# Effect of corrective long spinal fusion to the ilium on physical function in patients with adult spinal deformity

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Ryo Kondo, P.T., M.S.[1)]; Yu Yamato, M.D., Ph.D.[2)]; Tetsuyuki Nagafusa, M.D., Ph.D.[1)]; Takashi Mizushima, M.D., Ph.D.[1)]; Tomohiko Hasegawa, M.D., Ph.D.[2)]; Sho Kobayashi, M.D., Ph.D.[2)]; Daisuke Togawa, M.D., Ph.D. [2)]; Shin Oe, M.D. [2)]; Kenta Kurosu, M.D. [2)]; Yukihiro Matsuyama, M.D., Ph.D.[2)]

[1)] Department of Rehabilitation Medicine, Hamamatsu University, School of Medicine, University Hospital
1-20-1, Handayama, Higashi-ku, Hamamatsu-city, Shizuoka Japan 433-3192
[2)] Department of Orthopaedic Surgery, Hamamatsu University School of Medicine
1-20-1, Handayama, Higashi-ku, Hamamatsu-city, Shizuoka Japan 433-3192

Corresponding author: Ryo Kondo
E-mail: ptkondo@hama-med.ac.jp
Tel: (+81)-53-435-2746, Fax: (+81)-53-435-2748

**Abstract**

*Purpose* To identify the effects of corrective long spinal fusion to the ilium on physical function in patients with adult spinal deformity (ASD).

*Methods* Thirty patients who underwent corrective long spinal fusion to the ilium were prospectively analysed. Patients were divided into the ++ group (sagittal vertical axis [SVA] ≥95 mm and pelvic tilt [PT] ≥30°, 14 patients) and 0+ group (SVA <95 mm or PT <30°, 16 patients). Subjects' low back pain (visual analogue scale [VAS] [pain with motion]), muscle strength (knee extensors and hip flexors), balance (Timed Up and Go [TUG]), gait performance (10-metre walking test [10MWT, maximum speed], and 6-minute walk test [6MWT]) were assessed before surgery, at discharge, and 6 months and 12 months after the surgery.

*Results* All study patients had a significant improvement in the VAS score between baseline and at discharge, 6 months postoperatively, and 12 months postoperatively. The values of the TUG and 6MWT significantly improved 12 months postoperatively. The values of the TUG, 10MWT, and 6MWT improved significantly more in the ++ group than in the 0+ group at 12 months.

*Conclusion* Corrective long spinal fusion contributed to improving back pain at discharge and gait ability at 12 months in patients with ASD.

**Keywords** Adult spinal deformity; Corrective long spinal fusion; Muscle; Balance; Gait

## Introduction

Spinal reconstructive surgery is often performed in adults with progressive thoracolumbar spinal deformities [1]. Instrumented arthrodesis of the spine has been used extensively to treat pain, correct deformity, and improve overall health-related quality of life (HRQOL) in patients with adult spinal deformity (ASD). Glassman et al. reported that sagittal spinal malalignment is commonly defined by an increased sagittal vertical axis (SVA) [2], because function decreased as the magnitude of positive sagittal balance increased. Schwab et al. reported that SVA <50 mm is associated with a better HRQOL score, and global sagittal alignment, according to radiographic cut-offs of SVA (<40 mm, 40–95 mm, and >95 mm) and pelvic tilt (PT) (<20°, 20–30°, and >30°), is associated with increased pain and disability [3,4]. Recent reports have demonstrated the potential of surgical treatment for ASD to improve pain and overall HRQOL. Regardless, there are limited data on the effects of corrective long spinal fusion on physical function after corrective long fusion.

Preoperative and postoperative performance-based clinical data have not been extensively evaluated in those with ASD after corrective long spinal fusion to the ilium. The magnitude of the deformity is important to consider when evaluating patients with a positive sagittal balance. The extent of the symptoms may also be associated with the aetiology of the positive sagittal balance. We aimed to identify the effects of long spinal fusion to the ilium on physical function in patients with ASD.

## Methods

We hypothesized that significant changes would be observed in patients with ASD after corrective long spinal fusion at 6 and 12 months postoperatively, and physical function would improve after surgery as the magnitude of the preoperative SVA and PT increased.

*Setting and Participants*

Patients were recruited from the inpatient clinic of the Department of Orthopaedic Surgery at our institution. Forty-seven patients with ASD who underwent long spinal fusion were enrolled between August 2013 and September 2014.

Inclusion criteria were as follows: (1) patients older than 40 years; (2) those without a history of spinal surgery; and (3) patients who underwent corrective long spinal fusion from the thoracic spine to the ilium. Exclusion criteria were as follows: (1) patients who could not walk without assistance; (2) those who did not complete the study; and (3) individuals who did not consent to participate. Our university's Research Ethics Committee approved this study, and all patients provided written informed consent.

Patients were divided into two groups according to whether their sagittal plane was balanced on lateral full spine standing radiographs: ++ group (SVA ≥95 mm and PT ≥30° before surgery) and 0+ group (SVA <95 mm or PT <30° before surgery).

*Physical therapy programme*

The physical therapist conducted inpatient rehabilitation exercises with all patients for about 40–60 minutes five times per week during their entire stay at our hospital. The exercise intensity was customized for each patient according to the individual's tolerance level, physiologic parameters, or physiotherapist's judgment. After discharge, we advised patients to perform a progressive walking-based home exercise, muscle stretching, and muscle resistance training

on their own. They were instructed to wear a hard brace all day for 6 months after surgery and then transition to a soft brace after 7 months postoperatively.

*Study Design*

*Radiographic outcome measures*

Total spinal and pelvic radiographs in standing position were obtained preoperatively and postoperatively, and the radiographic parameters (SVA, lumbar lordosis [LL], thoracic kyphosis [TK], sacral slope [SS], pelvic incidence [PI], PT, C7 plumb line-central sacral vertical line, and Cobb angle) were measured by using Surgimap software (Nemaris Inc.). Seven orthopaedic surgeons conducted the radiographic measurements (Fig. 1).

*Physical function outcome measures*

We used performance-based outcomes for low back pain (the visual analogue scale [VAS] [pain with motion]), maximal isometric strength (hip flexion and knee extension), dynamic balance (Timed Up and Go [TUG] test), and gait performance (10-metre walking test [10MWT] and 6-minute walk test [6MWT]) to evaluate functional recovery.

VAS scores were obtained by measuring the distance in millimetres from the origin of a horizontal line [5]. The maximal isometric strength was measured twice to assess lower limb strength with a hand-held dynamometer (μTas F-1, Anima Corp.). Testing positions have been very reliable for measuring isometric strength in previous studies on the hip and knee muscle [6,7]. The TUG measured the time it takes a subject to stand up from an armchair, walk a distance of 3 metres, turn, walk back to the chair, and sit down. It was developed as a clinical measure of balance in elderly people [8,9]. To test the 10MWT, the maximum walking speed was recorded as each patient walked on a flat, straight, 10-metre walkway [10]. The 6MWT was performed according to the American Thoracic Society's recommendations [11]. The 6MWT is useful because of its ease of administration, similarity to normal daily activities, and it is a submaximal test of aerobic capacity. Data for the maximal isometric strength, TUG, and 10MWT were obtained during two recorded trials, and the results were averaged for use in data analysis. We measured these variables before surgery, at discharge, and at 6 months and 12 months postoperatively. Functional outcome measures were conducted by one trained physical therapist.

*HRQOL*

Standardized HRQOL measures were recorded and included in the Oswestry Disability Index (ODI) and Scoliosis Research Society-22 (SRS) scores. These variables were measured before surgery and at 6 months and 12 months postoperatively [12,13].

*Statistical Analysis*

Differences in the measured and improved values between the two groups were evaluated for statistical significance by using the independent t-test and Mann-Witney's U-test. Measured and improved values at discharge and at 6 months and 12 months postoperatively were compared to those before surgery by using repeated-measures analysis of variance with Bonferroni correction for multiple comparisons. A 2-tailed $P < 0.05$ was considered significant. Data are presented as a mean ± standard deviation. Statistical analyses were performed with the Statistical Package for the Social Science software, version 21.0 (IBM Corp.).

**Results**

*Clinical and Demographic Characteristics*

Forty-seven patients were screened. After excluding patients who could not walk independently (n = 3), those

who were not followed up to 12 months postoperatively (n = 10), and patients who did not consent to participate (n = 4), 30 patients were enrolled (0+ group, 16; ++ group, 14) (Table 1). Twenty patients had major comorbidities: heart disease, 3; respiratory disease, 2; mental disease, 2; high blood pressure, 5; diabetes, 4; rheumatism, 2; hydrocephalus, 1; and lacunar infarction, 1. Seven postoperative complications occurred (spinal epidural hematoma on the left side of L3 that caused a decrease in muscle strength, 1; right leg numbness, 1; delirium, 2; ileus 1; atelectasis, 1; and pneumonia, 1), and 14 delayed complications occurred (proximal junctional kyphosis, 12; hook dislodgment, 1; and upper instrumented vertebra fracture, 1). Three patients were transferred to rehabilitation centres to receive additional rehabilitation treatment for 1-2 months.

*Radiographic Outcomes*

The SVA, LL, SS, PT, and Cobb angle significantly improved after corrective long spinal fusion in all study patients ($P < 0.01$) (Table 2; Fig. 2).

*Improvement in Functional Outcomes*

All study patients had significant improvement in the VAS scores during movement after surgery ($P < 0.01$). Values of the TUG and 6MWT significantly improved from baseline to 12 months (Table 3). In the ++ group, values of the TUG, 10MWT, and 6MWT significantly improved from baseline to 12 months (Table 4).

The times of the TUG (3.4 vs. 0.5 sec, $P = 0.012$) and 10MWT (1.8 vs. 0.1 sec, $P = 0.007$) were significantly more improved in the ++ group than in the 0+ group at 12 months postoperatively. Improvement in the distance for the 6MWT was significantly higher in the ++ group than in the 0+ group at discharge (-4.3 vs. -71.8 m, $P = 0.029$), and 6 months (98.5 vs. 34.0 m, $P = 0.041$) and 12 months postoperatively (127.8 vs. 66.0 m, $P = 0.048$). There were no differences in the improvement of the other functional outcomes between the groups.

*Measurement of the HRQOL Outcomes*

All study patients had significant improvement in the ODI and SRS subtotal scores at 6 months and 12 months postoperatively ($P < 0.01$). However, there were no significant differences in the ODI and SRS scores at any time between the groups (Table 5).

**Discussion**

We observed improvement in patients' physical function and ability after corrective long spinal fusion. This is the first study to use diverse objective physical function assessment measures to compare the physical function of patients with ASD before and after surgery. In contrast, Engsberg et al. reported no difference in the gait endurance, speed, and cadence before surgery and 2 years after surgery in patients who underwent their first long spinal fusion to the distal lumbar spine or sacrum for scoliosis [14,15].

In our study, corrective long spinal fusion to the ilium improved gait ability at 12 months postoperatively in patients with ASD. The increase in the change in gait endurance for all patients was not similar to that previously reported in patients with ASD who underwent long spinal fusion surgery. Numerous factors can affect gait endurance; thus, correct spinal alignment can reduce back pain and improve dynamic balance. Our findings suggest that gait endurance has to compensate for changes after long spinal fusion surgery and physical exercise in patients with ASD. Additionally, our study had older patients than a previous study, so this may have affected the results of gait endurance.

Low back pain during movement was reduced postoperatively, and the gait speed was significantly decreased between the preoperative period and time of discharge. These findings may have been affected by the altered spino-pelvic dynamics from corrective long spinal fusion. Moreover, these results suggest that muscle strength significantly decreased at discharge and preventing the loss of muscle strength is very important. Clinically, it would seem that physical therapy strategies for improving muscle strength can be implemented to further improve the gait performance of these patients. All patients should begin physical therapy immediately postoperatively to establish a bed-level muscle strength exercise programme. It is important to teach bed-level muscle strength exercise to patients and their caregivers preoperatively, so that it can be performed as soon as possible.

After subdividing our study population, there was clear evidence of improvement in the gait speed and endurance as the magnitude of the SVA and PT increased. However, the dynamic balance, gait speed, and endurance were higher in the ++ group than in the 0+ group at 12 months postoperatively. There are several possible reasons for this finding. Since patients with an SVA of <95 mm or PT <30° before surgery maintained their gait endurance, their preoperative 6MWT distances were high; thus, improvement in the 6MWT distance was limited. However, patients with an SVA ≥95 mm and PT ≥30° before surgery had a low preoperative 6MWT distance due to severe progressive lumbar spinal deformities. Patients with severe ASD are generally unwilling to participate in aerobic physical activities because of their deformity or non-compliance with instructions to avoid strenuous exertion; therefore, they live a sedentary lifestyle. It seems that the preoperative spinal deformity of patients with an SVA ≥95 mm and PT ≥30° before surgery has a substantial influence on gait speed and endurance. Consequently, surgical correction enabled them to achieve a significant improvement in balance, gait speed, and endurance postoperatively.

***Study Limitations***

The small sample size and short follow-up period were study limitations. Thus, we need to perform a longer follow-up of 5 or more years to further analyse complications. Additionally, the absence of a control group limits the validity of our observed outcome. However, our study group was more homogeneous than that in a previous study.

## Conclusion

Corrective long spinal fusion improves back pain at discharge, and it improves balance and gait ability at 12 months postoperatively in patients with ASD.

## Conflict of Interest

All authors declare no conflict of interest.

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Table 1. Average clinical and demographic characteristics of patients with adult spine deformity

| | All study patients | 0+ group | ++ group |
|---|---|---|---|
| No. of cases | 30 | 16 | 14 |
| Sex (female:male) | 28:2 | 15:1 | 13:1 |
| Age (years) | 65.9 ± 10.7 | 62.3 ± 12.2 | 70.1 ± 4.9 * |
| BMI (kg/m$^2$) | 22.5 ± 3.5 | 23.0 ± 3.7 | 22.0 ± 3.3 |
| Length of stay (days) | 41.4 ± 13.0 | 42.8 ± 14.7 | 39.8 ± 11.1 |
| Assistive device (cane:none) | 10:20 | 2:14 | 8:6 |
| Diagnosis | | | |
| KS:K:VF:AS:CD | 8:11:5:4:2 | 4:5:1:4:2 | 4:6:4:0:0 |
| Surgical variables | | | |
| Osteotomy (PSO:VCR:PCO) | 7:8:15 | 3:2:11 | 4:6:4 |
| Number of fused levels | 11.3 ± 1.9 | 11.6 ± 2.2 | 11.1 ± 1.7 |
| Operating time (min) | 409.0 ± 73.9 | 415.2 ± 89.7 | 401.9 ± 53.0 |
| TBL (cc) | 1,706.1 ± 997.5 | 1,413.8 ± 1,010.5 | 2,040.1 ± 903.5 |

0+ group, sagittal vertical axis (SVA) <95 mm or pelvic tilt (PT) <30°; ++ group, SVA ≥95 mm and PT ≥30°; BMI, body mass index; KS, kyphoscoliosis; K, kyphosis; VF, vertebral fracture; AS, adult scoliosis; CD, congenital deformity; PSO, pedicle subtraction osteotomy; VCR, vertebral column resection; PCO, posterior column osteotomy; TBL, total blood loss. Values are presented as mean ± standard deviation. * Significant difference between the ++ and 0+ groups ($P < 0.05$).

Table 2. Average radiographic measurements for patients with adult spine deformity

| | All study patients | | 0+ group | | ++ group | |
|---|---|---|---|---|---|---|
| Before surgery | | | | | | |
| SVA (mm) | 117.4 ± 84.4 | | 73.9 ± 79.2 | | 178.5 ± 71.2 | ‡ |
| LL (degrees) | 15.2 ± 26.3 | | 24.3 ± 27.0 | | 4.8 ± 21.9 | † |
| TK (degrees) | 30.8 ± 22.8 | | 24.9 ± 23.9 | | 38.4 ± 20.0 | |
| SS (degrees) | 18.6 ± 11.7 | | 22.7 ± 13.0 | | 13.9 ± 8.3 | † |
| PI (degrees) | 51.0 ± 8.2 | | 51.3 ± 10.0 | | 50.8 ± 6.0 | |
| PT (degrees) | 32.4 ± 9.5 | | 28.6 ± 10.5 | | 36.9 ± 5.7 | † |
| C7PL-CSVL (mm) | 12.3 ± 39.1 | | 7.7 ± 27.9 | | 17.5 ± 49.5 | |
| Cobb angle (degrees) | 35.5 ± 26.3 | | 44.3 ± 28.6 | | 23.8 ± 16.8 | † |
| After surgery | | | | | | |
| SVA (mm) | 21.2 ± 33.3 | * | 3.9 ± 25.3 | * | 39.8 ± 31.2 | * ‡ |
| LL (degrees) | 50.4 ± 6.2 | * | 51.1 ± 6.2 | * | 49.6 ± 6.4 | * † |
| TK (degrees) | 33.5 ± 10.4 | | 29.3 ± 8.7 | | 38.0 ± 10.5 | |
| SS (degrees) | 33.1 ± 7.2 | * | 34.3 ± 6.3 | * | 31.8 ± 8.1 | * |
| PI (degrees) | 50.2 ± 7.4 | | 49.1 ± 8.4 | | 51.4 ± 6.2 | |
| PT (degrees) | 17.1 ± 6.5 | * | 14.8 ± 7.8 | * | 19.5 ± 3.7 | * |
| C7PL-CSVL (mm) | 2.7 ± 30.6 | | 3.3 ± 23.4 | | 2.1 ± 38.1 | |
| Cobb angle (degrees) | 12.2 ± 11.8 | * | 14.1 ± 13.3 | * | 9.0 ± 8.4 | * |

0+ group, sagittal vertical axis (SVA) <95 mm or pelvic tilt (PT) <30°; ++ group, SVA ≥95 mm and PT ≥30°; LL, lumbar lordosis; TK, thoracic kyphosis; SS, sacral slope; PI, pelvic incidence; PT, pelvic tilt; C7PL-CSVL, C7 plumb line-central sacral vertical line. Values are presented as mean ± standard deviation. * Significant difference compared to baseline ($P < 0.01$). † Significant difference between the ++ and 0+ groups ($P < 0.05$). ‡ Significant difference between the ++ and 0+ groups ($P < 0.01$).

Table 3. Average performance-based clinical data of patients with adult spine deformity

| | Before surgery | Discharge | 6 months postoperatively | 12 months postoperatively |
|---|---|---|---|---|
| VAS (mm) | | | | |
| Motion | 55 ± 27 | 25 ± 25 † | 19 ± 21 † | 15 ± 18 † |
| IMS (kgf/kg) | | | | |
| KE (Rt) | 0.40 ± 0.15 | 0.26 ± 0.14 † | 0.41 ± 0.15 | 0.45 ± 0.16 |
| KE (Lt) | 0.40 ± 0.17 | 0.27 ± 0.13 † | 0.39 ± 0.14 | 0.41 ± 0.13 |
| HF (Rt) | 0.28 ± 0.10 | 0.17 ± 0.07 † | 0.26 ± 0.09 | 0.27 ± 0.08 |
| HF (Lt) | 0.26 ± 0.10 | 0.17 ± 0.07 † | 0.25 ± 0.08 | 0.26 ± 0.08 |
| TUG test (sec) | 10.9 ± 4.6 | 13.4 ± 4.8 | 10.6 ± 5.8 | 9.2 ± 3.3 * |
| 10MWT (sec) | 8.4 ± 2.8 | 10.5 ± 2.6 † | 8.1 ± 2.2 | 7.6 ± 2.0 |
| 6MWT (m) | 341.6 ± 117.7 | 300.0 ± 75.8 | 403.1 ± 94.6 † | 432.1 ± 99.0 † |

VAS, visual analogue scale; IMS, isometric muscle strengths; KE, knee extension; HF, hip flexion; TUG, Timed Up and Go; 10MWT, 10-metre walking test; 6MWT, 6-minute walk test. Values are presented as a mean ± standard deviation. * Significant difference compared to the preoperative value ($P < 0.05$). † Significant difference compared to the preoperative value ($P < 0.01$).

Table 4. Average performance-based clinical data of the 0+ group and ++ group

| | | Before surgery | | | | Discharge | | | | 6 months postoperatively | | | | 12 months postoperatively | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0+ group | VAS (mm) | | | | | | | | | | | | | | | | |
| | Motion | 53 | ± | 29 | | 28 | ± | 29 | | 26 | ± | 21 | * | 15 | ± | 19 | * |
| | IMS (kgf/kg) | | | | | | | | | | | | | | | | |
| | KE (Rt) | 0.40 | ± | 0.13 | | 0.28 | ± | 0.17 | | 0.40 | ± | 0.16 | | 0.46 | ± | 0.16 | |
| | KE (Lt) | 0.41 | ± | 0.18 | | 0.29 | ± | 0.15 | * | 0.40 | ± | 0.14 | | 0.40 | ± | 0.13 | |
| | HF (Rt) | 0.29 | ± | 0.09 | | 0.17 | ± | 0.08 | † | 0.25 | ± | 0.09 | | 0.26 | ± | 0.08 | |
| | HF (Lt) | 0.27 | ± | 0.08 | | 0.17 | ± | 0.08 | † | 0.24 | ± | 0.09 | | 0.25 | ± | 0.08 | |
| | TUG test (sec) | 9.4 | ± | 3.7 | | 12.5 | ± | 5.3 | | 11.2 | ± | 7.8 | | 8.9 | ± | 3.9 | |
| | 10MWT (sec) | 7.6 | ± | 2.5 | | 10.0 | ± | 2.9 | † | 8.0 | ± | 2.9 | | 7.5 | ± | 2.4 | |
| | 6MWT (m) | 388.3 | ± | 124.4 | | 316.5 | ± | 85.9 | * | 422.3 | ± | 110.7 | | 454.3 | ± | 93.7 | * |
| ++ group | VAS (mm) | | | | | | | | | | | | | | | | |
| | Motion | 57 | ± | 25 | | 22 | ± | 19 | † | 12 | ± | 20 | † | 14 | ± | 18 | † |
| | IMS (kgf/kg) | | | | | | | | | | | | | | | | |
| | KE (Rt) | 0.40 | ± | 0.18 | | 0.24 | ± | 0.09 | * | 0.42 | ± | 0.15 | | 0.45 | ± | 0.16 | |
| | KE (Lt) | 0.38 | ± | 0.17 | | 0.24 | ± | 0.10 | * | 0.37 | ± | 0.15 | | 0.42 | ± | 0.13 | |
| | HF (Rt) | 0.28 | ± | 0.12 | | 0.17 | ± | 0.06 | * | 0.28 | ± | 0.10 | | 0.29 | ± | 0.09 | |
| | HF (Lt) | 0.26 | ± | 0.11 | | 0.16 | ± | 0.06 | | 0.25 | ± | 0.07 | | 0.27 | ± | 0.08 | |
| | TUG test (sec) | 12.7 | ± | 5.1 | | 14.4 | ± | 4.1 | | 9.9 | ± | 2.5 | | 9.3 | ± | 2.7 | * |
| | 10MWT (sec) | 9.4 | ± | 2.9 | | 11.0 | ± | 2.2 | | 8.2 | ± | 1.3 | | 7.6 | ± | 1.5 | * |
| | 6MWT (m) | 284.0 | ± | 80.3 | ‡ | 279.7 | ± | 58.1 | | 382.5 | ± | 72.1 | † | 411.8 | ± | 81.7 | † |

0+ group, SVA <95 mm or PT <30°; ++ group, SVA ≥95 mm and PT ≥30°; VAS, visual analogue scale; IMS, isometric muscle strengths; KE, knee extension; HF, hip flexion; TUG, Timed Up and Go; 10MWT, 10-metre walking test; 6MWT, 6-minute walk test. Values are presented as mean ± standard deviation. * Significant difference compared to the preoperative value ($P < 0.05$). † Significant difference compared to the preoperative value ($P < 0.01$). ‡ Significant difference between the ++ and 0+ groups ($P < 0.05$).

Table 5. Average HRQOL measurements for patients with adult spine deformity

| | All study patients | 0+ group | ++ group |
|---|---|---|---|
| Before surgery | | | |
| ODI | 40.2 ± 12.6 | 38.1 ± 11.7 | 42.6 ± 13.6 |
| SRS subtotal | 2.5 ± 0.6 | 2.6 ± 0.5 | 2.4 ± 0.6 |
| 6 months postoperatively | | | |
| ODI | 30.1 ± 16.0 † | 28.1 ± 14.7 * | 32.5 ± 17.6 † |
| SRS subtotal | 3.4 ± 0.5 † | 3.4 ± 0.6 † | 3.3 ± 0.5 † |
| 12 months postoperatively | | | |
| ODI | 28.0 ± 17.7 † | 23.8 ± 11.1 * | 31.9 ± 19.8 * |
| SRS subtotal | 3.3 ± 0.8 † | 3.3 ± 1.0 † | 3.3 ± 0.7 † |

ODI, Oswestry Disability Index; SRS, Scoliosis Research Society-22. 0+, sagittal vertical axis (SVA) <95 mm or pelvic tilt (PT) <30°; ++ group, SVA ≥95 mm and PT ≥30°. Values are presented as a mean of the improved score ± standard deviation. * Significant difference compared to the preoperative value ($P < 0.05$). † Significant difference compared to the preoperative value ($P < 0.01$).

**Figure Captions**

**Fig. 1** Measurements of coronal (A) and sagittal (B) spinal alignment

C7PL-CSVL, C7 plumb line-central sacral vertical line; SVA, sagittal vertical axis; LL, lumbar lordosis; TK, thoracic kyphosis; SS, sacral slope; PI, pelvic incidence; PT, pelvic tilt

**Fig. 2** Representative patient

Preoperative coronal (A) and sagittal (B) and postoperative coronal (C) and sagittal (D) whole spine radiographs in standing position

This 75-year-old woman with kyphoscoliosis underwent staged L2–S1 posterior lumbar interbody fusion and posterior spinal instrumented fusion from T9 to the ilium. The radiographs show that the sagittal vertical axis, lumbar lordosis, and pelvic tilt improved (preoperative values: 176 mm, -5°, and 46°; postoperative values: 42 mm, 60°, and 19°, respectively). The preoperative functional visual analogue scale (motion) score and 6-minute walk test distance improved from 71 mm and 200 m to 38 mm and 329 m, respectively.

Fig. 1

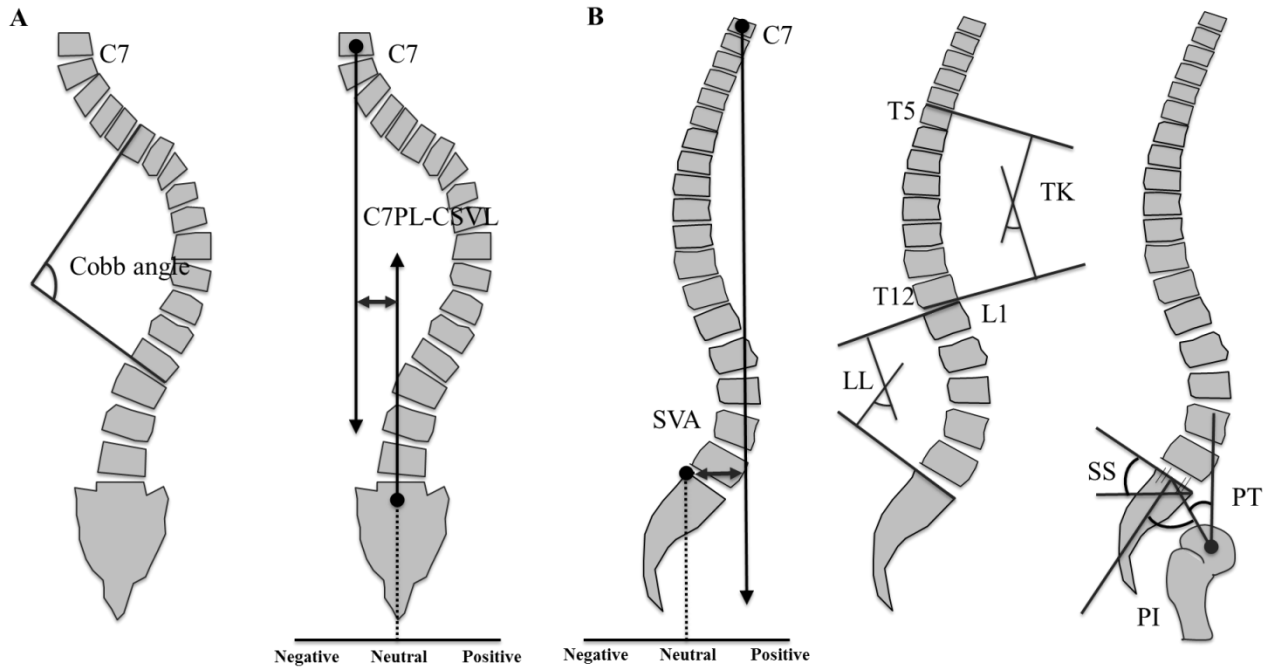
A
C7
Cobb angle
C7
C7PL-CSVL
Negative
Neutral
Positive
B
C7
SVA
Negative
Neutral
Positive
T5
TK
T12
L1
LL
SS
PT
PI

Fig. 2