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CLINICAL AND RADIOLOGICAL OUTCOMES OF LONG SPINAL FUSION TERMINATING AT L5 VERSUS S1 IN ADULT SPINAL DEFORMITY

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ABSTRACT

Objective: In this retrospective analysis, we evaluated differences in clinical and radiological outcomes between elderly patients with degenerative spinal deformity whose extended posterior spinal fusion terminated at L5 and those whose fusion extended to S1/S2.

Materials and Methods: We retrospectively reviewed the medical records of 113 patients aged 60 years and older who underwent long posterior spinal fusion for degenerative spinal disease and had a minimum follow-up of two years. According to the caudal extent of fusion, patients were categorized into two groups: those in whom fusion terminated at L5 (lumbar group, n=39) and those in whom fusion extended to S1 or S2 (sacral group, n=74). Pain levels and functional status were evaluated using the visual analog scale and the Oswestry disability index (ODI), respectively.

Results: Patients in both groups showed notable improvements in back pain, leg pain, and ODI scores following surgery. Both groups showed a significant increase in lumbar lordosis, with higher postoperative values in the lumbar group (p=0.005). Thoracic kyphosis did not change significantly in either group; however, the direction and magnitude of change differed between groups (p=0.041). Overall complication and reoperation rates were similar between groups. Distal adjacent segment disease was observed in four patients (10.26%) in the lumbar group, whereas none were detected in the sacral group (p=0.013).

Conclusion: Long posterior spinal fusion terminating at either L5 or the sacrum provides comparable postoperative pain relief and radiographic outcomes. Sacral distal fusion is associated with greater functional improvement, while lumbar distal fusion carries a higher risk of distal adjacent segment disease. Distal fusion level selection should therefore be individualized based on patient-specific clinical and radiological characteristics.

Keywords: Adult spinal deformity, long spinal fusion, distal fusion level, L5 versus S1, spinopelvic parameters, adjacent segment disease, functional outcomes

INTRODUCTION

Adult spinal deformity (ASD) refers to a broad and complex group of conditions that predominantly involve the lumbar and thoracolumbar regions, causing abnormal curvatures in both the coronal and sagittal planes. These may present as scoliosis (coronal plane deviation), kyphosis or lordosis (sagittal plane abnormalities), or kyphoscoliosis when both planes are affected. With the aging global population, ASD has become a significant disease burden[1]. In the general population, ASD prevalence varies widely between 2% and 32%, and it is estimated to reach 68% among the elderly[2,3]. The most common causes of ASD are iatrogenic flat back and degenerative scoliosis[3]. Degenerative changes disrupt normal spinal curvature, leading to sagittal alignment abnormalities[4].

Back pain, neurological symptoms caused by nerve compression, and reduced quality of life are frequent findings among patients diagnosed with ASD[3]. The management of ASD typically begins with a thorough physical examination focusing on gait and posture, combined with radiographic assessment, with planning largely based on risk stratification indices[5]. While non-operative management is generally the first-line approach, surgical intervention may be required and is shown to indicate greater radiographic and clinical results compared with conservative treatment[3,5].

The main objectives of surgical intervention for adult lumbar deformity are to prevent progression, alleviate back and

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leg pain, preserve lumbar lordosis (LL), restore coronal and sagittal balance and achieve a solid fusion[6]. Careful selection of instrumentation levels and osteotomy sites can reduce the risk of proximal junctional kyphosis (PJK) and surgical failure[4]. Potential risks include mechanical complications, neurovascular injury and pseudarthrosis[1]. Among these decisions, selection of the distal fusion level represents a critical and still controversial aspect of long-segment spinal fusion surgery. The choice of distal fusion level in long fusions involving the lower lumbar spine (L5 versus S1/2) is still a topic of debate[6,7]. The L5 fusion level is often reserved for patients with a relatively healthy L5-S1 disc who have preserved LL[6]. If significant deformities or degenerative pathologies are detected at L5-S1, the fusion is often extended to the sacrum[7]. One advantage of L5 fusion is that this approach can preserve the lumbosacral motion segment. This can reduce stress on the lumbosacral junction, shorten operative time, and it is also possible that preserving function and applying less surgical manipulation can decrease complication frequency and the need for reoperation. However, this approach also forgoes fixation at L5-S1, which may allow for subsequent degeneration, pain, and sagittal imbalance-which could necessitate revision surgery[6-8]. Conversely, extending the fusion to S1 provides greater stability in the mechanical sense, but may increase the risk of implant failure, pseudarthrosis and other surgical complications[7]. A better understanding of radiographic spinopelvic parameters and their relationship to deformity and postoperative outcomes might be crucial to the fusion level decision and may improve surgical outcomes and patient satisfaction[4].

Although several studies have compared distal fusion levels in ASD, reported results regarding functional outcomes, radiographic correction and complication profiles remain inconsistent, particularly in elderly patients with degenerative pathology.

Therefore, the aim of current study was to compare the radiological and clinical outcomes of long posterior spinal fusion terminating at L5 versus S1 in patients older than 60 years with degenerative spinal deformity. We hypothesized that sacral distal fusion would provide greater functional improvement, whereas lumbar distal fusion would be associated with a higher risk of distal adjacent segment disease.

MATERIALS AND METHODS

The study retrospectively examined patients older than 60 with degenerative lumbar pathology who underwent posterolateral fusion surgery utilizing pedicle screw instrumentation spanning more than six levels and terminating at lumbar (L5) or sacral (S1/S2) levels. All surgeries had occurred between January 2010 and February 2015. Prior to data collection, the study protocol was approved by the Medline Hospital Local Ethics Committee (approval no: 06, date: 10.07.2025). The research was performed following the ethical principles set forth in the Declaration of Helsinki.

Plain radiography and magnetic resonance imaging were used to verify the diagnosis of degenerative lumbar disease. Inclusion was limited to patients experiencing back pain accompanied by radiculopathy. We excluded individuals who had previously undergone decompression or fusion procedures at L5 or S1-S2. In total, 113 patients meeting these criteria and having a minimum of two years' follow-up were analyzed. Based on the distal extent of fusion, patients were categorized into either a lumbar group (n=39) or a sacral group (n=74).

Each procedure was performed by one of two senior spine surgeons, employing a posterior thoracolumbar approach combined with pedicle screw instrumentation and laminectomy. In a small subset of cases, selective interbody fusion using a cage and graft was performed. To ensure fair comparison between groups, patients who received L5-S1-S2 interbody fusion with grafting were excluded from the study. The decision regarding the distal fusion level was based on preoperative radiographic findings, disc degeneration at the L5-S1-S2 level and surgeon preference in accordance with contemporary guidelines. Although lumbar distal fusion was more frequently performed before 2013 and sacral distal fusion after this period, surgical techniques, instrumentation systems and postoperative rehabilitation protocols remained consistent throughout the study period.

Patient age, sex, follow-up duration, number of fused segments, Oswestry disability index (ODI), visual analog scale (VAS) scores, complications and data from radiographic measurements were recorded. Bone mineral density (BMD) was measured from the femur neck and recorded for each subject. Both anteroposterior and lateral full-length standing X-rays were obtained at two time points: before the operation and shortly after surgery, at one month after surgery and at each routine follow-up thereafter. For the purposes of the present analysis, baseline preoperative and final postoperative radiographs were evaluated. These radiographs were analyzed to obtain radiographic parameters, including sagittal vertical axis (SVA), T1 pelvic angle (TPA), three pelvic parameters [pelvic tilt (PT), pelvic incidence (PI) and sacral slope (SS)] and two spinal parameters [LL and T5-T12 thoracic kyphosis (TK)]. Representative postoperative radiographs demonstrating constructs terminating at L5 and extending to the sacrum are provided in Figure 1A-B.

Functional outcomes were assessed using the ODI and pain intensity was measured with the VAS both preoperatively and postoperatively.

Documented complications encompassed hardware-related issues (implant failure, screw malposition), cerebrospinal fluid (CSF) fistula, fracture, infection, hematoma, as well as junction-related problems including PJK, proximal junctional failure (PJF), and distal adjacent segment disease.

VAS

We assessed pain intensity with a 10-cm VAS. On this scale, 0 indicated no pain while 10 signified unbearable pain, and

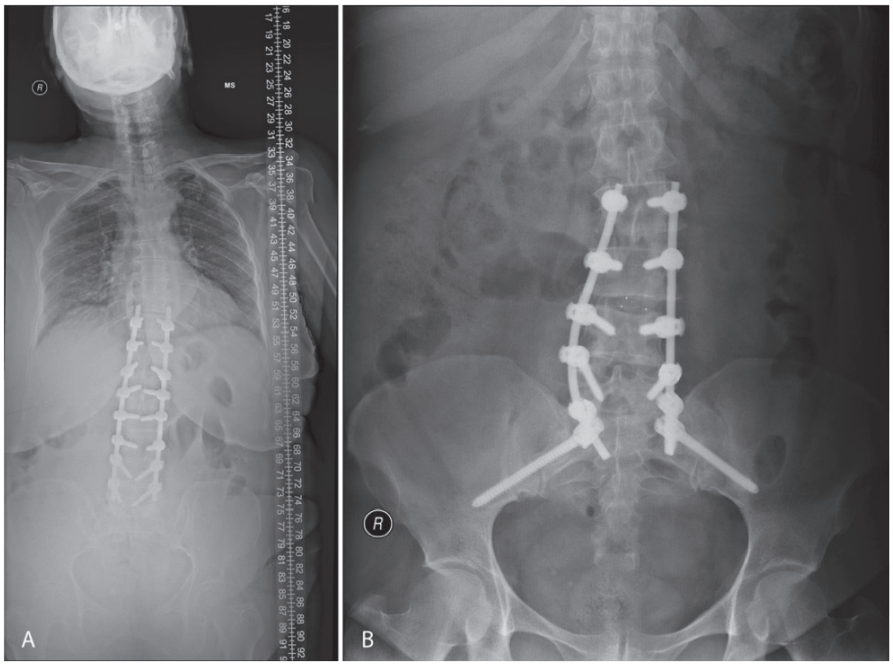

Figure 1. Representative postoperative standing anteroposterior radiographs illustrating distal fusion constructs. **(A)** Long posterior spinal fusion terminating at L5, preserving the L5-S1 motion segment. **(B)** Long posterior spinal fusion extending to S1/S2 with sacropelvic fixation (iliac screws)

patients selected the point that best reflected their current pain level. Greater scores corresponded to higher pain intensity.

ODI

Functional outcomes were evaluated using the ODI, a 10-item questionnaire covering pain intensity, personal care, lifting and carrying, walking, sitting, standing, sleeping, social activities, traveling, and changes in pain severity. Each item is rated on a 6-point scale (0 to 5), with higher scores reflecting greater disability. The total ODI score is expressed as a percentage using the formula: (sum of item scores/50)×100, yielding an overall disability level[9].

Statistical Analysis

All statistical analyses were carried out using IBM SPSS version 27 (IBM Corp., Armonk, NY, USA). A p-value below 0.05 was deemed statistically significant. Normality was evaluated using the Shapiro-Wilk test along with histogram and Q-Q plot examination. For descriptive statistics, normally distributed continuous data were presented as mean ± standard deviation, whereas non-normally distributed data were summarized using median and interquartile range (25^{th}-75^{th} percentile) and frequency (percentage) for categorical variables. Between groups comparisons of continuous variables were performed using the Student's t-test or Mann-Whitney U test depending normality of distribution. Repeated measurements of normally distributed continuous variables were analyzed using two-way repeated measures analysis of variance. Repeated measurements of non-normally distributed continuous variables were analyzed using the Wilcoxon signed-ranks test. Between groups comparisons of categorical variables were performed using the chi-square test or Fisher's exact test.

RESULTS

A total of 113 patients were enrolled, with 39 in the lumbar group and 74 in the sacral group. The two groups were similar in age (p=0.407) but differed significantly in sex distribution (p=0.002), as the sacral group had a notably higher proportion of female patients (93.24% versus 69.23%). There were no significant between-group differences in BMD (p=0.486), implant type (p=0.140), number of fused segments (p=0.525), or cage utilization (p=0.213). The lumbar group did, however, have a significantly longer follow-up period than the sacral group (p=0.022). A complete summary and comparison of patient characteristics is provided in Table 1.

Both groups exhibited significant postoperative reductions in back pain VAS scores relative to baseline (both p<0.001), with no significant difference in the degree of improvement between groups (p=0.471). Leg pain VAS scores also improved significantly after surgery in both the lumbar and sacral groups (both p<0.001), and the extent of improvement was comparable (p=0.279). ODI scores decreased significantly from preoperative values in both groups (both p<0.001). Notably, however, the sacral group demonstrated a significantly greater reduction in disability compared to the lumbar group (p=0.032).

With regard to spinopelvic parameters, SVA remained unchanged in the lumbar group (p=0.387) but decreased significantly in the sacral group (p<0.001); nonetheless, the magnitude of change was similar between groups (p=0.222).

Table 1. Patient demographics, operative parameters, and pre- versus post-surgical findings between lumbar and sacral groups

	Lower level		
	Lumbar (n=39)	Sacral (n=74)	p-value (between groups)
Age	70.67±7.02	69.36±8.32	0.407†
Sex			
Female	27 (69.23%)	69 (93.24%)	0.002#
Male	12 (30.77%)	5 (6.76%)	
BMD, femur neck	-1.94±1.10	-2.14±1.04	0.486†
Type of implant			
Titanium	9 (50.00%)	53 (71.62%)	0.140#
Chrome cobalt	9 (50.00%)	21 (28.38%)	
Number of levels	9.77±1.98	10.08±2.69	0.525†
Cage	2 (5.13%)	11 (14.86%)	0.213‖
Follow-up time, months	66 (39-74)	54 (31-65)	0.022§
Back pain VAS			
Preoperative	8 (8-9)	8 (7-9)	0.158§
Postoperative	4 (2-5)	4 (2-6)	0.692§
p-value for pre-post comparison	<0.001¶	<0.001¶	
Difference(1)	-4 (-6--2)	-4 (-6--2)	0.471§
Leg pain VAS			
Preoperative	8 (6-8)	8 (7-9)	0.405§
Postoperative	4 (2-5)	3 (1-5)	0.227§
p-value for pre-post comparison	<0.001¶	<0.001¶	
Difference(1)	-4 (-5--3)	-4 (-6--2)	0.279§
ODI (%)			
Preoperative	64.74±18.80	70.41±18.82	0.131‡
Postoperative	48.56±21.27	45.72±22.00	0.510‡
p-value for pre-post comparison	<0.001‡	<0.001‡	
Difference(1)	-16.18±19.62	-24.69±19.95	0.032‡
SVA (mm)			
Preoperative	84 (46-131)	95.5 (60-130)	0.221§
Postoperative	68 (37-110)	69.5 (45-100)	0.923§
p-value for pre-post comparison	0.387¶	<0.001¶	
Difference(1)	-11 (-52-32)	-21.5 (-48-2)	0.222§
Pelvic tilt (°)			
Preoperative	27.72±11.53	26.65±9.26	0.593‡
Postoperative	29.44±6.81	28.57±9.31	0.608‡
p-value for pre-post comparison	0.306‡	0.116‡	
Difference(1)	1.72±11.41	1.92±9.87	0.923‡
Sacral slope (°)			
Preoperative	30.64±6.54	28.01±10.93	0.172‡
Postoperative	25.23±6.99	22.96±8.11	0.141‡
p-value for pre-post comparison	0.002‡	<0.001‡	
Difference(1)	-5.41±8.53	-5.05±11.70	0.867‡
Pelvic incidence (°)			
Preoperative	57.85±9.66	54.82±13.21	0.210‡
Postoperative	55.56±9.76	51.18±12.92	0.069‡

Table 1. Continued

	Lower level		
	Lumbar (n=39)	Sacral (n=74)	p-value (between groups)
p-value for pre-post comparison	0.330†	0.035†	
Difference(1)	-2.28±15.37	-3.63±14.10	0.641‡
Lumbar lordosis (°)			
Preoperative	33.62±16.96	28.62±14.44	0.103‡
Postoperative	39.18±15.48	32.31±10.16	0.005‡
p-value for pre-post comparison	0.026†	0.042†	
Difference(1)	5.56±20.97	3.69±11.52	0.540‡
Thoracic kyphosis (°)			
Preoperative	35.23±19.62	30.83±16.43	0.212‡
Postoperative	31.31±11.71	34.07±11.10	0.240‡
p-value for pre-post comparison	0.155†	0.124†	
Difference(1)	-3.92±20.32	3.13±15.11	0.041†
TPA			
Preoperative	22 (19-37)	27 (23-36)	0.411§
Postoperative	25 (20-33)	29.5 (23-38)	0.162§
p-value for pre-post comparison	0.542¶	0.761¶	
Difference(1)	-2 (-6-5)	0 (-5-6)	0.510§
Complication(2)	19 (48.72%)	38 (51.35%)	0.946#
Implant failure	7 (17.95%)	18 (24.32%)	0.591#
Screw malposition	1 (2.56%)	5 (6.76%)	0.663ǁ
CSF fistula	1 (2.56%)	3 (4.05%)	1.000ǁ
Fracture	0 (0.00%)	2 (2.70%)	0.544ǁ
Infection	0 (0.00%)	4 (5.41%)	0.297ǁ
Hematoma	0 (0.00%)	1 (1.35%)	1.000ǁ
PJK	5 (12.82%)	11 (14.86%)	0.990#
PJF	2 (5.13%)	5 (6.76%)	1.000ǁ
Distal adjacent segment disease	4 (10.26%)	0 (0.00%)	0.013ǁ
Reoperation	11 (28.21%)	35 (47.30%)	0.078#

†: Student's t-test, ‡: Two-way repeated measures analysis of variance (ANOVA), §: Mann-Whitney U test, ¶: Wilcoxon signed-ranks test, #: Chi-square test, ǁ: Fisher's exact test, (1): Difference between postoperative and preoperative measurements, negative values represent decrease and positive values represent increase in measurements, (2): Patients may have more than one of the followings, BMD: Bone mineral density, VAS: Visual analog scale, ODI: Oswestry disability index, SVA: Sagittal vertical axis, TPA: T1 pelvic angle, CSF: Cerebrospinal fluid, PJK: Proximal junctional kyphosis, PJF: Proximal junctional failure

PT showed no significant change in either group (lumbar: p=0.306; sacral: p=0.116). SS decreased significantly in both groups (lumbar: p=0.002; sacral: p<0.001), with comparable changes observed (p=0.867). PI did not change significantly in the lumbar group (p=0.330) but decreased significantly in the sacral group (p=0.035), though the difference in change between groups was not significant (p=0.641). LL improved significantly in both groups (lumbar: p=0.026; sacral: p=0.042), and postoperative LL values were significantly higher in the lumbar group (p=0.005), despite similar magnitudes of change (p=0.540). TK did not change significantly in either group (lumbar: p=0.155; sacral: p=0.124), yet the direction of change differed significantly between groups (p=0.041)-the lumbar group showed a decrease while the sacral group showed an increase. TPA remained stable in both groups (lumbar: p=0.542; sacral: p=0.761), with no intergroup differences (p=0.510).

Overall complication rates were similar between groups (p=0.946). The most frequently observed complications were implant failure (lumbar: 17.95%; sacral: 24.32%) and PJK (lumbar: 12.82%; sacral: 14.86%). Of note, distal adjacent segment disease developed in 4 of 39 patients (10.26%) in the lumbar group but was not observed in any patient in the sacral group (p=0.013). Reoperation rates were 28.21% in the lumbar groups and 47.30% in the sacral group, though this difference did not reach statistical significance (p=0.078).

DISCUSSION

When conservative treatment fails and spinal instability or advanced degenerative disc disease is present, spinal fusion has become a cornerstone in the surgical management of ASD[10]. Despite its widespread use, there is still no consensus regarding the level for long-segment fusions[6,11], which often leaves the decision to the surgeons who may have different opinions or experiences regarding the balance between the purpose of radiographic correction and clinical outcomes. In this context, our study directly compares patients undergoing long spinal fusions terminating at either lumbar or sacral levels. The present results demonstrate that both methods are largely similar in terms of radiographic outcomes; however the sacral fusion group showed significantly greater improvement in functional status as measured by ODI. LL increased significantly in both groups, with higher postoperative values observed in the lumbar group, whereas TK demonstrated opposite trends between groups. These findings suggest that distal fusion level selection influences functional outcomes and segmental alignment, even when overall sagittal balance parameters remain similar.

Previous evidence indicates that in ASD patients, long posterior spinal fusion terminating at either L5 or the sacrum consistently results in significant postoperative reductions in back and leg pain and meaningful improvements in functional outcomes, with no substantial differences observed between distal fusion levels[3]. Consistent with previous reports, both lumbar and sacral distal fusion in ASD patients resulted in significant postoperative reductions in back and leg pain and meaningful improvements in functional capacity, and our data also supports prior research in terms of the similarities between the two methods[3,10,12-15]. However, the significantly greater ODI improvement observed in the sacral group suggests that sacral fusion may provide superior functional recovery, which warrants further investigation.

The absence of significant differences in pain scores between groups suggests that distal fusion level has a limited impact on pain control and functional outcomes. Therefore, both lumbar and sacral distal fusions, when applied in appropriately selected patients, provide comparable pain relief, allowing surgeons flexibility in distal level selection based on patient characteristics and surgical objectives. Furthermore, as postoperative outcome assessment in this study was limited to a minimum of 2 years of follow-up, representing early to mid-term outcomes (which is also the case for many studies in the literature), there is a need for further research into the long-term effects of these approaches.

In long-segment spinal fusion for deformity correction, distal fusion terminating at either L5 or S1 has been reported not to compromise early sagittal or coronal balance, with comparable long-term clinical outcomes[10,11,14]. In the present study, LL increased significantly in both groups, with the lumbar group demonstrating significantly higher postoperative values compared to the sacral group (p=0.005). SS decreased significantly in both groups, while SVA decreased significantly only in the sacral group. PI decreased significantly in the sacral group but not in the lumbar group. In terms of TK, the opposing trajectories of change in the two groups (decrease in the lumbar group vs. increase in the sacral group) resulted in a significant difference in the amount of change between groups (p=0.041), which may be an important finding that would necessitate further studies into the exact nature of this change (other than the direct impact of fusion level) and how it might influence clinical outcomes. Nonetheless, the similarities in PT and TPA suggest that both distal fusion levels preserve sagittal balance in the early to mid-term period and have minimal impact on overall spinopelvic alignment. Furthermore, the similarity in spinopelvic outcomes between groups may reflect the homogeneity of baseline deformity severity, number of fused segments and surgical technique among patients.

Although lumbar distal fusion preserves the motion segment, long-term follow-up has shown that advanced L5-S1 disc degeneration and adjacent segment disease can develop in patients undergoing lumbar distal fusion[8,13]. In a study by Wang et al.[16] the biomechanical consequences of spinal fusion on adjacent segments were evaluated, demonstrating increased stress within the annulus fibrosus, nucleus pulposus, facet joints and intervertebral discs of the adjacent segments. It is therefore crucial to perform careful monitoring of biomechanical load accumulation in the distal segments of patients undergoing lumbar distal fusion. Several studies have also indicated that sacral distal fusion restores LL more effectively than L5 and improves overall sagittal balance[12,13,17]. In contrast to these reports, our study showed that LL increased significantly in both groups, with the lumbar group achieving higher postoperative LL values. This finding suggests that lumbar fusion may also effectively restore lordosis, although the clinical implications of this difference require further investigation. Conversely, the higher postoperative lordosis values observed in the lumbar group may reflect the preservation of the natural biomechanical flexibility of the L5-S1 segment and the maintained motion segment. However, it is important to note that while pain outcomes were similar between groups, the sacral group demonstrated significantly greater functional improvement.

As mentioned previously, lumbar fusion has been associated with lower rates of pseudarthrosis, implant-related complications and proximal adjacent segment disease, whereas sacral fusion may be contributing to the preservation of sagittal alignment and maintenance of distal segment integrity[3]. Several studies have reported that although sacral fusion provides superior LL restoration and increased stability, it may be associated with higher complication rates compared with lumbar distal fusion.[12,17,18]. Conversely, selected patients undergoing lumbar fusion have been

reported to have an increased risk of revision surgery due to the potential need for additional fusion[19]. In the present study, when overall complications were considered, no significant differences in complication rates were observed between lumbar and sacral distal fusion groups, consistent with previous reports[3,15]. Although the reoperation rate was numerically higher in the sacral group (47.30% vs. 28.21%), this difference did not reach statistical significance (p=0.078). Nevertheless, the types of complications arising among patients is an important factor, as some complications cause greater risks. Complications such as CSF fistula, PJK/PJF and distal adjacent segment disease originate from different places and have differing mechanisms. PJK is typically related to the proximal fusion endpoint, whereas distal adjacent segment disease is influenced by distal level selection and biomechanical load distribution. In our study, distal adjacent segment disease occurred in 10.26% of patients in the lumbar group, suggesting that while lumbar distal fusion appears safe in the short term, biomechanical stress accumulation at the lower segment may predispose to long-term degeneration. In contrast, in line with previously reported findings[17,19], adjacent segment disease did not occur in the sacral fusion group -possibly due to the additional stability achieved by sacral fusion. Although adjacent segment disease frequently associated with lumbar fusion is often linked to loss of LL or positive sagittal imbalance, the likelihood of symptomatic presentation is relatively low[13]. The higher incidence of distal adjacent segment disease in the lumbar group observed in this study, despite comparable pain outcomes between groups, draws further attention to the criticality of this result.

Consistent with previous meta-analysis and retrospective series[3,11,15], the present study demonstrates that distal fusion at either lumbar or sacral levels yields comparable outcomes in terms of pain and overall complications. However, the sacral group demonstrated significantly greater functional improvement, which may be an important consideration in surgical planning. The motion-preserving advantage of lumbar fusion may be crucial for select patients; however, sacral fusion may provide superior functional recovery and may be improving stability, which may be important for other cases. To summarize, in patients with a healthy L5-S1 disc and minimal lower lumbar deformity, lumbar distal fusion maintains postoperative pain control while preserving motion segments and minimizing operative time and intraoperative trauma. Conversely, in cases with significant lower lumbar deformity or where functional recovery and spinal stability are prioritized, sacral distal fusion could be the preferred option to facilitate long-term stability. Recent advances, ranging from minimally invasive surgical techniques to other tools for risk prediction, may improve surgical planning in spinal deformity management[1,20]. Despite the similarities in short- to mid-term clinical outcomes, distal fusion level is a strategic decision that should integrate patient-specific morphological characteristics, deformity severity, functional expectations and potential long-term complications.

Study Limitations

Although the sample size was larger than many similar studies, the retrospective design could introduce potential biases in patient selection and data collection. The lumbar or sacral fusion decisions were based on the changes in management strategies according to available guidelines and expert opinions, resulting in a lack of randomization and potential selection bias, which may particularly limit the interpretation of clinical and radiographic differences between groups. The significant difference in sex distribution between groups (93.24% female in the sacral group vs. 69.23% in the lumbar group) and the difference in follow-up duration may have influenced the outcomes and should be considered when interpreting the results. Additionally, missing data for BMD, implant type and TPA in a subset of patients in the lumbar group may have affected the analyses of these parameters. Radiographic analyses were restricted to preoperative and final postoperative measurements, and therefore, we do not have analyses showing the trends in these parameters. Pain and functional outcomes were assessed using patient-reported measures, which are subjective and may be influenced by individual perceptions. Additionally, the mid-term follow-up limits the assessment of late complications, including pseudarthrosis and late-onset distal segment degeneration. Despite these limitations, the present study provides valuable evidence comparing the clinical and radiographic impact of distal fusion levels throughout at least 2 years of follow-up.

CONCLUSION

In long posterior spinal fusion surgery, distal fusion level at either lumbar or sacral levels appears to yield comparable outcomes in terms of postoperative pain and changes in spinopelvic parameters. However, sacral fusion demonstrated significantly greater functional improvement as measured by ODI. While both groups showed significant increases in LL, the lumbar group achieved higher postoperative values. Lumbar fusion preserves motion segments and limits surgical manipulation, but is associated with a significantly higher risk of distal adjacent segment disease. Both approaches have a similar safety profile with respect to overall complications and reoperations; however, patients undergoing lumbar distal fusion are more susceptible to distal adjacent segment disease which may necessitate reoperation.

Ethics

Ethics Committee Approval: Prior to data collection, the study protocol was approved by the Medline Hospital Local Ethics Committee (approval no: 06, date: 10.07.2025).
Informed Consent: Retrospective design.

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Footnotes

Authorship Contributions

Surgical and Medical Practices: T.E., M.Ç., M.A., M.G., Concept: T.E., M.Ç., Design: T.E., M.Ç., M.G., Data Collection or Processing: T.E., M.Ç., M.A., M.G., Analysis or Interpretation: T.E., M.Ç., M.G., Literature Search: T.E., M.Ç., Writing: T.E.

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