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Research Article

Surgical Outcomes Following Instrumented Fusion in Low-Grade Spondylolisthesis: A 26-Month Retrospective Analysis

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Abstract

Background: Spondylolisthesis is characterized by the anterior or posterior displacement of a vertebra relative to the adjacent inferior vertebra. Patients with grade I-IV spondylolisthesis are initially treated by conservative measures, but surgical intervention becomes necessary for those with persistent symptoms. Surgical options range from pars repair in spondylosis to various fusion techniques, including instrumented reduction and fusion, or instrumented in situ fusion. The study aimed to evaluate the functional outcomes of surgical instrumentation in low-grade spondylolisthesis.
Methods: This retrospective study included 30 patients with low-grade spondylolisthesis who underwent surgical instrumentation. Pain and functional outcomes were evaluated using the Visual Analog Scale (VAS) and modified Oswestry Disability Index (ODI) at baseline and follow-up intervals.
Results: The baseline mean VAS score of 7.4 improved significantly at 6, 12, and 24 months ($P < 0.01$). The baseline mean ODI score of 66.8 also improved significantly at these intervals, with a final mean score of 12.51 at 24 months. Complications occurred in 3 patients, including neurological deficits and bone graft retropulsion.
Conclusion: Surgical instrumentation leads to significant improvements in pain and function in patients with low-grade spondylolisthesis, offering excellent outcomes for those unresponsive to conservative treatment.

Keywords: Spondylolisthesis; Spinal Fusion; Pain Measurement; Postoperative Complications; Low Back Pain

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Background

Spondylolisthesis is characterized by the anterior or posterior displacement of a vertebra relative to the adjacent inferior vertebra. The two most common pathologies for this condition are degenerative erosion of the articular surface and defects in the pars interarticularis (1). It is categorized into five types: dysplastic, isthmic, degenerative, traumatic, pathologic, and iatrogenic (2). The condition occurs in 5-6 percent of white men and 2-3 percent of women, with the lumbosacral junction (L5-S1) being the most frequent site (82%), followed by the lumbar L4-L5 region (11%) (3).

Spondylolisthesis typically progresses with age, often starting around 8 years in women and 12 years in men. Initially asymptomatic, it becomes clinically evident as pain develops, with 90% of symptomatic patients demonstrating slippage of less than 30% (4).

Conservative management is the first-line approach; however, surgery is indicated when conservative measures fail or for cases with significant instability or neurological compromise. Surgical management varies depending on the grade and etiology, ranging from pars repair and instrumented in situ fusion to instrumented reduction and fusion, utilizing posterior, anterior, or circumferential techniques (5, 6). The prognosis of spondylolisthesis is closely associated with neurological deficits, radicular symptoms, and the underlying pathology necessitating surgical stabilization (1).

Posterior lumbar interbody fusion (PLIF) is one of the most popular fusion and instrumentation techniques employed in managing spondylolisthesis (7, 8). This approach involves the use of synthetic cages filled with autografts allografts to maintain disc height and achieve fusion (9). However, bone grafting can lead to a variety of complications, including graft resorption and device failure. Lately, threaded fusion cages have shown promise in maintaining disc height and achieving favorable fusion rates (10).

Additional surgical options include anterior lumbar interbody fusion (ALIF) and transforaminal lumbar interbody fusion (TLIF), with TLIF being increasingly performed (11, 12). Minimally invasive approaches, such as minimally invasive TLIF (MI-TLIF), are also gaining popularity for their potential to reduce perioperative morbidity (13, 14).

This study aims to evaluate the clinical and functional outcomes of instrumentation in grade I-IV (lower grades) spondylolisthesis, utilizing the modified Oswestry Disability Index (ODI) as a measure of patient outcomes (15, 16).

Methods

Study Design and Population: This single-arm retrospective observational study was conducted from

2021 to 2023 at a tertiary care center, following approval from HBT Medical College and Dr. R. N. Cooper Hospital Institutional Ethics Committee (Registration no. DHR-EC/NEW/INST/2021/2272). A total of 30 patients with symptomatic spondylolisthesis were enrolled after obtaining informed consent.

Inclusion criteria were:

- Meyerding grade I to IV spondylolisthesis (17, 18)
- Single-level involvement between L3-S1
- Age between 20 to 65 years
- Failure to respond to conservative treatment.

Exclusion criteria were:

- Meyerding grade V spondylolisthesis or spondyloptosis
- Age < 20 or > 65 years
- Previous lumbar surgery.

All patients had unrelenting back pain that had not responded to conservative treatment, with or without neurogenic intermittent claudication. The mean duration of symptoms at initial presentation was one year. All patients were evaluated with anteroposterior (AP), lateral, and oblique lumbosacral spine radiographs.

Surgical Technique: The patients were positioned prone to surgery. A midline incision was performed, and total bone exposure was achieved with dissection until the transverse processes were exposed. Medial laminectomy and extensive foraminotomy after medial facetectomy were performed. Nerve root retraction was done medially after ligamentum flavum resection. After complete discectomy and distraction of the disc space, end plate preparation was performed. A cage size was measured with trial and an appropriate sizeable cage with bone graft was filled into the intervertebral disc. Following the insertion of interbody cages along with autologous bone grafting, pedicle screw rod instrumentation was carried out using standard methods. Bone graft was taken from the laminae, articular facets, and spinous processes.

Follow-up and Assessment: Patients were followed up monthly for the first three months, then every three months during the first year. Assessment included physical examination at each visit, Visual Analog Scale (VAS) for low back pain (19), ODI at regular intervals, radiographic evaluation (AP and lateral) at immediate postoperative period, 1, 6, 12, and 24 months, and multi-slice helical computed tomography (CT) scan with multiplanar reconstruction at average 14 months post-surgery. The correlation between the degree of fusion and the patient's functional outcome during the final follow-up was analyzed.

The ODI evaluation included ten sections (pain intensity, personal care, lifting, walking, sitting, standing, sleeping, sex life, social life, and traveling and a max score of 5 for each), with scores interpreted as:

- 0 to 20 percent: minimal disability
- 21-40 percent: moderate disability
- 41-60 percent: severe disability
- 61-80 percent: crippled
- 81-100 percent: bed-bound.

Statistical Analysis: Data analysis was performed using SPSS software (version 22, IBM Corporation, Armonk, NY, USA). The significance level was set at $P < 0.05$, using Student's t-test and chi-square test for group comparisons.

Results

Among the study subjects, 21 (70%) were men and nine (30%) were women. Most of the participants (n = 24, 80%) were from the age group of > 50 years with a mean age of 56 years and a standard deviation (SD) of 5.49 years. Level of fusion includes L3-L4, L4-L5, and L5-S1 were found among 3 (10%), 18 (60%), and 9 (30%) subjects, respectively. Degenerative instability was revealed in 20 (66.67%) subjects while isthmic instability in 10 (33.33%) (Table 1).

Table 1. Distribution of fusion levels and origin of instability (n = 30)

Fusion level	n (%)	Origin of instability	n (%)
L3-L4	3 (10.00)	Degenerative	20 (66.67)
L4-L5	18 (60.00)	Isthmic	10 (33.33)
L5-S1	9 (30.00)	Total	30 (100)
Total	30 (100)		

At baseline, the VAS score among the study subjects was 7.4. After one month of surgery, the mean VAS score reduced to 5.78. At six-month, 12-month, and 24-month follow-up, the mean VAS score was 2.06 ± 1.24, 0.93 ± 1.20, and 0.41 ± 0.23, respectively. There was a statistically significant difference between the preoperative mean VAS score and the follow-up VAS score, except one month, when the difference was not significant. At baseline, the ODI score among the study subjects was 66.8. After one month of surgery, the mean ODI score reduced to 58.13. At six-month, 12-month, and 24-month follow-up, the mean ODI score was 34.69 ± 5.17, 21.72 ± 5.80, and 12.51 ± 2.90, respectively. When the preoperative mean ODI score was compared statistically with the follow-up ODI score, a statistically significant difference was found except at one month as $P < 0.01$ (Table 2).

Table 2. Clinical outcomes: Visual analog scale (VAS) and Oswestry Disability Index (ODI) scores over time

Variables	VAS (mean ± SD)	P-value†	ODI (mean ± SD)	P-value†
Preoperative	7.40 ± 1.30	-	66.80 ± 6.20	-
1 month	5.78 ± 1.90	0.07	58.13 ± 6.90	0.07
6 months	2.06 ± 1.24	< 0.01*	34.69 ± 5.17	< 0.01*
12 months	0.93 ± 1.20	< 0.01*	21.72 ± 5.80	< 0.01*
24 months	0.41 ± 0.23	< 0.01*	12.51 ± 2.90	< 0.01*

*Statistically significant; †P-value compared to preoperative scores
SD: Standard deviation; VAS: Visual analog scale; ODI: Oswestry Disability Index

Complications occurred in 3 patients: one case of neurological deficit and two instances of bone graft retropulsion (Table 3).

Table 3. Postoperative complications

Complication type	n (%)
Neurological deficit	1 (3.30)
Bone graft retropulsion	2 (6.67)
Infection	0 (0)
Pedicle screw malposition	0 (0)
Deep vein thrombosis	0 (0)

Discussion

In the current study, we demonstrated that surgical instrumentation provided significant clinical and functional improvements in patients with low-grade spondylolisthesis. Pain and disability, measured using VAS and ODI scores, showed marked reductions at follow-up intervals, specifically beyond the first month.

The L4-L5 and L5-S1 levels were more frequently involved in our patients, consistent with findings in previous studies. Similarly, Kruse et al. revealed that the most common level involved was L4-L5 (20). Degenerative spondylolisthesis is most commonly associated with the L4-L5 level, whereas isthmic spondylolisthesis typically affects the L5-S1 level (15). Similar distributions were also reported by Nimmagadda et al. (21) and PST et al. (22) reinforcing the characteristic anatomical predilections of these conditions.

Pain outcomes, as measured by VAS scores, improved significantly over time in this study. At the final follow-up, the VAS scores showed substantial reductions compared to baseline. Nimmagadda et al. similarly reported over 90% improvement in back pain and over 80% improvement in radiating pain at one year (21). Comparable results have been reported by PST et al. where the preoperative mean VAS score for back pain significantly reduced from 8.2 to 2.1 at final follow-up (22). Additionally, Varun et al. demonstrated similar improvements for back pain with and without instrumentation. However, for radiating pain, the non-instrumented group showed greater improvement (94.9% vs. 89.3%, $P < 0.001$) (1).

Functional outcomes assessed using ODI scores demonstrated similar improvements, with significant reductions from baseline to all follow-up intervals beyond the first month. The final ODI scores in this study align closely with those reported in previous research. Similarly, Varun et al. reported that the improvement in ODI was greater in the instrumented group than in the non-instrumented group (69.5% vs. 64.6%, $P < 0.001$) (1). PST et al. similarly documented a reduction in ODI scores from 72 preoperatively to 14 at final follow-up (22). Nimmagadda et al. reported comparable results, with an average ODI score of 22 at one-year follow-up, reflecting a 63.35% improvement (21). Grob et al. also observed significant improvements in pain and function in both decompression-only and instrumentation groups, although no significant difference was noted between the two approaches. This suggests that while instrumentation provides mechanical stability, decompression alone can also yield substantial clinical benefits for selected patients (23). Sharma et al. conducted a study on 40 patients with single-level lumbar canal stenosis with grade 1 and 2 spondylolisthesis and showed significant improvement in ODI score with excellent outcome score of 90% in TLIF and 85% in laminectomy (24).

The complication rate in this study was low, with only three patients experiencing adverse events (one neurological deficit and two cases of bone graft retropulsion). This is consistent with previous reports of surgical outcomes in spondylolisthesis, where complications are typically minimal. According to PST et al., of the 76 patients, 12 patients presented with neurological deficits. Sensory weakness was found in eight patients and motor weakness in four patients (22).

The limitations of the study are the lack of control groups and its retrospective nature.

Conclusion

This study demonstrated the efficacy and safety of surgical instrumentation for low-grade spondylolisthesis. While conservative management remains the first-line approach, surgical intervention is a reliable option for patients with persistent symptoms, yielding significant pain relief and functional improvement. Future studies could explore long-term outcomes and comparative effectiveness of different surgical techniques to further refine the management of this condition.

Conflict of Interest

The authors declare no conflict of interest in this study.

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