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# THE EFFICACY OF *IN SITU* FUSION FOR LOW-GRADE SPONDYLOLISTHESIS: A RETROSPECTIVE STUDY

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ABSTRACT

**Objective:** To investigate the clinical and radiological outcomes of lumbar decompression and instrumented fusion without reduction in a cohort of female patients with degenerative spondylolisthesis.

**Materials and Methods:** A retrospective analysis was conducted on 25 female patients who underwent posterior lumbar decompression and instrumented fusion at a single institution between January 2010 and January 2020, all of whom were followed up for at least 12 months. The study measured changes in pain and disability using the Visual Analogue Scale (VAS) and Oswestry Disability Index (ODI), along with changes in vertebral alignment, olisthesis, grade, and slip angle.

**Results:** Significant reductions were observed in pain intensity (VAS scores decreased from 7.4 to 4.08, p<0.001) and disability levels (ODI scores reduced from 65.12 to 31.04, p<0.001). Improvements were also noted in the listhesis grade (from 2.08 to 1.28, p<0.001) and a decrease in sacral slope (p=0.017). The change in the slip angle was not statistically significant (p=0.074). No significant changes were observed in pelvic tilt (p=0.353). The only reported complication was adjacent segment degeneration in one patient, which required revision.

**Conclusion:** *In situ* fusion without reduction can effectively alleviate pain, improve function, and lead to spontaneous correction of olisthesis grade in patients with degenerative lumbar spondylolisthesis, particularly those with low-grade slips. These outcomes support the efficacy of *in situ* fusion as a safer, less invasive alternative to vertebral reduction. This approach could influence clinical decision-making in the management of degenerative spondylolisthesis, although further studies with larger cohorts and extended follow-up are necessary to validate these findings.

**Keywords:** Spondylolisthesis, *in situ* fusion, instrumented fusion

## INTRODUCTION

Spondylolisthesis, defined as the forward displacement of a vertebral body over its adjacent counterpart, is a prevalent spinal disorder affecting approximately 4-6% of the general population[1]. It is classified into five distinct types by Wiltse et al.[2] -dysplastic, isthmic, degenerative, traumatic, and pathologic- and is radiographically assessed using the Meyerding classification, which ranges from Grade 0 (no slippage) to Grade 4 (76-100% slippage)[2,3]. Grade 1 and 2 slips are generally considered low-grade, while Grade 3 and 4 slips are deemed high-grade[1].

Degenerative spondylolisthesis, most commonly presenting as a low-grade slip (Grade 1 or 2), typically manifests with chronic low back pain and, in more severe cases, neurological dysfunction of the lower extremities[1]. Typically, at least three months of nonoperative management, including the use of braces, exercises, and other conservative modalities, yields satisfactory results[4,5]. However, for patients whose symptoms persist or worsen, or those who develop neurological deficits despite these treatments, surgical intervention may be warranted[4,5].

The surgical goal is to decompress the affected neural structures and secure vertebral fusion, which can be performed with or without the reduction of the slipped vertebra[6]. While reduction might theoretically enhance biomechanical alignment and facilitate fusion, it is associated with inherent risks, including potential neurological injury and operative complications[7].

In light of these considerations, this study seeks to investigate the mid-to-long term clinical and radiological outcomes of lumbar decompression and instrumented fusion without reduction in a cohort of female patients with degenerative spondylolisthesis. By evaluating changes in pain, disability, and vertebral alignment over time, this research aims to elucidate the efficacy and safety of *in situ* fusion as a viable surgical strategy for this

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patient population, thereby informing clinical decision-making and ultimately improving patient care.

## MATERIALS AND METHODS

A retrospective review was conducted on patients who underwent surgical treatment for degenerative lumbar spondylolisthesis at the authors' institution between January 2010 and January 2020. Patients were included if they had a confirmed diagnosis of degenerative lumbar spondylolisthesis, underwent posterior lumbar decompression (laminectomy) and instrumented fusion, and had at least 12 months of follow-up with complete medical records. Patients with other types of spondylolisthesis, those who did not undergo surgical treatment, those with insufficient follow-up, or those with missing information were excluded. A total of 25 female patients met the inclusion criteria and were included in the study. This was due to the consecutive nature of patient selection, resulting in a higher number of female participants. This approach was essential for maintaining the methodological rigor of the study.

Surgical indications for these patients included persistent pain unresponsive to at least 6 months of conservative treatments, progressive motor deficit, and/or cauda equina syndrome. The surgical procedure consisted of posterior lumbar decompression (laminectomy) and instrumented fusion with pedicle screws (Figure 1, 2). The number of laminectomy levels performed was dependent on the extent of stenosis and the specific surgical goals for each patient. For cases where laminectomy was applied only to the segment with spondylolisthesis, this was explicitly stated as the surgical approach. For patients who underwent long segment fusion, such as the L1-S1 fusion cases, a comprehensive laminectomy was performed at all levels of stenosis, even if not all were associated with spondylolisthesis. This was done to ensure complete neurological decompression and to address multi-level stenosis that might contribute to postoperative outcomes.

Pedicle screws were placed at the levels necessary to achieve stable fixation, spanning from the uppermost instrumented vertebra to the sacrum (S1) in all cases. The inclusion of S1 in the fusion construct was deemed necessary to optimize spinal stability and improve overall outcomes, particularly in patients with osteoporosis or other risk factors for nonunion, as well as to address concomitant lumbar degenerative scoliosis or significant deformity.

The decision for long-segment fusions (spanning three or more levels) was primarily driven by the presence of comorbidities such as multi-level stenosis or degenerative scoliosis. These patients required more extensive surgical intervention to address their complex spinal pathology and ensure adequate correction and stabilization.

The following data were collected from the patient archive: demographic characteristics, follow-up periods, surgical details, complications, preoperative and postoperative Oswestry Disability Index (ODI), Visual Analogue Scale (VAS) scores, and radiographic measurements (Listhesis Grade, Sacral Slope, Slip angle, Pelvic Tilt). The ODI is a validated questionnaire that measures the degree of disability and its impact on daily activities, while the VAS is a scale for assessing pain intensity[8,9].

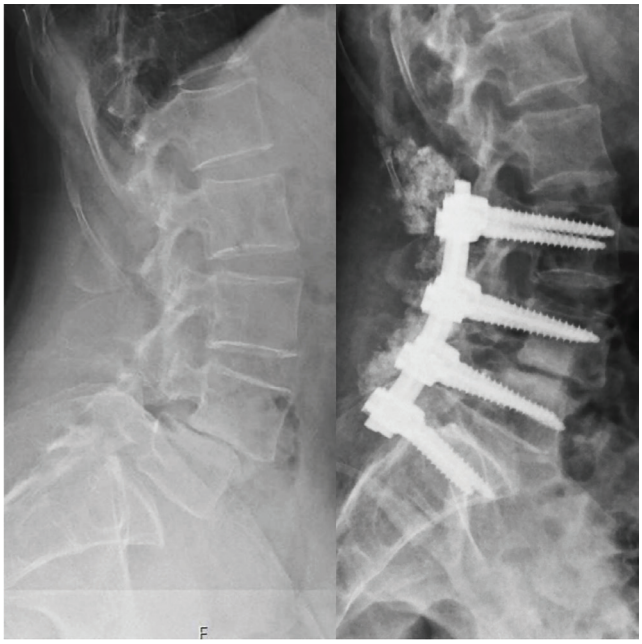

**Figure 1.** Preoperative and postoperative lateral X-rays of a 57 year-old woman underwent listhesis surgery: the preoperative X-ray (left) showed a Grade 2 listhesis at L4-L5. The postoperative X-ray (right) showed stabilization from L3 to S1 with pedicle screws, improving the alignment to Grade 1

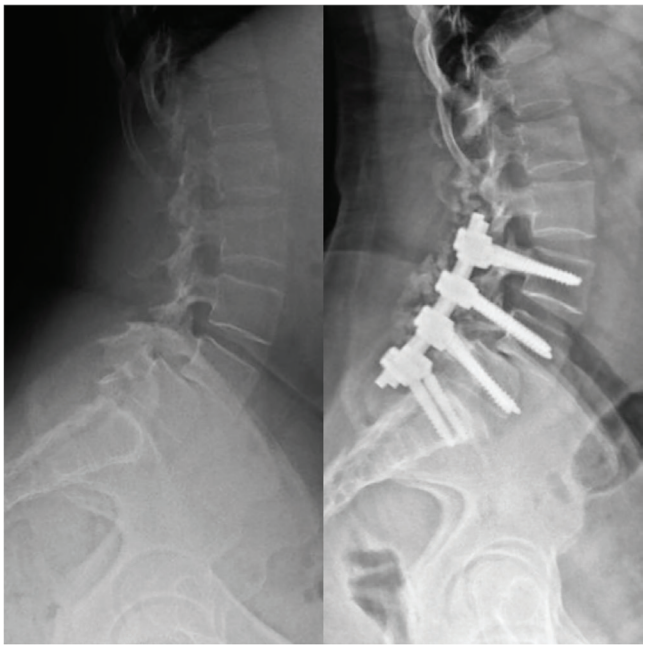

**Figure 2.** Preoperative and postoperative lateral X-rays of a 63 year-old woman underwent listhesis surgery: the preoperative X-ray (left) showed a Grade 2 listhesis at L4-L5. The postoperative X-ray (right) showed stabilization from L3 to S1 with pedicle screws, the alignment remained unchanged

Radiographic parameters were used to evaluate spinal alignment and spondylolisthesis severity. All radiographic measurements were performed independently by three blinded investigators. Inter-observer reliability was assessed using Cohen's kappa coefficient, which showed a high level of agreement between raters [κ=(0.86)]. Measurements were performed at two different time periods: preoperative and at designated control dates.

The study protocol was approved by the University of Health Sciences Turkey Antalya Training and Research Hospital Ethical Committee (approval number: 5/22-2024, date: 25.04.2024). A written informed consent was obtained from each patient. The study was conducted in accordance with the principles of the Declaration of Helsinki and its subsequent updates.

### Statistical Analysis

Statistical analyses were conducted using SPSS 23.0 for Windows (SPSS Inc., Chicago, IL, USA). We first assessed the normality of our data using the Shapiro-Wilk test to determine the appropriateness of statistical tests. Categorical variables were expressed as numbers and percentages [n (%)], and continuous variables were presented as both mean ± standard deviation and median values along with their range (minimum-maximum value). To compare preoperative and postoperative continuous data, we applied the Wilcoxon signed-rank test, which is suitable for paired samples when data are not normally distributed. A p-value of less than 0.05 was considered statistically significant.

## RESULTS

Twenty-five female patients with a mean age of 57.4 years (range 40-70) were included in this study. The mean postoperative follow-up time was 51 months (range 17-117). Fusion levels ranged from L1-S1 to L5-S1, with L3-S1 being the most common (40%). Preoperative listhesis grades were mostly grade 2 (76%), and postoperative listhesis grades were mostly grade 1 or 2 (48% each). (Table 1 presents a detailed description of the study participants, focusing on their demographic and clinical characteristics). Fusion occurred in all patients, as confirmed through radiographic and clinical assessments. Continuous bone bridging, minimal loss of disk height, and absence of hardware complications were observed in the radiographs and computed tomography scans, while significant pain reduction and functional improvement indicated successful clinical outcomes. Among 25 patients, one experienced postoperative adjacent segment degeneration (ASD) requiring revision with extended fixation, representing the only complication.

Pain intensity, as measured by the VAS, significantly decreased after surgery (p<0.001). The mean VAS score dropped from 7.4 preoperatively to 4.08 postoperatively. Similarly, disability, assessed using the ODI, showed marked improvement after surgery (p<0.001). The mean ODI score decreased from 65.12 preoperatively to 31.04 postoperatively. Grade of listhesis significantly improved after surgery (p<0.001). After *in situ* fusion, the mean listhesis grade at the final follow-up improved significantly from 2.08 preoperatively to 1.28 (p<0.05). The sacral slope showed a small but statistically significant decrease after surgery (p=0.017). The mean sacral slope decreased from 47.01° preoperatively to 42.69° postoperatively. While the slip angle showed a decrease after surgery, this change did not reach statistical significance (p=0.074). The mean slip angle decreased from 12.62° preoperatively to 9.42° postoperatively. Pelvic tilt did not significantly change after surgery (p=0.353). The mean pelvic tilt was 18.27° preoperatively and 19.45° postoperatively (the clinical findings of this study are presented in Table 2, detailing preoperative and postoperative measures and their statistical significance).

## DISCUSSION

The study's most significant finding was that *in situ* spinal fusion alone, without intentional reduction, can substantially alleviate pain (VAS score), reduce disability (ODI score), improve listhesis grade, and lead to a reduction in sacral slope. This

**Table 1.** Demographic and clinical characteristics of the participants (n=25)

| **Variables** | |
|---|---|
| **Age (year)** | |
| Mean ± SD | 57.4±9.01 |
| Median (min.-max.) | 59 (40-70) |
| **Gender, n (%)** | |
| Male | 0 (0.0) |
| Female | 25 (100.0) |
| **Fusion levels, n (%)** | |
| L1-S1 | 1 (4.0) |
| L2-S1 | 5 (20.0) |
| L3-S1 | 10 (40.0) |
| L4-S1 | 8 (32.0) |
| L5-S1 | 1 (4.0) |
| **Postoperative follow-up time, months** | |
| Mean ± SD | 51.04±32.01 |
| Median (min.-max.) | 30 (17-117) |
| **Listhesis levels, n (%)** | |
| L1-S1 | 0 |
| L2-S1 | 0 |
| L3-L4 | 1 (4.0) |
| L4-L5 | 12 (48.0) |
| L5-S1 | 12 (48.0) |
| **Preoperative listhesis grade, n (%)** | |
| Grade 1 | 2 (8.0) |
| Grade 2 | 19 (76.0) |
| Grade 3 | 4 (16.0) |
| **Postperative listhesis grade, n (%)** | |
| Grade 0 | 3 (12.0) |
| Grade 1 | 12 (48.0) |
| Grade 2 | 10 (40.0) |

SD: Standard deviation, min.: Minimum, max.: Maximum

**Table 2.** Preoperative and postoperative radiological and clinical scores of the patients

| | Preop | Postop | p-value* |
|---|---|---|---|
| **VAS score** | | | |
| Mean ± SD<br>Median (min.-max.) | 7.4±1.26<br>8 (5-9) | 4.08±2.58<br>4 (0-9) | <0.001 |
| **Total ODI score** | | | |
| Mean ± SD<br>Median (min.-max.) | 65.12±16.44<br>62 (46-98) | 31.04±21.46<br>30.0 (2-78) | <0.001 |
| **Listhesis grade, n (%)** | | | |
| Mean ± SD<br>Median (min.-max.) | 2.08±0.49<br>2 (1-3) | 1.28±0.68<br>1 (0-2) | <0.001 |
| **Sacral slope** | | | |
| Mean ± SD<br>Median (min.-max.) | 47.01°±11.15°<br>44.3° (29.4°-68.6°) | 42.69°±9.07°<br>43.4° (27.5°-70.3°) | 0.017 |
| **Slip angle** | | | |
| Mean ± SD<br>Median (min.-max.) | 12.62°±8.82°<br>10.9° (0.8°-34.3°) | 9.42°±8.33°<br>6.9° (0.5°-35.4°) | 0.074 |
| **Pelvic tilt** | | | |
| Mean ± SD<br>Median (min.-max.) | 18.27°±10.47°<br>15.9° (2.7°-45.1°) | 19.45°±11.67°<br>16.2 (4.9°-47.3°) | 0.353 |

*Wilcoxon test, SD: Standard deviation, min.: Minimum, max.: Maximum, ODI: Oswestry Disability Index

suggests that the fusion process itself, by stabilizing the affected segment, can incidentally contribute to improved vertebral alignment and symptom relief.

These pivotal findings not only underscore the efficacy of *in situ* fusion but also pave the way for examining their clinical implications in pain management and functional recovery. The substantial postoperative reduction in VAS scores signifies a marked improvement in pain management, aligning with a core objective of surgical intervention in lumbar spondylolisthesis. This observation is consistent with the commonly held view that neurological decompression and vertebrae fusion are the primary objectives of surgery[10]. Furthermore, the considerable improvement in ODI scores post-surgery reflects a significant enhancement in patient-reported functional outcomes and quality of life. These findings are corroborated by a meta-analysis on "Fusion *In Situ* versus Reduction for Spondylolisthesis Treatment" which documented comparable enhancements in quality of life metrics, including ODI and VAS, following surgical interventions for spondylolisthesis[11]. These collective findings underscore the efficacy of surgical intervention in not only mitigating pain but also in restoring functionality and enhancing the overall well-being of patients with degenerative lumbar conditions.

To better understand the context of our findings, it's important to review the classification of spondylolisthesis and the current treatment approaches for different grades. Spondylolisthesis is classified by the Meyerding system, ranging from Grade 0 (no slippage) to Grade 4 (76-100% slippage). Grades 1 and 2 are considered low-grade, while 3 and 4 are high-grade[1]. The management of spondylolisthesis, especially in high-grade cases, remains controversial, with debate surrounding the benefits and risks of reduction versus *in situ* fusion[6]. Reduction of high-grade spondylolisthesis offers potential advantages over *in situ* fusion, particularly in patients with significant lumbosacral kyphosis[12-14]. These advantages include direct decompression of neural elements by reducing canal and foraminal stenosis, and improvement of the biomechanical environment for fusion by decreasing tension on the fusion mass[12,13]. However, the decision to pursue reduction is not without controversy. The primary concern revolves around the potential for increased intraoperative complications due to nerve root distraction during the corrective procedure. Studies have reported higher rates of neurologic deficits and loss of reduction postoperatively in patients who underwent reduction compared to those who underwent arthrodesis *in situ*[15]. Despite these concerns, research findings regarding neurologic deficits following reduction are not entirely consistent. While some studies have found a significant difference in neurologic deficits between the two procedures[6], a systematic review concluded that reduction was not associated with a greater risk of developing neurologic deficits compared to arthrodesis *in situ*[16]. In addition to the potential for neurologic complications, reduction may also lead to increased operative time[15]. Therefore, the decision to pursue reduction should be made carefully, weighing the potential benefits against the risks and considering individual patient factors.

In contrast to the contentious strategies for high-grade cases, our study predominantly involved patients with low-grade spondylolisthesis, aligning with the literature indicating that degenerative spondylolisthesis commonly presents as a low-grade slip (Grade 1 or 2)[1]. Remarkably, significant improvement in listhesis grade were observed following *in situ*

fusion, which occurred naturally without intentional reduction. This spontaneous reduction often fell below grade 1 and was still statistically significant, aligning with previous research by Lambrechts et al.[17] which indicates that such reductions are safe. By achieving spontaneous correction within this safe range, we avoided potential complications associated with more aggressive reduction techniques while still securing positive patient outcomes. This underscores the notion that achieving stable fusion can inadvertently lead to correction of the slippage over time. Naderi et al.[18] further emphasized that in cases of low-grade spondylolisthesis, the focus should be on achieving solid fusion rather than forcing a reduction, as the fusion itself often leads to a natural correction of the slippage over time. This perspective is supported by the findings of Hagenmaier et al.[19], who concluded that the clinical outcomes in lumbar fusion for low-grade spondylolisthesis are not directly contingent upon the degree of radiographic correction. While some studies propose a positive impact of repositioning the slipped vertebra on clinical outcomes, the lack of comparative studies leaves these results inconclusive[20,21].

Building on these findings, the significance of sagittal spinopelvic balance in the surgical management of spondylolisthesis is further highlighted. A significant reduction in sacral slope was observed following surgery in this study, indicating effective correction of pelvic retroversion. This adjustment enhances spinal alignment over the pelvis, essential for improving outcomes in spinal disorders. Harroud et al.[22] have documented the importance of restoring global sagittal alignment to improve health-related quality of life for patients, especially with high-grade spondylolisthesis. This is supported by additional research which corroborates the link between improved sagittal alignment and better patient outcomes[23,24]. Furthermore, the debate regarding the necessity of reduction versus achieving sagittal balance suggests that restoring sagittal balance may offer crucial biomechanical advantages over mere reduction of slip percentage in spondylolisthesis management[12]. Our results affirm that modifications in spinopelvic parameters can lead to substantial improvements in biomechanical and functional outcomes, thus supporting less invasive surgical strategies that prioritize alignment correction over aggressive repositioning techniques. However, the minimal change in pelvic tilt suggests that either the surgery did not affect the rotational balance of the pelvis or that the pelvis had already adapted to a position that provided the best possible balance, given the pre-existing spinal conditions. This underscores the complexity of spinal biomechanics and the need for individualized surgical planning to optimize each patient's outcome based on their specific anatomical challenges[25,26].

The selection of long segment versus short segment fusion, including the decision to extend the fusion to S1, was based on a comprehensive assessment of the patient's spinal pathology and overall health status. The inclusion of S1 in the fusion construct was necessary to achieve optimal spinopelvic alignment and stability, particularly in cases with multi-level degenerative changes or significant deformities. The potential impact on the sacroiliac joint and the risk of pseudoarthrosis were considered, with long-term outcomes such as VAS and ODI scores being carefully monitored. Patients selected for long segment instrumentation had indications such as multi-level degenerative scoliosis, significant sagittal imbalance, or instability that extended beyond the levels affected by spondylolisthesis, necessitating a more extensive surgical approach.

In addition to the changes in listhesis grade and sagittal alignment, our study also revealed a trend towards improvement in the slip angle postoperatively, although the reduction was not statistically significant. This parameter is essential for understanding the degree of anterolisthesis correction, and while our results did not show a statistically significant change, they do indicate a potential for some biomechanical correction through surgery. This finding aligns with other studies that have noted varying degrees of slip angle correction with stabilization techniques, though these changes are often more pronounced with active reduction strategies[11,16].

While our findings contribute positively to the literature on spinal fusion, it remains imperative to consider the potential complications, which our study also documented. Among these, the incidence of ASD following spondylolisthesis surgery remains a topic of ongoing investigation. Previous studies have reported variable rates of ASD, with incidences ranging from 35% to 75% at 10 year follow-up[27,28]. In contrast, our study observed a lower incidence of just 4% over a mean follow-up of 51 months. This discrepancy may be attributed to several factors, including our relatively short follow-up duration, the natural aging process of the spine, and the spontaneous reduction in listhesis grade observed in our study. Our results align with previous studies suggesting a potential protective effect of *in situ* fusion on ASD development[27-29] but longer-term studies are needed to definitively assess this relationship and elucidate the complex interplay between surgical intervention, spondylolisthesis reduction, and ASD.

### Study Limitations

Our study, while providing valuable insights into the efficacy of *in situ* fusion for lumbar spondylolisthesis, is not without limitations. Primarily, the retrospective nature of the study and the relatively short follow-up duration (mean 51 months) may not fully capture the long-term effects of *in situ* fusion, particularly regarding the development of ASD. Additionally, our relatively small sample size and predominance of low-grade spondylolisthesis in our sample may restrict the generalizability of our findings to other spondylolisthesis populations with varying subtypes and severities. Furthermore, all patients in the study were female, which may limit the applicability of the results to a broader population, including males. The absence of a control group prevents direct comparison with other surgical approaches, such as reduction and fusion, making it difficult to isolate the specific contribution of spontaneous correction to the observed outcomes.

The patient group consisted mostly of patients with grade 2 degenerative spondylolisthesis. The improvements in VAS and ODI scores observed may be secondary to decompression. While decompression alone can lead to immediate pain relief and functional improvement, the fusion procedure likely contributed to sustaining these benefits over time by addressing underlying mechanical instability. Future studies should aim to differentiate the effects of decompression alone from those combined with fusion procedures, particularly focusing on long-term outcomes. This will help to further elucidate the specific contributions of each component of the surgical intervention in patients with degenerative lumbar spondylolisthesis.

Future prospective, randomized controlled trials with longer follow-up periods and diverse patient populations are warranted to validate our findings and provide a more comprehensive understanding of the long-term benefits and risks of *in situ* fusion for spondylolisthesis.

## CONCLUSION

In conclusion, our study demonstrates that *in situ* spinal fusion alone, without intentional reduction, can lead to significant pain relief, functional improvement, and spontaneous correction of listhesis grade in patients with degenerative lumbar spondylolisthesis, particularly those with low-grade slips. The observed improvement in sagittal spinopelvic balance further supports the notion that restoring spinal alignment plays a crucial role in achieving optimal patient outcomes. While our findings suggest a potential protective effect of *in situ* fusion on ASD development, further investigation with longer follow-up periods is needed to confirm this observation. Overall, our study provides compelling evidence for the efficacy of *in situ* fusion as a less invasive and potentially safer alternative to reduction and fusion in carefully selected patients with degenerative lumbar spondylolisthesis. These findings have the potential to inform surgical decision-making and contribute to improved patient care in the management of this prevalent spinal disorder.

### Ethics

**Ethics Committee Approval:** The study protocol was approved by the University of Health Sciences Turkey, Antalya Training and Research Hospital Ethical Committee (approval number: 5/22-2024, date: 25.04.2024).

**Informed Consent:** A written informed consent was obtained from each patient.

### Authorship Contributions

Surgical and Medical Practices: Ö.F.E., A.Y., Ö.F.K., H.S., V.N., Concept: Ö.F.E., Ö.F.K., M.A.T., V.N., Design: Ö.F.E., A.Y., Ö.F.K., V.N., Data Collection or Processing: A.Y., M.A.T., H.S., Analysis or Interpretation: Ö.F.E., A.Y., M.A.T., H.S., Literature Search: Ö.F.E., A.Y., Ö.F.K., M.A.T., H.S., V.N., Writing: Ö.F.E., A.Y., Ö.F.K., V.N.

**Conflict of Interest:** The authors have no conflicts of interest to declare.

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