THE PLANET

Original Article

Comparative Study of the Effectiveness of MIS TLIF for Degenerative vs. Isthmic Low-Grade Spondylolisthesis: A Subgroup Analysis of Clinical and Radiological Results

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ARTICLE INFO

Received: 14 Apr 2026
Accepted: 23 Apr 2026
Published Online: 5 May 2026

DOI:

Volume: 9, Number: 2, Page: 166-172

e-ISSN: 2789-5912
ISSN: 2617-0817

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ABSTRACT

Background: Low-grade spondylolisthesis, whether degenerative or isthmic, is a common cause of disability and pain among adults. Minimally invasive transforaminal lumbar interbody fusion (MIS-TLIF) has emerged as a standard surgical approach, though comparative outcomes between etiological subgroups remain underreported, particularly in low- and middle-income countries. The current study aimed to compare clinical, radiological, and perioperative outcomes of MIS-TLIF in degenerative versus isthmic low-grade spondylolisthesis. **Methods & Materials:** This quasi-experimental study was conducted at BSMMU and Popular Medical College Hospital, Dhaka, from March 2022 to September 2024. Included 20 patients (10 degenerative, 10 isthmic) undergoing single-level MIS-TLIF. Baseline characteristics, surgical metrics, and postoperative outcomes were assessed over 12 months using VAS, ODI, Bridwell fusion grading, and Modified Macnab's criteria. **Results:** Both groups experienced significant improvements in back and leg pain (VAS) and disability (ODI), with no statistically significant intergroup differences ($p > 0.5$). Fusion outcomes favored the degenerative group at 12 months (Grade I fusion: 70% vs. 50%), though not significantly ($p = 0.18$). Clinical outcomes per Macnab's criteria showed more excellent ratings in degenerative cases (80% vs. 70%). **Conclusion:** MIS-TLIF is effective for both degenerative and isthmic low-grade spondylolisthesis, offering comparable functional and radiographic results. A mild trend toward superior outcomes in degenerative cases warrants further investigation in larger cohorts.

Keywords: *MIS-TLIF, Degenerative Spondylolisthesis, Isthmic Spondylolisthesis, Minimally Invasive Spine Surgery*

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INTRODUCTION

Lumbar spondylolisthesis is a prevalent spinal disorder characterized by the anterior displacement of one vertebral body over another, often leading to chronic low back pain and neurological symptoms. Globally, it represents a significant cause of spinal morbidity, contributing notably to disability-adjusted life years (DALYs) due to musculoskeletal disorders. In particular, low-grade spondylolisthesis (Meyerding Grade I–II , Fig. 1) is the most commonly diagnosed form, especially among the middle-aged to elderly population, and is frequently encountered in both primary and tertiary spine care settings [1]. While the overall prevalence varies across populations, studies suggest rates between 5–12% in older adults, with gender-specific variation favoring females due to postmenopausal changes in spinal biomechanics [1,2]. In regions like South Asia, and especially in Bangladesh, the burden of lumbar spondylolisthesis is increasingly recognized with the gradual expansion of surgical infrastructure. However, local data and contextual research remain scarce, limiting evidence-based planning in these resource-constrained settings [3]. Two predominant etiological types of spondylolistheses—degenerative (DS) and isthmic (IS) differ markedly in their underlying pathophysiology, anatomical characteristics, and clinical presentation.(Fig. 2) Degenerative spondylolisthesis typically arises due to age-related degeneration of facet joints and intervertebral discs, most often at the L4–L5 level, and is more frequently observed in elderly women [4,5]. In contrast, isthmic spondylolisthesis results from a defect in the pars interarticularis, often attributed to stress fractures or congenital anomalies, and is more commonly diagnosed at a younger age, typically at the L5–S1 level [6]. Despite these distinctions, both types frequently present as low-grade slips in clinical practice, making surgical decision-making nuanced and requiring careful subtype consideration. Surgical intervention, particularly in symptomatic or progressive cases, has evolved substantially over the decades. Conventional open transforaminal lumbar interbody fusion (TLIF) techniques remain effective in achieving spinal stability and neural decompression but are associated with significant intraoperative morbidity, including greater blood loss, prolonged hospital stays, and delayed functional recovery [7]. In response, minimally invasive surgery (MIS) approaches, especially minimally invasive TLIF (MIS-TLIF), have gained widespread adoption for treating low-grade lumbar spondylolisthesis. MIS-TLIF has demonstrated advantages such as reduced soft tissue trauma, lower infection rates, shorter operative times, and faster postoperative recovery, while maintaining comparable or superior fusion rates [8–10]. Several meta-analyses and prospective observational studies reinforce the safety and efficacy of MIS-TLIF, particularly in low-grade spondylolisthesis cases [11,12]. However, these studies have primarily evaluated lumbar spondylolisthesis as a homogeneous entity, with few addressing subgroup-specific outcomes based on etiology. This represents a critical limitation, as the biomechanical profiles of DS and IS are inherently distinct, and may influence fusion dynamics, screw fixation stability, sagittal alignment, and recovery trajectories [13,14]. For instance, IS is often associated with anterior instability and greater segmental motion due to the loss of pars continuity, whereas DS involves progressive facet collapse and disc height loss, which may present a more constrained biomechanical environment. These fundamental differences could potentially affect fusion success, complication rates, and postoperative functionality. Despite the clear theoretical implications, direct comparative data on MIS-TLIF outcomes between DS and IS are scarce. Existing studies that do stratify by etiology tend to be

limited by small sample sizes or retrospective design, and most originate from high-resource settings with access to advanced imaging and intraoperative technologies [6,14]. This leaves a substantial evidence gap in LMIC contexts, where surgical accessibility is improving, but where clinicians lack tailored data to guide surgical decisions across spondylolisthesis subtypes. In countries like Bangladesh, where orthopedic and spine surgery practices are transitioning into minimally invasive paradigms, context-specific data on surgical efficacy, complication rates, and patient outcomes stratified by spondylolisthesis etiology are urgently needed. The present study seeks to address this knowledge gap by conducting a comparative subgroup analysis of clinical and radiological outcomes following MIS-TLIF in patients with degenerative versus isthmic low-grade spondylolisthesis within a Bangladeshi surgical cohort. By analyzing etiology-specific differences, this research aims to contribute nuanced insights to the global spine literature and offer practical value to surgeons operating in similar low-resource or transitional healthcare settings.

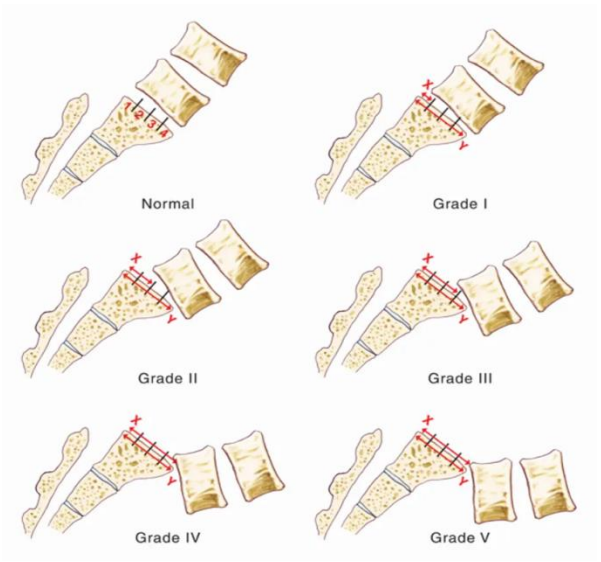

Figure 1 Radiological classification (Meyerding grading)

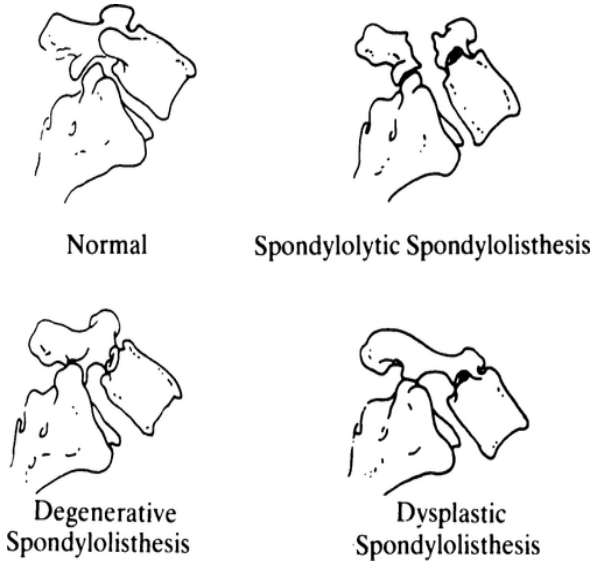

Figure 2 Radiographic Profile of Spondylolysis and Spondylolisthesis

METHODS & MATERIALS

This quasi-experimental study was conducted at BSMMU and Popular Medical College Hospital, Dhaka, from March 2022 to September 2024. This study included 20 patients who underwent minimally invasive transforaminal lumbar interbody fusion (MIS-TLIF) for single-level low-grade spondylolisthesis (Meyerding Grade I–II). Patients were divided into two etiological subgroups: degenerative spondylolisthesis (DS; n = 10) and isthmic spondylolisthesis (IS; n = 10). All procedures were performed at a single spine surgery center in Bangladesh using a uniform MIS-TLIF technique. Data were collected from hospital records and outpatient follow-ups, including demographic profiles, clinical scores, and radiological parameters. Clinical outcomes were assessed preoperatively and at final follow-up using the Visual Analog Scale (VAS) for back and leg pain, Oswestry Disability Index (ODI), and SF-36 physical and mental component scores. Radiological assessments included slip percentage, slip angle, segmental lordosis, and fusion status. Statistical analyses were performed to compare variables between DS and IS groups, with significance set at $p < 0.05$.

RESULTS

The table shows that baseline characteristics were comparable between the degenerative and isthmic groups. The mean age was similar (48.2 ± 9.8 vs. 46.7 ± 10.5 years; p = 0.62). Although males were more common in the degenerative group and females in the isthmic group, the difference was not significant (p = 0.40). Both groups had identical BMI distributions, with 80% overweight (p = 1.00). Occupational status was also similar across groups (p = 0.85). Overall, no statistically significant differences were observed (*Table I*).

Table I
Baseline Characteristics of Patients (*n* = 20)

Variable	Degenerative (n=10)	Isthmic (n=10)	p-value
Age (years)			
Mean ± SD	48.2 ± 9.8	46.7 ± 10.5	0.62
Sex, n (%)			
Male	6 (60%)	4 (40%)	0.40
Female	4 (40%)	6 (60%)	
BMI Category, n (%)			
Normal	2 (20%)	2 (20%)	1.00
Overweight	8 (80%)	8 (80%)	
Occupation, n (%)			
Service/Teacher	5 (50%)	4 (40%)	0.85
Housewife	3 (30%)	4 (40%)	
Others	2 (20%)	2 (20%)	

At baseline, all patients in both the degenerative (DS) and isthmic (IS) groups presented with low back pain, radiculopathy, and neurogenic claudication. Sensory and motor involvement were observed in 90% of DS patients and 80% of IS patients, with no statistically significant differences (p = 0.60 for both parameters). Reflex abnormalities were relatively infrequent and comparable between groups, with diminished knee jerk noted in 30% of DS and 20% of IS patients (p = 0.61), while diminished ankle jerk was present in 20% and 10% respectively (p = 0.53). Radiologically, features of spondylosis were more prevalent in the DS group (90%) compared to the IS group (70%), though this was not statistically significant (p = 0.28). Reduced disc space was observed in nearly all patients 100% in the DS group and 90% in the IS group (p = 0.29). In terms of slip grade, Grade I spondylolisthesis was more frequent in the DS group (70%), whereas Grade II slips were more common in the IS group (50%), although these differences did not reach statistical significance (p = 0.36). Segmental instability was observed in 20% of patients in both groups (p = 1.00), indicating similar dynamic behavior across subtypes at presentation (*Table II*).

Table II
Clinical and Radiological Features at Baseline (*n* = 20).

Feature / Finding	Degenerative (n=10)	Isthmic (n=10)	p-value
Clinical Features			
Low back pain	10 (100%)	10 (100%)	–
Radiculopathy	10 (100%)	10 (100%)	–
Neurological claudication	10 (100%)	10 (100%)	–
Sensory involvement	9 (90%)	8 (80%)	0.60
Motor involvement	9 (90%)	8 (80%)	0.60
Diminished knee jerk	3 (30%)	2 (20%)	0.61
Diminished ankle jerk	2 (20%)	1 (10%)	0.53
Radiological Findings			
Spondylosis	9 (90%)	7 (70%)	0.28
Reduced disc space	10 (100%)	9 (90%)	0.29
Grade I spondylolisthesis	7 (70%)	5 (50%)	0.36
Grade II spondylolisthesis	3 (30%)	5 (50%)	0.36
Instability	2 (20%)	2 (20%)	1.00

Operative parameters were also comparable between the groups. The mean per-operative blood loss was 208.2 ± 11.0 ml in the DS group and 210.5 ± 9.8 ml in the IS group (p = 0.58). Duration of surgery was similar as well, averaging 161.2 ± 9.0 minutes in the DS group and 160.1 ± 8.5 minutes in the IS group (p = 0.71). One peri-operative complication was noted in each group (10%), with no significant difference (p = 1.00). The average length of hospital stay was slightly longer in the DS group (3.5 ± 0.5 days) compared to the IS group (3.4 ± 0.5 days), but this difference was not statistically significant (p = 0.63) *Table III*.

Table III
Operative Profile (*n* = 20).

Variable	Degenerative (Mean ± SD)	Isthmic (Mean ± SD)	p-value
Per-operative blood loss (ml)	208.2 ± 11.0	210.5 ± 9.8	0.58
Duration of surgery (min)	161.2 ± 9.0	160.1 ± 8.5	0.71
Peri-operative complications, n (%)	1 (10%)	1 (10%)	1.00
Hospital stays (days)	3.5 ± 0.5	3.4 ± 0.5	0.63

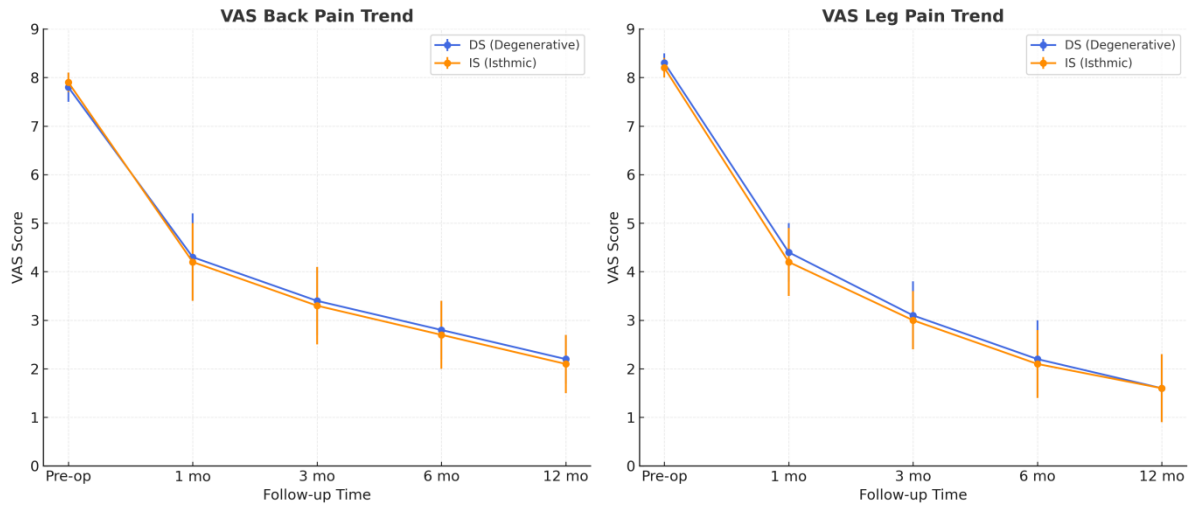

Figure 3 Trends in VAS Scores for Back and Leg Pain (DS vs. IS)

Preoperative leg pain scores were slightly higher than back pain scores, averaging 8.3 ± 0.2 in the DS group and 8.2 ± 0.2 in the IS group (p = 0.62). These scores decreased substantially by the first postoperative month (4.4 ± 0.6 and 4.2 ± 0.7, respectively), and continued to decline at three months (3.1 ± 0.7 vs. 3.0 ± 0.6), six months (2.2 ± 0.8 vs. 2.1 ± 0.7), and twelve months (1.6 ± 0.7 in both groups). No statistically significant differences in leg pain reduction were observed between the groups at any follow-up interval (all p > 0.05). (*Figure 3*)

Disability levels, as assessed by the Oswestry Disability Index (ODI), improved markedly in both the degenerative (DS) and isthmic (IS) groups following MIS-TLIF. Preoperatively, mean ODI scores were comparable between the groups, with the DS group averaging 46.0 ± 12.5 and the IS group 45.5 ± 13.0 (p = 0.81), indicating moderate to severe functional impairment in both subgroups prior to surgery. Postoperative assessments showed a steady decline in ODI scores over time in both groups. At one month, scores decreased to 31.8 ± 5.0 in the DS group and 31.0 ± 4.5 in the IS group (p = 0.74), with further reductions observed at three months (25.8 ± 4.2 vs. 25.2 ± 4.1; p = 0.79) and six months (21.8 ± 4.0 vs. 21.3 ± 4.1; p = 0.82). By the 12-month follow-up, mean ODI scores had decreased to 17.8 ± 3.2 in the DS group and 17.5 ± 3.1 in the IS group (p = 0.86), reflecting a transition to minimal disability. At all-time points, there were no statistically significant differences between the groups, suggesting that both degenerative and isthmic spondylolisthesis patients experienced similar functional recovery following MIS-TLIF (*Table IV*).

Table IV
Oswestry Disability Index (ODI) (*n* = 20).

Time Point	Degenerative (Mean ± SD)	Isthmic (Mean ± SD)	p-value
Preoperative	46.0 ± 12.5	45.5 ± 13.0	0.81
1 month	31.8 ± 5.0	31.0 ± 4.5	0.74
3 months	25.8 ± 4.2	25.2 ± 4.1	0.79
6 months	21.8 ± 4.0	21.3 ± 4.1	0.82
12 months	17.8 ± 3.2	17.5 ± 3.1	0.86

Radiological assessment of interbody fusion was performed using the Bridwell grading system at both three and twelve months postoperatively. At the three-month mark, no patients in either group achieved Grade I fusion, but partial progress was evident: 60% of patients in both the degenerative (DS) and isthmic (IS) groups demonstrated Grade II fusion, while 40% in each group remained at Grade III. Indicating Fig. 6, by the twelve-month follow-up, fusion progression was more pronounced. In the DS group, 70% of patients achieved Grade I fusion compared to 50% in the IS group, although this difference did not reach statistical significance (p = 0.18). Grade II fusion was observed in 30% of patients in both groups, while no DS patients remained at Grade III, unlike the IS group where 20% still had Grade III fusion (p = 0.12) *Table V*.

Table V
Bridwell Interbody Fusion Grading (*n* = 20).

Grade	Degenerative – 3 mo	Isthmic – 3 mo	Degenerative – 12 mo	Isthmic – 12 mo	p-value
Grade I	0 → 5 (50%)	0 → 2 (20%)	7 (70%)	5 (50%)	0.18
Grade II	6 (60%)	6 (60%)	3 (30%)	3 (30%)	1.00
Grade III	4 (40%)	4 (40%)	0 (0%)	2 (20%)	0.12

Patient-reported satisfaction and global clinical outcome were assessed at 12 months using the Modified Macnab's criteria. Most patients in both groups reported highly favorable outcomes, with 80% of DS patients and 70% of IS patients rating their result as "Excellent" (p = 0.63). An additional 10% in each group reported a "Good" outcome, and another 10% rated their recovery as "Fair." Notably, one IS patient (10%) reported a "Poor" outcome, while none in the DS group did; however, this difference was not statistically significant (p = 0.29) *Table VI*.

Table VI
Modified Macnab's Criteria at 12 Months (*n* = 20).

Outcome	Degenerative (n=10)	Isthmic (n=10)	p-value
Excellent	8 (80%)	7 (70%)	0.63
Good	1 (10%)	1 (10%)	1.00
Fair	1 (10%)	1 (10%)	1.00
Poor	0 (0%)	1 (10%)	0.29

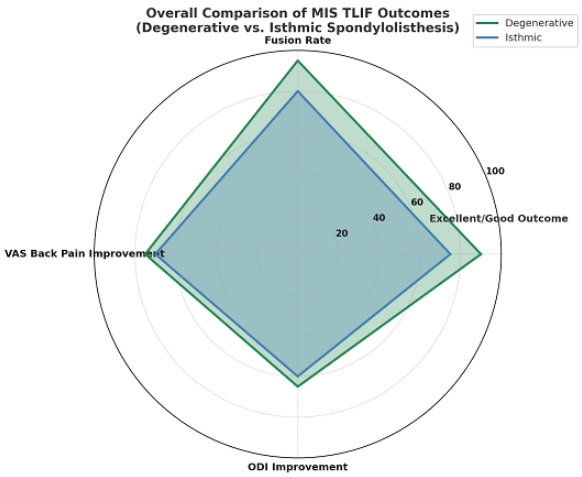

Figure 4 Radar Chart of Overall MIS-TLIF Outcomes

Radar chart comparing degenerative and isthmic spondylolisthesis subgroups across four outcome domains (fusion rate, excellent/good functional outcome, VAS back pain improvement, and ODI improvement). Both groups showed substantial improvements. Degenerative cases demonstrated numerically higher fusion rates (70% vs 50% at 12 months) and a greater proportion of excellent/good outcomes (90% vs 80%), with slightly greater improvements in pain and disability scores. However, none of these differences reached statistical significance (all $p > 0.05$). The chart illustrates directional trends rather than definitive superiority (*Figure 4*).

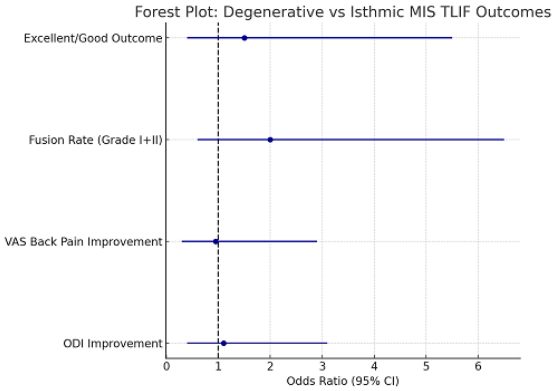

Figure 5 Forest Plot of Clinical and Radiological Outcomes

Figure 5 shows, forest plot comparing odds ratios (with 95% confidence intervals) for key clinical and radiological outcomes between degenerative and isthmic spondylolisthesis groups following MIS-TLIF. Evaluated endpoints include proportion of patients achieving excellent/good outcomes (Modified Macnab's criteria), fusion rate (Bridwell Grades I + II), VAS back pain improvement, and ODI improvement at 12 months postoperatively. The odds ratios are consistently in favor of the degenerative group across all metrics; however, the wide confidence intervals indicate statistical non-significance. The vertical dashed line at OR = 1 represents no difference between groups.

DISCUSSION

This study presents a comparative analysis of clinical, radiological, and surgical outcomes following minimally invasive transforaminal lumbar interbody fusion (MIS-TLIF) in patients with degenerative versus isthmic low-grade (Grade I–II) spondylolisthesis in a Bangladeshi context. The findings indicate generally favorable outcomes across both etiological subtypes, with some modest trends suggesting better fusion and clinical recovery in degenerative cases, though without statistical significance. These observations are largely consistent with existing literature. The demographic profile of patients in both groups was comparable in terms of age, sex, BMI, and occupation. This aligns with findings from Massel et al., who reported no significant differences in demographic characteristics between patients with degenerative and isthmic spondylolisthesis undergoing MIS-TLIF [6]. The clinical presentation was also similar in both groups, with all patients experiencing low back pain, radiculopathy, and neurogenic claudication. Although minor variations in motor and sensory deficits were observed, these did not translate into statistically meaningful differences, echoing the observations by Kim et al., who also noted shared symptom profiles between subtypes [15]. Radiological features at baseline showed a higher incidence of spondylosis and Grade I slips in the degenerative group and more Grade II slips in the isthmic group. While this reflects known pathophysiological trends age-related facet degeneration in degenerative spondylolisthesis and higher slip degrees in isthmic due to pars defects no significant differences were found. This supports the observations by Fan et al., who similarly noted radiological heterogeneity but no clear prognostic value in predicting surgical outcomes [16]. The intraoperative parameters blood loss, operative duration, complication rate, and hospital stay were nearly identical between groups, underscoring the procedural consistency of MIS-TLIF regardless of etiology. This is consistent with the findings of Qin et al., whose meta-analysis demonstrated equivalent

perioperative safety profiles between degenerative and isthmic cases treated via MIS-TLIF [12]. The low complication rates in both groups (10%) further affirm the procedural safety in carefully selected low-grade cases. Both groups experienced substantial and sustained improvements in back and leg pain, as measured by VAS scores, with no significant intergroup differences at any time point. These improvements are congruent with those reported by Kim et al., who found that both spondylolisthesis subtypes showed significant VAS reduction at 12 months post-MIS-TLIF [15]. Likewise, ODI scores declined steadily over time in both groups, reflecting improved function and quality of life. Zhang et al. reported similar ODI improvements in isthmic patients following MIS-TLIF, reinforcing the efficacy of the technique across etiologies [17]. Bridwell grading at 12 months revealed a higher proportion of Grade I fusions in degenerative cases (70% vs. 50%), with Grade III fusion observed only in the isthmic group. Although these differences did not reach statistical significance, they hint at potential biomechanical distinctions in healing potential between subtypes. This observation is partially supported by Fan et al., who found slightly inferior fusion rates in isthmic patients, potentially due to greater segmental instability or challenges in graft incorporation [16]. However, Qin et al. concluded that overall fusion rates in MIS-TLIF remain high for both subtypes when meticulous surgical technique is employed [12]. Based on Modified Macnab's criteria, 80% of degenerative patients and 70% of isthmic patients achieved excellent outcomes, with no poor outcomes in the degenerative group. These results mirror those of Massel et al., who reported similarly high rates of patient satisfaction and excellent/good outcomes in both groups following MIS-TLIF [6]. Although not statistically significant, the trend towards better clinical recovery in degenerative cases may reflect differences in biomechanical load distribution, fusion kinetics, or graft integration potential. Radar and forest plot analyses visually reinforced the modest superiority of outcomes in the degenerative group across multiple domains. However, none of the odd's ratios reached statistical significance, highlighting the need for cautious interpretation. This visual trend echoes the findings by Kim et al., who observed a non-significant trend toward better early outcomes in degenerative cases but called for larger cohorts to confirm such distinctions [15]. The findings of this study have practical implications for clinical decision-making in low-resource settings such as Bangladesh, where surgical access is improving but still limited. Our results suggest that MIS-TLIF offers comparable safety and efficacy in both degenerative and isthmic spondylolisthesis, supporting its broader adoption across etiologies. However, the slight trends favoring degenerative cases in fusion and satisfaction metrics merit further exploration, particularly in biomechanically focused trials with larger populations.

LIMITATIONS

The study was conducted in two hospitals with a small sample size. So, the results may not represent the whole community.

CONCLUSION

This comparative analysis of minimally invasive transforaminal lumbar interbody fusion (MIS-TLIF) in patients with low-grade degenerative and isthmic spondylolisthesis reveals that both subtypes benefit significantly from the procedure in terms of pain relief, functional recovery, and fusion rates. Although no statistically significant differences were observed between the two groups across clinical, radiological, and surgical outcome parameters, degenerative cases exhibited a modest trend toward superior fusion grade and a higher proportion of excellent clinical outcomes. The overall safety profile was favorable, with minimal complications and comparable perioperative parameters across groups. These findings suggest that MIS-TLIF is a reliable and effective surgical option for both degenerative and isthmic etiologies of low-grade spondylolisthesis. However, the subtle differences observed warrant further exploration through larger, multicenter trials to better inform subgroup-specific surgical planning, especially in resource-constrained settings like Bangladesh, where tailored evidence is currently limited.

FUNDING

No funding sources

CONFLICT OF INTEREST

None declared

ETHICAL APPROVAL

The study was approved by the Institutional Ethics Committee.

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