Postoperative translation of the upper instrumented vertebra in thoracic adolescent idiopathic scoliosis

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OBJECTIVE The aim of this retrospective study was to analyze the influence of upper instrumented vertebra (UIV) translation from the C7 plumb line (C7PL) on the long-term postoperative results of patients with main thoracic (MT) adolescent idiopathic scoliosis (AIS).

METHODS Twenty-five patients had been treated surgically for AIS with a Lenke type 1 curve and had been followed up for a mean period of 18.2 years. Radiographic parameters, pulmonary function measurements, and clinical outcomes were compared between the patients (n = 15) with UIV translation < 20 mm and those (n = 10) with UIV translation ≥ 20 mm at the final follow-up. Correlations between UIV translation and radiographic or pulmonary function parameters were analyzed.

RESULTS Patients with ≥ 20 mm UIV translation at the final follow-up had a significantly larger preoperative UIV translation than that in the patients with < 20 mm UIV translation at follow-up. The former group also had a significantly lower correction rate of the MT curve, higher chest cage ratio, and lower radiographic shoulder height (p = 0.01, 0.005, and 0.025, respectively) at the final follow-up. The Scoliosis Research Society (SRS)–30 Questionnaire scores were equivalent between the two groups. Correlation analysis showed that the following parameters were significantly associated with UIV translation: MT curve correction rate (r = −0.481, p = 0.015), chest cage ratio (r = 0.673, p < 0.001), and percent-predicted forced expiratory volume in 1 second (r = −0.455, p = 0.033).

CONCLUSIONS The UIV translation should be considered an important factor that influences postoperative results. In MT AIS patients whose preoperative upper end vertebra (UEV) is distant from the C7PL, the UIV should be selected above the UEV to prevent large UIV translation at the postoperative follow-up.

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KEYWORDS adolescent idiopathic scoliosis; main thoracic curve; anterior spinal fusion; upper instrumented vertebra; UIV translation; spine

THE current gold standard treatment for adolescent idiopathic scoliosis (AIS) is posterior spinal fusion (PSF) with pedicle screw instrumentation.^{6,20} However, three-dimensional corrections with the fusion of fewer motion segments can be established through anterior spinal fusion (ASF),^{1,4,8,16} which remains an attractive option for treating thoracolumbar and lumbar AIS curves.^{5,17,21} Another potential advantage of the anterior approach to the thoracic spine is the ability to restore kyphosis within the range of the main thoracic (MT) curve.^{1,4,8,14,16,24} Sudo et al. recently reported that overall radiographic findings

and patient outcome measures after ASF for Lenke type 1 AIS were satisfactory at an average follow-up of 15 years, although the procedure decreased pulmonary function.²²

Another potential disadvantage of ASF is the limited choice of the upper instrumented vertebra (UIV). Given the presence of the scapular arch, it is very difficult for vertebral screws to be inserted into the vertebral bodies and vertebral plates. Instrumentation levels are determined from end-to-end vertebrae on standing films in most cases because surgeons resort to a short fusion strategy in relation to the UIV with the aim of preventing additional

ABBREVIATIONS AIS = adolescent idiopathic scoliosis; ASF = anterior spinal fusion; AVT = apical vertebral translation; C7PL = C7 plumb line; CSVL = center sacral vertical line; FEV₁ = forced expiratory volume in 1 second; FVC = forced vital capacity; LEV = lower end vertebra; LIV = lower instrumented vertebra; MT = main thoracic; PSF = posterior spinal fusion; PT = proximal thoracic; RSH = radiographic shoulder height; SRS = Scoliosis Research Society; UEV = upper end vertebra; UIV = upper instrumented vertebra.

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operation time, bleeding, muscle damage, and skin incision as well as preserving mobile spinal segments. However, no reports have evaluated the selection of the UIV in Lenke type 1 AIS curve correction using ASF. During the long-term follow-up of ASF for Lenke type 1 AIS, we have noticed that the translation of the UIV increases in some cases, which might be related to postoperative results. Hence, the purpose of this study was to assess the incidence of UIV translation after ASF in the treatment of Lenke type 1 AIS and to analyze the influence of UIV translation on radiographic parameters, pulmonary function, and clinical outcome scores. In addition, we assessed preoperative factors that might determine postoperative UIV translation. Such factors may be important for the surgical strategy in terms of fusion level determination.

Methods

This study was approved by the institutional review board of Hokkaido University Hospital. We retrospectively reviewed the data on 25 consecutive patients (3 males, 22 females) with Lenke type 1 MT AIS curves⁷ who had undergone anterior MT curve correction at our institution between 1994 and 2000.²² Study exclusion criteria consisted of the presence of syndromic, neuromuscular, and congenital scoliosis, a follow-up < 10 years, and the presence of other thoracic scoliosis curves such as Lenke type 2 double thoracic curves. None of the patients in the study had clinical lung function issues. An independent spine surgeon collected all data. No cases were lost to follow-up. Radiographs, pulmonary function, and the Scoliosis Research Society (SRS) outcome instrument (SRS-30 Questionnaire) scores^{10,15} were evaluated for all patients. The SRS-30 Questionnaire scores were available only at the final follow-up. The patient records were de-identified and analyzed anonymously.

Standing long-cassette posteroanterior and lateral radiographs were evaluated for multiple parameters before

and after surgery and at the final follow-up. Curve flexibility was evaluated preoperatively with supine bending radiographs. Coronal Cobb measurements of the proximal thoracic (PT) and MT curves were obtained. End vertebrae levels were determined on preoperative radiographs and were measured on subsequent radiographs to maintain consistency for statistical comparisons.²¹ The sagittal measurement assessed was the instrumented level. Global coronal balance was measured by the lateral displacement of the C7 plumb line (C7PL) from the center sacral vertical line (CSVL).³ For regional alignment, MT apical vertebral translation (AVT) was measured as the distance between the geometrical center of the apical vertebra and the C7PL.²³ The chest cage ratio is the ratio of the thorax width (horizontal distance from the geometrical center of the apex vertebra to each outline of the left and right thoracic cage) on the left side to the thorax width on the right side. The radiographic shoulder height (RSH) is the vertical distance between the most cephalad margin of the acromion to the soft-tissue outline immediately above the acromion and a horizontal reference line, with a positive value indicating that the left side is high.¹¹

The radiographic parameters relevant to the UIV were measured as follows: UIV translation was measured as the distance between the geometrical center of the UIV and the C7PL (Fig. 1).⁹ The UIV tilt was defined as the inclination of the upper endplate of the UIV from the horizontal. The coronal disc angle immediately superior to the UIV was considered the UIV disc angle. The UIV tilt and UIV disc angle were defined as negative when they opened to the preoperative convex side and as positive when they opened to the preoperative concave side, as previously reported.^{18,23} Sagittal balance was evaluated by measuring the absolute displacement value of the C7PL relative to the S1 posterior superior corner as the sagittal vertical axis.¹⁹ Finally, proximal junctional kyphosis was defined as the sagittal disc angle between the UIV and the proximal vertebra.

FIG. 1. Radiographs obtained in a 20-year-old woman with UIV translation ≥ 20 mm. The UIV translation was measured as the distance between the geometrical center of the UIV and the C7PL. The UIV translation was 51 mm before surgery (A), was corrected to 27 mm after surgery (B), and was 45 mm at the final follow-up (C).

Pulmonary function tests, both preoperatively and at the final follow-up, included the forced vital capacity (FVC) and forced expiratory volume in 1 second (FEV₁), and these tests were conducted with the patient in a standing position.² Each measurement was repeated three times, and the highest absolute and percent-predicted values were used for analysis.

The SRS-30 Questionnaire, which is divided into 5 domains based on the question type, was used to measure patient outcomes during the follow-up. The domains are pain, function, self-image, mental health, and satisfaction. All questions are scored from 1 to 5 (optimal); the average score for each domain was used for analysis.¹⁰

Surgical Technique

Both standing and bending films were used to select the fusion level. The instrumentation levels were determined from end-to-end vertebrae on standing films in most cases, and the vertebra without rotation on bending films was selected as the lower instrumented vertebra (LIV).²² When a neutral vertebra was located one level above the lower end vertebra (LEV), the chosen LIV was one level proximal to the LEV. Although the PT curve was corrected below 25° on side bending in all patients, flexibility < 50% of the PT compensatory curve represented a rigid curve, which could cause decompensation if fused to the upper end vertebra (UEV). In such cases, one segment below the UEV was selected.

The surgical technique has been described previously.^{4,22} In brief, the patient was placed in the lateral decubitus position with the convex side up. After rib resection, thoracotomy was performed by incising the resected rib. After exposing the vertebral bodies, the intervertebral discs and intervening cartilage plates located within the fusion area were removed. The anterior rod was placed in the screws after securing each vertebral body in the curve with vertebral screws inserted through a vertebral staple. The rod was then rotated to decrease vertebral rotation. After resected chipped ribs were grafted into the discectomy gaps, the rod was bent to create thoracic kyphosis, and compression forces were applied between the screws to correct the scoliosis. First, compression force was applied to the anterior rod to create the kyphosis in the thoracic spine more effectively; thereafter, the posterior rod was applied in neutralization. Occasionally, it was difficult to insert 2 screws into 1 vertebral body; therefore, a 1-rod system or fixation at the proximal vertebra (9 patients), a 2-rod fixation at the distal segments (3 patients), or a combined system (13 patients) was used. Patients who were treated with a 2-rod system and were well balanced were allowed to ambulate without braces.²² For patients who showed postoperative imbalance and those treated with a 1-rod or combined system, a cervico-thoraco-lumbo-sacral orthosis was applied for 4–6 months after surgery.²²

Statistical Analysis

All data are expressed as the mean ± standard deviation. Independent samples t-tests (Student t-test or Welch's correction) were used to compare between-group differences in demographic data, radiographic parameters, and

pulmonary function. Pearson's correlation test was used to assess the correlation of UIV translation with radiographic parameters and pulmonary function. Statistical significance was defined as $p < 0.05$.

Results

The cohort was divided into two groups based on the UIV translation at the final follow-up. The group with UIV translation < 20 mm ($n = 15$) was defined as having UIV translation below the mean translation distance of the entire cohort (20 mm). The group with UIV translation ≥ 20 mm ($n = 10$) was defined as having UIV translation above the mean translation distance. Among all the patients, the average age at surgery was 14.7 years (range 11–20 years), and the average Risser sign was 3.1 (range 0–5). The average follow-up period was 18.2 years (range 15–21 years). The two groups were similar at baseline with respect to the following parameters: age, Risser sign, Cobb length (from UEV to LEV), instrumentation length, and follow-up period (Table 1).

On average, 6.5 segments were instrumented in the group with < 20 mm UIV translation and 6.4 segments in the group with ≥ 20 mm translation. The cephalad instrumented vertebra ranged from T4 to T7 (the UIV was T4 in 1 patient, T5 in 14, T6 in 8, and T7 in 2), and the caudal instrumented vertebra ranged from T10 to L2. In all patients in the < 20-mm group, the UIV was placed at the preoperative UEV. In the ≥ 20 -mm group, 1 patient had the UIV placed below the UEV; the other 9 patients had the UIV placed at the preoperative UEV. None of the patients in either group required an extension of the fusion.

Radiographic Results

The radiographic parameters in the coronal plane are summarized in Table 2. In the preoperative and immediately postoperative periods, there was no difference in the MT curve between the groups. At the final follow-up, however, a significantly higher MT curve correction rate and lower correction loss were observed in the group with < 20 mm UIV translation compared with those in the ≥ 20 -mm group ($p = 0.010$ and 0.003 , respectively). No differences in the PT curve or global coronal balance were observed between the groups at the preoperative, immediately post-

TABLE 1. Summary of data in 25 patients surgically treated for AIS with a Lenke type 1 curve

Parameter	UIV Translation <20 mm	UIV Translation ≥ 20 mm	p Value
No. of patients	15	10	
Age at surgery (yrs)	14.4 ± 2.5	15.1 ± 2.9	0.528
Risser sign	3.1 ± 1.1	3.0 ± 1.4	0.790
Cobb length (from UEV to LEV)	6.6 ± 0.7	6.7 ± 0.9	0.770
Instrumentation length (no. of segments)	6.5 ± 0.6	6.4 ± 0.7	0.627
FU period (yrs)	18.4 ± 1.7	18.0 ± 1.8	0.579

FU = follow-up.

TABLE 2. Radiographic parameters in the coronal plane among 25 patients surgically treated for AIS with a Lenke type 1 curve

Parameter	UIV Translation <20 mm	UIV Translation ≥20 mm	p Value
No. of patients	15	10	
MT curve			
Preoperatively (°)	57.8 ± 5.5	63.8 ± 9.3	0.053
Flexibility (%)	64.9 ± 14.6	56.9 ± 8.0	0.131
Immediately postop (°)	15.7 ± 7.3	19.0 ± 7.8	0.299
Correction rate at postop (%)	72.9 ± 12.6	70.4 ± 11.6	0.622
Final FU (°)	22.6 ± 8.8	31.6 ± 6.1	0.010*
Correction rate at final FU (%)	61.2 ± 14.2	50.0 ± 10.1	0.010*
Correction loss (°)	6.9 ± 4.2	12.6 ± 4.1	0.003*
PT curve			
Preoperatively (°)	32.6 ± 7.2	30.7 ± 6.4	0.505
Flexibility (%)	51.0 ± 14.8	55.0 ± 20.8	0.576
Immediately postop (°)	16.5 ± 4.6	14.1 ± 7.1	0.320
Correction rate at postop (%)	48.7 ± 13.9	57.0 ± 20.2	0.234
Final FU (°)	18.6 ± 5.4	17.7 ± 6.7	0.715
Correction rate at final FU (%)	41.6 ± 17.2	44.1 ± 14.3	0.712
Global coronal balance (mm)			
Preoperatively	9.4 ± 9.4	14.5 ± 9.1	0.191
Immediately postop	11.5 ± 10.9	8.2 ± 8.3	0.420
Final FU	9.1 ± 5.2	7.1 ± 9.3	0.505
AVT (mm)			
Preoperatively	52.7 ± 11.8	62.2 ± 10.6	0.052
Immediately postop	11.8 ± 11.7	18.9 ± 10.9	0.140
Final FU	20.5 ± 5.9	35.2 ± 7.8	<0.001*
Chest cage ratio			
Preoperatively	1.8 ± 0.2	1.9 ± 0.3	0.248
Immediately postop	1.3 ± 0.2	1.4 ± 0.1	0.462
Final FU	1.3 ± 0.1	1.5 ± 0.1	0.005*
RSH (mm)			
Preoperatively	-5.1 ± 8.7	-7.8 ± 7.0	0.436
Immediately postop	3.3 ± 8.1	-1.6 ± 12.2	0.256
Final FU	2.0 ± 8.9	-8.0 ± 11.5	0.025*

* Statistically significant.

operative, and final follow-up time points. With regard to AVT, chest cage ratio, and RSH, there were no differences between the groups in either the preoperative or immediately postoperative period. At the final follow-up, however, the ≥ 20-mm group had a significantly larger AVT, higher chest cage ratio, and lower RSH than the < 20-mm group ($p < 0.001$, $p = 0.005$, and $p = 0.025$, respectively).

Radiographic parameters in the upper adjacent segments are summarized in Table 3. The ≥ 20-mm group showed significantly higher UIV translation than the < 20-mm group at the preoperative, immediately postoperative, and final follow-up time points ($p < 0.001$, $p = 0.002$, and $p < 0.001$, respectively). No significant differences in the preoperative UIV tilt or UIV disc angle were found

TABLE 3. Radiographic parameters in the upper adjacent segments in 25 patients surgically treated for AIS with a Lenke type 1 curve

Parameter	UIV Translation <20 mm	UIV Translation ≥20 mm	p Value
No. of patients	15	10	
UIV translation (mm)			
Preoperatively	21.9 ± 7.7	36.8 ± 9.2	<0.001*
Immediately postop	6.0 ± 6.4	16.3 ± 8.3	0.002*
Final FU	12.6 ± 4.9	30.0 ± 7.5	<0.001*
UIV tilt (°)			
Preoperatively	29.9 ± 4.9	32.7 ± 4.9	0.200
Immediately postop	8.3 ± 3.9	10.4 ± 4.5	0.238
Final FU	14.6 ± 4.1	20.8 ± 4.2	0.001*
UIV disc angle (°)			
Preoperatively	2.2 ± 1.7	1.7 ± 2.5	0.560
Immediately postop	-2.2 ± 1.1	-3.2 ± 1.8	0.104
Final FU	-1.9 ± 0.9	-3.5 ± 2.7	0.047*

* Statistically significant.

between the two groups. At the final follow-up, however, the group with ≥ 20 mm UIV translation showed a significantly larger UIV tilt and lower UIV disc angle than the < 20-mm group ($p = 0.001$ and 0.047 , respectively).

Radiographic parameters in the sagittal plane are summarized in Table 4. Preoperative instrumented level kyphosis was significantly higher in the < 20-mm group than in the ≥ 20-mm group ($p = 0.016$). At the final follow-up, however, no significant difference regarding instrumented level kyphosis was found between the two groups. There was no significant difference in the proximal junctional kyphosis and global sagittal balance between the groups at the preoperative, immediately postoperative, and final follow-up time points.

Pulmonary Function Results

Pulmonary function data are presented in Table 5. Clinically, no patients had complaints related to pulmonary function. At the preoperative or final follow-up assessments, no difference in the FVC, percent-predicted FVC, or FEV₁ was found between the groups. The percent-predicted FEV₁ decreased at the final follow-up in each group. Preoperatively, the group with UIV translation ≥ 20 mm had a significantly lower percent-predicted FEV₁ than the group with translation < 20 mm ($p = 0.046$). At the final follow-up, however, no significant difference in the percent-predicted FEV₁ was observed between the groups.

Correlation Analysis

Correlation analysis was conducted between the UIV translation values and radiographic parameters at the final follow-up (Table 6). The UIV translation was significantly correlated with the MT curve correction rate and correction loss ($r = -0.481$, $p = 0.015$; $r = 0.463$, $p = 0.020$, respectively). Similarly, UIV translation was significantly correlated with the AVT and chest cage ratio ($r = 0.844$, p

TABLE 4. Radiographic parameters in the sagittal plane in 25 patients surgically treated for AIS with a Lenke type 1 curve

Parameter	UIV Translation <20 mm	UIV Translation ≥20 mm	p Value
No. of patients	15	10	
Instrumented level kyphosis (°)			
Preoperatively	12.8 ± 10.8	1.5 ± 10.5	0.016*
Immediately postop	17.5 ± 5.6	13.2 ± 6.2	0.083
Final FU	20.3 ± 6.0	16.1 ± 5.6	0.091
Proximal junctional kyphosis (°)			
Preoperatively	1.2 ± 0.4	1.2 ± 0.4	1.000
Immediately postop	1.9 ± 1.0	1.6 ± 1.1	0.426
Final FU	2.1 ± 1.0	2.8 ± 1.0	0.137
Sagittal vertical axis (mm)			
Preoperatively	6.3 ± 17.6	8.9 ± 15.1	0.710
Immediately postop	10.8 ± 17.1	20.2 ± 20.8	0.229
Final FU	4.5 ± 23.0	16.1 ± 20.6	0.213

* Statistically significant.

< 0.001; $r = 0.673$, $p < 0.001$, respectively). Conversely, no correlation was found between UIV translation and RSH. In addition, correlation analysis was conducted between UIV translation and pulmonary function at the final follow-up. A significant correlation was found between UIV translation and the percent-predicted FEV₁ at the final follow-up ($r = -0.455$, $p = 0.033$).

SRS-30 Questionnaire Data

The SRS-30 Questionnaire total and individual domain scores at the final follow-up are shown in Table 7. The mean total score was 4.1 in the group with UIV translation < 20 mm and 3.9 in the group with ≥ 20 mm UIV

TABLE 5. Pulmonary function in 25 patients surgically treated for AIS with a Lenke type 1 curve

Parameter	UIV Translation <20 mm	UIV Translation ≥20 mm	p Value
No. of patients	15	10	
FVC (L)			
Preoperatively	2.4 ± 0.3	2.5 ± 0.5	0.299
Final FU	2.4 ± 0.4	2.5 ± 0.7	0.539
% predicted FVC			
Preoperatively	82.6 ± 13.1	82.3 ± 14.2	0.956
Final FU	74.6 ± 11.4	72.4 ± 10.9	0.658
FEV ₁ (L)			
Preoperatively	2.1 ± 0.3	2.0 ± 0.4	0.555
Final FU	2.1 ± 0.3	2.1 ± 0.7	0.862
% predicted FEV ₁			
Preoperatively	83.6 ± 12.2	73.6 ± 8.9	0.046*
Final FU	73.2 ± 9.4	65.4 ± 12.0	0.102

* Statistically significant.

TABLE 6. Correlation analysis between UIV translation and other variables at the final follow-up

Variable	Correlation Coefficient (r)	p Value
Radiographic parameters		
Correction rate	-0.481	0.015*
Correction loss	0.463	0.020*
AVT	0.844	<0.001*
Chest cage ratio	0.673	<0.001*
RSH	-0.274	0.195
Pulmonary function		
FVC	-0.024	0.916
% predicted FVC	-0.267	0.230
FEV ₁	-0.172	0.444
% predicted FEV ₁	-0.455	0.033*

* Statistically significant.

translation. There was no significant difference between the groups in the total or individual domain scores.

Discussion

Although selection of the LIV is thought to be an important factor affecting distal junctional problems or postoperative global imbalance,¹² and even though radiographic parameters such as RSH, T1 tilt, and UIV tilt are established parameters indicating shoulder imbalance and a proximal adding-on effect, UIV translation has not been fully discussed because few studies have focused on the selection of the UIV. In the current study, we demonstrated that a large UIV translation from the C7PL is associated with a lower correction rate of the MT curve, lower RSH, and diminished pulmonary function. These results suggest that selection of the UIV is also an important factor influencing postoperative results.

In PSF for thoracic AIS, it is recommended that the UIV be fused to T2, T3, T4, or T5, depending on the shoulder level and flexibility of the PT curve.²⁵ Conversely, selection of the UIV is controversial in ASF for Lenke type 1 AIS, although the procedure can provide short fusion within end-to-end vertebrae. Anterior spinal fusion for thoracic scoliosis limits the selection of the PT vertebrae,

TABLE 7. SRS-30 clinical scores at the final follow-up

Parameter	UIV Translation <20 mm	UIV Translation ≥20 mm	p Value
No. of patients	15	10	
Score			
Function/activity	4.4 ± 0.3	4.2 ± 0.3	0.124
Pain	4.3 ± 0.4	4.3 ± 0.5	0.841
Self-image/appearance	3.6 ± 0.5	3.5 ± 0.6	0.469
Mental health	4.2 ± 0.6	3.8 ± 0.6	0.210
Satisfaction w/ management	3.9 ± 0.7	3.6 ± 0.5	0.332
Total	4.1 ± 0.3	3.9 ± 0.4	0.200

for example, using T1 to T3 for the UIV, because instrumentation to the upper thoracic vertebrae is very difficult given the presence of the scapular arch. Consequently, the UIV is usually selected at or below the preoperative UEV. In this study, the UIV was placed at the preoperative UEV in all patients except for one whose UIV was placed below the UEV. Although the level of the UIV was identical to that of the UEV in most cases, UIV translation became larger over the long follow-up period in some cases.

Upper instrumented vertebra translation may be a factor influencing postoperative results. Liu et al. reported that Lenke type 5C thoracolumbar/lumbar AIS patients who had greater UIV translation before ASF surgery might have a higher risk of developing immediate postoperative coronal imbalance.⁹ Furthermore, these authors found that postoperative UIV translation was significantly correlated with immediate postoperative coronal balance. In the present study, at the final follow-up, patients with a UIV translation ≥ 20 mm showed a lower MT curve correction rate and lower RSH than those with a UIV translation < 20 mm. Furthermore, UIV translation had a significant negative correlation with pulmonary function at the final follow-up. However, no differences in global balance were observed between the groups, and patients with UIV translation ≥ 20 mm had a mean C7PL-CSVL distance within 10 mm. This is because the UIV tilt was increased by approximately 10° in the group with UIV translation ≥ 20 mm, compensating for coronal imbalance.⁹

Because the patients with a UIV translation ≥ 20 mm at the final follow-up had had a significantly larger preoperative UIV translation than the patients whose final follow-up UIV translation was < 20 mm, preoperative UIV translation may be a predictive factor for a large UIV translation at the postoperative follow-up. In addition, a significant correlation was found between preoperative UIV translation and the MT curve at the final follow-up ($r = 0.482$, $p = 0.017$), indicating that preoperative UIV translation should be considered an important factor influencing the postoperative MT curve. We cannot suggest a strict baseline for acceptable UIV translation because this study was an intergroup trial. However, in MT AIS patients whose preoperative UEV is distant from the C7PL, the UIV may need to be placed above the UEV to decrease UIV translation because the preoperative UIV translation can be smaller when the UIV is selected above the UEV than when the UIV is selected at the UEV.

Selection of the UIV may also be important for preventing the proximal adding-on effect. Nohara et al. reported that 10 years after ASF surgery, disc wedging $> 5^\circ$ at segments adjacent to the UIV was found in 27% of thoracic AIS patients whose UIV had been placed at or below the preoperative UEV.¹⁵ However, there was no proximal adding-on effect in the PSF patients, all of whom had had the UIV placed above the preoperative UEV except for one patient whose UIV had been placed at the preoperative UEV.¹⁵ In the current study, the UIV disc angle in both groups was $< 5^\circ$ at the final follow-up, and this was considered as not clinically significant. However, the group with UIV translation ≥ 20 mm showed a significantly lower UIV disc angle than that in the group with < 20 mm UIV translation at the final follow-up, suggesting that UIV

translation may be a factor influencing UIV disc wedging and the proximal adding-on effect.

An open anterior approach is associated with a decline in pulmonary function.^{14,21,22} In the current study, a significant negative correlation was found between UIV translation and the percent-predicted FEV₁. In addition, the group with ≥ 20 mm UIV translation had a significantly higher chest cage imbalance, indicating that a large UIV translation was associated with chest cage imbalance, which may be associated with a decrease in pulmonary function.

When examining patient-based outcomes, we found no significant difference in SRS-30 scores between the groups at the final follow-up perhaps because most patients achieved good correction of the MT curve and global coronal balance, and the shoulder imbalance was not severe enough to impact patient satisfaction with the results of surgery.¹³

Conclusions

More selective ASF has been touted as offering similar-to-superior outcomes in terms of scoliosis correction, as compared with less selective PSF. However, an increase in the UIV translation after ASF for Lenke type 1 AIS was significantly correlated with MT curve correction loss and decreased pulmonary function, indicating that UIV translation should be considered an important factor influencing postoperative results. Selection of the UIV is critical as it can lead to decompensation later in life. In Lenke type 1 MT AIS patients, whose preoperative UEV is distant from the C7PL, surgeons would likely consider extending the UIV above the UEV to prevent a large UIV translation at the postoperative follow-up. In other words, when the UEV for a relatively rigid and moderate-to-severe type 1 AIS is at or above T4, correction involving ASF will be difficult. Thus, the UIV above the UEV level may be chosen (i.e., T3, T2, or T1); however, fusion will be very challenging owing to the scapular arch. In such cases, PSF will most likely be considered.

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Disclosures

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Author Contributions

Conception and design: Sudo. Acquisition of data: Sudo, Shono. Analysis and interpretation of data: Sudo, Yamada, Abe. Drafting the article: Sudo, Yamada. Critically revising the article: Sudo. Reviewed submitted version of manuscript: Sudo, Kaneda, Shono, Abe, Iwasaki. Approved the final version of the manuscript on behalf of all authors: Sudo. Statistical analysis: Sudo. Administrative/technical/material support: Kaneda. Study supervision: Sudo, Iwasaki.

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