SCIENTIFIC ARTICLE

Lumbar isthmic spondylolisthesis: comparative insights into patient selection, surgical techniques, and clinical outcomes

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Abstract

Background: Lumbar isthmic spondylolisthesis (SL), often resulting from underlying spondylolysis, is a prevalent cause of chronic lower back pain and radiculopathy. The optimal surgical strategy—particularly in relation to the severity of SL and sequence of intervention—remains a topic of clinical interest. This study aims to compare one-stage versus two-stage surgical approaches in patients with Grade 1–4 SL, with a focus on functional outcomes, complication rates, and sagittal alignment.

Methods: A retrospective observational study was conducted involving 80 patients (49 women, 31 men; aged 18–89 years) diagnosed with spondylolysis and SL. Patients were stratified into four groups (1A, 1B, 2A, 2B) based on SL grade and surgical strategy (single- or two-stage). Surgical interventions included transforaminal lumbar interbody fusion (TLIF), minimally invasive TLIF (MISS-TLIF), and posterior lumbar interbody fusion (PLIF), with decompression and interbody fusion using autograft and cages. Outcomes were assessed using the Frankel Scale, Karnofsky Index, ECOG/WHO Performance Status, and McCaffrey Pain Assessment.

Results: Sagittal alignment was restored in most cases. Group 1B (single-stage TLIF) showed complete balance restoration, while 1A (two-stage) showed sustained correction with minimal complications (3.75%). Group 2A achieved stability through staged decompression and fusion, with a 5% complication rate. Neurological improvements and reduced pain perception were noted across all groups.

Conclusion: Tailored surgical planning based on SL grade and neurological status is critical. One-stage TLIF is effective in lower-grade SL, while staged surgery is preferred in advanced cases with instability or neurological compromise. Interbody fusion significantly enhances sagittal alignment and functional outcomes.

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Introduction

Low back pain (LBP) is a frequent occurrence in neurosurgical practice and can affect patients of all ages [1]. Spondylolysis, which results from a disruption of the pars interarticularis portion of the vertebral arch, is a common etiology of LBP and predisposes individuals to isthmic spondylolisthesis (SL), which typically develops in young adolescent athletes.

Approximately, 90% of patients with spondylolysis either present with or will eventually develop spondylolisthesis; According to recent research, SL affects 5-7% of the population. [3]. Spondylolysis most commonly affects the L5 vertebral level, with the L4 being significantly less affected. [11]. Radiological techniques such as AP and lateral lumbar X-rays play a crucial role in the diagnostic process. The grades for SL are assigned based on the degree of slippage, starting at 25% in grades I-IV and rising by one quartile in subsequent grades [5]. This study aims to compare spondylolisthesis in two groups (A and B, grades 1-4).

Materials and methods

This retrospective observational study involved 80 patients, with an age range of 18 to 89 years, comprising 49 women (61%) and 31 men (39.2%). The patients were admitted to our Spine rehabilitation center, part of the Vertebrology Division at NCC No. 2, Petrovskovo Academy, Moscow, Russia, between January 2020 and March 2025. The study was conducted in accordance with the principles of the Declaration of Helsinki. The study was conducted with the official permission of the Ethics Committee of the Petrovsky National Research Center of Surgery and Traumatology (Petrovsky NRCS) in Moscow. (Ref. ESN/6_1222).

Inclusion criteria

The study included patients aged 18 years and older who were diagnosed with spondylosis or spondyloarthritis and had progressed to lumbar isthmic spondylolisthesis, anterolisthesis, or retrolisthesis requiring surgical correction. The following surgical techniques were employed: transforaminal lumbar interbody fusion (TLIF) as the primary technique, minimally invasive surgical TLIF (MISS TLIF), and posterior lumbar interbody fusion (PLIF), for better fixation of pedicle screws, stabilization, and decompression to restore the spine's dynamics.

Exclusion criteria

Patients were excluded if they had no spondylolisthesis, were under 18 years of age, or had extraforaminal disc herniation without vertebral displacement.

Statistical Analysis

The data analysis was conducted using Excel and R software (https://www.r-project.org), distributed according to the following scales: Frankel scale, Karnofsky index, and the Eastern Cooperative Oncology Group/World Health Organization Performance Status (ECOG/WHO PS). The results were presented as mean ± standard deviation (SD) values. To estimate outcome measures based on individual data from included studies, statistical analyses were conducted. A p-value of less than 0.05 was deemed significant.

Results

In this study, 80 patients were included, and those with spondylolysis and spondylolithesis of the lumbosacral spine were diagnosed and treated. In group 1A, N=19 patients, or 23.7%, were present via consultation, with a percentage of ≥90 based on the Karnofsky index scale. No noteworthy circumstances were observed. Group 1B, N=14, at the same level, 17.5%. Between 70 and 89, group 1A had three patients (3.7%) and group 1B had four patients (5%). Groups 2A and 2B, N=17 and N=5, respectively, represent 21% and 6%. 50–69; N=3, 3.7%; only found in group 2A. N=9, or 11%, in group 2B, the same category. 5% is represented by group 2A, which is 30-49 on the scale. Group 2B; 2.5%, N=2. 10-29, no information, no fatalities. Shown in table 2. Prior to surgery, the clinical and neurological symptoms of the patients were rated using the Frankel, Eastern Cooperative Oncology Group-World Health Organization (ECOG-WHO), and Karnofsky performance scales. The McCaffrey Initial Pain Assessment Tool (MCIPAT) was used to assess the level of pain a person was experiencing. The surgical intervention in all groups involved reducing the dislocated spinal segment and interbody fusion in addition to repositioning and stabilizing the lumbar spine using transpedicular reduction screws. The groups that underwent TLIF and MISS-TLIF procedures experienced varying degrees of nerve root decompression, spinal alignment reduction, and an algorithm for ordering the operations.

Patients were divided into groups 1A and 1B and 2A and 2B, according to the sequence in which spondylosynthesis and interbody fusion were performed. Patients in Group 1 had SL grades of 1 or 2, an unstable spinal motion segment, and bearable discomfort from a slight radiculopathy. Patients in Group 2 had SL grades 3 and 4 [7].

A two-stage operation was used in patients in group 1A. By reducing the dislocated vertebrae, spondylosynthesis was corrected, and the spine was realigned without damaging the spinal cord. Anterior fusion was then performed using autologous bone. In group 1B, a single-stage procedure was used. Through the TLIF approach, vertebral reduction and anterior interbody fusion were achieved, as shown in Tables 1 and 2 and Figures 1, 2, 3, and 4. While 19 patients in group 1A maintained restoration of sagittal balance after spondylolythesis correction, with a rate of 23.75%, only 3 patients in this group experienced complications, at a rate of 3.75%. In total, 22 patients in this group underwent surgery, with a rate of 27.75%.

Postoperative problems affected a total of 9 individuals, or 11.25% of the participants. For 14 patients in Group 1B, the sagittal alignment of the SL section was restored to decompress the nerve roots. Interbody fusion implants were implanted using autologous bone and implants via a posterior approach during the same session or via a ventral approach during the following 7 to 10 days. Only 4 patients were excluded, representing 5%, and in total, 18 patients were excluded, accounting for 22.5%.

Table 1: Age and gender distribution of patients included in the study.

Age	Male		Female		Total number of patients
	Number of patients	Percentage %	Number of patients	Percentage %	
16–20	1	1.25	2	2.50	3
21-30	2	2.50	4	5	6
31-40	5	6.25	5	6.25	10
41-50	4	5	10	12.50	14
51-60	9	11.25	14	17.50	23
61-70	7	8.75	8	10	15
71-80	3	3.75	6	7.50	9
Total	31	38.75	49	61.25	80

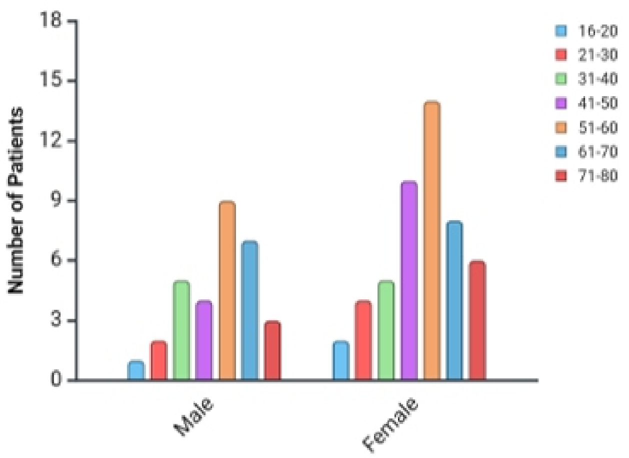
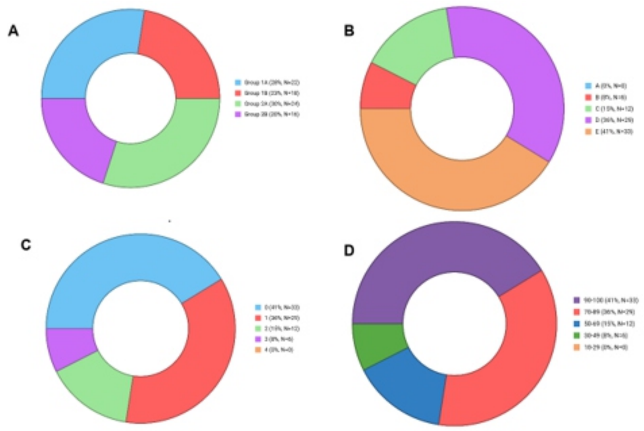


Figure 1: Patient distribution in the study according to age and sex

Table 2: Distribution of patients based on the severity of their neurological symptoms and the surgical procedures they underwent, categorized according to different scales.

Frankel scale	Karnofsky index, %	ECOG -WHO	Number of patients							
			1A	%	1B	%	2A	%	2B	%
E	≥90	0	19	23.75	14	17.50	0	0	0	0
D	70-89	1	3	3.75	4	5	17	21.25	5	6.25
C	50-69	2	0	0	0	0	3	3.75	9	11.25
B	30-49	3	0	0	0	0	4	5	2	2.5
A	10-29	4	0	0	0	0	0	0	0	0
(Total no of patients= 80)			22	27.50	18	22.50	24	30	16	20



Figures 2: Distribution of patients included in the study according to the assigned groups (A), the Frankel Scale (B), the ECOG-WHO Scale ©, and the Karnofsky Performance Scale (D).

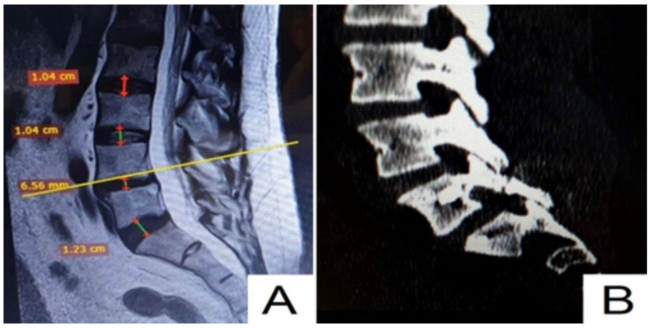


Figure 3: Case example of a 66-year-old female patient with bilateral isthmic spondylolisthesis, presenting with chronic lower back pain radiating to both legs. She was diagnosed with Grade 1 spondylolisthesis and bilateral pars defects at the L5–S1 level.

A) T1-weighted sagittal MRI of the lumbar spine showing narrowing of the intervertebral disc spaces.

B) Sagittal non-contrast CT scan of the same patient demonstrating bilateral pars interarticularis defects at the L5–S1 level.

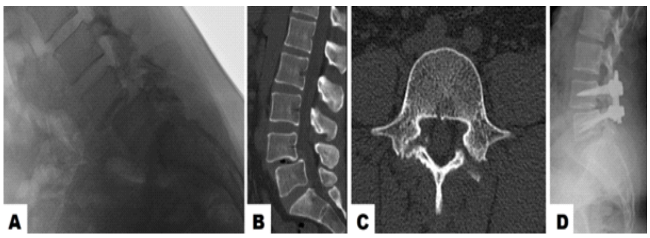


Figure 4: A case example of a 40-year-old female patient who presented with chronic low back pain (LBP) radiating to her left leg.

Despite undergoing multiple conservative treatment modalities, she experienced no pain relief.
A) Preoperative lumbar lateral flexion X-ray showing Grade II spondylolisthesis at the L4-5 vertebral level.
B) Preoperative sagittal non-contrast-enhanced CT scan confirming spondylolisthesis and detecting a vacuum phenomenon in the intervertebral disc space between the L4 and L5 vertebrae, which may indicate spinal instability.
C) Preoperative axial non-contrast-enhanced CT scan revealing a bilateral pars interarticularis defect (L4-L5).
D) Postoperative lateral lumbar X-ray after lumbar stabilization depicting the correction of the deformity.

Group 2 included patients characterized by grade III and IV SL, instability of the spinal motion segment confirmed by dynamic X-rays, and severe neurological disorder. These patients underwent bilateral laminectomy, foraminotomy, and flavectomy. We allowed decompression of the spinal roots; the vertebral reduction was performed in the displaced area, accompanied by visual neuromonitoring of the spinal roots (or by electroneuromyography (ENMG)) [9].

In all patients, interbody fusion was performed using autologous bone and various implants. The sequence of implementation of spondylosyndesis and interbody fusion varied between subgroups 2A and 2 B in this category of patients. They underwent TLIF and MISS-TLIF, which yielded excellent results after surgery [10].

Subgroup 2A patients received a two-level surgical procedure. The first stage involved posterior spondylosyndesis, open decompression of the operated vertebrae, and restoration of the normal function of the spinal cord neurons. A discectomy was carried out from the ventral access on the seventh to tenth day following the initial procedure, along with anterior interbody fusion utilizing autologous bone or an implant.

Patients in subgroup 2B got posterior decompression, correction, and stabilization. The decompression of the spinal nerve roots with spinal reduction was followed promptly by interbody fusion and final transpedicular spondylosyndesis. This group generally consisted of patients whose morbidity would be significantly increased by a second intervention and complications after the first surgery [11].

While 17 patients in group 2A recovered their sagittal balance, only four patients required postoperative intervention, resulting a rate of 5%. Meanwhile, three patients in this group experienced postoperative complications, corresponding to a rate of 3.75%. The percentage of patients in group 2A, out of the 17 patients who underwent restoration of sagittal balance with SL, was 21.25%, corresponding to a total of 24 patients, or a rate of 30%. While the percentage of patients in group 2B who had uncomplicated restoration of balance and a normal pain threshold was 20%, with a total of 16 patients, or 20%.

Patients underwent follow-up exams for 12 months and 2-3 years after surgery. Three years is a limiting time indicator because the supporting interbody bone or bone-fibrous block has fully developed. In the process of analyzing the results of surgical intervention for patients with spondylolysis and SL in both categories, pain perception dynamics, neurological deterioration pre- and postoperatively, and changes in labor function following therapy were assessed [12].

According to changes in radicular sensitivity, a total of 21 patients (26.25%) experienced paresthesia, hypesthesia, and hyperalgesia. In 14 people (17.5%), there were sensory changes, including hypoesthesia and paresthesia in the extremities with the corresponding dermatome.[13]. Only nine patients (11.25%) said they had severe pain that only narcotic analgesics (i.e., McCaffee of 3 points) could manage. Other patients assessed their pain as satisfactory (i.e., McCaffee of 1-2 points) [14].

In contrast to group 2B, where the majority of patients showed improvement (n=12), all patients in group 1B experienced a complete restoration of sagittal equilibrium. Lower pain scores were seen once after therapy. Additionally, a 20% improvement in the Karnofsky Performance Index and a one-point decline on the ECOG-WHO scale were both achieved. Only 16 (12.8%) and 10 (8%) of the patients in groups 1A and 2A, respectively, demonstrated restoration of sagittal equilibrium after one level of therapy, which has been shown high success by reclining the disc to restore lordosis.

Patients in groups 1A and 2A underwent anterior lumbar interbody fusion postoperatively to enhance stability at the second level. 11.25% experienced postoperative complications. In group 2A, 5 cases (6.25%) of postoperative sagittal imbalance syndrome were reported. The grade 4 SL long-term subtype present in this group of individuals, surgical decompression of the spinal canal composition, further transpedicular SL, and corpodesis were performed. Approximate signs of surgical therapy for people with spondylolysis and SL were evaluated many years after surgery was finished. Computed tomography (CT) was conducted on each patient after the postoperative period [15].

Discussion

Clinical and radiological characteristics

In this study, patients with grade I and II SL are managed conservatively, with the primary goals of lowering LBP and stoping the slippage from getting worse. If conservative therapy is unsuccessful, neurological symptoms may get worse and the slippage may get unstable (grade III or above), necessitating the need for surgery. Grade 2–3 spondylolisthesis, including L4–L5 disc protrusion and L5 anterolisthesis, who did not respond to conservative treatment, were selected for surgical evaluation. On clinical examination, marked paravertebral tenderness was consistently observed at the L2–L5 and S1 levels. Cervical spine involvement was limited to only three patients, presenting with tenderness at the C5–Th4 levels and muscle hypertonicity in both cervical and thoracic regions, suggesting compensatory musculoskeletal strain.

Radiological analysis revealed that 87% of patients exhibited foraminal stenosis at the L5–S1 level due to listhesis of the L5 vertebra. Among the patients with vertebral displacement, 13% demonstrated L4–L5 anterolisthesis, while 35% had retrolisthesis. Furthermore, post-traumatic vertebral deformities affecting L1–L3 were seen in 9% of cases, typically associated with vertebrogenic and radicular syndromes.

Postoperative observations

Following surgery, the majority of deformities at the L1–S1 levels were successfully corrected. In particular, cases involving listhesis caused by L5 spondylolysis and foraminal narrowing at L5–S1 showed substantial improvement. Most patients also presented with degenerative spinal changes, including osteochondrosis, spondyloarthrosis, and spondylosis. Painful vertebrogenic and radicular syndromes were resolved in a high percentage of patients after deformity correction.

Surgical technique and approach

The surgical interventions employed included nerve root decompression at the L4, L5, and S1 levels, intervertebral disc resection, and interbody fusion using cages and autologous bone grafts. Rigid posterior fixation at L4–L5 or L3–L5 was performed based on the extent of instability. Decompressive laminectomy with instrumentation was the most frequently used procedure.

The TLIF technique, performed under fluoroscopic guidance, allowed for precise instrumentation. After a midline incision and exposure of the spinous processes and facet joints, pedicle screws were placed, and bilateral decompression was achieved through facetectomy and interlaminectomy. Interbody fusion was performed with properly sized cages (10–12 mm) filled with autologous bone, ensuring spinal stability. No canal compression was observed postoperatively, and radiological control confirmed optimal implant positioning.

Clinical outcomes and neurological status

Surgical treatment resulted in a significant reduction in radicular pain and neurogenic claudication. Approximately 86.6% of patients expressed satisfaction with their recovery. Neurological deficits were observed in only 2.5% of cases, all of whom had chronic, long-standing spondylolisthesis (type B). These patients failed to improve, presenting with persistent neurological symptoms and paraparesis. In such cases, decompressive surgery was only partially successful, likely due to irreversible chronic changes.

The majority of Grade I and II spondylolisthesis cases were initially managed conservatively. However, progression to instability or neurological deterioration necessitated surgical intervention. When surgical decompression, vertebral reduction, and stabilization were applied in a timely and technically appropriate manner, outcomes were favorable, with restored sagittal alignment and improvement in both pain and function.

One-stage vs. Two-stage surgery

In our cohort, both one-stage and two-stage surgical protocols demonstrated comparable success. One-stage TLIF was effective in Grades I and II, allowing vertebral reduction and stabilization without the need for cauda equina decompression. In higher-grade spondylolisthesis (Grades III–IV) or in the presence of neurological deficits, staged surgery—with initial neural decompression followed by reduction and fusion—was preferred to minimize the risk of traction injury to the spinal cord and nerve roots.

Fusion, function, and rehabilitation

Complete interbody fusion was achieved in all patients. Six individuals required revision surgery due to recurrent slippage, but no adjacent segment disease was observed during the follow-up period. Postoperative rehabilitation enabled most patients to return to their preoperative levels of activity within two years. The overall outcome was classified as excellent in 26.4% of patients and satisfactory in 33.6%. Persistent deficits were observed in only 6.25% of cases and were associated with long-standing disease or adhesions.

Current perspectives and literature comparison

Our findings align with recent literature highlighting the effectiveness of interbody fusion techniques such as TLIF and MISS-TLIF in restoring vertebral height, correcting instability, and achieving solid fusion. Anterior cage placement during TLIF has been associated with improved postoperative lordosis and spinal alignment. Although the North American Spine Society has addressed the potential role of anterior fusion in supporting posterior instrumentation, no definitive consensus has yet been reached.

Dynamic assessments suggest that reduction of neurological deficits and nociceptive pain are the most reliable indicators of surgical success. Several authors have emphasized the importance of balancing spinal realignment with the risk of overcorrection and potential neurological deterioration, especially in patients undergoing aggressive vertebral reduction.

Clinical implications

The results of this study highlight the importance of individualized surgical planning, based on the spondylolisthesis grade, neurological status, and spinal stability. One-stage TLIF offers a reliable and efficient solution for lower-grade cases. When performed with appropriate technique, interbody fusion and posterior fixation can restore sagittal alignment, decompress neural elements, and significantly improve patient quality of life. These findings support the ongoing refinement and application of tailored surgical strategies in the treatment of lumbar isthmic spondylolisthesis.

Conclusion

In the surgical management of spondylolisthesis, it is recommended that the patient be positioned prone on non-abrasive pads that provide adequate support while accommodating instrument dynamics. This helps avoid excessive lumbar lordosis and reduces the risk of canal compromise during screw placement.

In our study, Group 1A maintained spinal balance following sagittal restoration. In contrast, Group 2A exhibited initial instability, which resolved postoperatively. Group 2B demonstrated straightforward balance restoration, with 20% of patients reporting a normal pain threshold. Postoperative complications were observed in 11.25% of cases. In Group 1B, the sagittal alignment of the spondylolisthesis segment was restored to achieve nerve root decompression. Interbody fusion was performed using autologous bone and implants, either during the same session via a posterior approach or within 7 to 10 days via an anterior (ventral) approach.

Surgery in Group 1A was performed in two stages: first, skeletonization and spinal decompression; followed by vertebral reduction and spondylosynthesis, which realigned the spine without compromising the spinal canal. Anterior fusion using autologous bone was then completed. In contrast, Group 1B underwent a single-stage procedure. Vertebral reduction and anterior interbody fusion were achieved via a transforaminal lumbar interbody fusion (TLIF) technique. Postoperative pain was managed conservatively, and the majority of patients were discharged without major complications.

Ethics approval

Ethical approval was obtained, and this study was carried out according to the latest revision of the Helsinki

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No funding was received for this study.

Conflict of Interest Statement

The authors declare no conflicts of interest.

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N/A

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