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Research Article

Does the lower instrumented vertebra matter? The impact of lower instrumented vertebra level on long-term health-related quality of life

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ABSTRACT

Objective: This study aimed to investigate the relationship between the lower instrumented vertebra (LIV) level and long-term health-related quality of life (HRQoL) in patients with adolescent idiopathic scoliosis (AIS) after posterior spinal fusion.

Methods: This retrospective cohort study included 120 patients who underwent posterior fusion surgery for AIS between 1991 and 2019 and had clearly identifiable fusion levels with a minimum follow-up of 5 years. In 2024, all patients completed 4 patient-reported outcome instruments, including the Scoliosis Research Society-22 revised questionnaire (SRS-22r), the Turkish version of the Spinal Appearance Questionnaire (Tr-SAQ), the Oswestry Disability Index, and the EQ-5D-3L.

Results: When outcomes were analyzed according to the level of the LIV, no significant differences in SRS-22r pain scores were observed among fusion levels up to L4. In contrast, patients with LIV at L5 demonstrated significantly lower SRS-22r pain scores than those fused to L2, L3, and L4 (P=.035). Likewise, EQ-Visual Analog Scale scores were significantly lower in the L5 group than in patients with fusion levels from L1 to L4 (P=.025).

Conclusion: In patients undergoing fusion surgery for AIS, no significant differences in quality of life scores were observed among fusion levels up to L4. In contrast, patients with fusion extending to L5 demonstrated comparatively poorer outcomes. However, the findings regarding fusion extending to L5 are based on a small subgroup and require further validation.

Level of Evidence: Level III, Prognostic Study.

Introduction

The selection of fusion levels in scoliosis has long been debated and remains a significant challenge for spine surgeons. Numerous studies have investigated the optimal level of the lower instrumented vertebra (LIV).[1-7] The primary goal of posterior fusion in adolescent idiopathic scoliosis (AIS) is to achieve deformity correction while maintaining spinal balance.[8-10] Although longer fusions may provide superior deformity correction, they are associated with a greater loss of flexibility within the fused segments.[11-13] This reduction in motion may result in hypermobility at adjacent segments, early disc degeneration, low back pain, and, ultimately, the need for more extensive fusion in adulthood.[14,15] Consequently, there is a growing consensus in favor of shorter fusions to preserve mobile segments whenever feasible. As the LIV extends distally, the loss of motion segments and overall spinal flexion becomes more pronounced.[11-13] The lumbosacral junction represents a critical biomechanical transition between the mobile lumbar spine and the relatively rigid pelvis. Because of this unique role in load transmission, the L5-S1 segment is exposed to substantial mechanical forces during spinal motion.[16] However, several studies have reported that reduced range of motion does not necessarily correlate with health-related quality of life (HRQoL) outcomes.[17,18] Previous studies have often evaluated distal fusion levels by grouping multiple vertebral levels together (e.g., L3 and above vs. L4 and below). Such grouping strategies may obscure potential differences between individual lumbar levels, particularly the biomechanically distinct L5 segment. Therefore, the present study aimed to evaluate each LIV level individually in order to better clarify the specific impact of distal fusion level on long-term HRQoL outcomes. The objective of this study was to examine the association between the level of the LIV and long-term HRQoL outcomes in patients with AIS following posterior spinal fusion.

Materials and methods

This retrospective study included 120 patients who underwent posterior spinal fusion for AIS between 1991 and 2019. The study protocol was approved by the Dokuz Eylül University Ethics Committee (date: 13.03.2024, no: 2024/10-05) and written informed consent was obtained from all participants and/or their legal guardians. Posterior spinal fusion was the standard surgical approach throughout the study period. Although implant systems evolved over time, the core surgical team remained largely unchanged, and fusion procedures were performed according to broadly

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similar surgical principles. While certain aspects of operative strategy, including distal fusion level selection, may have evolved with the emerging literature over the 3-decade study period, the overall treatment philosophy remained largely consistent. Therefore, the potential impact of surgical variation across different eras was considered minimal. The inclusion criteria were as follows: (1) diagnosis of idiopathic scoliosis; (2) age between 10 and 18 years at the time of diagnosis; (3) treatment with posterior spinal fusion only; (4) no history of revision surgery; (5) availability of imaging of sufficient quality to clearly identify fusion levels; and (6) completion of all four outcome measures (Scoliosis Research Society-22 revised questionnaire [SRS-22r], Turkish version of the Spinal Appearance Questionnaire [Tr-SAQ], Oswestry Disability Index [ODI], and EQ-5D-3L) in 2024. Descriptive statistics were presented as frequency (n), percentage (%), mean ± SD, median, minimum, maximum, and interquartile range. The Shapiro–Wilk test was used to assess normality. Comparisons across groups were performed using a robust Rank-Transform Multivariate Analysis of Variance (MANOVA). Post hoc pairwise comparisons were conducted using Bonferroni correction. Spearman correlation was used to assess associations between continuous variables, and the Fisher–Freeman–Halton exact test was used for categorical comparisons. Patients with incomplete data were excluded prior to analysis; therefore, no missing data were present in the final dataset. A P value of < .05 was considered statistically significant.

Results

Lenke classification was unavailable for 15 patients due to missing preoperative side-bending radiographs.

Age and follow-up duration are reported as both mean ± SD and median values to better describe the distribution of the data.

A total of 120 patients were included in the study. The descriptive characteristics of the patients are presented in Table 1. Of these, 102 (85.0%) were female and 18 (15.0%) were male. All patients underwent surgery during adolescence, and the mean age at the time of outcome assessment was 26.7 ± 6.3 years (range, 15-46). Eighteen patients (15.0%) were active smokers, and 3 patients (2.5%) had a history of smoking at least 5 pack-years before quitting. According to the preoperative Lenke classification, 57 patients (54.3%) had MT (type 1), 10 patients (9.5%) had MT+PT (type 2), 7 patients (6.7%) had MT+TL (type 3), 1 patient (1.0%) had MT+PT+TL (type 4), 19 patients (18.1%) had TL (type 5), and 11 patients (10.4%) had TL+MT (type 6). The mean preoperative Cobb angle was 63.2 ± 11.6° (range, 41-91°), and the mean Cobb angle at a minimum 2-year follow-up was 24.0 ± 8.0° (range, 2-55°). No significant trunk shift (<2 cm) was observed. The postoperative follow-up period ranged from 5 to 33 years, with a median of 13 years. There were 43 patients with 3-9 years of follow-up, 39 patients with 10-14 years, and 38 patients with ≥15 years. Regarding the level of the LIV, 14 patients (11.7%) had fusion ending at T12 or above, 24 patients (20.0%) at L1, 14 patients (11.7%) at L2, 38 patients (31.7%) at L3, 22 patients (18.3%) at L4, and 8 patients (6.6%) at L5.

Table 1. Patient demographics and characteristics

Variables	N	Statistics
Sex, n (%)		
Female	120	102 (85.0)
Male		18 (15.0)
Age (year)		
±ss	120	26.7 ± 6.3
M (min-max)		26.5 (15.0-46.0)
Smoking status, n (%)		
Non-smoker	120	99 (82.5)
Smoker		18 (15.0)
≥5 pack-years		3 (2.5)
Preop Lenke, n (%)		
MT	105	57 (54.3)
MT+PT		10 (9.5)
MT+TL		7 (6.7)
MT+PT+TL		1 (1.0)
TL/L		19 (18.1)
TL/L+MT		11 (10.4)
Time since sugery, (years)		
±ss	120	13.0 ± 6.1
M (min-max)		13.0 (5.0-33.0)
Time since sugery n (%)		
3-9 year	120	43 (35.8)
10-14 year		39 (32.5)
15 year and above		38 (31.7)
Lower instrumented vertebra (LIV) level, n (%)		
T12 and above	120	14 (11.7)
L1		24 (20.0)
L2		14 (11.7)
L3		38 (31.7)
L4		22 (18.3)
L5		8 (6.6)

M, median; N, total number of patients with available data; n, number of patients in each category; SD, standard deviation.

Data are presented as median (interquartile range). ǂ: Rank-Transform MANOVA. Superscript letters (a, b) indicate differences between levels within the same row; levels sharing the same superscript letter do not differ significantly. Effect sizes for significant outcomes were η^2=0.07 for the SRS-22r pain domain and η^2=0.15 for the EQ-Visual Analog Scale (EQ-VAS) general well-being scale.

According to Table 2, SRS-22r pain domain scores differed significantly among LIV levels (P=.035). Patients with fusion ending at L5 had significantly lower SRS-22r pain scores (indicating worse pain-related outcomes) compared with those fused to L2, L3, and L4. Although not significant, pain scores in the L5 LIV group were also lower than those in the T12 and above group and the L1 group. No significant differences were observed among the other LIV groups. EQ-VAS general well-being scale scores differed significantly among LIV levels (P=.025). Patients with fusion ending at L5 had significantly lower EQ-VAS general well-being scale scores compared with those fused to L1, L2, L3, and L4. Similarly, although not significant, EQ-VAS scores in the L5 group were lower than those in the T12 and above group. According to Table 2, no significant differences were observed among the other HRQoL scale results across different LIV

HIGHLIGHTS

- This study evaluated the effect of the lower instrumented vertebra level on long-term health-related quality of life in patients with adolescent idiopathic scoliosis after posterior fusion surgery.
- No significant differences in quality of life scores were found in fusions extending up to the L4 level.
- Patients with fusion extending to L5 demonstrated significantly lower SRS-22r pain and EQ-Visual Analog Scale general well-being scores, both of which indicate poorer patient-reported outcomes.
- The results suggest that selecting L5 as the distal fusion level may be associated with less favorable long-term outcomes, whereas avoiding fusion to L5 when surgically feasible may help preserve pain control and general health status.

Table 2. Comparison of all HRQoL scale results according to lower instrumented vertebra levels

	HRQoL scale results according to lower instrumented vertebra levels						
	T12 and above	L1	L2	L3	L4	L5	*P*‡
SAQ appearance	20.00 (15.50)	16.00 (9.75)	17.50 (13.25)	14.00 (13.25)	13.00 (5.75)	20.50 (13.00)	.071
SAQ expectation	10.00 (11.25)	13.00 (11.50)	10.00 (10.25)	9.00 (13.25)	6.50 (7.25)	17.00 (10.00)	.068
SAQ total score	33.50 (19.75)	28.50 (17.75)	29.50 (18.75)	30.00 (23.00)	20.00 (14.50)	37.50 (18.50)	.079
SRS-22r function/activity	4.70 (0.45)	4.40 (0.60)	4.80 (0.65)	4.60 (0.65)	4.70 (0.80)	4.10 (1.20)	.263
SRS-22r pain	4.10 (1.05)^{ab}	3.90 (1.30)^{ab}	4.40 (0.65)^{a}	4.30 (0.85)^{a}	4.30 (0.45)^{a}	3.60 (1.55)^{b}	**.035**
Self image	4.00 (0.50)	4.30 (0.95)	4.20 (1.15)	4.10 (1.00)	4.20 (0.80)	3.70 (0.95)	.174
Mental health	3.30 (1.30)	3.60 (0.95)	3.60 (0.85)	3.80 (1.05)	3.90 (0.70)	3.00 (0.85)	.124
Satisfaction with treatment	4.50 (1.00)	4.75 (1.38)	4.75 (1.00)	4.50 (1.00)	4.50 (1.00)	4.25 (1.00)	.995
Total score	4.05 (0.48)	4.15 (0.70)	4.25 (0.68)	4.10 (0.63)	4.25 (0.50)	3.70 (0.85)	.071
ODI score	28.00 (25.50)	30.00 (32.50)	22.00 (32.50)	32.00 (24.50)	24.00 (23.50)	50.00 (41.00)	.409
EQTTO index score	0.85 (0.17)	0.80 (0.30)	1.00 (0.31)	0.85 (0.28)	0.87 (0.21)	0.71 (0.20)	.059
VAS index score	0.78 (0.23)	0.75 (0.33)	1.00 (0.34)	0.78 (0.30)	0.80 (0.27)	0.68 (0.17)	.071
EQ- visual analog scale (VAS)	80.0 (21.25)^{ab}	90.0 (28.75)^{a}	90.0 (16.25)^{a}	90.0 (16.25)^{a}	90.0 (12.00)^{a}	75.0 (31.25)^{b}	**.025**

Data are presented as median (interquartile range). Superscript letters (a and b) indicate pairwise differences between LIV levels within the same row. Levels sharing the same superscript letter are not significantly different from one another.
‡, rank-transform multivariate analysis of variance.

levels. Although the L5 subgroup included only 8 patients, which limits the statistical power of comparisons involving this group, additional analyses were performed to assess the magnitude of differences between fusion levels. The effect size for SRS-22r pain scores was moderate (η^2=0.07, 95% CI: 0.00-0.14), and the effect size for EQ-VAS general well-being was large (η^2=0.15, 95% CI: 0.0-0.28). These findings suggest that fusion extending to L5 may be associated with poorer pain and general well-being outcomes; however, due to the limited sample size of the L5 subgroup, the results should be interpreted cautiously and considered preliminary.

In Figures 1 and 2, each point represents the scale outcome score of an individual patient at each LIV level. Because the scoring system calculates the mean by dividing the total score of each domain by the number of items, identical values may occur, leading to overlapping points.

Discussion

The principal finding of this study is that HRQoL outcomes were largely comparable across LIV levels up to L4, whereas fusion extending to L5 was associated with less favorable SRS-22r pain (Table 2) (Figure 1) and EQ-VAS general well-being scores (Table 2) (Figure 2).

Comparison with the literature

The findings are consistent with previous reports. Fan et al[17] and Uehara et al[18] demonstrated that although lumbar range of motion decreases with more distal fusion levels, this reduction does not result in significant differences in SRS-22r domains or pain scores up to L3 or L4. Similarly, Winter et al[19] reported that spinal motion is well preserved as long as fusion does not extend to L4, further supporting the concept that mobility can be maintained when distal fusion is limited. In line with these findings, Ding et al[20] also reported no significant differences in HRQoL outcomes between fusions extending to L3 and those extending to L4. Similarly, Enercan et al[21] reported that terminating fusion at L3 versus L4 did not lead to significant differences in distal disc or facet joint degeneration on MRI at a minimum 5-year follow-up, and no significant differences in clinical outcomes were observed between the groups. In a meta-analysis, Ruffilli et al[22] reported no significant difference in distal disc

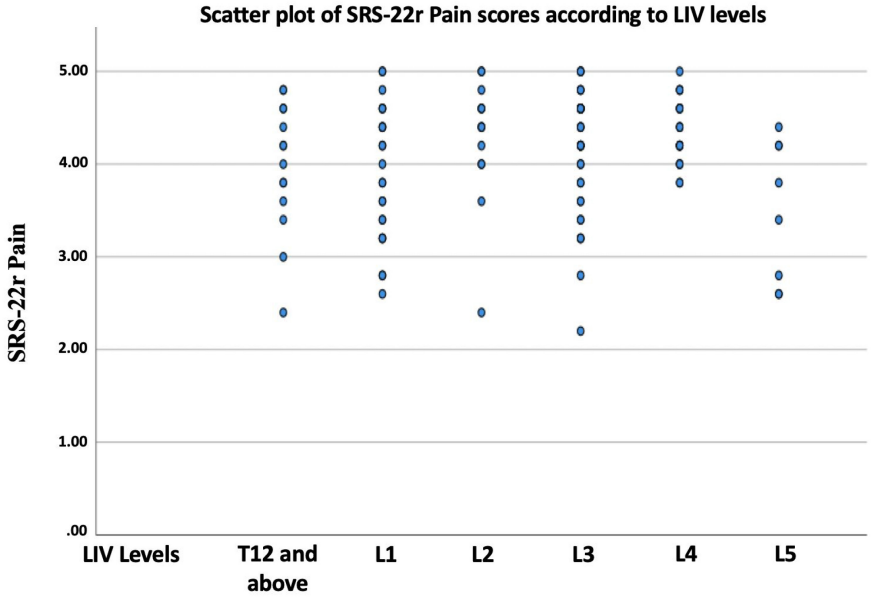

Figure 1. Scatter plot of SRS-22r pain scores according to lower instrumented vertebra levels.

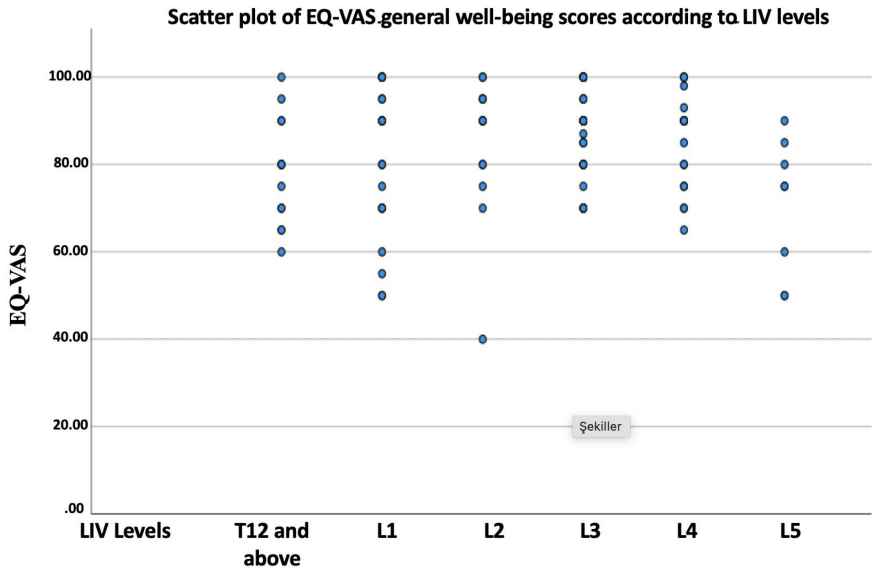

Figure 2. Scatter plot of EQ-VAS general well-being scores according to lower instrumented vertebra levels. EQ-VAS, EQ-Visual Analog Scale; LIV, lower instrumented vertebra.

degeneration between fusions extending to L3 and those extending to L4. Likewise, no significant differences were observed in clinical or radiological outcomes, supporting the findings of the present study.

Moreover, studies that group L4 and L5 (and sometimes S1) together have often reported poorer outcomes in the distal fusion group. For example, Marie-Hardy et al[23] reported significantly lower SF-12 physical scores and higher VAS pain scores in patients with fusion extending to L4-L5 compared with those fused to L3. Similarly, Ahonen et al[24] found poorer HRQoL outcomes when the LIV was at L3 or below.

In addition, Lander et al[25] compared patients with LIV at L3 and above versus L4 and below at long-term follow-up and reported higher rates of additional surgery, along with a trend toward worse ODI and SRS-7 scores in the distal group, although some differences did not reach statistical significance. These findings, which likely reflect the negative impact of including L5 and S1 in the distal fusion construct, are consistent with the observation that fusions extending beyond L4 are associated with less favorable outcomes. Taken together, these studies support the view that fusion levels up to L4 may yield broadly comparable outcomes, whereas less favorable results become more apparent when more distal levels are included in the analysis.

Grouping methods and interpretability

The commonly used classification of L3 and above as "short fusion" and L4 and below as "long fusion" combines biomechanically distinct segments such as L3, L4, and L5 within the same category.[25-28] This approach may misattribute the poor outcomes observed in L5 and S1 fusions to L3 and L4 LIV levels, thereby suggesting that fusions ending at these levels yield similarly unfavorable results and thus lead to a misleading conclusion. However, L3, L4, and L5 differ significantly in terms of lumbar ROM, overall spinal flexion, and the severity of disc degeneration. Therefore, each level should be analyzed individually to allow meaningful clinical interpretation.[17,29]

When the results were analyzed according to LIV level, no statistically significant differences were observed among fusion levels up to L4. Importantly, patients in the T12 group and above, representing cases treated with selective thoracic fusion, as well as those in the L1 group, did not demonstrate significantly different HRQoL outcomes compared with patients whose fusion extended to more distal levels. Despite the absence of structural lumbar curves in many patients treated with selective thoracic fusion, their long-term HRQoL outcomes were not significantly different from those observed in patients with more distal fusion levels. These findings suggest that, in long-term follow-up, patient-reported quality of life outcomes may be influenced by factors beyond the simple preservation of distal motion segments.

Possible mechanism

The adverse effect of fusion extending to L5 may be explained by biomechanical factors. The L1-L2 and particularly the L4-L5 intervertebral discs contribute a substantial portion of lumbar spinal mobility.[16] Inclusion of the L4-L5 disc in the fusion construct eliminates a major source of flexion and overall lumbar range of motion. Consequently, mechanical loads may be transferred predominantly to the L5–S1 segment, which represents the lumbosacral transition between the mobile lumbar spine and the rigid pelvis. Previous studies have reported that instrumentation with long constructs terminating at L5 may lead to radiographic adjacent segment degeneration at the L5-S1 level in up to 67%-69% of cases.[4,30] In addition, the facet joints and intervertebral disc at this level contribute significantly to load sharing and motion control, and alterations in spinal mechanics may increase stress at the lumbosacral junction. These biomechanical factors may partly explain the poorer HRQoL outcomes observed in patients with fusion extending to L5. Consistent with this, Edwards et al[31] demonstrated that more distal fusion levels adversely affect spinopelvic compensation by altering sagittal alignment parameters, suggesting a reduced ability to maintain physiological balance. In support of this interpretation, Uto et al[32] reported that more distal fusion levels were associated with greater degenerative changes in adjacent spinal structures, including increased facet joint degeneration and fatty infiltration of the paraspinal muscles at 5-year follow-up, although these radiological changes did not translate into significantly worse SRS-22 outcomes.

Potential confounding in distal fusion level selection

The selection of the LIV remains one of the most challenging aspects of surgical planning in AIS. All patients included in this study were

diagnosed with AIS and underwent surgery during adolescence, including the subgroup with fusion extending to L5. Numerous radiographic parameters have been proposed to guide the determination of the optimal distal fusion level, including the Cobb-to-Cobb concept, the neutral vertebra, the stable vertebra, the last touched vertebra, vertebral rotation, and overall sagittal alignment.[7,33,34] In patients with structural thoracolumbar/lumbar (TL/L) curves, the generally accepted surgical principle is to perform the shortest possible fusion while preserving as many distal motion segments as feasible, in order to reduce the risk of long-term low back pain and accelerated disc degeneration. However, in cases with more pronounced structural lumbar involvement, such as larger curve magnitude, caudal displacement of the curve apex, increased vertebral rotation, or disturbed sagittal alignment, the resulting non-physiological spinal biomechanics may already predispose patients to degenerative changes and mechanical low back pain.

In the present cohort, many of the patients with fusion extending to L5 were operated on during the earlier years of the study period; therefore, preoperative HRQoL data were not available. Consequently, the less favorable HRQoL outcomes observed in the L5 group may reflect not only the distal fusion level itself but also the underlying severity of the structural lumbar deformity that necessitated fusion to this level.

Among the 105 patients for whom Lenke classification could be determined, 38 had structural thoracolumbar curves (Lenke types 3, 4, 5, and 6), including 19 patients with primary structural TL/L curves (Lenke type 5). Fusion extending to L5 was performed in 8 patients; however, these patients did not all belong to Lenke type 5. Three patients were classified as Lenke type 5, 2 as Lenke type 6, and 1 as Lenke type 4, while Lenke classification could not be determined in 2 patients because preoperative side-bending radiographs were unavailable. In addition, some patients with similar Lenke type 5 curves underwent fusion terminating at more proximal levels rather than extending to L5. Taken together, these observations suggest that the less favorable HRQoL outcomes observed in the L5 group are likely multifactorial and should be interpreted with caution when assessing the relationship between distal fusion level and long-term HRQoL outcomes.

Clinical implications

These findings suggest that avoiding LIV at L5, when surgically feasible, may be important for preserving long-term HRQoL. As demonstrated by the statistically significant findings presented in Table 2, extension of fusion to L5 was associated with worse pain-related outcomes, as reflected by lower SRS-22r pain scores, as well as poorer overall health status, as indicated by lower EQ-VAS scores. Although HRQoL scores appear to be maintained despite reduced mobility up to L4, extension of fusion to L5 was associated with significantly worse pain and general well-being scores. From a surgical planning perspective, sparing the L5 level may represent a more favorable strategy for maintaining long-term quality of life.

Limitations

This study has several limitations. First, HRQoL scores may vary over time, but the authors included all patients with ≥5 years of follow-up, which may introduce heterogeneity in long-term outcomes. Second, preoperative HRQoL data were not available. Because validated patient-reported outcome measures were not routinely used during the early years of the study period, baseline HRQoL status and true pre- to postoperative changes cannot be assessed. In addition, patients requiring fusion extending to L5 may have had more pronounced lumbar deformities at baseline, including greater sagittal or coronal imbalance, increased rotational components, altered facet joint relationships, or early degenerative changes. These factors may have influenced both the decision to extend the fusion to L5 and long-term clinical outcomes. Therefore, in the absence of preoperative HRQoL data, it remains difficult to determine whether less favorable outcomes are attributable to the distal fusion level itself or to the underlying severity of the deformity.

Third, preoperative side-bending radiographs were unavailable for 43 patients, which prevented complete Lenke classification and limited curve-type–based analyses. Fourth, the number of patients with LIV at L5 was relatively small (n=8), limiting the statistical power of comparisons involving this subgroup. Accordingly, the findings related to L5 should be interpreted with caution and considered preliminary. However, the direction and magnitude of the observed differences suggest that fusion extending to L5 may be associated with less favorable HRQoL outcomes, a finding that warrants further validation in larger prospective studies.

In this study, no significant differences in SRS-22r pain scores were observed among patients fused up to L4. However, patients with LIV at L5 had significantly lower SRS-22r pain scores compared with those fused to L2, L3, and L4, and also demonstrated significantly worse EQ-VAS general well-being scores compared with L1-L4. These findings suggest that the selection of the distal fusion level has a greater impact on long-term HRQoL than curve correction alone. Although fusions ending at L4 appear to preserve quality of life in the long term, extension to L5 may be associated with less favorable pain and general well-being outcomes, and therefore should be avoided whenever possible when surgically feasible. Future prospective studies including preoperative HRQoL assessments and larger cohorts of patients with fusion extending to L5 are warranted to further validate these findings.

Data Availability Statement: The data that support the findings of this study are available on request from the corresponding author.

Artificial Intelligence Usage Statement: During the preparation of the manuscript, ChatGPT (OpenAI) was used solely for language editing and grammatical correction. The authors reviewed and approved all content and are fully responsible for the final manuscript.

Ethics Committee Approval: Ethical committee approval was received from the Ethics Committee of University of Dokuz Eylül University (Approval No.: 2024/10-05; Date: March 13, 2024).

Informed Consent: Written informed consent was obtained from the patients/patient who agreed to take part in the study.

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Declaration of Interests: Haluk Berk is a member of the Editorial Board of Acta Orthopaedica et Traumatologica Turcica. However, his involvement in the peer review process was as solely as an author. Other authors have no conflict of interest to declare.

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References

1. Trobisch PD, Ducoffe AR, Lonner BS, Errico TJ. Choosing fusion levels in adolescent idiopathic scoliosis. *J Am Acad Orthop Surg.* 2013;21(9):519-528. [CrossRef]

2. Burton DC, Asher MA, Lai SM. The selection of fusion levels using torsional correction techniques in the surgical treatment of idiopathic scoliosis. *Spine*. 1999;24(16):1728-1739. [CrossRef]
3. Lenke LG, Edwards CC 2nd, Bridwell KH. The Lenke classification of adolescent idiopathic scoliosis: how it organizes curve patterns as a template to perform selective fusions of the spine. *Spine*. 2003;28(20):S199-S207. [CrossRef]
4. Kuhns CA, Bridwell KH, Lenke LG, et al. Thoracolumbar deformity arthrodesis stopping at L5: fate of the L5-S1 disc, minimum 5-year follow-up. *Spine*. 2007;32(24):2771-2776. [CrossRef]
5. Akazawa T, Kotani T, Sakuma T, et al. Spinal fusion on adolescent idiopathic scoliosis patients with the level of L4 or lower can increase lumbar disc degeneration with sagittal imbalance 35 years after surgery. *Spine Surg Relat Res*. 2017;1(2):72-77. [CrossRef]
6. Burrows KR, Henzell IS, Martin G, Chisholm CV, Carstens A, Hodgson BF. Long-term adjacent segment degeneration at average 21-year follow-up of posterior instrumented fusion for adolescent idiopathic scoliosis. *Spine Deform*. 2023;11(4):933-941. [CrossRef]
7. Wang Y, Hansen ES, Høy K, Wu C, Bünger CE. Distal adding-on phenomenon in Lenke 1A scoliosis: risk factor identification and treatment strategy comparison. *Spine*. 2011;36(14):1113-1122. [CrossRef]
8. Weinstein SL, Dolan LA, Cheng JC, Danielsson A, Morcuende JA. Adolescent idiopathic scoliosis. *Lancet*. 2008;371(9623):1527-1537. [CrossRef]
9. Suk SI, Kim WJ, Lee SM, Kim JH, Chung ER. Thoracic pedicle screw fixation in spinal deformities: are they really safe? *Spine*. 2001;26(18):2049-2057. [CrossRef]
10. Suk SI, Lee SM, Chung ER, Kim JH, Kim SS. Selective thoracic fusion with segmental pedicle screw fixation in the treatment of thoracic idiopathic scoliosis: more than 5-year follow-up. *Spine*. 2005;30(14):1602-1609. [CrossRef]
11. Danielsson AJ, Romberg K, Nachemson AL. Spinal range of motion, muscle endurance, and back pain and function at least 20 years after fusion or brace treatment for adolescent idiopathic scoliosis: a case-control study. *Spine*. 2006;31(3):275-283. [CrossRef]
12. Wilk B, Karol LA, Johnston CE 2nd, Colby S, Haideri N. The effect of scoliosis fusion on spinal motion: a comparison of fused and nonfused patients with idiopathic scoliosis. *Spine*. 2006;31(3):309-314. [CrossRef]
13. Engsberg JR, Lenke LG, Reitenbach AK, Hollander KW, Bridwell KH, Blanke K. Prospective evaluation of trunk range of motion in adolescents with idiopathic scoliosis undergoing spinal fusion surgery. *Spine*. 2002;27(12):1346-1354. [CrossRef]
14. Benli IT, Ates B, Akalin S, Citak M, Kaya A, Alanay A. Minimum 10 years follow-up surgical results of adolescent idiopathic scoliosis patients treated with TSRH instrumentation. *Eur Spine J*. 2007;16(3):381-391. [CrossRef]
15. Bjerkreim I, Steen H, Brox JI. Idiopathic scoliosis treated with Cotrel-Dubousset instrumentation: evaluation 10 years after surgery. *Spine*. 2007;32(19):2103-2110. [CrossRef]
16. Lee BS, Walsh KM, Healy AT, et al. Biomechanics of L5/S1 in long thoracolumbosacral constructs: a cadaveric study. *Glob Spine J*. 2018;8(6):607-614. [CrossRef]
17. Fan H, Wang Q, Huang Z, et al. Comparison of functional outcome and quality of life in patients with idiopathic scoliosis treated by spinal fusion. *Med (Baltim)*. 2016;95(19):e3289. [CrossRef]
18. Uehara M, Takahashi J, Ikegami S, et al. Correlation of lower instrumented vertebra with spinal mobility and health-related quality of life after posterior spinal fusion for adolescent idiopathic scoliosis. *Clin Spine Surg*. 2019;32(7):E326-E329. [CrossRef]
19. Winter RB, Carr P, Mattson HL. A study of functional spinal motion in women after instrumentation and fusion for deformity or trauma. *Spine*. 1997;22(15):1760-1764. [CrossRef]
20. Ding R, Liang J, Qiu G, Shen J, Li Z. Evaluation of quality of life in adolescent idiopathic scoliosis with different distal fusion level: a comparison of L3 versus L4. *J Spinal Disord Tech*. 2014;27(5):E155-E161. [CrossRef]
21. Enercan M, Kahraman S, Yilar S, et al. Does it make a difference to stop fusion at L3 versus L4 in terms of disc and facet joint degeneration: an MRI study with minimum 5 years follow-up. *Spine Deform*. 2016;4(3):237-244. [CrossRef]
22. Ruffilli A, Traversari M, Manzetti M, et al. Comparable rates of lumbar disc degeneration at long-term following adolescent idiopathic scoliosis spinal fusion extended to L3 or L4: systematic review and meta-analysis. *Spine Deform*. 2024;12(4):877-901. [CrossRef]
23. Marie-Hardy L, Besse M, Chatelain L, Pannier S, Glorion C, Ferrero E. Does the distal level really matter in the setting of health-related quality of life? Assessment of a series of adolescent idiopathic scoliosis patients at more than 7 years following surgery. *Spine*. 2022;47(16):E545-E550. [CrossRef]
24. Ahonen M, Syvänen J, Helenius L, et al. Back pain and quality of life 10 years after segmental pedicle screw instrumentation for adolescent idiopathic scoliosis. *Spine*. 2023;48(10):665-671. [CrossRef]
25. Lander ST, Thirukumaran C, Saleh A, et al. Long-term health-related quality of life after Harrington instrumentation and fusion for adolescent idiopathic scoliosis: a minimum 40-year follow-up. *J Bone Joint Surg Am*. 2022;104(11):995-1003. [CrossRef]
26. Helenius I, Remes V, Yrjönen T, et al. Comparison of long-term functional and radiologic outcomes after Harrington instrumentation and spondylodesis in adolescent idiopathic scoliosis: a review of 78 patients. *Spine*. 2002;27(2):176-180. [CrossRef]
27. Danielsson AJ, Nachemson AL. Back pain and function 23 years after fusion for adolescent idiopathic scoliosis: a case-control study-part II. *Spine*. 2003;28(18):E373-E383. [CrossRef]
28. Sanchez-Raya J, Bago J, Pellise F, Cuxart A, Villanueva C. Does the lower instrumented vertebra have an effect on lumbar mobility, subjective perception of trunk flexibility, and quality of life in patients with idiopathic scoliosis treated by spinal fusion? *J Spinal Disord Tech*. 2012;25(8):437-442. [CrossRef]
29. Pearcy M, Portek I, Shepherd J. The effect of low-back pain on lumbar spinal movements measured by three-dimensional X-ray analysis. *Spine*. 1985;10(2):150-153. [CrossRef]
30. Ozkunt O, Karademir G, Sariyilmaz K, Gemalmaz HC, Dikici F, Domanic U. Analysing the change of sagittal balance in patients with Lenke 5 idiopathic scoliosis. *Acta Orthop Traumatol Turc*. 2017;51(5):377-380. [CrossRef]
31. Edwards CC 2nd, Bridwell KH, Patel A, Rinella AS, Berra A, Lenke LG. Long adult deformity fusions to L5 and the sacrum. A matched cohort analysis. *Spine*. 2004;29(18):1996-2005. [CrossRef]
32. Uto T, Yokogawa N, Kato S, et al. Degenerative changes in the disc, facet joint, and paraspinal muscle after adolescent idiopathic scoliosis surgery: a five-year MRI-based follow-up. *Cureus*. 2025;17(7):e88116. [CrossRef]
33. Suk SI, Lee SM, Chung ER, Kim JH, Kim WJ, Sohn HM. Determination of distal fusion level with segmental pedicle screw fixation in single thoracic idiopathic scoliosis. *Spine*. 2003;28(5):484-491. [CrossRef]
34. Parisini P, Di Silvestre M, Lolli F, Bakaloudis G. Selective thoracic surgery in the Lenke type 1A: King III and King IV type curves. *Eur Spine J*. 2009;18(suppl 1):82-88. [CrossRef]