The association between proximal fusion level selection and outcomes in Lenke type-1 adolescent idiopathic scoliosis

Abstract

Aim: This study aimed to evaluate the effect of PFL on clinical and radiological outcomes in Lenke type 1 AIS patients.

Methods: The study was retrospective and included patients diagnosed with Lenke type 1 AIS with deformity correction and spinal fusion with the right main thoracic curve. The patients were allocated into two groups according to the selection of PFL, as T2 and T4 groups. Outcome measures and classification parameters were Scoliosis Research Society - 22r (SRS - 22r) score, Oswestry disability index (ODI) Turkish version, Lenke classification and Risser sign. The data of the two groups were compared.

Results: Postoperative shoulder imbalance and trunk shift values were significantly lower in the T2 group whereas SRS - 22r scores were significantly higher in the T2 group ($p < 0.05$ for all). While the preoperative bending angles were significantly lower in the T4 group ($p < 0.05$), the two groups were similar in the postoperative Cobb measurement, thoracic kyphosis and lumbar lordosis angles, sagittal imbalance, and T1 tilt values ($p > 0.05$ for all).

Conclusions: The selection of the T2 vertebra as the PFL is more advantageous in terms of clinical and radiological results. Additionally, there is no difference between T2 and T4 fusion levels in terms of complications.

Key words: adolescent idiopathic scoliosis; proximal fusion

Level of evidence: Level III study

What is already known about this topic: Surgical correction is still considered an effective option in adolescent idiopathic scoliosis (AIS). Different proximal fusion levels (PFL) have been studied in the literature. Selection of the PFL has still not been clarified.

What does this article add: This study evaluated the effect of PFL on clinical and radiological outcomes in Lenke type 1 AIS patients and to provide the most appropriate level selection.

Introduction

Surgical correction is still considered an effective option in the reatment of adolescent idiopathic scoliosis (AIS), especially with a scoliotic curve > 45^0 [1]. The goals of surgically treating AIS is to safely correct spinal deformity, achieve well-balanced fusion centered with respect to the pelvis, prevent further progression, minimize complications and improve the cosmetic appearance [2-4]. Herein, selection of the proximal and distal fusion level is complex and still controversial [4, 5].

In the pertinent literature, there are several studies regarding the distal fusion level (DFL) [4-6]. The purpose in selecting the DFL is to avoid adding-on phenomena or decompensation and to maintain as many mobile lumbar segments as possible [7]. On the other hand, the selection of the proximal fusion level (PFL) has a greater impact on patients' radiological results as well as their cosmetic appearance and satisfaction [8]. The reason for this idea is that studies have shown that shoulder imbalance is an established predictor of post-surgical satisfaction and self-image in AIS patients, and the selection of the PFL is an important determinant of shoulder imbalance [9, 10]. Therefore one of the most emphasized criterion in scoliosis therapy evaluation is shoulder imbalance [3, 4, 7, 8]. However, the method of selection of the PFL has still not been clarified and different methods were used other than shoulder imbalance; including rigidity of thoracic curves and thoracic 1 (T1) vertebral tilt [4, 11]. Successful results have been reported in all of these various studies. A recent study suggested using the 7th cervical – lowest instrumented vertebra (C7 - LIV) line, which is a new method in addition to those common methods mentioned above for PFL selection [12]. However, there is no consensus among surgeons regarding surgical planning [13]. Therefore, considering that each scoliosis type has its own characteristics and results, studies involving more homogeneous and specific groups are required. When assessing all types of AIS, Lenke [14] type 1 has been reported as the most common type (51 %) [11, 12]. Therefore, in this current study, we studied the effect of the PFL (T2 vs. T4) on clinical and radiological outcomes in Lenke type 1 AIS patients. Our hypothesis is that patients with Lenke type 1 scoliosis, other than those with a depressed left shoulder, will have better postoperative satisfaction rates and functional and radiological results with the selection of a T2 PFL.

Methods

Study design and data collection

Our study, after obtaining the approval of the local ethics committee was carried out retrospectively. Between January 2008 and April 2015, the patients diagnosed with Lenke type 1 AIS with right main thoracic curve and who underwent surgery for deformity correction and posterior spinal fusion using a pedicle screw construction, in a tertiary hospital, were enrolled. Criteria included being between 10 to 18 years of age, having a main thoracic curve Cobb angle > 45^0, preoperative, postoperative and a 5-year follow-up two plane X-ray films. Exclusion criteria were: other types of scoliosis, such as neuromuscular and congenital scoliosis, infection, cancer, and any other spinal disorders. In addition, left main thoracic and AIS types other than Lenke type 1 were excluded in order to obtain more homogeneous cohorts. The patients were allocated into two groups according to the selection of PFL, as T2 and T4 groups. As suggested by Lenke et al. [11], in preoperative full-spine two plane X-ray films, T4 for the patient with right shoulder height and T2 when the left shoulder was high was determined as PFL **(Figure 1A, 1B, 2A and 2B)**. The data of the two groups were compared. Data were gained from the patient files. Clinical and demographic properties (age, sex, height, and perioperative or postoperative complications) were recorded.

Surgical method

All patients with Risser grade 2 and higher skeletal maturity and post-menarche girls were surgically treated. The procedures were administered with a posterior surgical approach using the same spinal surgical team (the same senior surgeon) with the patient in prone position on the radiolucent surgical table. PFL selection was determined by preoperative evaluation of the rigidity of the curvatures as well as shoulder imbalance. In the determination of DFL, in addition to preoperative evaluations, all patients are evaluated with C-arm fluoroscopy while under general anesthesia and traction. The surgical procedure included spinal neuro-monitoring, facet joint resection, instrumentation with pedicle screws and posterolateral arthrodesis with posterior iliac crest auto-graft. Deformity correction was achieved by de-rotation, rod translation, distraction on the concave side of the curvature and compression on the convex side [2]. Herein, nut components in the most proximal instrumentation were left loose to avoid proximal junctional kyphosis [15], until the correction maneuvers were finished. Then, shoulder imbalance and screw placements were checked with C-arm fluoroscopy on anteroposterior and lateral views. As a result of this evaluation, it was observed that adequate shoulder balance and deformity correction could not be achieved in 2 patients who were planned as T4 PFL, and the instrument was raised to the T2 level. Then, the surgical procedure was completed. All patients were encouraged to be mobile one day after the surgery. After the discharge, patients were followed clinically and radiologically.

Outcome measures

Radiological and clinical results were evaluated according to the guidelines of the Scoliosis Research Society (SRS) Terminology Committee and Working Group [16]. Outcome measures and classification parameters were SRS - 22r score [17], Oswestry disability index (ODI) Turkish version [18], Lenke classification [14] and Risser sign [19]. Preoperative standard whole-spine and lateral-bending radiographs were used to evaluate the curves. The curves were measured by Cobb technique according to SRS criteria [16] and Lenke classification [14]. Thoracic kyphosis was measured by the angle between the superior endplate of T4 and the inferior endplate of T12, and the lumbar lordosis by the angle between the superior endplates of L1 and S1. Sagittal balance (SB) was assessed by the thoracic kyphosis and lumbar lordosis. The SB was described as the distance between the sagittal vertical axis passing through the C7 plumb line (PL) and the anterior end of the S2 endplate. The shoulder imbalance was described as the difference between the horizontal lines passing through both acromion tips. The trunk shift was defined as the distance between the C7 PL and the central sacral vertical line. T1 tilt was calculated as the angle between the inferior endplate of the T1 and the horizontal plane. Skeletal maturity was assessed by the degree of ossification in the iliac crest according to Risser sign [19]. Postoperative sagittal and coronal radiographic measurements - were performed by the same spine surgeon.

Statistical Analysis

SPSS software package program (SPSS Inc., version 16, Chicago, IL, USA) was used for statistical evaluation. Descriptive data were given as mean, standard deviation, median, number, or percentage. Numerical data of the groups were compared using the Student's t test or Mann Whitney U test according to the normal distribution. Baseline and after-surgery data were compared using the Paired t test or Wilcoxon signed-rank test. The Chi Square Test or Fischer's Exact Test was used to compare the categorical data of the groups. Pearson correlation analyses

were performed for the correlation analyses. A value of $p < 0.05$ was accepted as statistically significant.

Results

Demographic values are compared in **Table 1**. The T2 group comprised 62 patients (25 male, 37 female), and the T4 group comprised 53 patients (20 male, 33 female). The mean age of the T2 group was 14.63 ± 1.4 years (ranging 12 to 18 years), and the mean age of the T4 group was 14.81 ± 1.6 years (ranging 12 to 18 years). No significant differences were determined between the groups in terms of age, gender, follow-up period, Risser grade and DFL ($p > 0.05$ for all).

Clinical and radiological outcomes are presented in **Table 2.** Postoperative shoulder imbalance and trunk shift values were significantly lower in the T2 group whereas SRS - 22r scores were significantly higher in the T2 group, except for pain domain score ($p < 0.05$ for all). While the preoperative bending angles were significantly lower in the T4 group ($p < 0.05$), there was no difference between the two groups in the postoperative Cobb measurement, thoracic kyphosis and lumbar lordosis angles, sagittal imbalance, and T1 tilt values ($p > 0.05$ for all). Additionally, complication rates were similar between the two groups ($p > 0.05$ for all).

Discussion

The aim of the current study was to evaluate the effect of PFL on clinical and radiological outcomes in Lenke type 1 AIS patients. Three main findings emerged from this study. First; the T2 group exhibited superior outcomes in the SRS - 22r score values, except the pain domain score. Second, the T2 group displayed better improvement in radiological parameters, such as shoulder imbalance and trunk shift, when preoperative and postoperative values were compared. Third, while the preoperative bending angles were significantly lower in the T4 group, there was no difference between the two groups in the postoperative Cobb angles.

There are several studies exploring the relationship between PFL selection and postoperative radiological results in Lenke type 1 AIS patients [3, 4, 9]. However, most of them focused on the radiological results, and these studies mainly lack evaluation of functional and satisfaction scores such as SRS - 22r and ODI scores [1, 12]. Among these studies, one[1] stated that preventing the development of postoperative shoulder imbalance (PSI) affects the radiological and clinical results; to achieve this, the authors studied the apical vertebra translation (AVT) of the curvature in the thoracic spine. As a result, they proposed that the AVT of the thoracic curve be adequately corrected, avoiding the adding-on phenomenon to prevent the development of PSI. However, while emphasizing the importance of correction, the selection of the most appropriate PFL to achieve this goal was not studied. In another study [12], it has been reported that selecting the C7 - LIV line vertebra as the proximal instrumented vertebra for AIS Lenke Type 1 curves, can provide better trunk and shoulder balance without reducing the correction rate. The limitations of these studies are in their use of widely heterogeneous groups, including other Lenke types (1-6) [1] and PFL selections (T2 to T7) [12]. Some authors have recommended T2 as the PFL [5, 20]. However, differing opinions have also been suggested; Lenke et al. [11] proposed the selection of T2 or T4 as PFL according to the preoperative shoulder imbalance. They suggested proximal fusion to T4 for the patient with right shoulder elevation and emphasized that the PFL likely needs to be T2 when the left shoulder is high before surgery. In our present study, preoperative full-spine radiographs, bending radiographs and traction table fluoroscopic images were used to evaluate the most appropriate PFL and DFL selection. Lee et al [7] demonstrated

that the proximal thoracic curve correction rate was higher with aT2 PFL than with a T4 PFL, with a more depressed right shoulder in the T4 group. They reported that no difference was observed in terms of correction rate of the main thoracic curve, trunk shift and shoulder imbalance. They suggested that these results may be due to the strong correction achieved using pedicle screws. In our current study, we found that the patients in the T2 group achieved better functional, mental, satisfaction and radiological results by the end of the follow-up period. In addition, the ODI score, which is the other functional evaluation scale indicating the disability status of the patient, was lower in the T2 group, although it was not statistically significant. Another fact that needs to be highlighted in our study was the similar DFL of the two groups, which demonstrates the importance of comparing more homogenous groups. Due to the relatively less mobile segments of the thoracic spine as compared to the lumbar spine [21], the appropriate correction of the curve and satisfactory balance are the priorities of the present study. The benefits of the T2 PFL is that it allows full coverage of the proximal curvature and provides stronger correction with more instrumented segments.

PFL was previously found to be related to shoulder imbalance in AIS surgery [3, 4, 7, 8]. Lenke [11] proposed the selection of T2 or T4 as the PFL according to the PSI. However, there are also studies reporting no association between shoulder imbalance and PFL, whereby the authors attributed this difference to patient selection, measurement errors and sample size[1]. In our study, T2 was associated with improvement in shoulder imbalance and better overall outcomes. In another study, Smyrnis et al.[22] stated that shoulder asymmetry of 2 cm or greater postoperatively is a potential cause of patient dissatisfaction. In accordance with that study, we found that as the shoulder imbalance value decreased, the satisfaction value increased proportionately. Another study determined that PSI was correlated with a higher Risser grade [23]. However, in our study, there was no correlation in terms of Risser grade between the groups.

Purpose of surgical treatment of AIS is to safely correct spinal deformity while achieving a well-balanced fusion. It has been reported that factors affecting postoperative outcomes in Lenke type 1 curves include the flexibility of thoracic curves [24]. However, Kuklo et al. [25] reported that the proximal thoracic and lateral bending proximal thoracic Cobb angle was not the most important factor determining postoperative outcomes. In our study, both groups were similar in terms of preoperative and postoperative Cobb angles. We offer that this was due to the rigid curvatures in the T2 group in preoperative lateral flexion x-rays. As a result of these data, the T2 PFL appears more effective in correcting Cobb angle.

Finally, we found that the groups were statistically similar in terms of thoracic kyphosis, lumbar lordosis angles and sagittal imbalance, T1 tilt values and complication rates. Due to the narrower pedicle anatomy in the

proximal segments, additional surgical exposure and imaging difficulties, screw displacement was higher in the T2 group, but it was not statistically significant. None of our patients had implant failure due to pseudarthrosis. Adding-on phenomenon was higher in the T4 group. We believe that this may be related to better shoulder imbalance results in the T2 group as a compensatory mechanism previously reported by Yang et al. [1].

The limitations of the present study are its retrospective design, lack of randomization, lack of preoperative functional scores and the relatively short follow-up period. Although the radiographs were taken in standardized fashion, the possibility remains that variation may still exist in patient positioning, which may be another limitation of our study.

Conclusions

In the light of our preliminary results, the selection of the T2 vertebra as the PFL is more advantageous in terms of clinical and radiological results. Additionally, there is no difference between T2 and T4 fusion levels in terms of complications. We know that the suggesting of Lenke et al. are generally successful in choosing PFL, but there are exceptions. According to the results of our study, regardless of which side the shoulder is high, shoulder balance can be successfully achieved by selecting T2 as the PFL. We think that maintaining shoulder balance, corrected trunk-shift and patient satisfaction after surgery is more important than losing 1 or 2 levels with low mobilization in the upper thoracic spine. Further studies in prospective designs comparing the different levels of proximal fusion are recommended.

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Ethical approval: All procedures performed in this study involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Local ethics committee number: 56-862/05.2020

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283 **Figure Legends**

284 **Figure 1A:** Preoperative evaluation of the cobb angle (59.4°) and shoulder balance of the patient with right main

285 thoracic curvature and height in the left shoulder.

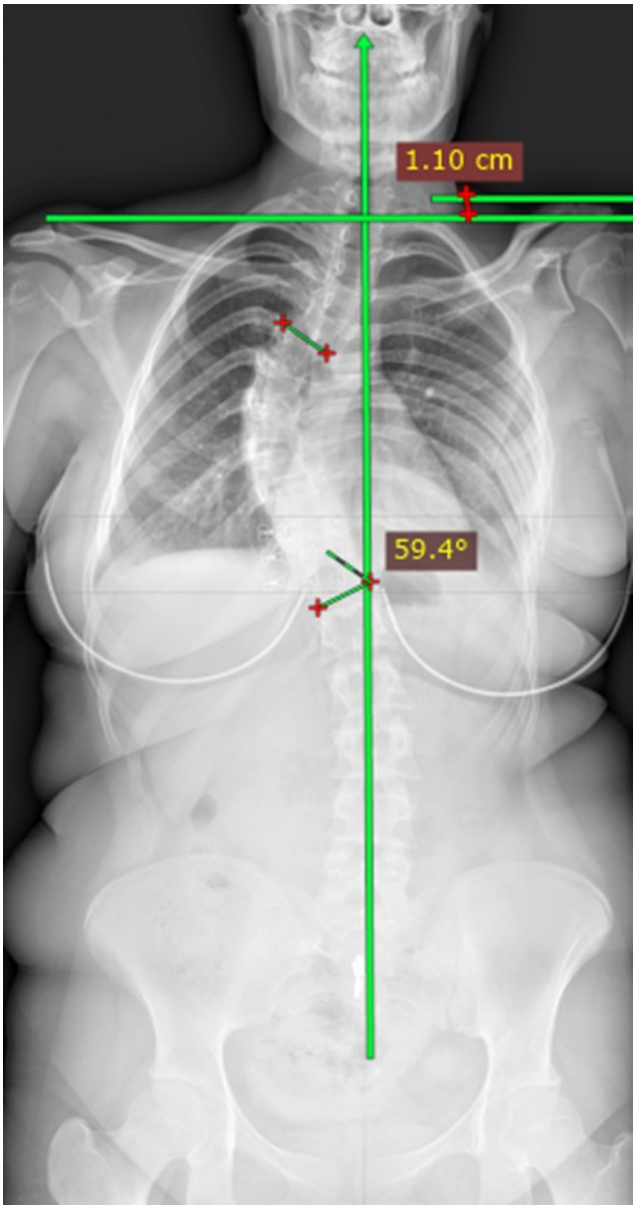

Figure 1B: Reduction of the postoperative cob angle of the patient to 16.8 and evaluation of shoulder balance.

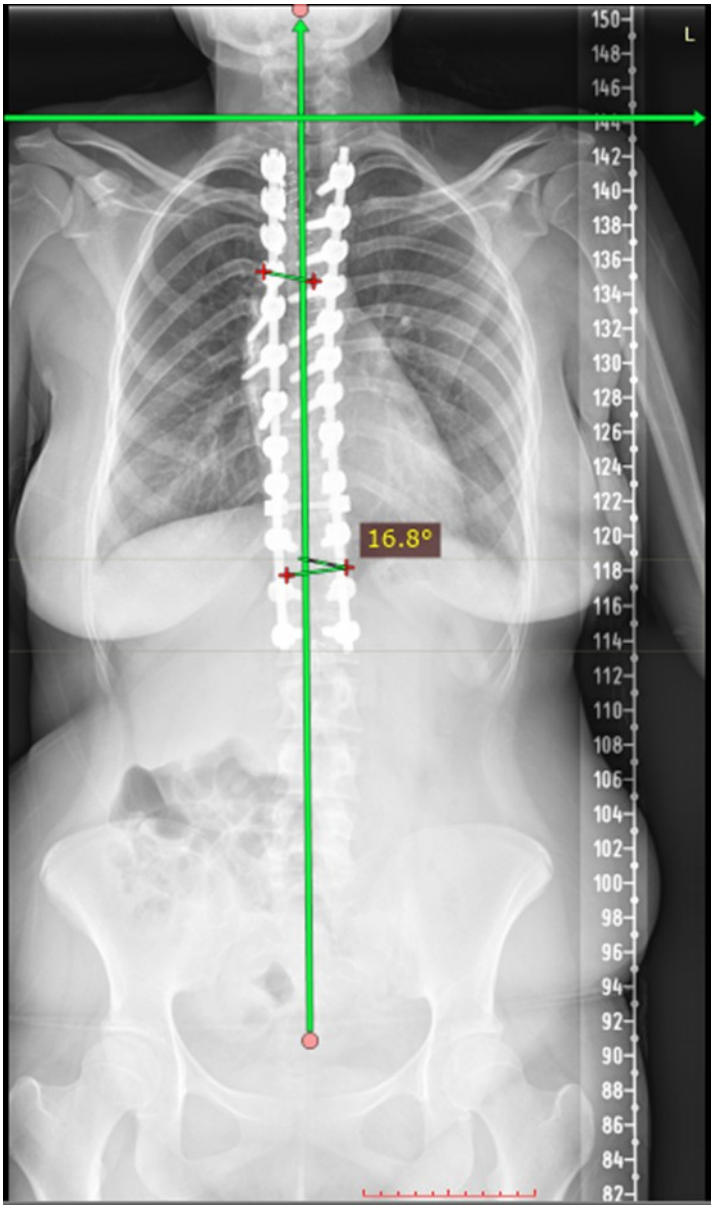

Figure 2A: Preoperative evaluation of the cobb angle (45.3°) and shoulder balance of the patient with right main thoracic curvature and height in the right shoulder.

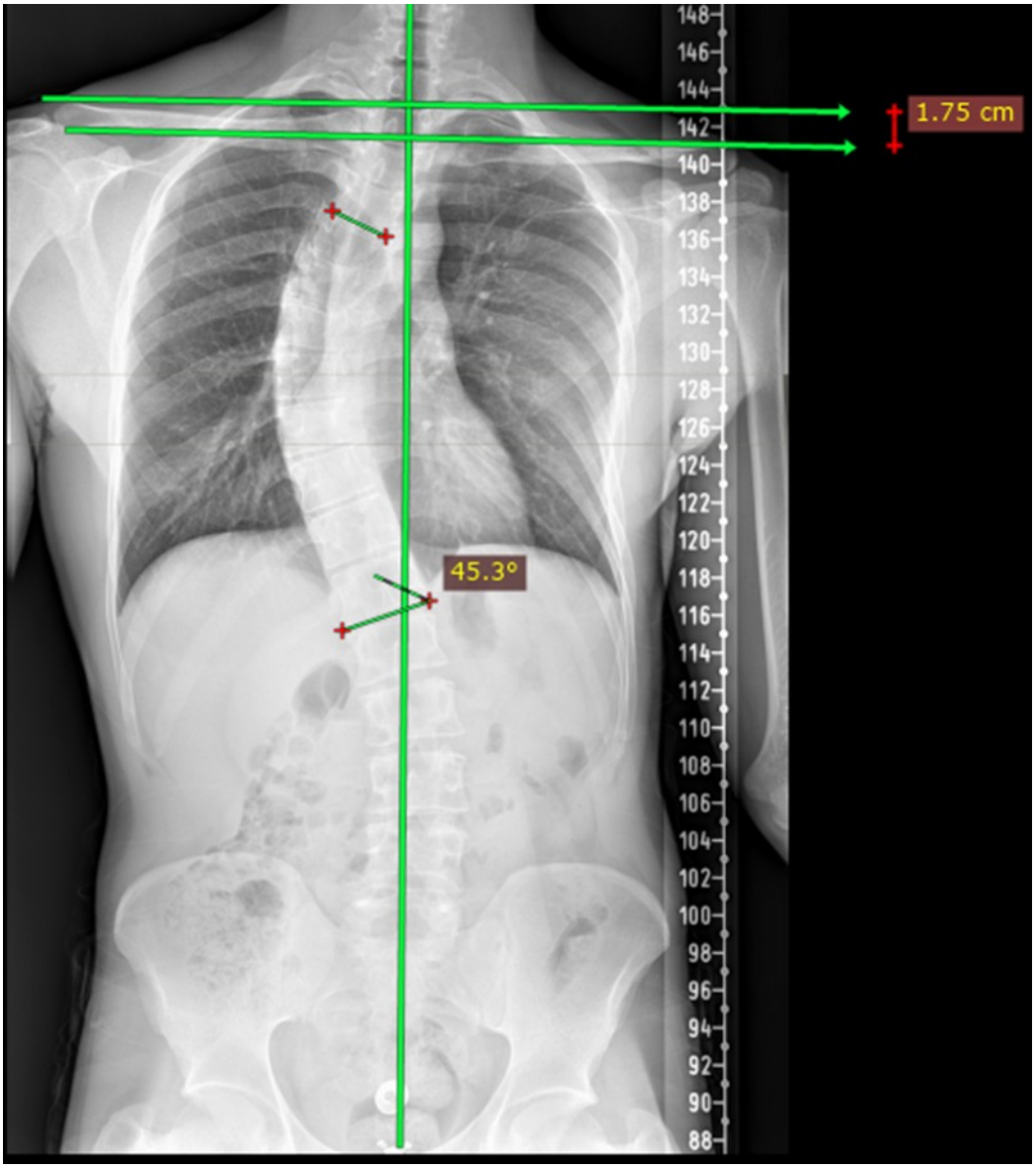

Figure 2B: Reduction of the postoperative cob angle of the patient to 17.3 and evaluation of shoulder balance.

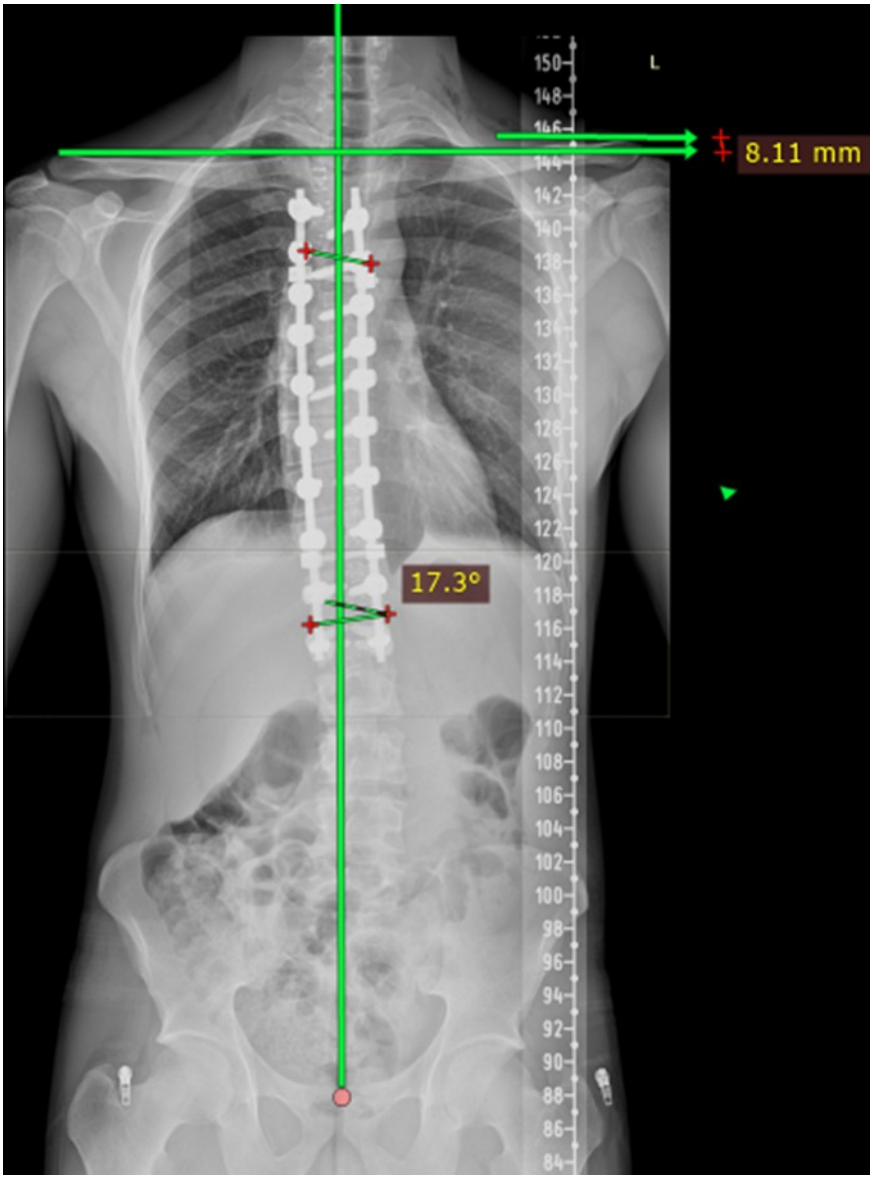

Table 1. Comparison of the demographic parameters between the groups

	Proximal fusion level		
Variables	**T2** (N=62)	**T4** (N=53)	**P value**
Age at the surgery (years)	14.6 ± 1.4	14.8 ± 1.6	0.511
Gender n, (%)			
-Male	25 (40)	20 (38)	0.777
-Female	37 (59.7)	33 (62.3)	
Follow-up (months)	66.2 ± 4.3	65.8 ± 4.2	0.580
Risser grade at the surgery	3.2 ± 0.9	3.0 ± 0.8	0.141
Height (cm)			
-Preoperative	159.3 ± 5.8	158.8 ± 6.0	0.690
-Postoperative	163.9 ± 6.1	162.4 ± 6.3	0.203
Distal fusion level n, (%)			
-T12	9 (14)	6 (11.3)	0.715
-L1	19 (30)	14 (26)	
-L2	34 (54)	33 (62)	

The data are given as mean ± standard deviation or n, (%)

T: Thoracic; **L:** Lumbar

Table 2. Comparison of the groups in terms of radiological and clinical parameters

	Proximal fusion level		
Variables	**T2 (N=62)**	**T4 (N=53)**	**P value**
Cobb angle (°)			
-Preoperative	52.9 ± 7.3	52.0 ± 7.0	0.481
-Preoperative bending	35.5 ± 5.5	33.3 ± 4.6	**0.017**
-Postoperative	8.1 ± 4.0	9.8 ± 6.4	0.077
Thoracic kyphosis angle (°)			
-Preoperative	17.8 ± 3.1	18.0 ± 3.3	0.807
-Postoperative	27.6 ± 4.3	26.9 ± 3.7	0.337
Trunk shift (mm)			
-Preoperative	28.8 ± 6.5	29.2 ± 6.7	0.754
-Postoperative	5.7 ± 2.7	6.9 ± 3.4	**0.047**
Shoulder imbalance (mm)			
-Preoperative	12.1 ± 3.7	12.4 ± 3.6	0.602
-Postoperative	2.9 ± 3.3	4.3 ± 3.3	**0.023**
T1 tilt angle (°)			
-Preoperative	8.7 ± 2.6	6.9 ± 2.4	**<0.001**
-Postoperative	4.0 ± 1.9	4.7 ± 1.9	0.054
Lumbar lordosis angle (°)			
-Preoperative	46.0 ± 5.2	45.8 ± 5.1	0.835
-Postoperative	48.4 ± 4.6	48.0 ± 4.2	0.610
Sagittal imbalance n, (%)			
-Neutral	55 (88)	48 (90)	0.802
-Positive imbalance	4 (6)	2 (4)	
-Negative imbalance	3 (5)	3 (5)	
SRS 22 score (final)			
-Pain	3.7 ± 0.5	3.9 ± 0.6	0.124
-Self-image	3.9 ± 0.7	3.6 ± 0.7	**0.013**
-Function/activity	4.0 ± 0.7	3.6 ± 0.8	**0.011**
-Mental health	3.7 ± 0.7	3.1 ± 0.6	**<0.001**
-Subtotal score	4.0 ± 0.5	3.5 ± 0.6	**<0.001**
-Satisfaction	4.4 ± 0.7	3.8 ± 0.9	**0.002**
-Total score	4.0 ± 0.5	3.5 ± 0.6	**<0.001**
ODI score (final)	4.3 ± 2.3	5.1 ± 2.4	0.065
Complications			
-Screw misplacement	9 (14)	3 (5)	0.140
-PJK	0 (0)	2 (4)	0.210
-Pseudarthrosis	0 (0)	0 (0)	N/A
-Adding-on	4 (6)	9 (17)	0.086

The data are given as mean ± standard deviation or n, (%); Bold p values are significant

SRS 22: Scoliosis patient questionnaire version 22; **ODI:** Oswestry disability index; **T:** Thoracic

PJK: Proximal Junctional Kyphosis