Clinical Study

ASJ

Asian Spine J. 2024;18(5): 699-705
https://doi.org/10.31616/asj.2024.0217
PISSN 1976-1902 • eISSN 1976-7846

Comparative advantages of activities with lumbosacral preservation for adult spinal deformity surgery: a retrospective Japanese cohort study

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Received Jun 5, 2024; **Revised** Jul 24, 2024; **Accepted** Aug 7, 2024
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Study Design: Retrospective cohort study.
Purpose: This study aimed to demonstrate the advantages of preservation of the lumbosacral segment (LSS) in adult spinal deformity (ASD) surgery.
Overview of Literature: Sacroiliac foundation enables sufficient restoration in ASD surgery; however, it could result in poor mobility. Thus, whether LSS provides better activities is still unknown.
Methods: Among 399 patients who underwent ASD surgery, 62 (≥5 levels fused, >2-year follow-up) underwent fusion from T9–10 to L5 (group L, n=21) or to S2–alar–iliac (group S, n=41). Spinal alignments, Scoliosis Research Society (SRS)-22 scores, performance of activities (clipping toenail, wiping buttock, and wearing socks), proximal and distal junctional failure (PJF+DJF), rod fractures (RFs), and overall revision rates (RRs) were compared between the groups.
Results: Group L included younger patients and had longer follow-ups when compared with group S. Although the preoperative pelvic incidence and SRS sagittal modifiers were better in group L, postoperative spinal restorations were nonpathological in both groups. Both groups showed similar deformity progression at the 2-year follow-up; however, group L had lower SRS-22 pain scores. Although "wiping buttocks" did not differ between the groups, the performance of "clipping toenails" and "wearing socks" was poorer in group S at 2 years (possible, group S; 40% vs. group L; 85%–90%). The RRs did not differ between the groups; however, the PJF+DJF rate was higher in group L. DJF was not observed in group S, but occurrence of RFs was noted.
Conclusions: Although poorer SRS-22 pain scores might be related to lumbosacral mobility, sufficient restoration, equivalent deformity progression, and similar RRs with better activity imply that lumbosacral preservation should be considered in younger patients with moderate deformities.

Keywords: Lowest instrumented level; Activities of daily living; Reoperation; Adult spinal deformity; Surgery

Introduction

Recent advances in spinal surgery have enabled sufficient restoration of spinal malalignment to regain the health-related quality of life (HRQOL) in older patients. The sacroiliac foundation provides a solid foundation for adult spinal deformity (ASD) surgery and rigid anchor for the restoration of poor spinal alignment [1-4]. No differences were found in the clinical outcomes or complication rates between sacroiliac and lumbar foundations [2]. However, Kuhns et al. [5] reported that 23% of the patients with a lumbar foundation required revision surgery. Witiw et al. [6] reported that fusion to the sacroiliac spine did not significantly change the revision risk after long fusion with a normal or mildly degenerated L5/S1 disc. Tan et al. [7] also reported that 15% of the lumbar range of motion (ROM) was related to the L5S disc. However, no studies have focused on the differences in the performance of activities by patients with or without sacroiliac fixation. Considering the comparative advantages of activities with lumbosacral preservation could help in achieving better clinical results for ASD surgery, we hypothesized that preserving the L5S disc after ASD surgery might be related to better mobility and performance of activities, such as wearing socks, wiping buttocks, and clipping toenails. Preserving patients' ability to perform these activities might also reduce the need for postoperative older adult care. Thus, this study aimed to compare the advantages and disadvantages of the sacroiliac foundations for ASD surgery in terms of spinal alignment, clinical outcomes, mechanical complications requiring revision surgery, and postoperative activity.

Materials and Methods

Study population

This retrospective cohort study was conducted in compliance with the principles of the Declaration of Helsinki. Our Institutional Review Board (IRB) at Akita Kousei Medical Center approved this study (approval IRB no., 193). Written informed consent was obtained from the patients. Patients with spinal instrumentations with ≥5 vertebral levels and at least 2 years of follow-up (March 2004–December 2019) were included. In total, 399 surgeries were selected from a prospectively enrolled database at Akita Kousei Medical Center. The inclusion criteria were as follows: patients with deformity correction who suffered from ASD with one or more Schwab-Scoliosis Research Society (SRS) sagittal modifiers (SMs) (sagittal vertical axis [SVA] >40 mm, pelvic incidence [PI]–lumbar lordosis [LL] >10°, and/or pelvic tilt [PT] >20°). Patients with spinal tumors, infections, or Parkinson's disease were excluded. Among the included patients, 62 who underwent fusion from T9–10 to L5 (group L, n=21) or to S2–alar–iliac (group S, n=41) were divided into two groups. Based on our institutional retrospective receiver operating characteristics analysis of preoperative and immediate postoperative spinal alignment in L5S-preserving deformity correction surgery, the following cutoff values for preserving the lumbosacral segment have been established: SVA <90 mm, PI–LL <45°, and PT <30°, with a normal L5S disc and without coronal lumbosacral tilt. We recommend preserving the L5S segment for younger patients because they typically engage in more physical activities than older patients. Patients with incomplete activity performance data or with spinal fusion at other levels were excluded from the analysis (Fig. 1). The average age, proportion of female patients, and body mass index (BMI) were 71.4±6.2 years (range, 57–82 years), 88.7%, and 23.6±3.9 kg/m^2, respectively. The mean postoperative period was 61.7±19.7 months. The total levels of the fused and upper instrumented vertebra (UIV) at T9/T10 were 8.47±0.95 and 9/53, respectively.

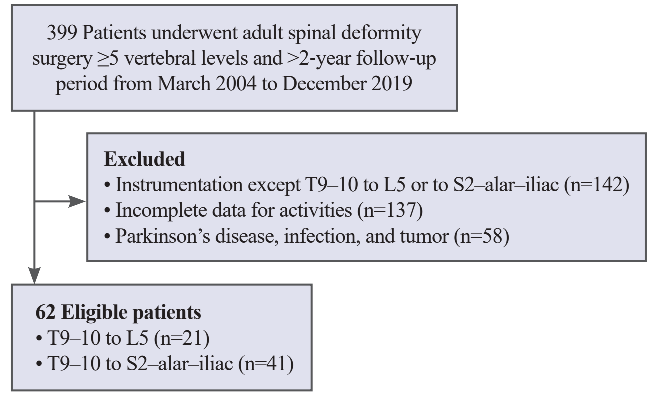

Fig. 1. Study flow chart.

Radiographic measurements and clinical outcomes

PI, LL (L1–S1), thoracic kyphosis (TK: T5–T12), T1 pelvic angle (T1PA: the angle between the line connecting the center of the femoral heads to the center of S1 and line from the femoral head to the center of T1), SMs (PI–LL, PT, and SVA), and coronal vertical axis (CVA) (the distance from the C7 plumb line to the central sacral vertical line) were evaluated from upright whole-spine radiographs preoperatively, immediately after surgery, and at the 2-year follow-up. The CVA <40 mm was defined normally, as was performed in a previous study [8]. The Scoliosis Research Society-22 (SRS-22) scores were evaluated preoperatively and at the 2-year follow-up to assess the clinical outcomes.

Activities of daily living

Activities of daily living (ADLs) related to spinal mobility, wearing socks, wiping buttocks, and clipping toenails were evaluated. Possible rates for each activity were considered for the deterioration and regaining of the ability during the preoperative, postoperative, and 2-year follow-up periods.

Mechanical failures

Mechanical complications that required revision surgery were evaluated for junctional failures (JFs) with proximal and distal fractures (PJF and DJF, respectively) and rod fractures (RFs). PJFs were mechanical failures that required revision surgery between the UIV and UIV+2. DJFs were mechanical failures that required revision between the lower instrumented vertebra (LIV) and surgery for the vertebra below the LIV, such as a postoperative increase in kyphosis ≥10°, adjacent segment disease, pseudarthrosis, and instrumentation failure [9,10].

Statistical analysis

Statistical analyses were conducted using EZR (Saitama Medical Center, Jichi Medical University, Saitama, Japan) [11], a modified version of R commander with a graphical user interface for R (The R Foundation for Statistical Computing, Vienna, Austria). Categorical variable data are presented as numbers (%) and continuous variable data as means±standard deviations. To evaluate the factors that affected lumbosacral preservation, differences between continuous variables were analyzed using Student *t*-test, and categorical data were analyzed using Fisher's exact probability test. Statistical significance was set at p<0.05. In the power analysis, with a sample size of 21 and 41 patients in groups L and S, 85.7% and 43.9% of the patients wore socks and 90.5% and 41.5% clipped their toenails, respectively. Using a two-sided significance level of p<0.05, the post-hoc power values after 2 years were 97.1% and 88.1% in groups L and S, respectively.

Results

Following the recommendation for L5S preservation in younger patients, group L included younger patients compared with group S (69.2 years versus 72.5 years, p=0.046). However, the proportion of female patients and BMI were not different between the groups (Table 1). The UIV was restricted and matched with T10 and T9 to highlight the significant effect of L5S preservation on activities. As a result, owing to lumbosacral preser-

Table 1. Demographic and baseline data with comparison between group L and group S

Characteristic	Group L (n=21)	Group S (n=41)	*p*-value
Age (yr)	69.2±7.6	72.5±5.1	0.046
Female	18 (85.7)	37 (90.2)	0.680
Body mass index (kg/m^2)	23.3±3.7	23.6±4.0	0.789
Level fused	7.2±0.4	9.1±0.3	<0.001
Follow-up (mo)	74.7±22.4	55.0±14.4	<0.001
Upper instrumented vertebra			0.251
T10	16 (76.2)	37 (90.2)	
T9	5 (23.8)	4 (9.8)	

Values are presented as mean±standard deviation or number (%).

Table 2. Comparison of radiographic parameters between group S and group L preoperatively, postoperatively, and at the 2-year follow-up

Variable	Group L (n=21)	Group S (n=41)	*p*-value
Preoperative			
PI (°)	45.0±12.4	52.8±10.3	0.011
PI–LL (°)	35.7±17.2	47.9±21.3	0.027
SVA (mm)	97.4±74.0	165.4± 95.4	0.006
PT (°)	27.8±9.7	36.1±10.9	0.005
LL (°)	9.2±16.0	4.9±18.9	0.367
TK (°)	24.9±15.1	25.0±16.7	0.978
T1PA (°)	30.9±13.3	44.5±15.2	0.001
CVA (mm)	12.3±23.2	31.3±28.6	0.010
Postoperative			
PI–LL (°)	2.6±14.5	2.8±11.1	0.961
SVA (mm)	37.2±38.0	20.0±32.2	0.066
PT (°)	18.6±9.1	17.5±8.5	0.630
LL (°)	42.3±12.1	50.0±9.1	0.007
TK (°)	36.5±12.5	38.1±10.6	0.599
T1PA (°)	17.7±8.5	13.5±8.0	0.063
CVA (mm)	14.1±14.7	10.7±9.5	0.280
2-yr follow-up			
PI–LL (°)	5.2±17.2	4.7±13.8	0.905
SVA (mm)	66.1±59.5	41.4±48.6	0.084
PT (°)	22.1±10.3	21.9±9.2	0.918
LL (°)	40.5±14.3	48.1±9.4	0.014
TK (°)	42.1±14.2	46.1±14.3	0.310
T1PA (°)	22.5±12.6	19.4±10.2	0.307
CVA (mm)	16.6±14.8	10.0±9.5	0.038

Values are presented as mean±standard deviation.
PI, pelvic incidence; LL, lumbar lordosis; SVA, sagittal vertical axis; PT, pelvic tilt; TK, thoracic kyphosis; T1PA, T1 pelvic angle; CVA, coronal vertical axis.

vation, group L showed a shorter LF than group S (9.1 versus 7.2, p<0.001). Therefore, the UIV levels were not different between the groups (Table 1).

Radiographic results

The preoperative radiographic parameters were better in group L than in group S (Table 2). PI (45.0° versus 52.8°, p=0.011), PI–LL (35.7° versus 47.9°, p=0.027), SVA (97.4 mm versus 165.4 mm, p=0.006), PT (27.8° versus 36.1°, p=0.005), T1PA (30.9° versus 44.5°, p=0.001), and CVA (12.3 mm versus 31.3 mm, p=0.010) were significantly smaller in group L than in group S (Table 2). Although the postoperative LL was smaller in group L than in group S (42.3° versus 50.0°, p=0.007), the postoperative alignments in both groups were within the nonpathological SMs and were not different (Table 2). At the 2-year follow-up, group L showed poorer LL (40.5° versus 48.1°, p=0.014) and CVA than group S (16.6 mm versus 10.0 mm, p=0.038) despite nonpathological PI–LL and CVA ranges. However, both groups progressed similarly, and moderate deformities of the SVA and PT developed in the SMs (Table 2). Out of 62 patients treated, most underwent combined anterior and posterior surgery, with 15 involving only posterior procedures. Regardless of the procedure used, both groups demonstrated comparable spinal restoration to normal parameters.

Clinical outcomes

The preoperative SRS-22 showed lower mental (2.8 versus 3.0, p=0.019) and higher self-image (2.4 versus 2.0, p=0.031) scores in group L compared with group S. All clinical outcomes significantly improved postoperatively; however, only postoperative SRS-22 pain scores (3.4 versus 4.0, p=0.001) were significantly poorer in group L than in group S (Table 3).

Activities of daily living

No difference in the preoperative performance of activities such as wearing socks, wiping buttocks, and clipping toenails was observed between the groups, and 90.5%–100% of the patients in both groups could perform these activities (Fig. 2). The performance of wiping buttocks was not different between the groups after surgery or at the 2-year follow-up. However, the postoperative performance of wearing socks (81.0% versus 46.3%, p=0.014) and clipping toenails (71.4% versus 31.7%, p=0.006) was higher in group L than in group S. The performance of the activities of wearing socks (85.7% versus 43.9%, p=0.002) and clipping toenails (90.5% versus 41.5%, p<0.001) was better in group L than in group S at the 2-year follow-up (Fig. 2). In group S, only 41.5%–43.9% of the patients could wear socks and clip their toenails at the 2-year follow-up. However, 85.7%–90.5% of the patients could perform these activities at the 2-year follow-up in group L (Fig. 2).

Table 3. Comparison of SRS-22 score between group L and group S preoperatively and at the 2-year follow-up

SRS score	Group L (n=21)	Group S (n=41)	p-value
Preoperative			
Mental health	2.8±0.3	3.0±0.4	0.019
Pain	3.0±0.5	3.0±0.7	0.666
Self-image/appearance	2.4±0.5	2.0±0.6	0.031
Function/activity	2.6±0.3	2.7±0.4	0.629
Sub-total	2.8±0.3	2.7±0.3	0.939
2-yr follow-up			
Mental health	3.2±0.4	3.2±0.4	0.894
Pain	3.4±0.7	4.0±0.5	0.001
Satisfaction	3.4±0.9	3.6±1.0	0.393
Self-image/appearance	3.3±0.5	3.6±0.9	0.253
Function/activity	3.3±0.4	3.5±0.5	0.059
Total	2.8±0.5	3.0±0.6	0.141

Values are presented as mean±standard deviation.
SRS, Scoliosis Research Society.

Table 4. Comparison of revision rate between group L and group S

	Group L (n=21)	Group S (n=41)	p-value
Total	4 (19.0)	3 (7.3)	0.214
Junctional failure	4 (19.0)	0	0.011*
Distal junctional failure	2 (9.5)	0	0.111
Proximal junctional failure	2 (9.5)	0	0.111
Rod fracture	0	3 (7.3)	0.545

Values are presented as number (%).
*p<0.05.

Mechanical failures

Four patients (19.0%) in group L and three patients (7.3%) in group S required revision surgery, and the overall revision rate (RR) was not different between the groups (Table 4). Although the PJF or DJF rates were not different between the groups, the overall JF rate (PJF+DJF) was significantly higher in group L than in group S (19.0% versus 0%, p=0.011). In contrast, RF occurred only in group S (Table 4).

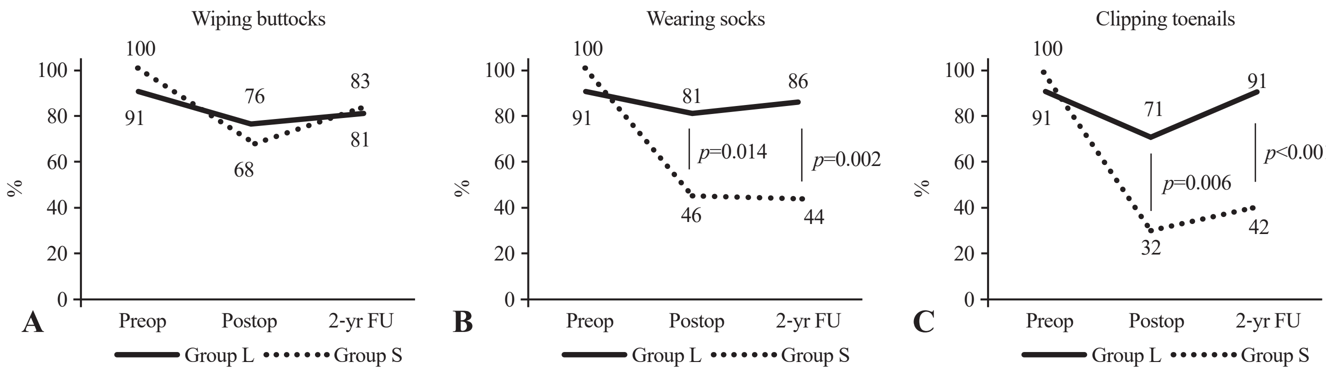

Fig. 2. (A–C) Over 90% of patients could perform activities preoperatively. Group S showed a poorer ability to wear socks and clip toenails postoperatively. Almost 90% of group L patients could perform all activities; however, 40%–50% in group S could not wear socks and clip toenails at the 2-year follow-up (FU). Preop, preoperative; Postop, postoperative.

Discussion

Reports are present on the comparative advantages of the LIV at lumbar or sacroiliac foundations associated with HRQOL, mechanical failures, or complications [1-4,6]. According to Yao et al. [2], fusion to the sacral±ilium resulted in better sagittal alignment restoration with greater PJK rates and PJK angles than fusion to L4/5. However, comparable clinical outcomes, RRs, and complications were found between the groups [2]. According to their study, the indications for a sacroiliac foundation include severe spinal malalignment and low PJK risk. Some studies did not report differences in patient outcomes with or without PJK in the mean follow-up of 3.5–4.3 years [12,13]; however, a recent study revealed differences in clinical outcomes and revisions with PJK in an average of 5.6 years [14]. The PJF rates were not different between the groups in the present study (Table 4). Restoring spinal alignment was more effective using a sacroiliac foundation; however, the longer follow-up might affect the PJF rates. Our institution recommends that patients should wear a thoracolumbosacral orthosis for the rest of their life after a long fusion. This might also explain the difference in the PJF rates in the present study from those in previous studies.

Although the DJF or PJF rates were not different, the DJF+PJF rates differed between the groups. Moreover, RF occurred only in group S, which implied that stress concentration occurred anywhere in the long construct. Although RF did not occur in group L, it was most frequently located in the lumbosacral junction in group S. The RF and JF appeared to be related to stress concentration or mobility at the lumbosacral level.

This might also cause lumbosacral pain in group L. The poor SRS pain score might result from lumbosacral mobility. Compared with the lumbar LIV, the sacroiliac LIV enabled better restoration with a rigid foundation. Accordingly, moderate preoperative spinal malalignment allows for a lumbar foundation with nonpathological postoperative SMs. Further analysis with longer follow-ups may reveal specific preoperative misalignment values for appropriate postoperative spinal alignment without a sacroiliac foundation.

Previous studies have not precisely described the advantages of preserving the mobile segments of L5S. Tan et al. [7] reported that the L5S disc was related to 15% of the lumbar ROM and suggested possible ADL preservation while retaining the L5S disc. In the present study, group L showed significant retention of the ability to perform the activities of clipping toenails and wearing socks postoperatively and at the 2-year follow-up. In group S, more than half of the patients were unable to perform activities related to reaching the toe tips, with lumbosacral fusion. However, 2 years later, 5%–10% of patients regained the ability to perform these activities, which might be related to the compensation of the ROM with the lower extremities by crossing the leg or increasing flexion or rotational thoracic ROM. However, excessive motions may be associated with mechanical complications.

Although this study did not show a difference in the DJF rates between the groups, the RR with DJF was 9.5%. Kuhns et al. [5] also reported that preserving the L5S disc was associated with 23% of RR with DJF for ASD surgery. L5S disc preservation allows for spinal motion despite the mechanical stress at the end of a longer construct. Moreover, poor spinal restoration is related to a higher stress concentration with a longer lever arm from the center of gravity [15]. This study did not show a significant difference in postoperative spinal restoration between the groups. Accordingly, the indications for lumbosacral preservation should be carefully planned preoperatively based on the possibility of nonpathological postoperative spinal restoration. Moreover, we recommend preserving the L5S for younger patients because they require more activity than older patients. Wherever possible, losses and benefits should be explained preoperatively based on the patients' backgrounds or lifestyles. Postoperative activity loss can also be compensated using a self-help device. ADL limitations do not negate the benefits of ASD surgery; however, a preoperative explanation is essential to achieve better patient satisfaction.

Given the retrospective designs, this study may have some limitations, such as selection bias and a small sample. Matching the number of fused levels to the control group reduced the total number of cases. The sample size was too small to draw robust conclusions. Therefore, a post hoc test was performed to estimate the power of statistical analysis for ADLs. However, regarding RR, the small sample size limited the generalizability of the findings. Other activities such as sitting on the ground or standing up from the floor were not assessed. Nonetheless, a previous study found decreased activities after ASD surgery with sacroiliac fusion [16]. In addition, patient satisfaction was evaluated, and nearly all patients expressed satisfaction with the surgery despite a decrease in activity levels postoperatively. Activities should be evaluated using the Barthel index or the lumbar stiffness disability index; however, old data were not evaluated using these scores. Our cohort included older patients who could not be followed up sufficiently because they moved to a nursing home or died. Although all patients with a minimum of 2-year follow-up were included in this study, longer follow-up periods could be related to a higher RR with mechanical failure. Older patients in their late 80s or 90s did not hope for revisions or could not undergo revisions because of comorbidities. However, a 5-year follow-up period would have provided more comprehensive data. Conducting a prospective study, establishing clear practice guidelines, and evaluating patient satisfaction would greatly aid in choosing the appropriate fusion levels.

Conclusions

Lumbosacral preservation might have comparative advantages for better postoperative activities, such as clipping toenails and wearing socks. However, it might limit the restoration of severe sagittal malalignment. Revisions with RF were rare while those with JF were higher. However, the overall RR was similar with or without lumbosacral fusion. Lumbosacral mobility might be related to poor SRS-22 pain scores at the 2-year follow-up due to sacroiliac pain. Comparative advantages should be considered in the selection of a foundation for the restoration of sufficient realignment, ADL preservation, and characteristics of revisions for ASD surgery.

Key Points

- Sacroiliac foundation enables sufficient restoration in adult spinal deformity surgery; however, it could result in poor mobility.
- Whether the lumbosacral segment allows for better activities remains unknown.
- Fusion from T9/10 to L5 (group L, n=21) or to S2–alar–iliac (group S, n=41) were compared for spinal alignments, Scoliosis Research Society (SRS)-22 scores, performance of activities, or revision rates.
- Both groups exhibited similar deformity progression and overall revision rate at 2 years; however, despite having lower SRS-22 pain scores, group L performed better in activities involving reaching toe tips.
- Although poorer SRS-22 pain scores might be related to lumbosacral mobility, sufficient restoration, equivalent deformity progression, and similar revision rates with better activity imply that lumbosacral preservation should be considered in younger patients who underwent surgery for moderate adult spinal deformity.

Conflict of Interest

No potential conflict of interest relevant to this article was reported.

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Conceptualization: YI, TK, EA. Data curation: YI. Formal analysis: YI. Funding acquisition: YI. Methodology: YI, EA. Project administration: TK, EA, NM. Visualization: YI. Writing–original draft: YI, TK, EA, RS, NM. Writing–review & editing: YI, TK, EA, RS, NM. Final approval of the manuscript: all authors.

References

1. 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 (Phila Pa 1976) 2004;29:1996-2005.
2. Yao YC, Kim HJ, Bannwarth M, et al. Lowest instrumented vertebra selection to S1 or ilium versus L4 or L5 in adult spinal deformity: factors for consideration in 349 patients with a mean 46-month follow-up. Global Spine J 2023;13:932-9.
3. Yasuda T, Hasegawa T, Yamato Y, et al. Lumbosacral junctional failures after long spinal fusion for adult spinal deformity: which vertebra is the preferred distal instrumented vertebra? Spine Deform 2016;4:378-84.
4. Zaborovskii N, Ptashnikov D, Mikhaylov D, et al. Spinal deformity in elderly patients: comparison of two distal termination sites of lumbar curve fusion. Eur J Orthop Surg Traumatol 2017;27:73-8.
5. 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 (Phila Pa 1976) 2007;32:2771-6.
6. Witiw CD, Fessler RG, Nguyen S, et al. Re-operation after long-segment fusions for adult spinal deformity: the impact of extending the construct below the lumbar spine. Neurosurgery 2018;82:211-9.
7. Tan Y, Aghdasi BG, Montgomery SR, Inoue H, Lu C, Wang JC. Kinetic magnetic resonance imaging analysis of lumbar segmental mobility in patients without significant spondylosis. Eur Spine J 2012;21:2673-9.
8. Glassman SD, Berven S, Bridwell K, Horton W, Dimar JR. Correlation of radiographic parameters and clinical symptoms in adult scoliosis. Spine (Phila Pa 1976) 2005;30:682-8.
9. McDonnell JM, Ahern DP, Wagner SC, et al. A systematic review of risk factors associated with distal junctional failure in adult spinal deformity surgery. Clin Spine Surg 2021;34:347-54.
10. Passias PG, Klineberg EO, Jalai CM, et al. Hospital readmission within 2 years following adult thoracolumbar spinal deformity surgery: prevalence, predictors, and effect on patient-derived outcome measures. Spine (Phila Pa 1976) 2016;41:1355-64.
11. Kanda Y. Investigation of the freely available easy-to-use software 'EZR' for medical statistics. Bone Marrow Transplant 2013;48:452-8.
12. Bridwell KH, Lenke LG, Cho SK, et al. Proximal junctional kyphosis in primary adult deformity surgery: evaluation of 20 degrees as a critical angle. Neurosurgery 2013;72:899-906.
13. Yagi M, King AB, Boachie-Adjei O. Incidence, risk factors, and natural course of proximal junctional kyphosis: surgical outcomes review of adult idiopathic scoliosis: minimum 5 years of follow-up. Spine (Phila Pa 1976) 2012;37:1479-89.
14. Park SJ, Park JS, Nam YJ, Choi YT, Lee CS. The long-term fate of asymptomatic proximal junctional kyphosis following long instrumented fusion in elderly patients with sagittal imbalance. Spine (Phila Pa 1976) 2021;46:E1097-104.
15. Berjano P, Damilano M, Pejrona M, Langella F, Lamartina C. Revision surgery in distal junctional kyphosis. Eur Spine J 2020;29(Suppl 1):86-102.
16. Ishikawa Y, Miyakoshi N, Kobayashi T, et al. Activities of daily living and patient satisfaction after long fusion for adult spinal deformity: a retrospective study. Eur Spine J 2019;28:1670-7.