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Should the upper end vertebra be selected as the upper instrumented vertebra in patients with Lenke type 5C adolescent idiopathic scoliosis?

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Abstract

Study Design

Retrospective study

Purpose

The upper end vertebra (UEV) is often selected as the upper instrumented vertebra (UIV) in patients with adolescent idiopathic scoliosis (AIS) with Lenke type 5C curves; however, the effect of adjusting UIV selection one level toward the cranial side (UEV+1) is unknown. Therefore, this study aimed to assess the effect of UIV extension on scoliosis correction and global alignment in patients with the UIV as the UEV and UEV+1.

Methods

Data of 52 patients with AIS with Lenke type 5C curves who underwent selective thoracolumbar/lumbar (TL/L) fusion with a minimum follow-up period of 2 years were retrospectively analyzed. The patients were divided according to the UIV in relation to the UEV: the UEV and UEV+1 groups. Radiographic parameters and clinical outcomes were compared between the two groups.

Results

Among the 52 patients, 24 and 28 were included in the UEV and UEV+1 group. Baseline data showed no intergroup differences except for the UIV level. While the UEV+1 group showed a significantly greater TL/L curve correction (72.9% vs. 62.8%, $p<0.05$) and a lower UIV tilt, it showed a significantly greater absolute value of radiographic shoulder height (RSH) (-7.9 vs. -0.9 mm, $p<0.05$) and coronal balance (-11.0 mm vs -4.8 mm, $p<0.05$) at 2 years postoperatively. The rate of post-operative shoulder imbalance (RSH $\geq$2 cm) was significantly higher in the

UEV+1 than in the UEV group. No intergroup differences were observed in the sagittal alignment and patient outcomes between the two groups.

Conclusion

When the UIV was selected as the UEV+1, correction of the TL/L curve improved; however, it increased the risk of shoulder and coronal imbalance. There is no clinical benefit observed in terms of extending the UIV to the UEV+1; therefore, the UIV should be selected as the UEV to maintain harmonious global alignment.

Keywords: adolescent idiopathic scoliosis, Lenke type 5C curves, coronal balance, upper instrumented vertebra, upper end vertebra, shoulder balance

Level of Evidence:

Level 3

Key points:

- We compared the spinopelvic parameters and clinical outcome in adolescent idiopathic scoliosis (AIS) patients with Lenke type 5C curves between those with UIV was selected as UEV and UEV+1.
- The data of 52 patients (24 and 28 patients in the UEV and UEV+1 group, respectively) with AIS type 5C who underwent selective thoracolumbar/lumbar (TL/L) fusion with at least 2 years of follow-up were analyzed.
- The UEV+1 group showed a significantly greater TL/L curve correction (72.9% vs. 62.8%, $p<0.05$) than the UEV group
- However, the UEV+1 group showed a significantly greater absolute value of radiographic shoulder height (-7.9 vs. -0.9 mm, $p<0.05$) and coronal balance (-11.0 vs -4.8 mm, $p<0.05$) at 2 years postoperatively.

Introduction

Surgical treatment in patients with adolescent idiopathic scoliosis (AIS) aims to achieve sufficient deformity correction and maintain global alignment. Lenke type 5C scoliosis is characterized by a thoracolumbar/lumbar (TL/L) curve with a non-structural main thoracic curve, and selective TL/L fusion is typically the surgical treatment choice. [1,2] Although some surgeons have attempted to reduce their fusion range (hyper-selective fusion) [3,4] the general fusion range is selected from the upper end vertebra (UEV) to the lowest end vertebra (LEV) [5]. For the lowest instrumented vertebra (LIV) selection, many surgeons prefer to select L3 as the LIV to conserve mobile spinal segments. [6,7], as several studies have reported a loss of lumbar motion that progressed to low-back pain when the fusion segment reached L4 [8-10]. However, stopping fusion at L3 sometimes leads to insufficient TL/L curve correction and distal deformity progression, especially in cases with the end vertebra as L4 [11-13]. Therefore, determining the LIV for a major TL/L curve remains controversial [14,15,11].

In contrast, few studies have focused on the upper instrumented vertebra (UIV) selection. Some reports have compared the surgical outcomes between patients with the UIV as the vertebra 1 level below the UEV (UIV=UEV-1) and patients with the UIV as the UEV (UIV=UEV) [4,16]. In these reports, the correction rate of the TL/L curve was smaller in the UIV=UEV-1 group. Compared with the LIV, the extension of the UIV level could be less harmful because it might have a smaller effect on spinal motion loss. We hypothesized that better scoliosis correction and prevention of correction loss could be achieved when the UIV was set as the UEV+1 compared to those when setting the UIV as the UEV through a longer fusion range. To the best of our knowledge, this is the first investigation of surgical outcomes of UIV selection that is one level toward the cranial side of the UEV (UEV+1) in patients with selective TL/L fusion.

Therefore, this study aimed to assess the effect of UIV extension on scoliosis correction and global alignment in patients with Lenke type 5C curves who underwent a posterior selective TL/L curve fusion with the UIV as the vertebra one level above the UEV (UIV=UEV+1) and the UIV as the UEV (UIV=UEV).

Methods

This retrospective study was conducted in accordance with the Declaration of Helsinki and approved by the Institutional Review Board of our institution (No. 19-305).

Patient population

The study included eligible Patients with AIS with major TL/L curves (Lenke type 5C curves), who underwent posterior spinal fusion surgery between July 2007 and August 2018 at one of the three university hospitals and had a minimum postoperative follow-up period of 2 years. Patients whose main thoracic (MT) curve was in the fusion range, whose UIV were selected below the UEV, and who required revision surgery within 2 years after the initial operation were excluded.

Radiographic parameters and clinical outcomes

The medical records of these patients were reviewed retrospectively. The Lenke classification defines a major TL/L curve with nonstructural thoracic curves (Cobb angle <25° on side bending film) [1]. Posterior spinal fusion was performed using all pedicle screw constructs. The surgeries were performed by board-certified spine surgeons at each institute, and the fusion range was determined for every institution.

Standing whole spine posterior-anterior (PA) and lateral standing radiographs were reviewed preoperatively, immediately postoperatively, and at 2 years postoperatively. The magnitudes of the MT and TL/L curves were measured using the Cobb method for the curve parameters. Additionally, measurements of the apical vertebral translation of the MT and TL/L curves, T1 tilt, L4 tilt, UIV tilt, LIV tilt, lumbosacral takeoff angle (LSTOA), radiographic shoulder height (RSH), and coronal balance (CB) were obtained. The LSTOA was defined as the angle between the center sacral vertical line (CSVL) and a line through the midpoints of L4, L5, and S1 [17]. The T1 tilt, L4 tilt, UIV tilt, LIV tilt, and RSH values were defined as positive when they were "left side up." The CB was measured as the horizontal distance between the C7 plumb line and the CSVL and was defined as positive when the C7 plumb line was located to the right of the CSVL.

Side-bending radiographs were obtained by bending the spine maximally to the right and left in the supine position before surgery, while maintaining the head and neck in a neutral rotation. Side-bending films were recorded to evaluate curve flexibility. Moreover, on radiography, an RSH of ≥2 cm was defined as a shoulder imbalance [18] and a CB of >2 cm was defined as a coronal imbalance [19].

Regarding sagittal parameters, thoracic kyphosis (TK; T5-T12 kyphosis), thoracolumbar kyphosis (TLK; T10-L2 kyphosis), and lumbar lordosis (LL; T12-S1 lordosis) were measured using whole spine lateral standing radiographs. These parameters were evaluated by three experienced scoliosis surgeons.

The 22-item Scoliosis Research Society questionnaire (revised) (SRS-22r) was administered both preoperatively and at 2 years postoperatively.

The patients were divided into two groups according to the UIV in relation to the UEV: the UEV was selected as the UIV (UEV group) and the UEV+1 was selected as the UIV (UEV+1 group). Demographic data, radiographic parameters, and SRS-22 scores were compared between the two groups.

Statistical analysis

Student's t-test and the Mann–Whitney U test were used to evaluate between-group differences in continuous variables, and the chi-squared and Fisher's exact tests were used to assess categorical data. All statistical analyses were performed using SPSS (version 23.0; IBM Corp., Armonk, NY, USA). Statistical significance was set at $p<0.05$.

Results

Patient characteristics

Among the 70 patients with AIS with Lenke type 5C curves who received posterior selective TL/L fusions and minimum postoperative follow-ups of 2 years, data from 18 patients were excluded due to the following factors: MT curve fusion (15 patients), the UIV at the UEV-1 (two patients), and reoperation due to thoracic curve progression (one patient). Finally, 52 patients (48 women and four men) were included in this study. The mean age and Risser grade at the time of surgery were 15.3 ± 2.1 (range, 12–19) years and 3.7 ± 0.9 (range, 1–5) years, respectively. The UIV was T7, T9, T10, T11, and T12 in one, 11, 22, 17, and one patient, respectively. The LIV was L2, L3, and L4 in one, 48, and three patients, respectively. Regarding the relationship between the UIV and UEV, 24 patients had the UIV at the UEV (UEV group) (Fig. 1), whereas 28 patients had the UIV at the UEV+1 (UEV+1 group) (Fig. 2). Except for the fusion length, no significant intergroup differences were found in the demographic data or preoperative radiographic parameters between the two groups (Table 1).

Radiographic parameters and clinical outcomes

The correction of the TL/L curve was significantly better in the UEV+1 than in the UEV group (72.9% vs. 62.8%, $p<0.05$), whereas no significant difference was observed in the MT curve correction (Table 2). The magnitude of the MT and TL/L curve tended to be greater in the UEV group at 2 years postoperatively, although there were no significant differences (Table 2). The postoperative progression of both the curves was not significant between the two groups (Table 2, Fig. 3). The absolute values of the UIV tilt immediately after surgery and of the L4 tilt at 2 years postoperatively were significantly greater in the UEV than in the UEV+1 group (Table 2). The change in the T1 tilt before and after the operation was significantly greater in the UEV+1 group that in the UEV group (2.6° vs. 1.0°), whereas no significant difference was observed at 2 years (Table 2, Fig. 3). In the UEV+1 group, the RSH was significantly deteriorated after the operation, and worse at 2 years post-operation when compared with that noted in the UEV group (-7.9 vs. -0.9 mm, $p<0.05$) (Table 2, Fig. 3). Regarding the rate of shoulder imbalance, right shoulder elevation was significantly higher in the UEV+1 than in the UEV group both immediately post-operation and at 2 years postoperatively (Table 2). Moreover, in the UEV+1 group, the CB was significantly worse immediately after the operation (-21.6 vs. -11.4 mm, $p<0.05$) as well as at 2 years postoperatively (-11.0 vs. -4.8 mm, $p<0.05$) when compared with that noted in the UEV group. However, the rate of coronal imbalance was not significantly different between the groups (Table 2, Fig. 3). As for sagittal parameters, although no significant intergroup difference was observed preoperatively, the UEV+1 group showed a greater LL than the UEV group at 2 years postoperatively ($p<0.05$), whereas no significant differences were observed for the TK and TLK (Tables 1 and 2). Concerning the SRS-22 score, no significant intergroup differences were observed in any domains either before surgery or at 2 years postoperatively (Table 3).

Discussion

In this study, we compared the outcome because of the difference in the UIV in relation to UEV (UIV=UEV and UIV=UEV+1) without any inter-group differences in baseline characteristics, scoliosis magnitude, the location of UEV, LEV, and the LIV for Lenke type 5C patients with AIS who underwent selective TL/L fusion (Table 1). TL/L curve correction was significantly better in the UEV+1 than in the UEV group, which indicated that a longer fusion segment towards the cranial side could result in an improved scoliosis correction, while having little effect on sagittal parameters and SRS-22 scores (Tables 2 and 3). However, the RSH and CB were significantly better in the UEV than in the UEV+1 group both immediately after the operation and at 2 years later (Table 2).

Posterior selective fusion is considered to be the main surgical treatment in patients with Lenke type 5C curves [1,2]. The goals of corrective surgery are to achieve sufficient deformity correction and maintain global alignment with the minimal fusion area. Improper fusion levels could lead to the progression of unfused segments, shoulder imbalance, and even coronal imbalance. In anterior surgery, Sudo et al. [6] reported that good clinical outcomes and maintenance of global alignment were achieved for over 20 years by short fusion surgery; thus, attempts have been made to shorten the fusion segments [20,6]. Compared with anterior surgery, posterior surgery requires a longer fusion range to achieve sufficient deformity correction[21]. Some authors have tried to reduce the UIV level to UEV-1 [4,22]. However, this strategy of shortening the fusion range in relation to the scoliotic range is controversial because it could potentially cause postoperative correction loss and global imbalance. Conversely, extending the fusion range could improve correction, reduce the risk of correction loss, and maintain coronal balance. For LIV selection, Sun et al. compared surgical outcomes between AIS Lenke type 5C patients with LIV=LEV and LIV=LEV+1 who underwent posterior selective fusion [23]. The correction rate and global alignment were not different between the two groups; thus, it was concluded that there was no benefit in fusing to LEV+1. However, regarding the UIV, to the best of our knowledge, no report has investigated surgical outcomes between patients with the UIV=UEV and the UIV=UEV+1.

Postoperative shoulder imbalance is a major complication that is sometimes observed in patients with AIS. Several risk factors for postoperative shoulder imbalance have been reported in patients with a main thoracic curve. These risk factors include a preoperative lumbar curve, the correction rate of each curve, and a postoperative UIV tilt [24-28]. However, Hong et al. showed that a postoperative shoulder imbalance was observed even in patients with a main TL/L curve [24]. Preoperative shoulder imbalances and greater T1 tilts were reported as risk factors for postoperative shoulder imbalance in patients with Lenke type 5C curves[29,30]. Moreover, Okada et al. [29] showed that an excessive correction of the TL/L curve was associated with a postoperative shoulder imbalance. In this study, the UEV+1 group showed a significantly worse RSH and a higher rate of shoulder imbalance (right shoulder elevation) postoperatively with a greater TL/L curve correction and a lower postoperative UIV tilt (Table 2). We considered that a greater TL/L curve correction with a lower UIV tilt could result in an extensive T1 tilt correction, leading to a higher RSH in the UEV+1 group (Figs. 3 and 4).

Concerning coronal imbalance, although we showed no significant differences in the rate of coronal imbalance, the patients in the UEV+1 group showed higher absolute values of CB immediately and at 2 years postoperatively than those in the UEV group (Table 2). Preoperative coronal imbalance is common in patients with a Lenke 5C curve [31]. Immediate postoperative coronal imbalance was frequently observed; in most cases, it was spontaneously corrected over a period of follow-up according to the compensatory mechanism [32-34]. However, postoperative coronal imbalance was reported as having an adverse effect on the patients' quality of life [33]. Among the several risk factors for postoperative coronal imbalance, postoperative UIV tilt was reported to be inversely correlated with CB [35,32]. Moreover, UIV tilt was negatively correlated with the TL/L curve correction rate [35]. In this study, smaller postoperative UIV tilts with higher TL/L curve correction rates could be linked to poorer CB values in the UEV+1 group (Table 2, Figs. 3 and 4).

Although the mechanisms of postoperative coronal imbalance and shoulder imbalance are still unclear, one possible mechanism could be that the excessive UIV tilt correction induced the left-sided shift of the proximal spine. The other possibility is that the UEV+1 vertebra belongs to the MT curve, which includes the fusion segment that negatively affected the spontaneous correction of the MT curve. In addition, the progression of the unfused MT curve might lead to coronal imbalance and shoulder imbalance (Fig. 4). CB and RSH were spontaneously corrected during the follow-up period through a UIV tilt increase and disc-wedging below a fixed TL/L curve [36]; however, coronal imbalance and shoulder imbalance remained to some degree (Fig. 3).

In this study, the UEV+1 group had smaller postoperative MT curves and better MT curve corrections than the UEV group (Table 2, Fig. 3). Spontaneous MT curve correction is usually accompanied by TL/L curve correction [37,2,38,39]. However, Zhang et al. reported that approximately half of the patients with Lenke type 5C curves demonstrated MT curve progression after selective TL/L fusion [40]. The degree of preoperative thoracic curvature, flexibility, and improper fusion area were reported as factors related to MT curve progression [37,7,40]. UIV selection at UEV+1 did not affect the correction and postoperative progression of the MT curve. However, careful assessment and surgical planning, including the indication of non-selective fusion, are needed to prevent postoperative MT curve progression.

For SRS-22r scores, no significant intergroup differences were observed (Table 3). These results indicated that the extension of the UIV level and the difference in the CB and the RSH did not significantly affect the clinical outcome.

This study had several limitations. First, this was a retrospective non-randomized study and the sample size was relatively small. Simplified whole spine biomechanical analysis comparing the different fusion levels is crucial to reveal the optimal UIV level for AIS type 5C patients. Second, we did not assess the relationship with LIV, although there was no difference in the location of the LEV and LIV between the UEV and UEV+1 groups. In surgical planning, LIV selection as well as UIV is also important and controversial [14,19-23]. Many surgeons prefer to select L3 as the LIV even in cases with LEV as L4 to conserve mobile spinal segments [6,7]. However, this poses a risk of curve progression at unfused segments postoperatively [13]. Oba et al. proposed a simple method (S-line) for the determination of the fusion area for Lenke type 5C curves [6]. The S-line connecting the centers of the concave-side pedicles of the UIV and LIV using preoperative standing whole-spine radiographs could decide the UIV and LIV simultaneously [7]. They revealed that when the UIV was shifted to the right with respect to the LIV, the risk of postoperative MT curve progression after selective TL/L fusion increased. Finally, we only assessed the short-term (2 years) outcomes of UIV selection in relation to the UEV. Hence, further long-term studies are needed to assess the effect of UIV differences on global alignment and clinical outcomes.

In conclusion, when the UIV was selected as the UEV+1 for selective fusion in patients with Lenke type 5C curves, better correction of the TL/L curve was achieved; however, it posed a risk of shoulder and coronal imbalance. There is no clinical benefit observed to select the UIV as the UEV+1; therefore, the UEV should be selected as the UIV to maintain harmonious global alignment.

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Figure Legends

Fig. 1 A 15-year-old girl in the UEV group.

a: Preoperative standing whole spine radiograph

b: Standing whole spine radiographs just after operation

c: Standing whole spine radiographs at 2 years postoperatively

The preoperative Cobb angles of the TL/L curve were 24° (T6–11) and 45° (T11–L3), respectively. T11–L3 fusion was performed. The TL/L curve was corrected to 18° (correction rate: 60%). Coronal decompensation or shoulder imbalance was not observed. (CB=-4 mm, RSH=-3 mm)

UEV, upper end vertebra; T;/L, thoracolumbar/lumbar; CB, coronal balance; RSH, radiographic shoulder height

Fig. 2 A 19-year-old girl in the UEV+1 group.

a: Preoperative standing whole spine radiograph

b: Standing whole spine radiographs just after the operation

c: Standing whole spine radiographs at 2 years postoperatively

The preoperative Cobb angles of the TL/L curve were 34° (T6–11) and 46° (T11–L3), respectively. T10–L3 fusion was performed. The TL/L curve was corrected to 13° (correction rate: 72%). Coronal decompensation and shoulder imbalance were observed. (CB=-24 mm; RSH=-20 mm)

UEV, upper end vertebra; T;/L, thoracolumbar/lumbar; CB, coronal balance; RSH, radiographic shoulder height

Fig. 3 Time course changes in the MT curve (a), TL/L curve (b), T1 tilt (c), RSH, and CB in the UEV and UEV+1 groups.

Error bars represent standard deviation.

* Statistically significant values at each point between the two groups

† Statistically significant change values between the two groups

UEV, upper end vertebra; T;/L, thoracolumbar/lumbar; CB, coronal balance; RSH, radiographic shoulder height; MT, main thoracic

Fig. 4 Illustration showing the mechanism of shoulder and coronal imbalances in a UEV+1 case comparing with a UEV case

The excessive UIV tilt correction could induce the left-sided shift of the proximal spine and right shoulder elevation.

UEV, upper end vertebra; UIV, upper instrumented vertebra

Table 1 Demographic and baseline characteristics of patients in the UEV and UEV+1 groups

	UEV group (n=24)	UEV+1 group (n=28)	p-value
Age (years)	15.1 ± 1.8	15.5 ± 2.5	0.493
Risser grade	3.8 ± 0.9	3.7 ± 0.9	0.660
Female (%)	23 (96%)	25 (89%)	0.366
BMI (kg/m^2)	19.4 ± 2.3	19.5 ± 2.0	0.878
UEV (T8 / T9 / T10 / T11 / T12)	0 / 1 / 8 / 14 / 1	1 / 0 / 10 / 14 / 3	0.569
LEV (L2 / L3 / L4)	0 / 14 / 10	1 / 18 / 9	0.535
UIV (T7 / T9 / T10 / T11 / T12)	0 / 1 / 8 / 14 / 1	1 / 10 / 14 / 3 / 0	<0.001*
LIV (L2 / L3 / L4)	0 / 24 / 0	1 / 24 / 3	0.156
Fusion length (levels)	5.4 ± 0.6	6.4 ± 0.8	<0.001*
Coronal parameters			
MT curve (°)	25.7 ± 8.7	26.5 ± 7.5	0.738
TL/L curve (°)	41.7 ± 7.2	44.5 ± 6.6	0.165
Bending MT curve (°)	13.3± 6.2	14.7 ± 6.7	0.445
Bending TL/L curve (°)	17.5 ± 8.2	17.2 ± 7.5	0.883
Flexibility MT curve (%)	47.7 ± 21.3	44.6 ± 22.5	0.619
Flexibility TL/L curve (%)	58.3 ± 17.7	61.2 ± 15.8	0.542
AVT-MT (mm)	11.6 ± 8.5	9.0 ± 6.7	0.225
AVT-TL/L (mm)	41.1 ± 8.9	43.1 ± 11.3	0.484
UIV tilt (°)	17.1 ± 9.4	16.6 ± 4.8	0.783
LIV tilt (°)	-21.7 ± 4.8	-23.9 ± 4.3	0.085
L4 tilt (°)	-21.4 ± 4.5	-21.3 ± 4.2	0.957
LSTOA (°)	14.9 ± 4.2	15.4 ± 4.5	0.671
T1 tilt (°)	-0.2 ± 3.4	0.5 ± 3.0	0.478
RSH (mm)	-1.8 ± 6.8	-2.3 ± 8.1	0.799
CB (mm)	-17.8 ± 10.3	-20.9 ± 10.2	0.282
Shoulder imbalance (%)	0	0	1.000
Coronal imbalance (%)	8 (33%)	13 (46%)	0.337
Sagittal parameters			
TK (°)	17.7 ± 10.6	18.9 ± 8.4	0.659
TLK (°)	4.9 ± 10.1	6.9 ± 8.7	0.439

LL (°)	40.9 ± 9.4	45.9 ± 10.4	0.081

Continuous data are presented as mean ± standard deviation of the median.

Categorical data are presented as number (%).

Abbreviations: BMI, body mass index; UEV, upper end vertebra; LEV, lowest end vertebra; UIV, upper instrumented vertebra; LIV, lowest instrumented vertebra; MT, main thoracic; TL/L, thoracolumbar/lumbar; AVT, apical vertebral translation; LSTOA, lumbosacral takeoff angle; RSH, radiographic shoulder height; CB, coronal balance; TK, thoracic kyphosis; TLK, thoracolumbar kyphosis; LL, lumbar lordosis.

* Statistically significant

Table 2 Radiographic parameters at post-operation and 2 years of patients in the UEV and UEV+1 groups

		UEV group (n=24)	UEV+1 group (n=28)	p-value
Coronal parameters				
MT curve (°)	Post-op	20.4 ± 9.3	18.3 ± 6.9	0.356
	2y	22.0 ± 10.7	20.0 ± 8.7	0.470
TL/L curve (°)	Post-op	17.9 ± 7.7	14.7 ± 6.0	0.096
	2y	22.5 ± 9.5	18.4 ± 6.7	0.079
MT curve correction (%)		21.8 ± 21.4	30.4 ± 19.1	0.129
TL/L curve correction (%)		62.8 ± 19.8	72.9 ± 14.6	0.041*
MT curve progression		4 (17%)	6 (21%)	0.470
TL/L curve progression		6 (25%)	5 (18%)	0.385
AVT -MT (mm)	Post-op	18.8 ± 10.9	19.0 ± 10.7	0.965
	2y	16.8 ± 11.2	15.4 ± 11.4	0.641
AVT -TL/L (mm)	Post-op	18.3 ± 9.4	16.1 ± 8.5	0.384
	2y	18.6 ± 11.1	15.1 ± 8.4	0.199
UIV tilt (°)	Post-op	9.1 ± 5.4	5.7 ± 4.4	0.016*
	2y	10.3 ± 6.2	8.4 ± 4.2	0.196
LIV tilt (°)	Post-op	-3.3 ± 6.1	-2.4 ± 5.8	0.586
	2y	-4.0 ± 6.5	-1.9 ± 6.7	0.277
L4 tilt (°)	Post-op	-7.6 ± 4.6	-6.9 ± 4.6	0.610
	2y	-10.5 ± 5.4	-7.6 ± 4.7	0.046*
LSTOA (°)	Post-op	9.4 ± 3.9	8.8 ± 3.6	0.572
	2y	10.2 ± 5.0	9.8 ± 4.0	0.715
T1 tilt (°)	Post-op	-1.1 ± 3.1	-2.1 ± 3.9	0.328
	2y	-0.1 ± 2.3	-1.4 ± 3.7	0.095
RSH (mm)	Post-op	-3.1 ± 10.8	-12.5 ± 14.3	0.011*
	2y	-0.9 ± 7.9	-7.9 ± 12.0	0.018*
CB (mm)	Post-op	-11.4 ± 13.7	-21.6 ± 14.9	0.013*
	2y	-4.8 ± 10.4	-11.0 ± 9.4	0.027*
Shoulder imbalance (%)	Post-op	1 (4%)	10 (46%)	0.006*
	2y	0	6 (21%)	0.019*
Coronal imbalance (%)	Post-op	7 (29%)	15 (54%)	0.076
	2y	1 (4%)	4 (14%)	0.227
Sagittal parameters				

TK (°)	Post-op	19.7 ± 9.8	22.3 ± 8.4	0.310
	2y	22.2 ± 12.8	27.7 ± 9.3	0.079
TLK (°)	Post-op	-5.3 ± 6.2	-4.2 ± 5.8	0.527
	2y	-2.3 ± 8.4	-2.8 ± 7.3	0.809
LL (°)	Post-op	39.8 ± 9.6	41.9 ± 10.7	0.471
	2y	43.0 ± 8.7	49.1 ± 10.6	0.029*

Continuous data are presented as mean ± standard deviation of the median.

Categorical data are presented as number (%).

Abbreviations: MT, main thoracic; TL/L, thoracolumbar/lumbar; AVT, apical vertebral translation; UIV, upper instrumented vertebra; LIV, lowest instrumented vertebra; LSTOA, lumbosacral takeoff angle; RSH, radiographic shoulder height; CB, coronal balance; TK, thoracic kyphosis; TLK, thoracolumbar kyphosis; LL, lumbar lordosis; Post-op 2y, post-operative 2 years

* Statistically significant

Table 3 SRS-22r scores of patients in the UEV and UEV+1 groups

SRS-22r Category	UEV group (n=24)	UEV+1 group (n=28)	p-value
Function			
Pre-op	4.4 ± 0.6	4.1 ± 0.9	0.314
2y	4.7 ± 0.4	4.6 ± 0.6	0.666
Pain			
Pre-op	4.5 ± 0.5	4.3 ± 0.6	0.338
2y	4.6 ± 0.5	4.6 ± 0.6	0.900
Self-image			
Pre-op	2.8 ± 0.6	2.7 ± 0.7	0.644
2y	3.8 ± 0.7	4.1 ± 0.7	0.292
Mental			
Pre-op	4.1 ± 0.7	3.9 ± 0.9	0.533
2y	4.2 ± 0.6	4.4 ± 0.7	0.539
Subtotal			
Pre-op	4.0 ± 0.4	3.9 ± 0.5	0.559
2y	4.3 ± 0.4	4.5 ± 0.3	0.141
Satisfaction	3.9 ± 0.8	4.0 ± 0.8	0.906

Data are presented as mean ± standard deviation unless otherwise indicated.

Abbreviations: Pre-op 2y, pre-operative 2 years; SRS-22r: The 22-item Scoliosis Research Society questionnaire (revised); UEV: upper end vertebra

* Statistically significant

Figure1

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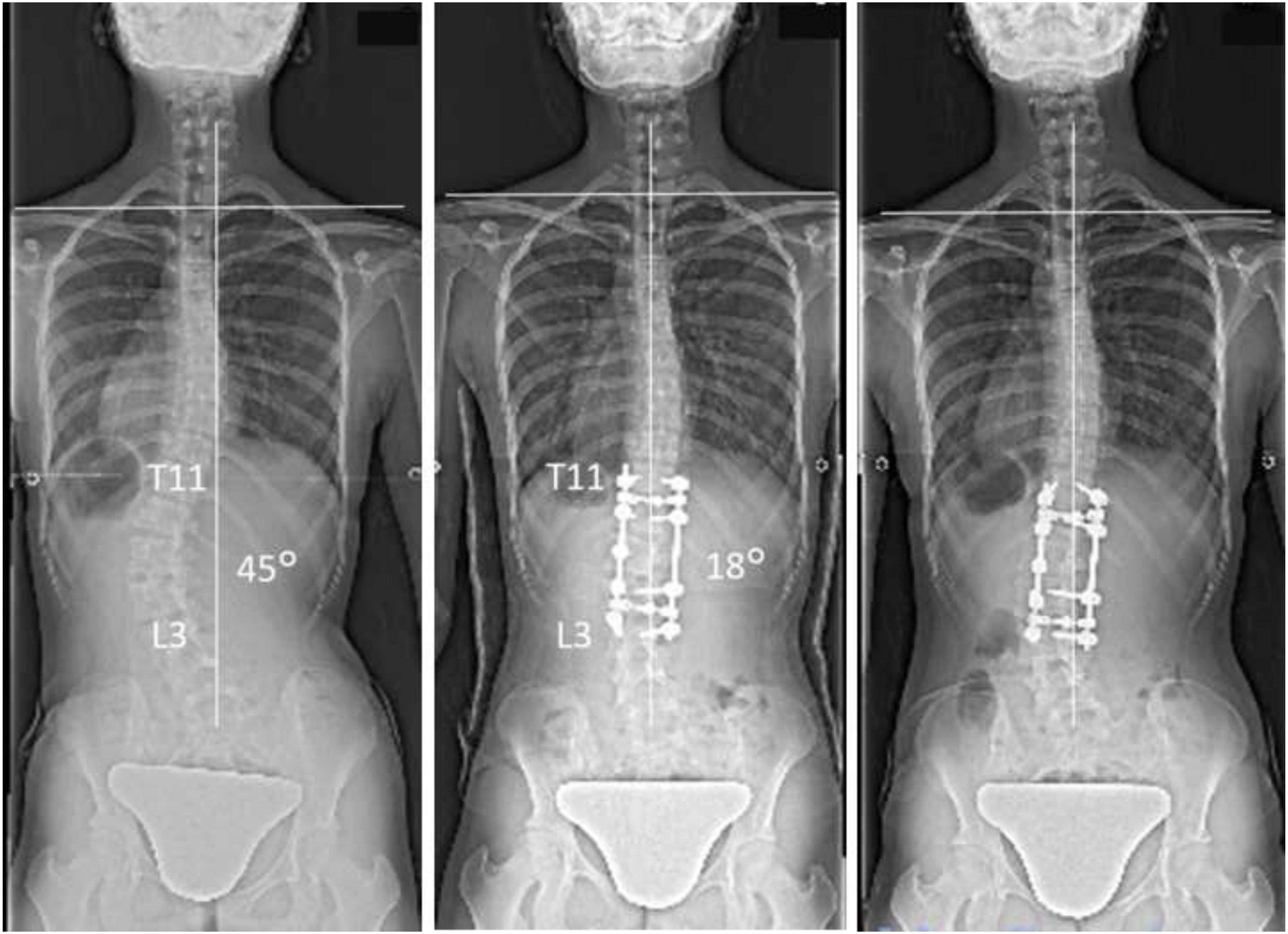

Figure2

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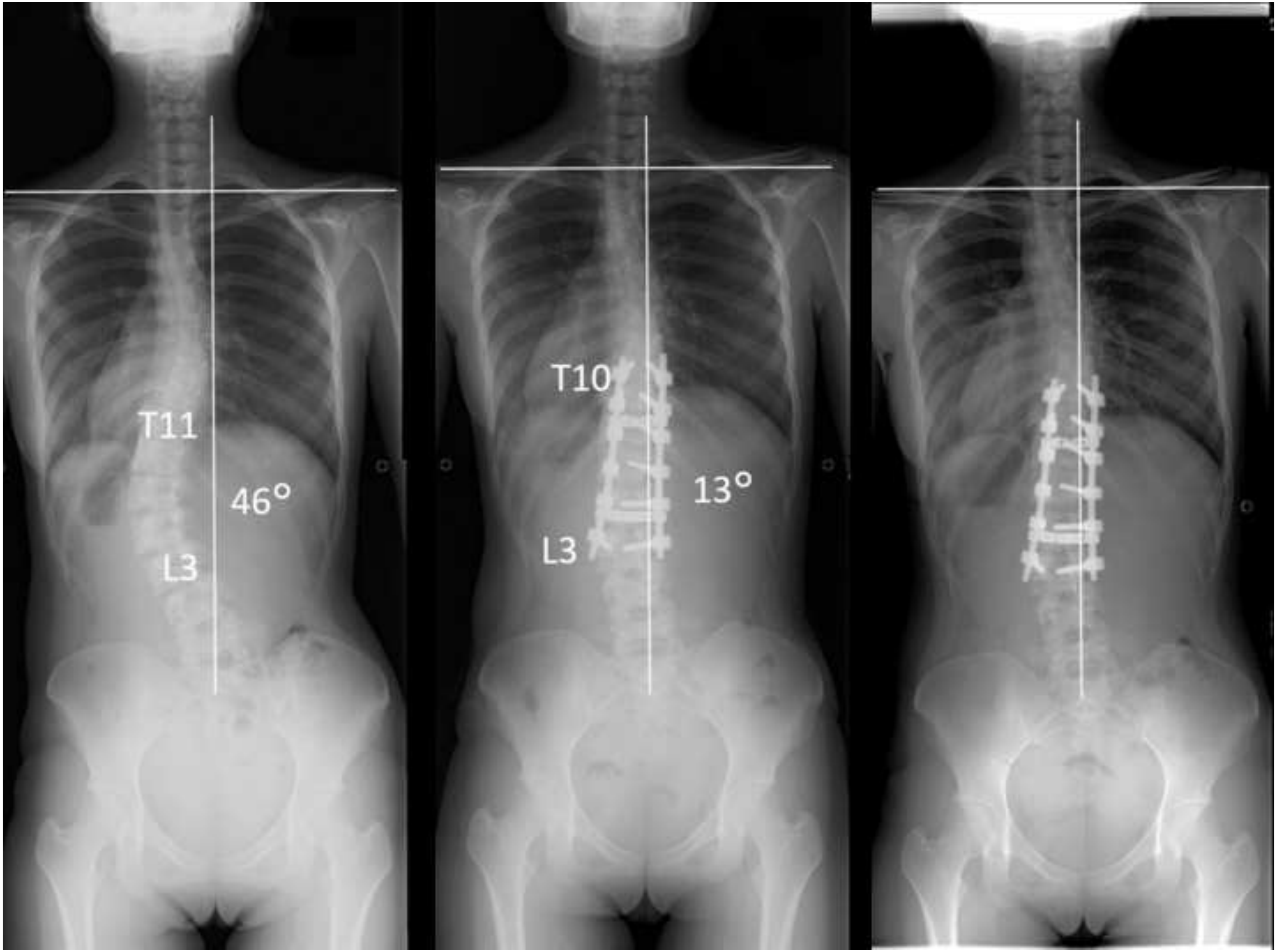

Figure3

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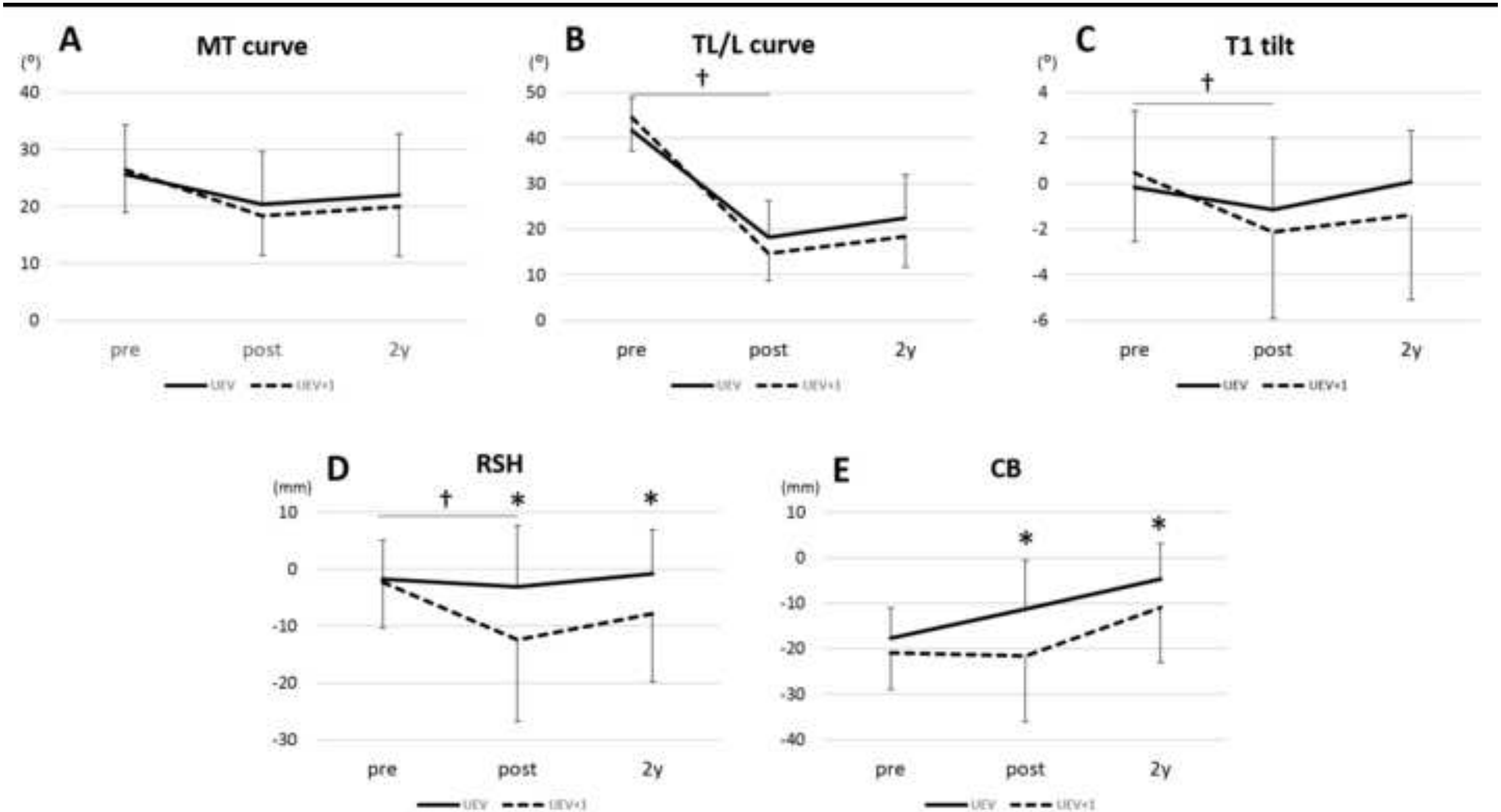

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