# Selection of the lowest instrumented vertebra in main thoracic adolescent idiopathic scoliosis – Is it safe to fuse shorter than the last touched vertebra?

**Authors**: Søren Ohrt-Nissen[1], MD, PhD
Keith DK Luk[2], MCh (Orth), FRCSE, FRCSG, FRACS, FHKAM (Orth)
Dino Samartzis[3], DSc
Jason Pui Yin Cheung[2], MBBS, MMedSc, MS, PDipMDPath, FRCS (Edin), FHKCOS

**Affiliations**: [1]Spine Unit, Department of Orthopedic Surgery, Rigshospitalet University of Copenhagen, Denmark
[2]Department of Orthopedics and Traumatology, The University of Hong Kong, Pokfulam, Hong Kong, SAR, China; and the
[3]Department of Orthopaedic Surgery, RUSH University Medical Center, Chicago, USA

**Ethics:** This study was approved by the Institutional Review Board at The University of Hong Kong.

**Disclosures:** The authors have no financial or competing interests related to this work.

**Funding:** No relevant funding to report

**Correspondence:** Søren Ohrt-Nissen
Spine Unit, Department of orthopedic surgery, Copenhagen University Hospital.
Blegdamsvej 9, 2100 Cph E, Denmark
Tel: +45 29915812
E-mail: ohrtnissen@gmail.com

Jason Pui Yin Cheung
Department of Orthopaedics and Traumatology
The University of Hong Kong
5/F Professorial Block
Queen Mary Hospital, Pokfulam,
Hong Kong SAR, China
Tel: +852 22554581
Fax: +852 28174392
Email: cheungjp@hku.hk

# Abstract

**Purpose:** To assess the radiographic and functional outcome using a standardized flexibility-based fusion strategy and to determine whether fusing shorter than the last touched vertebrae (LTV) was a safe approach in flexible main thoracic (MT) adolescent idiopathic scoliosis (AIS) curves.

**Methods:** This was a prospective study of consecutive patients with AIS surgically treated with alternate-level pedicle screw instrumentation. Only patients with selective fusion of the MT curves were included in the study. Fusion level selection was based on the fulcrum bending radiograph method. Preoperative, postoperative and two-year follow-up radiographs were used to determine the Cobb angle, apical translation of the MT, proximal thoracic and lumbar curves, and the LTV. The truncal shift, radiographic shoulder height, coronal and sagittal balance parameters were also measured, fusion mass shift, and lower instrumented vertebrae (LIV) disc angle were also measured. Patients were grouped based on the position of the LIV as proximal to the LTV (proxLTV), at the LTV (atLTV), and distal to the LTV (distLTV). Any adding-on was determined and the refined 22-item Scoliosis Research Society questionnaire was obtained. Univariate comparative analysis was performed between the groups and multiple logistic regression was used to examine variables contributing to adding-on.

**Results:** A total of 109 patients were included in the study and 43 were in the proxLTV, 45 were in the atLTV and 21 in the distLTV groups. Preoperatively, distLTV group had greater lumbar Cobb angle, lumbar apical translation and less flexibility in the MT curve. At two-year follow-up, the groups did not differ in MT curve correction but the distLTV had larger lumbar Cobb angle, more apical translation and worse coronal balance. Distal adding-on was most common in the proxLTV group (26%). Adding-on was only associated with younger patients at the time of surgery but not with any radiographic parameter. No differences in SRS-22r scores were observed between groups.

**Conclusions:** Proximal fusion carries the risk of adding-on but leaving unfused segments in the lower spine increases the potential for compensatory mechanisms to improve spinal and truncal balance. In mature patients with a flexible MT curve surgeons may consider fusion at or cranial to the LTV.

**Level of evidence:** II

**Key words:** Adolescent idiopathic scoliosis; AIS; selective thoracic fusion; adding-on; fusion mass shift; last touched vertebrae; fulcrum-bending radiograph; flexibility

## Background

Current surgical treatment for main thoracic (MT) adolescent idiopathic scoliosis (AIS) focuses on achieving a balanced spine, good curve correction and solid spinal fusion while leaving as many unfused segments as possible in the lumbar spine. Selection of the lowest instrumented vertebra (LIV) is of critical importance as it represents the distal junction where the rigid implant transitions into a mobile lumbar segment. Choosing a LIV that is too proximal can lead to progression of the unfused curves, spinal decompensation or adding-on while an LIV that is too distal results in unnecessary sacrifice of the lumbar area that may in turn lead to adjacent accelerated degenerative disc disease, chronic lumbar pain as well as unnecessary health-care costs[1–4]. Selection of the correct LIV is a challenging task.

As we broaden our understanding of curve behavior and instrumentation techniques improve, surgeons are becoming confident in selecting LIV more proximal than previously proposed. Traditionally, the stable vertebra (SV) has been considered a safe choice of LIV in MT curves but studies have shown that many curves can safely be treated with a LIV proximal to the SV[5]. Lenke et al and the Harms study group[6] showed that in MT and double thoracic curves, the last touched vertebra (LTV) was a useful landmark for LIV selection and that fusion shorter than the LTV may result in lumbar decompensation. This has been supported by other studies suggesting LTV as the LIV in main thoracic AIS[7, 8]. Other studies suggest that the neutral vertebra (NV) is a key reference for fusion selection[9]. The majority of studies, however, are based on the standing antero-posterior radiograph alone. MT AIS curves differs substantially in terms of flexibility and the need for instrumentation likely vary accordingly. The fulcrum bending radiograph (FBR) has shown a strong positive correlation with the surgical curve correction in thoracic curves for all-pedicle screw constructs[10]. Luk et al[11] published guidelines for selection for fusion levels based on curve flexibility. This approach has been shown to save fusion levels compared to conventional approaches based on the standing AP radiograph[12].

The aim of the current study was to assess the radiographic and functional outcome using a standardized flexibility-based fusion strategy. The main objective was to assess whether fusing shorter than the LTV was a safe approach in flexible MT AIS curves.

## Materials and methods

### Inclusion

Following ethics committee approval, we performed a prospective study of a consecutive series of patients with AIS treated surgically over a 5-year period with alternate-level pedicle screw instrumentation at a single institution. Only patients with selective fusion of the MT curve in Lenke types 1, 2, 3 and 4, with two-year follow-up were included. All patients underwent standard postero-anterior (PA), lateral radiographs and FBR of the MT curve prior to surgery. The method for obtaining FBR has been reported. In short, the patient was in the lateral decubitus position and hinged over a radiolucent fulcrum placed under the rib corresponding to the apex of the curve.

### Fusion selection

Selection of the fusion level was standardized and based on the protocol previously reported by Luk et al[1] (**Figure 1**). In general, based on the FBR, a line was drawn at the inferior endplate of the estimated LIV. From the midpoint of the line above at the estimated LIV, a perpendicular line was erected (center line). After the estimated proximal instrumented vertebra (PIV) was identified, a line was drawn at the superior endplate. The Cobb angle is determined based on the estimated LIV and PIV. If the shift from the PIV was greater than 20 mm from the center line, the next caudal vertebra was chosen as the LIV However, if the shift was less than 20 mm and the Cobb angle was greater than 20 degrees, then the next cranial vertebra was chosen as the estimated PIV. All patients underwent standardized correction strategies with alternate-level pedicle screw insertion, rod rotation maneuver and segmental distraction of the concavity and compression of the convexity.

**Data collection**

Radiographs were assessed preoperatively, postoperatively and at two-year follow-up. We determined the Cobb angle and apical translation of the MT, the proximal thoracic and the lumbar curve. Also, we measured the truncal shift, radiographic shoulder height, coronal and sagittal balance[13]. Truncal shift was defined by measuring the perpendicular distance from the center sacral vertical line (CSVL) to a line that bisects the distance from the lateral edges of the rib margins in the mid thoracic level. Coronal balance was defined as the degree of deviation from the center of the S1 upper end plate to a vertical line drawn from the C7 spinous process. Fusion mass shift was measured as previously reported[14]. LIV disc angle was measured as the angle between the inferior endplate of the LIV and the superior endplate of the LIV+1.

Two observers (first and last author) independently assessed the preoperative PA radiograph and determined the following parameters (**Figure 2**): Stable vertebra (SV): The most cephalad vertebra immediately below the end vertebra of the major curve that is most closely bisected by the CSVL. Last touched vertebra (LTV): To optimize reproducibility we defined the LTV as the last cephalad vertebra touched by the CSVL by more than 2 mm. Neutral vertebra (NV): The most cephalad vertebra below the apex of the major curve whose pedicles are symmetrically located within the radiographic silhouette of the vertebral body. Cases of disagreement was noted, and a consensus was made to establish a value to carry forward for analysis.

Based on the LIV, patients were grouped as proxLTV, if the LIV was proximal to the LTV, atLTV if the LIV was at the level of LTV or distLTV if LIV was distal to LTV. Adding-on was determined at the two-year follow-up and was defined as a progressive increase in the number of vertebrae included distally within the primary curve combined with either an increase of more than 5 mm in deviation from the CSVL of the first vertebra below the LIV, or an increase of more than 5° in the angulation of the first disc below the LIV[2] Patients were asked to fill out a validated version of the refined 22-item Scoliosis Research Society (SRS-22r) questionnaire both at the preoperative and two-year postoperative stage.

### Statistics

All statistical analyses were performed using R version 3.4.0 (R core team, 2014, Vienna, Austria). Data was reported as proportions (%), mean ± standard deviation or median with interquartile range. Data distribution was assessed by histograms. For the univariate comparative analysis, continuous data was compared between groups using analysis of variance (ANOVA) or Kruskal-Wallis with post-hoc analysis using Tukey's test. Categorical variables were compared using Pearson's chi-squared test or Fisher's test where appropriate. Multiple logistic regression was used to examine explanatory variables for adding-on. Cohen Kappa was used to assess the reliability between the two raters in determining the NV, LTV and SV. In accordance with Landis and Koch[15], the results of reliability (k) were classified into slight (<0.20), fair (0.21-0.40), moderate (0.41-0.60), substantial (0.61-0.80), and almost perfect agreement (>0.81). The significance level was set at 0.05.

## Results

Of the 109 patients included in the study, 93 cases (85%) were Lenke type 1 and 16 were type 2. There were 43 patients in the proxLTV, 45 in the atLTV and 21 in the distLTV group. (**Table 1**). Preoperative variables are seen in **table 2**. At the preoperative stage, the groups differed in terms of MT flexibility, lumbar apical translation and trunk shift ($p \leq 0.005$). The distLTV group had less flexible MT curves and had significantly larger thoracolumbar/lumbar (TLL) Cobb angle ($p = 0.009$).

At two-year follow-up, the groups did not differ in MT curve correction or radiographic shoulder height (**Table 3**). Again, the distLTV group had significantly larger TLL Cobb angle or more apical translation. Mean coronal balance was 9 ± 7, 11± 9 and 19 ± 16 mm ($p < 0.001$) in the proxLTV, atLTV and distLTV groups respectively. Trunk shift was 6 ± 5, 9 ± 7 and 15 ± 10. Two raters determined the preoperative LTV, NV and SV. Cohen's kappa was 0.85 (95%CI 0.77-0.93) for LTV, 0.72 (0.62-0.81) for NV and 0.85 (0.78-0.93) for SV.

**Adding-on subgroup analysis**

Distal adding-on was observed in 11 patients (26%) in the proxLTV group, four patients (9%) in the atLTV group and one patient (5%) in the distLTV group ($p = 0.031$) (**Table 3**). Adding-on thus occurred primarily in the proxLTV group and a post-hoc analysis was conducted on this group to identify potential explanatory variables for the development of adding-on (**Table 4**). Mean age at the time of surgery was 14.6 ± 2.1 and 12.9 ± 1.9 in the no adding-on and adding-on group respectively ($p = 0.024$). By similar degree, the median Risser grade was 4 (IQR: 3-4) and 2 (IQR: 0-4) ($p = 0.029$) respectively. At the immediate postoperative stage, the groups did not differ significantly in terms of MT or TLL Cobb angle trunk shift or coronal balance. At two-year follow-up, TLL Cobb angle was 11 ± 7 and 10 ± 8 ($p = 0.756$), trunk shift was 7 ± 6 and 5 ± 4 ($p = 0.236$) and radiographic shoulder height was 11 ± 8 and 10 ± 7 ($p = 0.584$) in the no adding-on and adding-on group respectively.

SRS22r scores at two-year follow-up on all patients is shown in **Figure 3.** The adding-on group and no adding-on group did not differ on any domain score or the total scores ($p \leq 0.279$).

## Discussion

The purpose of the present study was to challenge the principles of LIV selection primarily based on the PA radiograph. Using a flexibility-based fusion selection principle we saved one to two fusion levels in 43 patients. We found that in the proxLTV group that rate of distal adding-on was higher (26%) but patients were overall well balanced with better global balance and less truncal shift. Subgroup analysis showed that the main predictor for adding-on in the proxLTV group was young age and skeletal immaturity at the time of surgery. The adding-on group showed no increased trunk shift or global imbalance.

The distLTV group had a low rate of adding-on but we found lumbar decompensation with increased translation of the lumbar apex. However, it should be noted that this group had a larger TLL curve preoperatively, which may bias the follow-up results. Cao et al examined Lenke type 2A curves and found 50% rate of adding-on when fused proximal to the LTV (n=18). The authors found inferior curve correction in this group and did not see any difference in coronal balance. However, fusion selection was not based on curve flexibility but rather surgeon's discretion. With longer fusions in the distLTV group, there is a reduced capacity for compensation by the unfused lumbar segments. Adding-on is less frequent in this group and thus results in poorer global balance. It is important to note that the distLTV results were contributed by the same correction rate as proxLTV and atLTV but in less flexible curves. Our standardized method of alternate level pedicle screw strategy without releases may not be suitable for these stiffer curves with greater apical translation. A more aggressive approach to the correction or avoiding selective thoracic fusions may be necessary to achieve better radiographic outcomes.

Selection of the LIV is an important factor in the development of adding-on and since curve behavior can be unpredictable surgeons may be inclined to fuse longer rather than shorter. Preoperative planning and fusion selection has been shown to be highly variable between surgeons irrespective of whether LTV, NV or SV is used as reference[16–18]. We found that SV and LTV had very good interrater reliability and in this respect are good reference points for preoperative planning. NV had inferior reliability, which is in line with previous studies[19] and may not be considered a reliable preoperative reference as both intra- and interobserver variation is considerable. In the current study fusion selection was based on structured protocol taking into consideration the preoperative flexibility as well as the squared fusion mass principle. As mentioned in the methods, we aim to achieve a squared fusion mass by choosing the PIV and LIV that provides <20mm shift and <20 degrees in Cobb angle on FBRs. We also aim to achieve this intraoperatively with a whole spine radiograph after correction followed by further compression of the concavity and distraction of the convexity as necessary. Shown by similar fusion mass shift between the proxLTV, atLTV and distLTV, but larger residual Cobb angle in the distLTV group, we have compromised on less satisfactory Cobb angle correction and more fusion levels to achieve a parallel fusion mass using the similar correction strategy. As such, our results are not biased by surgeon preferences, which is a strength. However, in patients with greater lumbar deformity, greater lumbar apical translation, more trunk shift and less flexible MT curves, we may elect to perform more aggressive MT correction than our usual strategy to maximize outcomes. This will require further study to verify our hypothesis.

Adding-on is a radiological phenomenon that represents progression or “extension” of the primary curve. Although adding-on has not been linked to treatment failure, pain or decreased health-related quality of life it is generally considered a poor outcome as the potential for disc wedging may lead to degenerative changes later in life and/or the need for extending the fusion distally[20]. Our study was not able to identify a single significant predictor for adding-on (**Table 4**) but found that MT curve correction, truncal balance and choice of LIV plays a crucial role. At two-year follow-up, we did not see any signs of lumbar decompensation or imbalance in the adding-on group and we found no difference in SRS-22 scores. We hypothesize that while leaving unfused distal segments may predispose to disc wedging (adding-on) it also allows for a higher level of compensatory changes in the lumbar spine that ultimately leads to a balanced spine. We would encourage future studies to examine the long-term clinical consequences of disc wedging and its role as a primary focus in AIS deformity surgery.

## Conclusions

Proximal fusion shorter than the LTV carries the risk of adding-on but leaving unfused segments in the lower spine increases the potential for compensatory mechanisms to improve spinal and truncal balance. Previously deemed safer longer fusions with recruitment of more lumbar segments may lead to less adding-on but more coronal imbalance. Fusion selection remains an art and also a science. In mature patients with a flexible MT curve surgeons may consider fusion at or cranial to the LTV.

## References


1. Lee MC, Õunpuu S, Solomito M, et al (2013) Loss in spinal motion from inclusion of a single midlumbar level in posterior spinal fusion for adolescent idiopathic scoliosis. Spine (Phila Pa 1976) 38:1405–1410.

2. Marks M, Newton PO, Petcharaporn M, et al (2012) Postoperative segmental motion of the unfused spine distal to the fusion in 100 patients with adolescent idiopathic scoliosis. Spine (Phila Pa 1976) 37:826–832.

3. Sanchez-Raya J, Bago J (2012) The effect of the lower instrumented vertebra (LIV) on pain and quality of life in patients surgically treated for an idiopathic scoliosis. Scoliosis 7:437–442.

4. Larson AN, Polly DW, Ackerman SJ, et al (2016) What would be the annual cost savings if fewer screws were used in adolescent idiopathic scoliosis treatment in the US? J Neurosurg

Spine 24:116–23.

5. Erickson MA, Baulesh DM (2011) Lowest instrumented vertebra selection in AIS. J Pediatr Orthop 31:S69-76.

6. Lenke L, Newton P, Lehman R, et al (2017) Radiographic Results of Selecting the Touched Vertebra as the Lowest Instrumented Vertebra in Lenke Type 1 (Main Thoracic) & Type 2 (Double Thoracic) Curves at a Minimum 5-year Follow-up. Glob spine J 7:2S–189S

7. Cao K, Watanabe K, Kawakami N, et al (2014) Selection of lower instrumented vertebra in treating Lenke type 2A adolescent idiopathic scoliosis. Spine (Phila Pa 1976) 39:E253-61.

8. Lee CS, Hwang CJ, Lee DH, Cho JH (2016) Five major controversial issues about fusion level selection in corrective surgery for adolescent idiopathic scoliosis: A narrative review. Spine J 17:1033–1044.

9. Suk S-I, Lee S-M, Chung E-R, et al (2003) Determination of distal fusion level with segmental pedicle screw fixation in single thoracic idiopathic scoliosis. Spine (Phila Pa 1976) 28:484–91.

10. Cheung KMC, Natarajan D, Samartzis D, et al (2010) Predictability of the fulcrum bending radiograph in scoliosis correction with alternate-level pedicle screw fixation. J Bone Jt Surg Am 92:169–176

11. Luk KDK, Don AS, Chong CS, et al (2008) Selection of fusion levels in adolescent idiopathic scoliosis using fulcrum bending prediction: a prospective study. Spine (Phila Pa 1976) 33:2192–8

12. Samartzis D, Leung Y, Shigematsu H, et al (2015) Selection of fusion levels using the

fulcrum bending radiograph for the management of adolescent idiopathic scoliosis patients with alternate level pedicle screw strategy: Clinical decision-making and outcomes. PLoS One 10:e0120302

13. Ohrt-Nissen S, Kamath VHD, Samartzis D, et al (2018) Fulcrum flexibility of the main curve predicts postoperative shoulder imbalance in selective thoracic fusion of adolescent idiopathic scoliosis. Eur Spine J 27:2251–2261.

14. Shigematsu H, Cheung JPY, Bruzzone M, et al (2017) Preventing Fusion Mass Shift Avoids Postoperative Distal Curve Adding-on in Adolescent Idiopathic Scoliosis. Clin Orthop Relat Res 1–13.

15. Landis JR, Koch GG (1977) The measurement of observer agreement for categorical data. Biometrics 33:159–174.

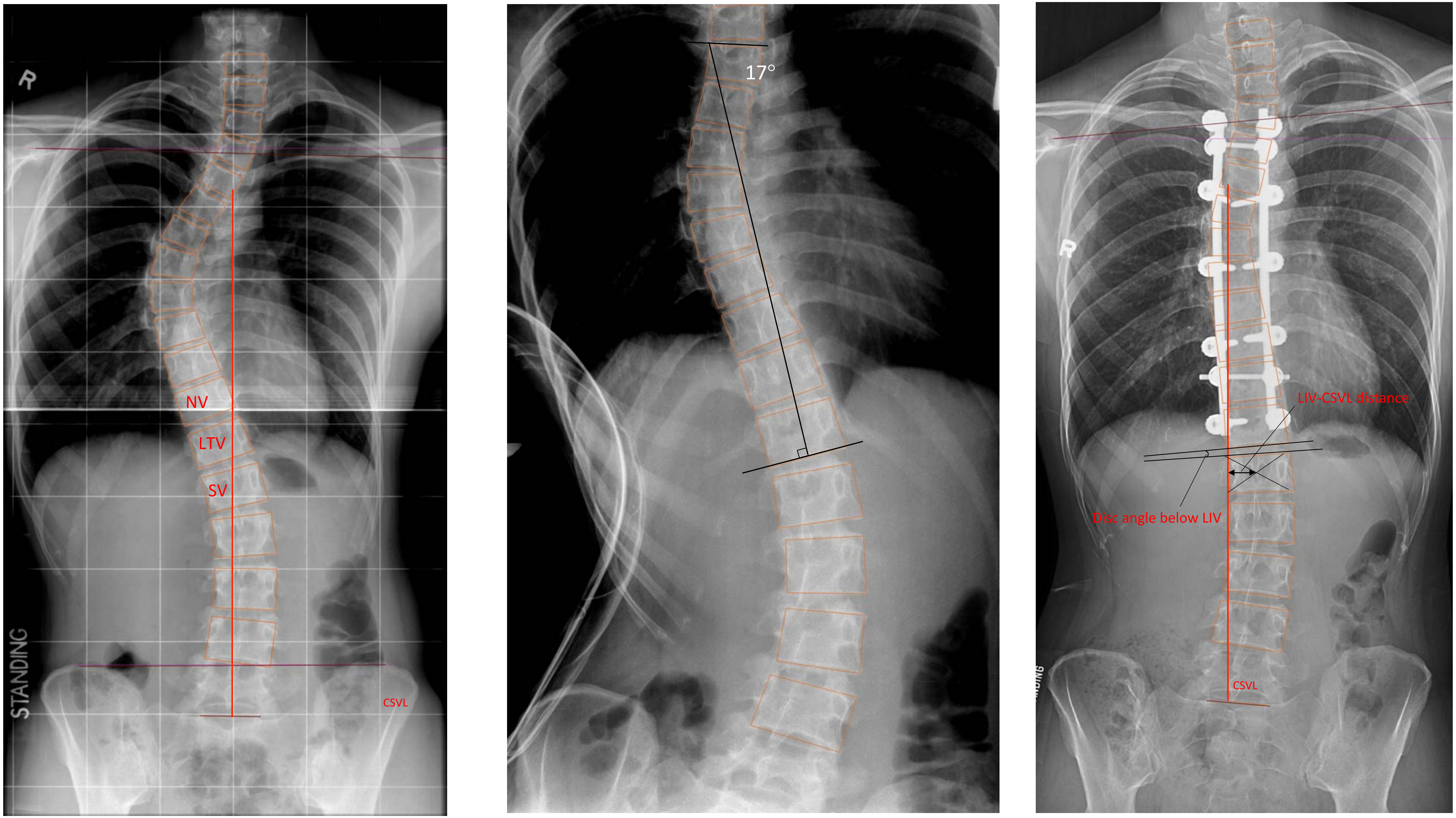
16. Aubin C-E, Labelle H, Ciolofan OC (2007) Variability of spinal instrumentation configurations in adolescent idiopathic scoliosis. Eur Spine J 16:57–64.

17. Robitaille M, Aubin CE, Labelle H (2007) Intra and interobserver variability of preoperative planning for surgical instrumentation in adolescent idiopathic scoliosis. Eur Spine J 16:1604–14.

18. Newton PO, Faro FD, Lenke LG, et al (2003) Factors involved in the decision to perform a selective versus nonselective fusion of Lenke 1B and 1C (King-Moe II) curves in adolescent idiopathic scoliosis. Spine (Phila Pa 1976) 28:S217-23.

19. DeFrancesco CJ, Pasha S, Miller DJ, et al (2018) Agreement Between Manual and Computerized Designation of Neutral Vertebra in Idiopathic Scoliosis. Spine Deform 6:.

20. Cho RH, Yaszay B, Bartley CE, et al (2012) Which Lenke 1A curves are at the greatest risk for adding-on... and why? Spine (Phila Pa 1976) 37:1384–90.



R
STANDING
NV
LTV
SV
CSVL
17°
R
LIV-CSVL distance
Disc angle below LIV
CSVL

**Figure 1**

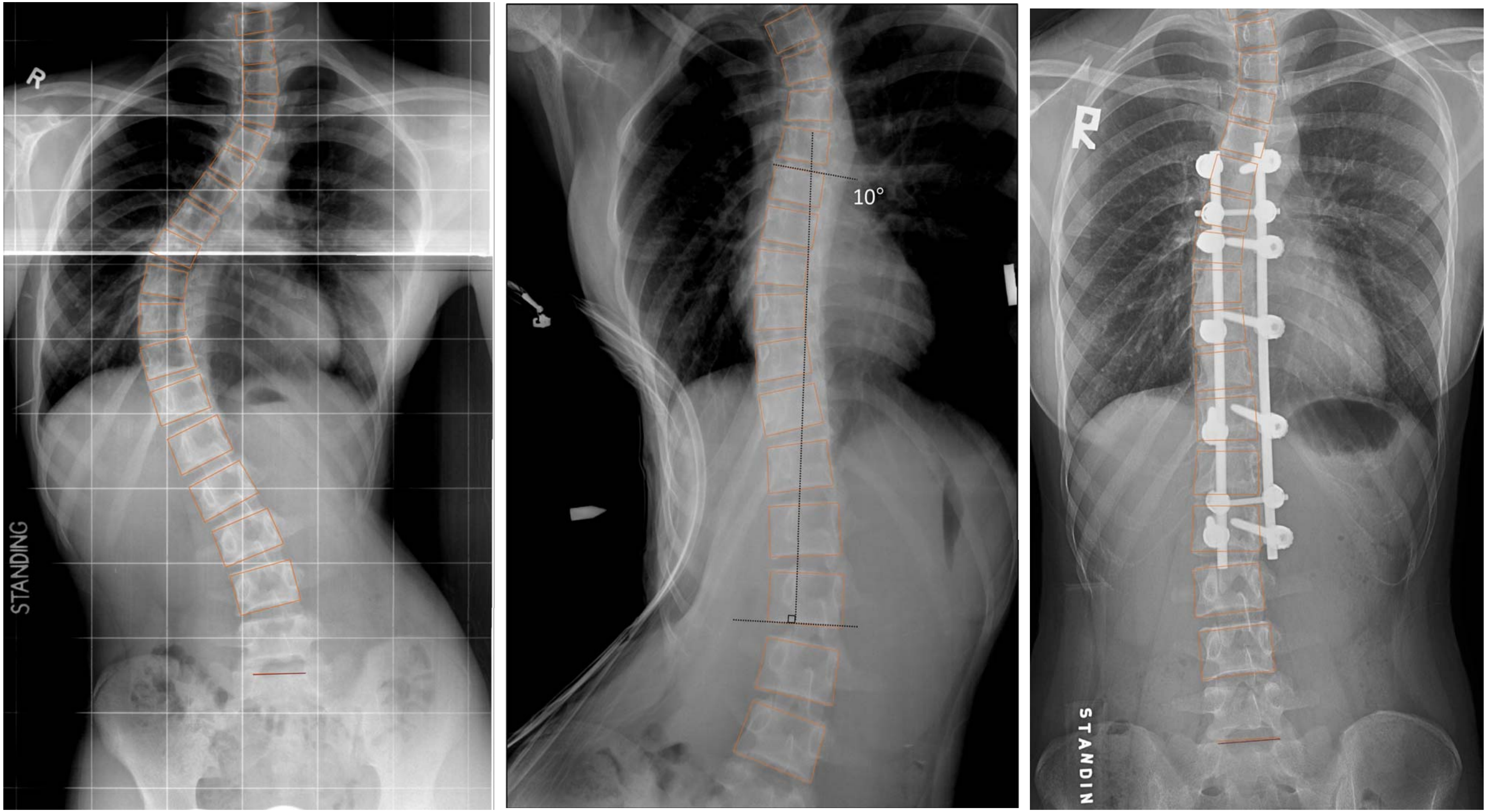

R
STANDING
10°
R
STANDIN

**Figure 2**

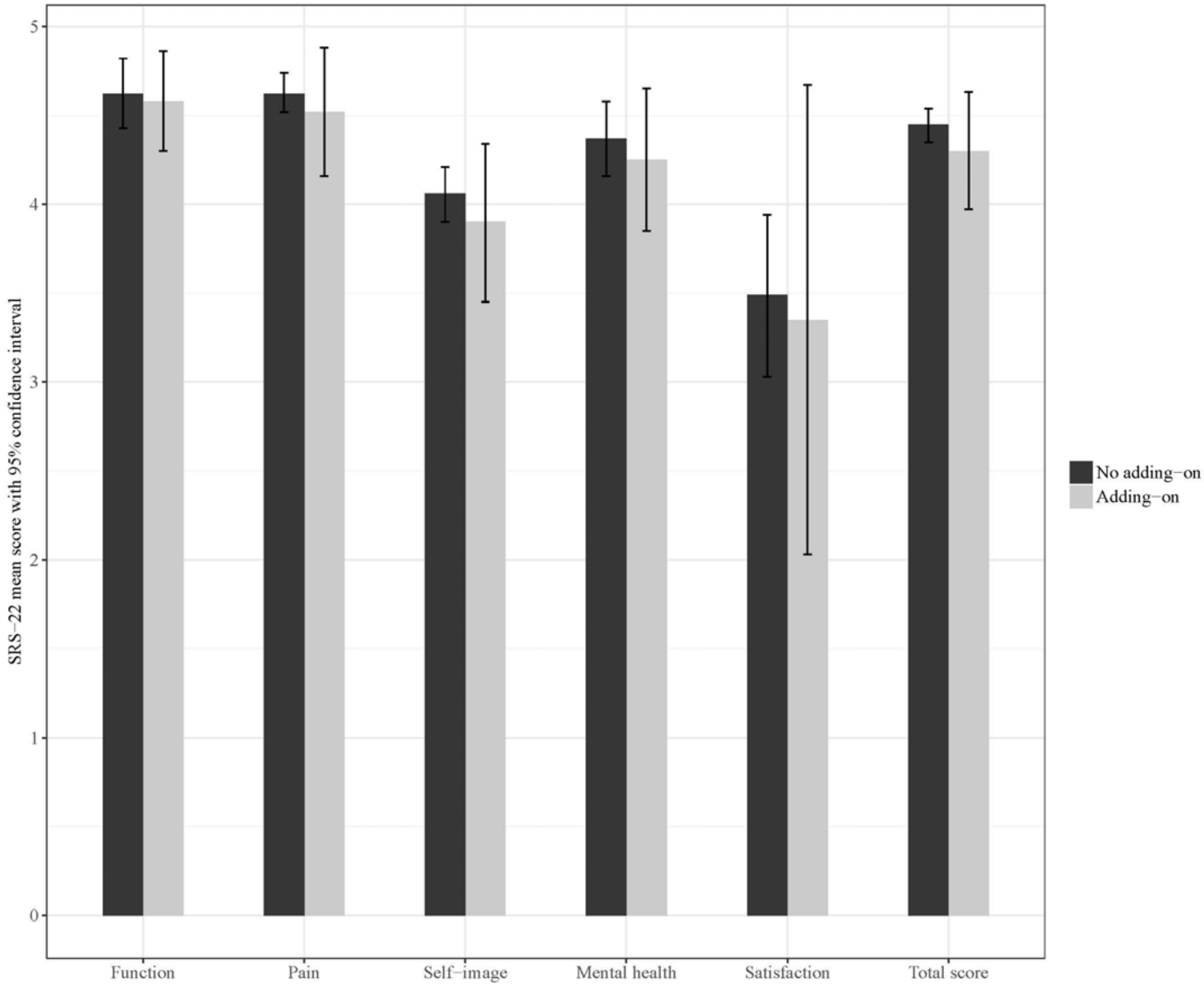

SRS−22 mean score with 95% confidence interval
0
1
2
3
4
5
Function
Pain
Self−image
Mental health
Satisfaction
Total score
No adding−on
Adding−on

**Figure 3**

| **Table 1. Fusion selection. Location of the lowest instrumented vertebra (LIV)** | | |
|---|---|---|
| **Location of LIV** | **No. of total patients (%)** | **Adding-on at 2y follow-up, No** |
| LTV -2 | 10 (9) | 3 |
| LTV – 1 | 33 (30) | 8 |
| LTV | 45 (41) | 4 |
| LTV +1 | 18 (17) | 1 |
| LTV +2 | 2 (2) | 0 |
| LTV +3 | 1 (1) | 0 |
| *LTV: Last touched vertebra* | | |

| **Table 2. Preoperative data** | | | | |
|---|---|---|---|---|
| | **proxLTV[1]<br>n = 43** | **atLTV[1]<br>n = 45** | **distLTV[1]<br>n = 21** | **p-value** |
| Age | 14.1 ± 2.2 | 15.6 ± 4.0 | 15.4 ± 2.2 | 0.062 |
| Risser grade, median [IQR] | 4 [2-4] | 4 [3-5] | 4 [4-4] | 0.056 |
| Cobb angle, main curve, ° | 56 ± 10 | 59 ± 10 | 59 ± 10 | 0.304 |
| Flexibility, main curve, % | 67 ± 13 | 57 ± 12 | 48 ± 12 | **< 0.001** |
| Cobb angle, TLL curve | 30 ± 8 | 32 ± 7 | 37 ± 6 | **0.009** |
| Flexibility, TLL curve | 73 ± 33 | 77 ± 27 | 77 ± 13 | 0.834 |
| Apical translation, lumbar, mm | 7 ± 5 | 9 ± 8 | 13 ± 6 | **0.005** |
| Disc angle below intended LIV | 4 ± 3 | 8 ± 5 | 11 ± 6 | < 0.001 |
| Global balance, mm | 13 ± 9 | 11 ± 8 | 11 ± 8 | 0.448 |
| Trunk shift, mm | 30 ± 11 | 24 ± 14 | 16 ± 12 | **< 0.001** |
| Radiographic should height, mm | 7 ± 6 | 8 ± 8 | 7 ± 7 | 0.565 |

[1] *Mean ± standard deviation unless otherwise specified*
*TLL: thoracolumbar/lumbar*
*LIV: Lowest instrumented vertebra*

**Table 3. Two-year follow-up**

| | proxLTV[1] | atLTV[1] | distLTV[1] | p-value |
|---|---|---|---|---|
| Cobb angle, main curve, ° | 20 ± 7 | 20 ± 7 | 21 ± 8 | 0.76 |
| Curve correction, main curve, % | 64 ± 12 | 66 ± 12 | 64 ± 11 | 0.790 |
| Cobb angle, TLL curve, ° | 11 ± 7 | 12 ± 8 | 21 ± 8 | **< 0.001** |
| Apical translation, TLL curve, mm | 6 ± 5 | 9 ± 7 | 18 ± 9 | **< 0.001** |
| Coronal balance, mm | 9 ± 7 | 11± 9 | 19 ± 16 | **< 0.001** |
| Trunk shift, mm | 6 ± 5 | 9 ± 7 | 15 ± 10 | **< 0.001** |
| Fusion mass shift, mm | 16 ± 12 | 15 ± 15 | 11 ± 11 | 0.381 |
| LIV distance from CSVL, mm | 14 ± 10 | 8 ± 5 | 20 ± 14 | **< 0.001** |
| Radiographic shoulder height, mm | 11 ± 8 | 12 ± 9 | 13 ± 9 | 0.607 |
| Adding-on, No. (%) | 11 (26) | 4 (9) | 1 (5) | **0.031** |

[1]*Mean ± standard deviation unless otherwise specified*
*TLL: thoracolumbar/lumbar*
*LIV: Lowest instrumented vertebra*
*CSVL: Central sacral vertical line*

**Table 4. Potentially explanatory variables for distal adding-on. Post hoc analysis on the proxLVT group.**

| | No adding-on[1] n=32 | Adding-on[1] n=11 | p-value |
|---|---|---|---|
| **Preoperative variables** | | | |
| Age, years | 14.6 ± 2.1 | 12.9 ± 1.9 | **0.024** |
| Risser grade, median (IQR) | 4 (3-4) | 2 (0-4) | **0.029** |
| Flex, % | 66 ± 15 | 67 ± 6 | 0.856 |
| Cobb angle , main curve, ° | 57 ± 11 | 53 ± 6 | 0.183 |
| Cobb angle TLL curve, ° | 30 ± 8 | 32 ± 6 | 0.491 |
| Trunk shift, mm | 31 ± 10 | 26 ± 15 | 0.141 |
| **Immediate postoperative variables** | | | |
| Curve correction, % | 73 ± 12 | 75 ± 7 | 0.501 |
| Cobb angle TLL curve, ° | 11 ± 8 | 10 ± 7 | 0.823 |
| Trunk shift, mm | 9 ± 7 | 9 ± 7 | 0.830 |
| Coronal balance, mm | 11 ± 9 | 9 ± 7 | 0.467 |
| Fusion mass shift | 13 ± 11 | 12 ± 10 | 0.959 |
| Tl tilt, ° | 9 ± 6 | 10 ± 6 | 0.657 |
| LIV_disc_angle, ° | 4 ± 3 | 3 ± 3 | 0.304 |
| LIV distance from CSVL, mm | 8 ± 6 | 7 ± 7 | 0.533 |

*[1] Mean ± standard deviation unless otherwise specified*
*TLL: thoracolumbar/lumbar*
*LIV: Lowest instrumented vertebra*