a "U"-shaped rod provides a precise approximation to either side of the defect, fostering optimal bone fusion. PSRS offers robust intrasegmental fixation and effective reduction for low-grade spondylolisthesis. This advantage of PSRS is evident in the significantly higher fusion rate observed in the PSRS group compared to the PSHS group at the 6-month follow-up. Our data indicate that PSRS technology yields a superior early outcome, underscoring its clear advantage in promoting early recovery. Considering the significance of early bone fusion in treating lumbar spondylolisthesis in adolescents and young adults, the PSRS technique emerges as a favorable option for patients in this demographic.

Study Limitations

This study has a few several limitations. Firstly, the sample size was relatively small, potentially limiting the generalizability of the findings. Additionally, the choice of surgical methods was determined by individual surgeons and their respective institutes, introducing variability. Despite these constraints, the insights provided by this work offer valuable considerations for the selection of surgical methods in young patients with spondylolysis.

CONCLUSION

In conclusion, this study highlights the efficacy of both the PSHS and PSRS techniques in achieving favorable clinical and radiological outcomes for young patients with symptomatic lumbar spondylolisthesis. Notably, the PSRS technique demonstrated a superior early recovery profile compared to PSHS. These findings contribute valuable insights to the treatment landscape for spondylolysis in the young patient population.

DECLARATIONS

The authors declare that there are no conflicts of interest.

FUNDING

The authors have no support or funding to report.

AUTHORS' CONTRIBUTIONS

Yao Zhao: Methodology, Patient follow-up, Data analysis, and Writing- Original draft preparation; Hongliang Wang: Patient follow-up; Guangjun Jiao and Lu Zhang: Assessment of the fusion state of the lumbar spondylolysis; Wenliang Wu: Statistical analysis; Haichun Liu: Supervision; Yunzhen Chen: Supervision.

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DATA AVAILABILITY

The simulation experiment data used to support the findings of this study are available from the corresponding author upon request.

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