Short-segment decompression/fusion versus long-segment decompression/fusion and osteotomy for Lenke-Silva type VI adult degenerative scoliosis

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Abstract

Background: The effect of short-segment decompression/fusion versus long-segment decompression/fusion and osteotomy for Lenke-Silva type VI adult degenerative scoliosis (ADS) has not been clarified. This study aimed to compare the clinical and radiographic results of short-segment fusion *vs.* long-segment fusion and osteotomy for patients with Lenke-Silva type VI ADS.

Methods: Data of 28 patients who underwent spinal surgery for ADS from January 2012 to January 2014 in the General Hospital of Northern Theater Command were reviewed. Of the 28 patients, 12 received long-segment fusion and osteotomy and 16 received short-segment fusion. Radiographic imaging parameters and clinical outcomes, including the sagittal vertical axis (SVA), lumbar lordosis (LL) angle, pelvic tilt (PT), sacral slope (SS), the visual analog scale (VAS), Japanese Orthopedic Association (JOA), Oswestry disability index (ODI), and lumbar stiffness disability index (LSDI) scores, were recorded. The difference between groups was compared using the dependent t test or Chi-squared test.

Results: The Cobb and LL angles and SVA improved in both groups; however, PT and SS angles did not improve following short fusion. There were significant differences in the post-operative SVA (26.8 ± 5.4 mm *vs.* 47.5 ± 7.6 mm, $t = -8.066$, $P < 0.001$), PT ($14.7 \pm 1.8°$ *vs.* $29.1 \pm 3.4°$, $t = -13.277$, $P < 0.001$), and SS ($39.8 \pm 7.2°$ *vs.* $26.1 \pm 3.3°$, $t = 6.175$, $P < 0.001$) between the long and short fusion groups. All patients had improved ODI, JOA, and VAS scores post-operatively (all $P < 0.001$), with no significant difference between the groups (all $P > 0.05$). The post-operative LSDI score was 3.5 ± 0.5 in the long fusion group, which was significantly higher than that of the short fusion group (1.4 ± 0.7; $P < 0.001$).

Conclusions: The clinical outcomes of patients with Lenke-Silva type VI ADS who underwent short-segment decompression/fusion were comparable to those of patients who underwent long-segment decompression/fusion and osteotomy despite poor correction of sagittal imbalance. Moreover, short-segment decompression/fusion showed a short operation time and reduced surgical trauma.

Keywords: Degenerative scoliosis; Short fusion; Long fusion; Spine surgery; Lenke-Silva type VI

Introduction

Adult degenerative scoliosis (ADS), typically defined as a curvature >10° using the Cobb method, is a common spinal deformity in a skeletally mature individual.[1,2] It is a process of degenerative changes of the disks and facets leading to progressive deformity in three dimensions: the coronal, sagittal, and axial planes.[3] Its prevalence has been reported in 9% of the middle-aged patients (>40 years) who have exhibited scoliosis, with a far higher rate of 68% in the elderly asymptomatic population (>60 years).[4,5] Patients with ADS usually present symptoms of spinal stenosis, aggravated back pain, radiculopathy, inability to stand in a normal posture, or a combination of these symptoms.[6] At present, with the rapid increase in the number of elderly Chinese population, ADS is becoming more prevalent with significant impact on health and disability.

Traditionally, non-operative management was initially recommended for patients with ADS with slight curvature and no spinal stenosis. For symptomatic patients with failed non-operative treatment, open decompression and fusion procedures were usually performed using posterior instrumentation with or without inter-body fusion.[7,8] Silva and Lenke[2] proposed six levels of treatment for ADS based on patient symptoms and radiographic findings as follows: level I, simple posterior lumbar decompression

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without fusion; level II, decompression and limited instrumented posterior spinal fusion; level III, decompression and posterior long-segment fixation and fusion; level IV, posterior lumbar decompression with anterior and posterior fusion; level V, thoracic instrumentation and fusion extension; and level VI, decompression and osteotomies for specific deformities and posterior fusion. Patients with Lenke-Silva treatment level VI ADS characterized by low back pain, Cobb angle >30°, flexibility <30%, detachment >2 mm, lateral slippage >6 mm, and sagittal vertical axis (SVA) >50 mm are required to undergo long-segment fusion and osteotomies. However, complex surgeries are associated with abundant blood loss and substantial complication and high risk of nerve damage.[9,10] Among a large number of studies comparing short-segment and long-segment fusion in patients with ADS,[11,12] only a few studies evaluated the curative effect of different fusion approaches for Lenke-Silva treatment level VI ADS. Moreover, under the premise of ensuring good post-operative results, minimizing surgical trauma has become a research topic of current DS (degenerative scoliosis) treatment. This study was conducted to compare the clinical and radiographic results of short-segment decompression/fusion *vs.* long-segment decompression/fusion and osteotomy for patients with Lenke-Silva treatment level VI ADS.

Methods

Ethical approval

The study was conducted in accordance with the *Declaration of Helsinki* and was approved by the Ethics Committee of the General Hospital of Northern Theater Command, Shenyang, China. Informed written consent was obtained from all patients prior to their enrollment in this study.

Patients

The retrospective study reviewed a total of 28 patients (6 men and 22 women; mean age of 64.5 ± 4.1 years, range: 55–75 years) who underwent spinal surgery for ADS in our hospital from January 2012 to January 2014. All patients presented with adult scoliosis defined by the coronal Cobb angle above 10° and meeting the diagnostic criteria of Lenke-Silva treatment level VI according to the Lenke-Silva classification for ADS.[1,2] They all exhibited symptoms of nerve root compression and intermittent claudication. The exclusion criteria were as follows: (1) history of previous scoliosis or spinal surgery; (2) spinal lesions including wound, tumor, and infection; and (3) incomplete follow-up data.

Among the 28 patients, 12 patients received long-segment decompression/fusion and osteotomy (long fusion group; 2 men and 10 women; mean age of 64.3 ± 4.1 years), and 16 patients underwent purely short-segment decompression/fusion (short fusion group; 4 men and 12 women; mean age of 64.6 ± 4.7 years). Non-steroidal anti-inflammatory drugs were administered in all patients; however, such drugs were less effective. Moreover, 19 patients (11 in the long-segment fusion group and eight in the short fusion group) who complained of severe lumbodorsal pain were unable to walk for a long period of time and had poor rest.

Operative procedures and follow-up

In this study, long fusion was performed in patients who exhibited sagittal imbalance, decreased back muscle strength, and more than two degenerated disk spaces which need to be fixed in multiple segments; patients with dynamic spinal instability and progressive kyphosis; and if the patient can tolerate long-segment fixation and fusion. Short fusion was mostly performed in patients with sagittal imbalance (1) whose spinal muscle strength was acceptable, (2) who had one degenerated disk space, (3) whose thoracic and lumbar kyphosis caused stiffness and had no angular deformity which required no osteotomy, and (4) who were unable to tolerate major surgery caused by poor physical condition. Thus, patients were placed in a prone position for surgical procedures. After disinfection and draping, the muscle tissue was peeled off layer by layer according to the pre-operative positioning incision, and the bilateral vertebral lamina was exposed. The pedicle screw was placed, and spinal canal decompression was performed followed by inter-vertebral exploration, nucleus pulposus removal, and fixation and fusion using interbody cages. Long-segment fixation reached the upper thoracic spine T10 and lower lumbar vertebrae L5 or S1. According to the pre-operative design, the titanium rods were fused to the spine to correct curvatures, and spine kyphosis was properly corrected. If fluoroscopic findings revealed a good internal fixation position and the orthopedic effect was satisfactory, the surgery was completed and suturing was performed.

Anteroposterior and lateral standing radiographs of the spinal column of each patient were evaluated by two experienced orthopedists before and after the surgery using the Surgimap Spine Imaging Software (version 2.2.9.7, www.surgimap.com; Nemaris Inc., New York, NY, USA).[13] The coronal balance parameter was the lumbar Cobb angle; the sagittal balance parameters consisted of the SVA and lumbar lordosis (LL) angle; and the pelvic parameters included the pelvic tilt (PT), pelvic incidence (PI), and sacral slope (SS). The SVA was the linear distance between the C7 plumb line and sacral posterior angle. Positive balance was defined in the case of the plumb line in the front; otherwise, negative balance was considered.[14] LL was measured as the angle from the upper endplate of L1 to the endplate of S1.[11]

Posterior lumbar decompression and fusion were performed by the same chief physician as previously described.[11] Intraoperative data such as operative time, blood loss volume, decompression segment, and hospital stay were recorded. The patients completed the evaluation questionnaires with the assistance of the resident physician pre-operatively during admission and post-operatively at the last follow-up, including the visual analog scale (VAS) score of skelalgia, the Japanese Orthopedic Association (JOA) score of low back pain,[15] Oswestry disability index (ODI),[16] and lumbar stiffness disability index (LSDI).[17] The full-length standing spinal radiographs were captured during the follow-up sessions at 3, 6, 12, and 18 months

Table 1: Demographic and intraoperative data of patients with Lenke-Silva level VI degenerative scoliosis.

Variables	Long fusion group ($n = 12$)	Short fusion group ($n = 16$)	Statistical values	P
Female/male	10/2	12/4	0.004*	0.950
Age (years)	64.3 ± 4.1	64.6 ± 4.7	–0.134†	0.890
Operative time (h)	6.9 ± 0.5	4.3 ± 0.9	8.047†	<0.001
Blood loss (mL)	1162.5 ± 117.3	571.9 ± 202.5	9.992†	<0.001
Decompression segment (n)	2.3 ± 1.1	2.5 ± 0.7	–0.704†	0.490
Length of stay (days)	15.3 ± 2.6	10.8 ± 2.3	4.874†	<0.001

The data are shown as n or mean ± standard deviation. * Chi-squared values. † t values.

Table 2: Pre- and post-operative radiographic imaging parameters of patients with Lenke-Silva level VI degenerative scoliosis.

Parameters	Long fusion group ($n = 12$)	Short fusion group ($n = 16$)	t	P
Lumbar Cobb angle (°)				
Pre-operative	21.8 ± 5.6	18.9 ± 4.1	1.465	0.160
Post-operative	2.8 ± 1.4	3.4 ± 2.0	–0.926	0.360
t	11.044	16.029		
P	<0.001	<0.001		
Sagittal vertical axis (mm)				
Pre-operative	81.2 ± 15.5	81.0 ± 18.0	0.037	0.970
Post-operative	26.8 ± 5.4	47.5 ± 7.6	–8.066	<0.001
t	14.616	8.159		
P	<0.001	<0.001		
Lumbar lordosis (°)				
Pre-operative	–28.1 ± 5.6	–30.5 ± 3.7	1.258	0.230
Post-operative	–40.8 ± 5.4	–38.5 ± 3.7	–1.279	0.220
t	10.792	8.114		
P	<0.001	<0.001		
Pelvic tilt (°)				
Pre-operative	29.3 ± 3.5	27.9 ± 3.9	0.986	0.330
Post-operative	14.7 ± 1.8	29.1 ± 3.4	–13.277	<0.001
t	17.505	–1.322		
P	<0.001	0.206		
Sacral slope (°)				
Pre-operative	26.9 ± 5.6	27.2 ± 4.2	–0.574	0.570
Post-operative	39.8 ± 7.2	26.1 ± 3.3	6.175	<0.001
t	–13.534	1.322		
P	<0.001	0.206		

The data are shown as mean ± standard deviation.

post-operatively. The average follow-up period was 1.5 years.

Statistical analysis

Data were shown as percentage or mean ± standard deviation and analyzed using the paired or dependent t test and Chi-squared test, respectively. All analyses were performed using the SPSS version 19.0 statistical software (SPSS Inc., Chicago, IL, USA). A $P \leq 0.05$ was considered as statistically significant.

Results

As shown in Table 1, patients in the long and short fusion groups were well-matched in terms of gender and age ($P > 0.050$ for both). The mean duration of long-segment decompression/fusion and osteotomy was 6.9 ± 0.5 h, which was longer than that of short-segment decompression/fusion (4.3 ± 0.9 h, $P < 0.001$). Patients in the short fusion group had less blood loss volume than that in the long fusion group (571.9 ± 202.5 mL *vs*. 1162.5 ± 117.3 mL, $P < 0.001$). No significant difference was observed in the decompression segment between the two operative procedures ($P = 0.490$). Post-operatively, two patients in the long fusion group suffered from poor wound healing and cerebrospinal fluid leakage. Meanwhile, no complications occurred among patients receiving short-segment decompression/fusion. The mean length of hospital stay following the short-segment decompression/fusion procedure was 10.8 ± 2.3 days, which was shorter than that of long-segment decompression/fusion and osteotomy procedure ($P < 0.001$).

Table 2 presents the radiographic imaging parameters of the patients. Pre-operative radiography revealed that both

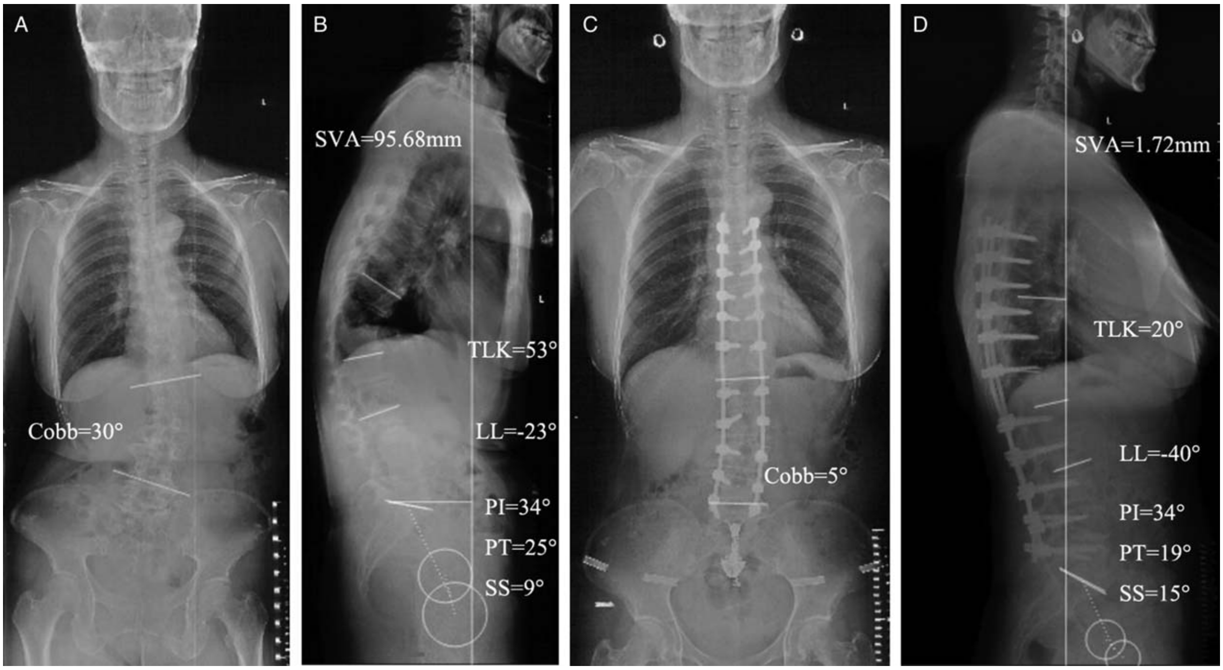

Figure 1: A 58-year-old female with Lenke-Silva level VI degenerative scoliosis was treated with long-segment decompression/fusion and osteotomy. Pre-operative anteroposterior (A) and lateral (B) X-ray indicated lumbar Cobb angle = 30°, SVA = 95.68 mm, LL = −23°, PT = 25°, PI = 34°, SS = 9°, and TLK = 53°. Post-operative anteroposterior (C) and lateral (D) X-ray showed the fusion segments of T10-L5 and osteotomy of T12, lumbar Cobb angle = 5°, SVA = 1.72 mm, LL = −40°, PT = 19°, PI = 34°, SS = 15°, and TLK = 20°. SVA: Sagittal vertical axis; LL: Lumbar lordosis; PT: Pelvic tilt; SS: Sacral slope; PI: Pelvic incidence; TLK: Thoracolumbar kyphosis.

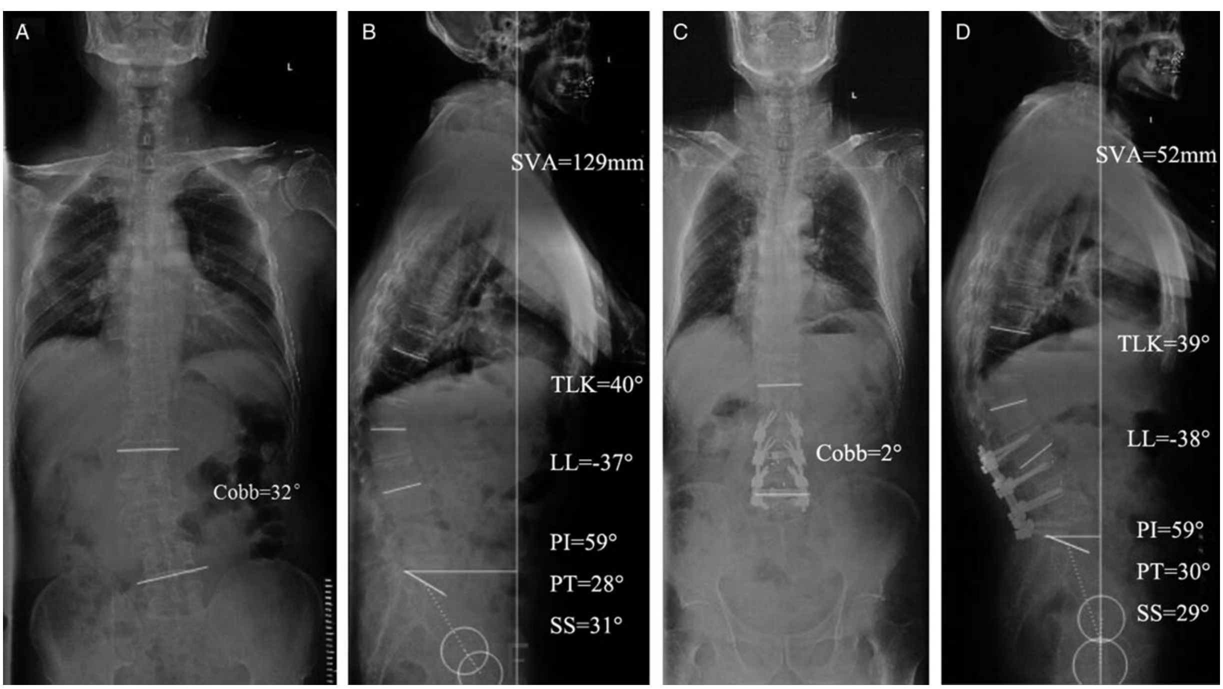

Figure 2: A 75-year-old female with Lenke-Silva level VI degenerative scoliosis was treated with short-segment decompression/fusion. Pre-operative anteroposterior (A) and lateral (B) X-ray indicated lumbar Cobb angle = 32°, SVA = 129 mm, LL = −37°, PT = 28°, PI = 59°, SS= 31°, and TLK = 40°. Post-operative anteroposterior (C) and lateral (D) X-ray at the last follow-up of 1.5 years showed the fusion segments of L2-L5 and no osteotomy, lumbar Cobb angle = 2°, SVA = 52 mm, LL = −38°, PT = 30°, and SS = 29°. SVA: Sagittal vertical axis; LL: Lumbar lordosis; PT: Pelvic tilt; SS: Sacral slope; PI: Pelvic incidence; TLK: Thoracolumbar kyphosis.

groups had similar Cobb and LL angles, SVA length, PT, and SS [Figures 1 and 2]. After the surgical treatment, the mean Cobb angle was corrected from 21.8 ± 5.6° to 2.8 ± 1.4° in the short fusion group ($t = 16.029$, $P < 0.001$). Meanwhile, such angle decreased from 18.9 ± 4.1° to 3.4 ± 2.0° in the long fusion group ($t = 11.044$, $P < 0.001$). The SVA length was 81.2 ± 15.5 mm and 81.0 ± 18.0 mm pre-operatively in

Table 3: Pre- and post-operative clinical outcomes of patients with Lenke-Silva level VI degenerative scoliosis.

Variables	Long fusion group ($n=12$)	Short fusion group ($n=16$)	t	P
Oswestry disability index				
Pre-operative	74.2 ± 6.6	72.7 ± 6.9	0.555	0.580
Post-operative	19.8 ± 5.9	15.9 ± 5.8	1.730	0.100
t	24.277	33.898		
P	<0.001	<0.001		
Japanese Orthopaedic Association score				
Pre-operative	8.7 ± 3.0	8.9 ± 2.8	–0.114	0.910
Post-operative	22.1 ± 2.7	22.1 ± 2.6	0.020	0.980
t	–14.562	–15.468		
P	<0.001	<0.001		
Visual analog scale				
Pre-operative	7.0 ± 1.0	7.2 ± 1.4	–0.402	0.690
Post-operative	2.6 ± 0.8	2.7 ± 1.0	–0.305	0.760
t	14.119	11.309		
P	<0.001	<0.001		
Lumbar stiffness disability index				
Post-operative	3.5 ± 0.5	1.4 ± 0.7	8.654	<0.001

The data are shown as mean ± standard deviation.

the long and short fusion groups, respectively, and decreased to 26.8 ± 5.4 mm and 47.5 ± 7.6 mm post-operatively ($P < 0.001$ for both). The LL angle decreased from –28.1 ± 5.6° pre-operatively to –40.8 ± 5.4° post-operatively in the long fusion group and changed from –30.5 ± 3.7° to –38.5 ± 3.7° in the short fusion group ($P < 0.001$ for both). The PT and SS angles significantly changed after long-segment decompression/fusion and osteotomy procedure (PT: 29.3 ± 3.5° *vs.* 14.7 ± 1.8°, $P < 0.001$; SS: 26.9 ± 5.6° *vs.* 39.8 ± 7.2°, $P < 0.001$). However, post-operative PT and SS angles were similar with the pre-operative values in the short fusion group ($P = 0.206$ for both). Furthermore, significant differences were noted in the post-operative SVA ($P < 0.001$), PT ($P < 0.001$), and SS ($P < 0.001$) between both groups. In addition, there was no significant difference in the mean PI between the long fusion (61.0 ± 3.5°) and short fusion groups (60.0 ± 2.8°, $P = 0.76$).

Furthermore, the clinical outcome was analyzed using the ODI, JOA, VAS, and LSDI evaluation questionnaires [Table 3]. Both groups had improved ODI, JOA, and VAS scores after the surgery ($P < 0.001$ for all), with no significant difference in the above mentioned variables between two groups ($P > 0.05$ for all). In addition, the post-operative LSDI score was 3.5 ± 0.5 in the long fusion group, which was significantly higher than 1.4 ± 0.7 in the short fusion group ($P < 0.001$).

Discussion

Recently, the surgical treatment of ADS has gradually attracted more attention because of the increasing concerns regarding the high quality of life.[18-20] Relief of lower back and radiating pain in the lower extremities along with the correction of the deformity should be the goals of surgical treatment.[11,21] Nevertheless, studies have shown that 81% of the total number of patients with ADS were accompanied with the loss of LL. Sagittal imbalance was more related to the clinical symptoms of ADS than spinal coronal imbalance. Hence, correction of sagittal imbalance was equally important as decompression of the stenotic segments.[22-25] With the complexity of the disease features of ADS and various best treatment methods for different cases, the surgical treatment strategies of ADS are currently controversial.[14]

Classification systems may be of great importance in determining the surgical approach for better disease awareness and development of surgical strategies. Previously, scholars have classified all DS patients using different systems such as the Schwab, Scoliosis Research Society,[26] Ploumis, Faldini, Simmons, and coronal imbalance classifications.[14] Moreover, the Lenke-Silva classification, a system proposed by Silva and Lenke[2] dividing the surgical treatments into six levels, has been the most commonly used system in choosing the type of surgery. In Lenke-Silva type VI ADS, long-segment decompression/fusion and osteotomy are required for correction of sagittal imbalance. However, as patients with ADS are typically quite elderly and usually have comorbidities, the surgery is associated with a high risk of complications and nerve injury. This study evaluated the clinical and radiographic results of short-segment decompression/fusion *vs.* long-segment decompression/fusion and osteotomy in patients with Lenke-Silva type VI ADS.

In this study, the Cobb and LL angle, SVA length, PT, and SS improved after long-segment decompression/fusion and osteotomy. In contrast, short-segment decompression/fusion had no effect on the PT and SS angles. Significant differences in the post-operative SVA, PT, and SS between the two groups suggested that long-segment decompression/fusion and osteotomy had better efficacy in the correction of sagittal imbalance. This was in contrast with a previous study by Faldini *et al*[12] that coronal imbalance was better improved by long fusion than by short fusion.

Nonetheless, correction of LL and sagittal imbalance was similar in both groups. The inconsistent results might be attributed to the different inclusion of patients, as patients in our study were all classified under the Lenke-Silva treatment level VI. Meanwhile, in his study, these patients received short- or long-segment fusion based on the defined criterion, and they had different Cobb and LL angles. The SS of the two groups was $26.9 \pm 5.6°$ in long-segment fusion group and $27.2 \pm 4.2°$ in short-segment fusion group, and the LL was $-40.8 \pm 5.4°$ in long-segment fusion and $-38.5 \pm 3.7°$ in short-segment fusion, respectively ($P > 0.050$). The difference was small and not statistically significant. This was because the previous study in our hospital suggested that the PI-LL value was controlled between 10° and 20°, and the post-operative function of the patient was better than that proposed by Schwab *et al*,[25,27] which indicated a correction strategy of $LL = PI \pm 9°$. Therefore, the patient's LL and SS correction rates were small. Hence, the difference in the LL and SS angle between both groups was small.

Being the main goal of surgical treatment, relief of leg and back pain was evaluated using the VAS, JOA, ODI, and LSDI scores. The result revealed that the post-operative ODI, JOA, and VAS scores were all improved during the last follow-up, with no significant difference in the short or long fusion groups. Sagittal imbalance following surgery or proximal junctional kyphosis is a relatively long-term complication in patients with ADS. It usually occurs 1 year after surgery.[28,29] We compared the patient's pre- and post-operative follow-up data and observed the spinal deformity correction and functional score. The patients were generally reviewed at 18 months post-operatively, and a three-dimensional CT of the spine was performed. After the fusion effect was determined, the patient was no longer examined. It was suggested that short-segment decompression/fusion had equal efficacy with long-segment decompression/fusion and osteotomy in terms of the clinical outcomes, despite poor correction of sagittal imbalance. In addition, the lower LSDI scores in the short fusion group further supported that short-segment decompression/fusion preserved more functions of the lumbar vertebra. In addition, short-segment fixation and fusion had less damage to the posterior spine and lower intraoperative risk and caused less bleeding. More lumbar function was retained after surgery.

Several limitations of our study must be addressed. First, this was a retrospective study and not a randomized control trial. Second, the number of included cases was insufficient because data collection was only performed for 2 years, and Lenke-Silva level VI ADS was infrequently encountered in the clinic. Third, the follow-up period was short. In general, patients were reviewed at 18 months post-operatively, and a three-dimensional CT of the spine was performed. After the fusion effect was determined, the patient was no longer examined. Long-term recovery of sagittal imbalance and operative complications were not observed. Furthermore, data on bone mineral density were incomplete. The incidence and degree of osteoporosis could not be obtained. Hence, further study is necessary to prospectively collect a large sample of patients with Lenke-Silva type VI ADS from multiple research centers during a long follow-up period and compare the treatment outcomes and operative complications of short-segment decompression/fusion *vs.* long-segment decompression/fusion and osteotomy. The specific indication of short-segment fusion treatment for these patients remains to be further studied.

In conclusion, the clinical outcomes of patients with Lenke-Silva type VI ADS who underwent short-segment decompression/fusion were comparable to those of patients who underwent long-segment decompression/fusion and osteotomy despite poor correction of sagittal imbalance. Moreover, short-segment decompression/fusion showed a short operation time, and reduced surgical trauma. However, the clinical indication of short-segment decompression/fusion for Lenke-Silva treatment level VI ADS is to be further determined.

Conflicts of interest

None.

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