Effect of direct vertebral body derotation on the sagittal profile in adolescent idiopathic scoliosis

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Abstract

Purpose We sought to clarify the effect of applying derotation maneuvers in the correction of adolescent idiopathic scoliosis (AIS) on the sagittal plane.

Methods We retrospectively queried a large, multicenter, prospectively collected database for patients who underwent surgical correction of AIS. All patients had at least 2 years of follow-up and documentation as to whether or not a derotation maneuver was performed during surgery. All patients underwent posterior spinal fusion with pedicle screw constructs. Patients who underwent concurrent anterior procedures were excluded.

Results A total of 323 patients were identified, of whom 66 did not have direct vertebral body derotation (DVBD) maneuvers applied during the deformity correction. The remaining 257 had a vertebral body derotation maneuver performed during their surgical correction. Although no significant differences were identified between the two groups when comparing pre-op and post-op thoracic kyphosis using T2–12 and T5–12 endplates, the absolute change in angulation measured from T2–12 was significantly

different between the two groups. Postoperatively, the derotation group had a mean decrease in thoracic kyphosis of $5.1 \pm 15.3^\circ$ as compared to $10.8 \pm 18.9^\circ$ in the control group, $P = 0.03$.

Conclusion Although patients in both groups had decreased mean thoracic kyphosis postoperatively, application of DVBD in the correction of scoliosis did not additionally worsen the sagittal profile.

Keywords Scoliosis · Spinal fusion · Derotation · Sagittal alignment

Introduction

Adolescent idiopathic scoliosis (AIS) is a pathophysiologic process involving relative lordosis of the thoracic spine that contributes to three-dimensional deformation of the spinal column [1, 2]. The relative hypokyphosis of the thoracic spine can typically be addressed during surgical correction of scoliosis, and surgeons often attempt to reproduce the natural thoracic kyphosis intraoperatively. In fact, the sagittal plane alignment seems to be closely tied to overall health related quality of life in patients with scoliosis [3]. Several authors have shown an improved ability to develop thoracic kyphosis surgically using anterior approaches, but with the advent of more powerful posterior instrumentation such as pedicle screw constructs, posterior spinal fusions have become more widely adopted [4–8].

Although pedicle screw instrumentation has permitted improved surgical outcomes in the coronal and axial plane [6, 7, 9], its use may have a detrimental influence on the sagittal profile [10, 11]. Several authors have noted a decrease in thoracic kyphosis with pedicle screw constructs [10, 11]. Both the use of pedicle screw only constructs and

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the implant density of pedicle instrumentation have been associated with decreased postoperative thoracic kyphosis [10, 11].

Newer surgical tools that supplement pedicle screw instrumentation have allowed for direct corrective rotational forces to be applied to the scoliotic spine and have permitted increased correction of axial rotation of the spine [5, 9]. Lee et al. [9] initially described the clinical application of direct vertebral body derotation (DVBD) in 1999 and reported a 42.5% apical correction of rotation compared to only 2.4% achieved by rod derotation. These powerful corrective techniques have helped further reduce asymmetric rib prominences and address scoliotic curves in all three dimensions.

However, the impact of improved correction in the axial plane on the sagittal and coronal planes remains uncertain. No study has addressed whether correction of the axial deformity occurs at the expense of sagittal or coronal alignment. Therefore, we sought to investigate the effects of DVBD on the sagittal profile in AIS.

Materials and methods

Instrumentation permitting DVBD has been available in the US since early 2001. All surgical cases performed from our multicenter database prior to then were therefore done without DVBD, although many included hybrid (hook and screw) constructs. However, to adhere to strict criteria and avoid erroneous conclusions, only patients who had clear documentation of posterior spinal fusions without DVBD confirmed by the operating surgeon were included in our control group (no derotation). The control group had correction performed though rod translation or rod derotation at the discretion of the surgeon with use of compression and distraction as well. Although both groups had their index surgery performed between 2003 and 2007, the majority of surgeries for the patients without derotation were performed in 2004–2005, whereas the index surgeries for those who underwent derotation took place primarily in 2006–2007. This reflected a trend in practice patterns within our study group over time towards application of DVBD during surgical correction of scoliosis.

Institutional Review Board (IRB) approval for the study was obtained locally from each contributing institution's review board, and consent was obtained from each patient prior to data collection. We retrospectively reviewed a prospectively collected multicenter database to identify pediatric patients (age <18) with adolescent idiopathic scoliosis. All patients underwent posterior spinal fusions with pedicle screw constructs (>80% of the fixation anchors were pedicle screws). Patients with any anterior procedure were excluded from our series. Patients in the derotation

group had undergone a DVBD maneuver (en bloc, segmental or both), while the control group patients did not have a DVBD maneuver performed. Patients were divided into one of three categories based on the corrective techniques applied at the time of the index surgery, therefore each group was treated as an independent variable. Segmental derotation was defined as application of axial rotatory corrective forces across one vertebral segment at a time, whereas en bloc derotation constituted corrective forces applied across multiple vertebrae simultaneously. All patients had a minimum of 2 years of follow-up.

Statistical analysis was performed using SPSS 7.0® software using ANOVA and Student *t* tests. A *P* value of 0.05 was considered statistically significant. All institutions contributing data to this study had previously agreed to measure clinical and radiographic variables using a standard technique. For this multicenter study, all radiographs were measured/assessed by one of two personnel dedicated to radiographic evaluation and measurement utilizing digital software. Our internal studies of inter/intra-rater reliability have shown good to excellent ICC statistics for all continuous measures (0.67–0.99). T1 tilt was measured from the angle subtended between a horizontal line and the superior endplate of T1; EIV angulation was defined as the angle subtended by the end instrumented vertebra (EIV) and a horizontal line; EIV translation was measured as the distance between the EIV and the adjacent uninstrumented level; T10–L2° represented the angle/kyphosis measured between the endplates of T10 and L2. Inclinator measures were obtained, using a “Scoliometer®” from Orthopedic Instruments Inc., by having patients stand upright with both feet together in parallel. Patients were then asked to lean forward with their arms extended reaching for the floor while keeping their legs straight. The inclinometer was then centered over the spinous process and translated rostrally and caudally to obtain the largest measure.

Results

A total of 323 patients were identified from the database for our cohort. Two hundred and fifty-seven patients had undergone a DVBD maneuver during their posterior spinal fusion (derotation group) and 66 patients served as our control group, having undergone posterior spinal fusion without derotation. The mean age of the entire cohort was 14.7 ± 2.1 years with 254 (79%) patients being female. Only 13 patients had open triradiate cartilages at the time of surgery, and 63 (20%) were Risser 0 or 1. One hundred and sixty-five patients (51%) presented with a Lenke type 1 curve, 58 with a Lenke 2, 25 with a Lenke 3, 9 with a Lenke 4, 36 with a Lenke 5, and 30 with a Lenke 6. Curve types were similarly represented in all subgroups of the

cohort with no significant difference between groups ($P = 0.87$). Stainless steel rods were most frequently used in both the derotation (88.7%) and control groups (85.1%) of which 5.5 mm rods were implanted in 96 and 95.5% of patients in the respective groups. The remaining patients had titanium instrumentation selected based on surgeon preference. No statistical difference was observed between the two groups with respect to instrumentation material ($P = 0.42$) or rod size ($P = 0.86$).

The mean preoperative thoracic curve magnitude was $52.2 \pm 13.0^\circ$ with a thoracic kyphosis from T5–12 of $24.4 \pm 12.9^\circ$. The thoracic curve corrected to a mean of $18.3 \pm 8.2^\circ$ translating into an average improvement of 65%. The 2 year postoperative T5–12 kyphosis for the entire cohort averaged $18.7 \pm 9.2^\circ$ which represented a mean decrease of 5.7° from the preoperative kyphosis ($P < 0.0001$).

When comparing preoperative variables between the two groups, the derotation group had significantly more flexible thoracic curves (46%) than the control group (35%, $P = 0.03$) as determined from the lateral bending radiographs. The remaining preoperative variables were comparable between both cohorts (Table 1).

When comparing postoperative variables at 2 years of follow-up (Table 2), significant differences were identified in respect to the magnitude of the upper thoracic and main thoracic curves as well as with proximal junctional kyphosis. The derotation group had a larger residual upper thoracic curve (14.3°) and residual main thoracic curve (19.2°) as compared to the control group (10.9 and 14.4° , respectively, $P = 0.0004$ for both). Further analysis based on the first erect and 1 year follow-up radiographs showed similar differences in curve magnitude at the earlier time intervals. A significant change was also noted postoperatively between the derotation group (-8.6°) and control group (8.2°) ($P < 0.0001$).

When evaluating thoracic kyphosis, no significant preoperative differences were identified between the groups

Table 2 Comparison of postoperative variables

Variable	Derotation group ($N = 257$)	No derotation ($N = 66$)	P value
Upper thoracic curve ($^\circ$)	14.3 ± 6.8	10.9 ± 5.7	0.0004
Thoracic curve ($^\circ$)	19.2 ± 8.0	14.4 ± 8.4	0.0004
Lumbar curve ($^\circ$)	14.9 ± 8.2	12.8 ± 7.7	0.09
Coronal plumb line (cm)	-0.85 ± 1.31	-0.58 ± 1.38	0.21
T1 tilt ($^\circ$)	4.4 ± 3.4	3.8 ± 3.7	0.25
EIV angulation ($^\circ$)	1.6 ± 7.8	1.7 ± 5.3	0.87
EIV translation (cm)	-0.44 ± 1.64	0.13 ± 3.50	0.26
T10–L2 ($^\circ$)	-2.6 ± 9.0	-2.1 ± 10.6	0.76
Sagittal plumb line (cm)	-0.60 ± 3.24	-1.40 ± 3.28	0.13
Proximal junctional kyphosis ($^\circ$)	-8.6 ± 11.6	8.2 ± 6.0	<0.0001
Distal junctional kyphosis ($^\circ$)	-8.6 ± 11.6	-9.5 ± 12.3	0.62

Bold values are statistically significant

(Table 3). Thoracic kyphosis as measured from both T2–12 and T5–12 were similar in both groups preoperatively ($P = 0.36$ and 0.84) and postoperatively ($P = 0.80$ and 0.45). However, when evaluating the absolute change in kyphosis from preoperative values to the 2-year interval follow-up, the derotation group had more thoracic kyphosis measured from T2–12. The derotation group had a mean decrease in thoracic kyphosis of $5.1 \pm 15.3^\circ$, whereas the control group had a mean decrease of $10.8 \pm 18.9^\circ$ ($P = 0.03$). The interval change in kyphosis, however, was not significant when comparing measurements in kyphosis across T5–12 ($P = 0.11$).

Further subgroup analysis evaluated the impact of various DVBD techniques on the sagittal profile (Table 4). Of the 257 patients undergoing DVBD maneuvers, 167 received segmental derotation, 68 had both procedures performed, and 22 had enbloc only (Figs. 1, 2, 3, 4, 5, 6).

Table 1 Comparison of preoperative variables

Variable	Derotation group ($N = 257$)	No derotation ($N = 66$)	P value
Age	14.7 ± 2.1	14.4 ± 2.3	0.32
Upper thoracic curve ($^\circ$)	26.3 ± 10.5	23.9 ± 11.2	0.13
Thoracic curve ($^\circ$)	52.5 ± 12.7	50.7 ± 14.0	0.36
Lumbar curve ($^\circ$)	39.7 ± 13.2	40.2 ± 11.6	0.74
Thoracic bend ($^\circ$)	28.2 ± 13.6	32.9 ± 15.6	0.03
Coronal plumb line (cm)	-0.53 ± 2.29	-0.48 ± 2.52	0.88
T1 tilt ($^\circ$)	3.7 ± 5.2	4.4 ± 5.0	0.31
EIV angulation ($^\circ$)	6.8 ± 21.2	11.9 ± 21.4	0.10
EIV translation (cm)	-0.36 ± 2.07	-0.18 ± 2.11	0.54
T10–L2 ($^\circ$)	0.35 ± 10.3	0.82 ± 11.6	0.77
Sagittal plumb line (cm)	-2.1 ± 3.8	-2.6 ± 3.7	0.34

Table 3 Comparison of thoracic kyphosis

	Derotation group (<i>N</i> = 257)	No derotation (<i>N</i> = 66)	<i>P</i> value
Preoperative kyphosis			
T2–12 (°)	33.0 ± 13.5 (–1 to 77)	34.7 ± 13.7 (–5 to 60)	0.36
T5–12 (°)	24.3 ± 12.8 (–9 to 75)	24.7 ± 13.3 (–7 to 56)	0.84
Postoperative kyphosis at 2 years			
T2–12 (°)	30.0 ± 11.8 (1 to 67)	29.5 ± 12.9 (5 to 64)	0.80
T5–12 (°)	18.9 ± 8.9 (0 to 56)	17.7 ± 10.8 (–1 to 57)	0.45
T2–12 change in kyphosis	–5.1 ± 15.3	–10.8 ± 18.9	0.03
T5–12 change in kyphosis	–6.7 ± 13.7	–10.0 ± 15.4	0.11

Table 4 Comparison of kyphosis by derotation technique

	Segmental derotation (<i>N</i> = 167)	En bloc derotation (<i>N</i> = 22)	Both techniques (<i>N</i> = 68)	<i>P</i> value
Pre-op T2–12 kyphosis (°)	32.1 ± 13.2 (3 to 77)	29.0 ± 11.0 (2 to 48)	36.2 ± 13.2 (–1 to 60)	0.04
Pre-op T5–12 kyphosis (°)	23.5 ± 12.6 (–8 to 75)	20.1 ± 11.5 (–9 to 41)	27.9 ± 13.2 (–4 to 53)	0.02
Post-op T2–12 kyphosis (°)	29.0 ± 11.2 (1 to 67)	28.8 ± 14.8 (7 to 66)	32.6 ± 11.9 (5 to 62)	0.11
Post-op T5–12 kyphosis (°)	18.5 ± 8.1 (0 to 51)	20.7 ± 12.8 (10 to 56)	19.5 ± 9.3 (0 to 51)	0.49

Fig. 1 Operative picture illustrating segmental derotation. **a** Initial image prior to derotation; **b** image after segmental derotation

Although significant variations existed preoperatively between the subgroups, at 2 years of follow-up the sagittal profile was comparable between all subgroups ($P = 0.11$ and 0.49). Comparison of curve flexibility between each of the derotation groups did not reveal any significant differences between the upper thoracic ($P = 0.98$) or main thoracic curves ($P = 0.70$) either. The mean main thoracic curve flexibility was $47 \pm 21\%$ for the combined group, $51 \pm 27\%$ for the enbloc only group and $50 \pm 21\%$ for the segmental derotation only. Axial rotation was inferred from

inclinometer measures and results from each subgroup were included in Table 5.

Patients were also divided into groups based on their Lenke sagittal modifier (–, *N*, +). Unfortunately analysis was limited as the majority of patients fell into the Lenke *N* category. In the no derotation group, only 8 patients were “–”, 46 were “*N*”, and 12 were “+”. In the derotation group, the Lenke “*N*” category was similarly over-represented ($N = 173$) and limited any significant statistical interpretation.

Fig. 2 Operative image illustrating en bloc derotation. **a** Initial picture prior to derotation; **b** image after en bloc derotation

Fig. 3 PA and lateral standing radiographs illustrating the application of segmental derotation maneuvers alone to: **a** a pre-operative 40° curve, **b** with 27° of kyphosis from T5–12, **c** post-operative correction to 15°, **d** and 19° of post-operative kyphosis

Discussion

Early spinal instrumentation to correct scoliosis primarily targeted improvement in alignment of the coronal plane. Harrington rod fixation has been associated with a loss of sagittal balance through flatback syndrome and has been shown to provide little correction in the axial plane [12–14]. With improved understanding of spinal biomechanics, greater focus has now been placed on the importance and alignment of the sagittal plane and its impact on health related quality of life [3]. Several authors have reported successful results using derotation to improve axial plane correction in AIS [5, 9], but the effects of these techniques on the sagittal plane have not been elucidated.

With improved instrumentation, pedicle screw constructs have become commonplace in AIS surgery. Thoracic pedicle screws provide more correction in both the coronal and axial planes [6, 7, 9, 11]. However, the use of pedicle screw constructs has been associated with less thoracic kyphosis. Helgeson et al. [10] showed that all screw constructs had a more significant reduction in thoracic kyphosis postoperatively ($18.2 \pm 8.6^\circ$) than hook constructs ($24.0 \pm 9.2^\circ$). Clements et al. [11] concluded that increasing implant density with pedicle screws was correlated with decreasing thoracic kyphosis. Patients with hook constructs in their cohort experienced a mean increase of $2 \pm 9^\circ$ of thoracic kyphosis, as compared a decrease in both groups with hybrid constructs ($-4.3 \pm 13^\circ$) and pedicle screw

Fig. 4 PA and lateral standing radiographs illustrating the application of en bloc derotation maneuvers alone to: **a** a pre-operative 58° curve, **b** with 12° of kyphosis from T5–12, **c** post-operative correction to 19°, **d** and 12° of post-operative kyphosis

Fig. 5 PA and lateral standing radiographs illustrating the application of both segmental and en bloc derotation maneuvers to: **a** a pre-operative 43° curve, **b** with 23° of kyphosis from T5–12, **c** post-operative correction to 15°, **d** and 18° of post-operative kyphosis

constructs ($-3.8 \pm 12^\circ$). The similarity in conclusions between these studies and our own are likely secondary to overlapping datasets. The results from these series and our own were queried from the same multicenter database although the specific study cohorts varied between groups with respect to their search criteria.

Although our understanding of the impact of pedicle screws on the sagittal profile is increasing, the effect of DVBD on that same plane has not yet been clearly evaluated. Lee et al. compared DVBD to rod derotation and reported a mean increase of 7° in thoracic kyphosis using DVBD, from 16 ± 3 to $23 \pm 4^\circ$ ($P < 0.05$). The group having only undergone rod derotation had a mean improvement of thoracic kyphosis of 5° (18 ± 3 – $23 \pm 3^\circ$,

$P < 0.05$). Both techniques appeared to improve the sagittal profile when compared to preoperative values, but no significant difference was identified between the techniques ($P > 0.05$).

Suk et al. [5] reported results from a larger cohort comparing the use of thoracoplasty, thoracoplasty and DVBD, or neither. They had a mean postoperative increase in thoracic kyphosis with all of their groups. Their control group had a mean change in thoracic kyphosis from 14.3 ± 8.4 to $22 \pm 8^\circ$, $P < 0.05$. The thoracoplasty alone group had a mean change from 16.6 ± 7.7 to $21.3 \pm 7.8^\circ$, $P < 0.05$, whereas the combined thoracoplasty and DVBD group developed an increase from 15.0 ± 9 to $22.4 \pm 8.5^\circ$, $P < 0.05$. Although they reported improved coronal curve

Fig. 6 PA and lateral standing radiographs illustrating the control group of no derotation maneuver to: **a** a pre-operative 53° curve, **b** with 25° of kyphosis from T5–12, **c** post-operative correction to 13°, **d** and 17° of post-operative kyphosis

Table 5 Comparison of inclinometer values by derotation technique

	No derotation	Segmental derotation	En bloc derotation	Both techniques	<i>P</i> value
Pre-op inclinometer (°)	13.8 ± 5.2	12.4 ± 5.1	13.5 ± 6.2	14.0 ± 5.3	0.12
Post-op inclinometer (°)	6.1 ± 4.1	6.6 ± 3.9	6.9 ± 3.2	6.3 ± 4.0	0.84

correction with DVBD and thoracoplasty, they did not note any difference between the thoracic kyphosis of their groups. Although present results differ in that they suggest a worsening of thoracic kyphosis using pedicle screw constructs, our outcomes similarly support that DVBD does not adversely impact the thoracic kyphosis.

Our DVBD cohort experienced a mean decrease in thoracic kyphosis of $5.1 \pm 15.3^\circ$ as compared to $10.8 \pm 18.9^\circ$ in the non-DVBD group ($P = 0.03$). The mean loss of kyphosis in our cohort was larger than that reported by both Helgeson et al. and Clements et al. Furthermore, Suk et al. noted improvement in their mean thoracic kyphosis in contrast to our results. All of these series, including our own, are retrospective in nature and thus limited by their study design. However, our cohort reflects a larger series of patients and may therefore more accurately portray the impact of pedicle screw instrumentation and DVBD on the sagittal profile of the spine. It is also possible that the increase of thoracic kyphosis experienced by other authors represents the results from developing more thoracic kyphosis through surgical technique such as rod contouring or instrumentation properties such as implant density or rigidity. Nonetheless, the addition of DVBD does not appear to further decrease the amount of thoracic kyphosis.

Although we did not note a difference between the two groups with respect to thoracic kyphosis at 2 years of follow-up, a difference was identified when we examined the amount of change in kyphosis from T2–12. We observed a greater loss of kyphosis in the group without DVBD (10°) as compared to the group that underwent derotation (5°). This change trended toward but did not achieve statistical significance when evaluating the thoracic kyphotic change from T5–12 ($P = 0.11$). Since the pre-op to post-op difference from the longer segment of T2–12 was only 5° of magnitude, the significance may have been lost by measuring only part of the thoracic kyphosis from T5–12, particularly as the difference between the two groups approached the limits of radiographic accuracy and reliability using Cobb angles [15–17].

Luk et al. [18] evaluated the relationship between coronal deformity correction and the resultant sagittal alignment in patients with AIS treated with standard rod rotation and either a hook system or pedicle screws. Luk et al. suggested that the natural coupling effect of the spine, which is influenced by the pre-operative flexibility, correlated with changes in sagittal kyphosis, but were not associated with the degree of kyphosis correction post-operatively. Our derotation group also had more flexible thoracic curves and less upper thoracic and main thoracic

correction at follow-up. However, these changes do not appear to be secondary to gradual loss of correction, as they were present on the first erect and 1 year follow-up radiographs. Alternatively, the larger curves seen with DVBD may have developed from loosening of fixation during application of axial correction and therefore caused a decrease in coronal correction.

The increased flexibility and decreased main thoracic curve correction in our derotation cohort are counterintuitive as increased flexibility is thought to allow for greater coronal curve correction after surgery. Theoretically, our bending radiographs estimate coronal flexibility, but may not account for flexibility in the sagittal plane which may hinder our axial correction. However, the decreased coronal correction may be associated with the smaller reduction in sagittal kyphosis (absolute change from T2–12, 5.1° vs. 10.8°). The decrease in coronal correction may be associated with less change in the sagittal profile as well possibly giving further credence to a coupled effect of the spine. No significant difference was identified in the flexibility of the curves between the differing derotation techniques. This may be secondary to the division of patients into smaller subgroups that may overlook subtle differences. Although the en bloc technique appeared to have the least lordotic effect of the DVBD maneuvers (Table 4), these results may be biased by the small numbers represented in the en bloc group. Possibly, the smaller decrease in thoracic kyphosis observed in the derotation group may also correlate with the lesser amount of coronal correction, although in the Luk cohort, no relationship was found between the degree of coronal and degree of sagittal correction for standard rod derotation. When we further examined the correlation between the correction in the coronal curvature and the sagittal plane in our cohort, no strong association was identified. When subdivided, the no derotation group had no significant correlation between the change in thoracic kyphosis and coronal correction ($P = 0.535$, $r = -0.090$). Although there was a statistically significant correlation between the change in the two variables within the derotation group ($P = 0.005$), the Pearson correlation was low ($r = 0.172$). Perhaps the smaller size of the no derotation group failed to identify a statistically significant association between coronal and sagittal changes whereas the larger population of the derotation group permitted more subtle variation to be identified. These results may also be interpreted to suggest that coronal curve correction alone does not have a significant impact on sagittal profile (no derotation group), but that the use of DVBD techniques does correlate with changes in the sagittal alignment. However, the correlation is nonetheless quite low and suggests that other factors may have a greater influence on the final sagittal profile. These findings concur with Luk et al.'s conclusion that the post-operative sagittal profile was

determined by both the natural coupling of the curves as well as the surgical correction.

Relative overgrowth of the anterior column or failure of sufficient posterior column growth have both been hypothesized to cause scoliosis [19, 20]. Alternatively, uncoupled neuro-osseous growth has also been proposed as a plausible etiology [21]. In an uncoupled neuro-osseous hypothesis, the relative differential growth between the neural elements and the osseous spine might lead to a functional tethering from the shorter neural elements contributing to the development of scoliosis. If the underlying pathophysiological cause is relative anterior overgrowth, surgical correction would more likely accentuate the thoracic lordosis and greater correction of the coronal plane would translate into increased thoracic lordosis as observed in our entire cohort. Therefore, the difference in change of thoracic kyphosis between the two groups may be reflective of the amount of coronal correction and not the DVBD technique alone.

Proximal junctional kyphosis was also significantly different between both groups. Although several authors have associated thoracic kyphosis with radiographic proximal junctional kyphosis [10, 22], its clinical significance remains ambiguous. Helgeson et al. [10] suggested redefining proximal junctional kyphosis using two standard deviations beyond the mean of their cohort, thus using 15° of change as the definition. If we adopted their criteria, the variation in proximal junctional kyphosis would be marginalized and less significant in our cohort.

Although pedicle screw constructs appear to decrease the amount of thoracic kyphosis, our results suggest that the addition of DVBD does not compound the adverse impact on the sagittal profile. As increasing attention is focused on the sagittal profile, further evaluation to determine the optimal parameters and associated factors is required. Surgeons should consider developing a normal sagittal contour and thoracic kyphosis during scoliosis correction.

IRB approval for the study was obtained locally from each contributing institution's review board, and consent was obtained from each patient prior to data collection.

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Conflict of interest None.

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