

# Does Thoracic Kyphosis Have any Importance in Selective Versus Nonselective Fusion Preference in Patients with Lenke Type 5C Adolescent Idiopathic Scoliosis?

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## ABSTRACT

**AIM:** To investigate the importance of thoracic kyphosis (TK) for treatment preference in patients with Lenke Type 5C adolescent idiopathic scoliosis by comparing radiological outcomes of the patients who underwent selective fusion (SF) or nonselective fusion (NSF).

**MATERIAL and METHODS:** Twenty-nine patients with Lenke Type 5C AIS were included and then divided into two groups as per the fusion procedure used in the surgical treatment. SF group including 16 patients (14 female patients; mean age = 15.56 yr; age range, 14–18) with normal TK and NSF group including 13 patients (nine female patients; mean age = 15.54 yr, age range, 13–18) with thoracic hyperkyphosis. Thoracolumbar/lumbar (TL/L) Cobb, thoracic (T) Cobb, TK and lumbar lordosis (LL), pelvic incidence (PI), pelvic tilt (PT), and sacral slope (SS) were measured on standing spine radiographs preoperatively and at the final follow-up. The correction rates (CRs) of Cobb angles and the difference in each other radiological parameters were calculated.

**RESULTS:** No significant differences were observed in the mean CRs of TL/L Cobb and T Cobb angles, PI, SS, and PT ( $p=0.313$ ,  $p=0.444$ ,  $p=0.51$ ,  $p=0.472$ , and  $p=0.14$ , respectively). However, significant differences were observed in the mean TK angle, which was  $-2.13^\circ \pm 13.52^\circ$  (range,  $29-27^\circ$ ) in SF group and  $28.46^\circ \pm 15.05^\circ$  (range,  $-4^\circ-47^\circ$ ) in NSF group ( $p=0.001$ ), and LL angle was  $0.88^\circ \pm 14.23^\circ$  (range,  $-21^\circ-32^\circ$ ) in SF group and  $11.54^\circ \pm 17.79^\circ$  (range,  $-31^\circ-34^\circ$ ) in NSF group ( $p = 0.016$ ).

**CONCLUSION:** In patients in whom Lenke's sagittal modifier is N, SF can be performed efficiently. NSF can be preferred for those with (+) Lenke's sagittal modifiers as it provides better TK control.

**KEYWORDS:** Adolescent idiopathic scoliosis, Selective fusion, Nonselective fusion, Thoracic kyphosis, Type 5C

## INTRODUCTION

The main goals of corrective surgery in adolescent idiopathic scoliosis (AIS) are to provide an optimally corrected and well-balanced spine, to prevent curve progression, and to provide maximum functionality of the spine with minimal fused motion segments (6,18). Considering

these goals, the concept of selective fusion (SF), in which the structural curve is fused while sparing the nonstructural curves to preserve the mobility of the spine, has gained popularity among spine surgeons for the past few decades (6,13,15,20,24,25). Most of these surgeons utilized the King–Moe classification until the 1980s. Lenke et al. (11) defined a new classification in 2001 to address King–Moe

classification's shortcomings, such as poor reliability and reproducibility (5). Unlike King–Moe classification, the Lenke classification, which evaluates not only the coronal plane but also the sagittal plane, is the most widely used classification today (Table I) (3).

According to the Lenke classification, Type 5 represents the third most prevalent curve type of AIS, and this curve type is characterized by a single structural thoracolumbar/lumbar (TL/L) curve with nonstructural or compensatory thoracic (T) curve (Table I). The Lenke classification suggests a selective TL/L fusion for all of the Type 5 curves (11). On the other hand, remarkable number of experienced scoliosis surgeons prefer considerably nonselective fusion (NSF) for the Type 5 curves (8,10). This often leads to the questioning of the treatment recommendations of the Lenke classification (3,15). Although Lenke classification analyzes the sagittal plane as (+), N, and (-), it does not consider it in the choice of treatment, and it has limitations with overall thoracic kyphosis (TK). This situation can be a dilemma for the spine surgeon who refers to the Lenke classification in the choice of treatment, especially in the treatment of AIS patients with advanced sagittal plane deformity.

The aim of this study is to investigate the importance of TK for the treatment choice in Lenke Type 5C patients by comparing the radiological outcomes of the patients who underwent SF or NSF with respect to this criterion. We hypothesize that NSF provides better correction of the TK and lumbar lordosis (LL),

and it has negligible superiority on restoring pelvic parameters in cases with (+) Lenke's sagittal modifier whereas SF improves TL/L Cobb and T Cobb angles as effective as NSF in cases with Lenke's sagittal modifier is N.

**MATERIAL and METHODS**

**Study Design and Setting**

This retrospective study was conducted on patients who were diagnosed and operated for Lenke Type 5C AIS by a single spine surgeon between 1998 and 2009 in a single tertiary referral center. A preprint version of this study is available on a preprint server (9).

Inclusion criteria for the study were as follows:

1. A diagnosis of Lenke Type 5C AIS with thoracic normal or hyperkyphosis;
2. Surgical treatment with posterior pedicle screw instrumentation;
3. Complete sets of preoperative and final follow-up standing full-length anteroposterior (AP) and lateral radiographs of the spine.

Exclusion criteria were as follows:

1. A history of previous spinal surgery (hybrid or anterior pedicle screw instrumentation or corrective osteotomies);

**Table I:** Curve Types Based on the Lenke Classification of Adolescent Idiopathic Scoliosis

| Curve Type          | Proximal Thoracic | Main Thoracic       | Thoracolumbar/lumbar | Description                            |
|---------------------|-------------------|---------------------|----------------------|--|
| Type 1              | Non-Structural    | Structural (Major)* | Non-Structural       | Main Thoracic                          |
| Type 2              | Structural        | Structural (Major)* | Non-Structural       | Double Thoracic                        |
| Type 3              | Non-Structural    | Structural (Major)* | Structural           | Double Major                           |
| Type 4 <sup>§</sup> | Structural        | Structural (Major)* | Structural           | Triple Major                           |
| Type 5              | Non-Structural    | Non-Structural      | Structural (Major)   | Thoracolumbar/lumbar                   |
| Type 6              | Non-Structural    | Structural          | Structural (Major)   | Thoracolumbar/lumbar-<br>Main Thoracic |

|   |  |
|---|--|
| *Major = Largest Cobb measurement, always structural<br>Minor = All other curves with structural criteria applied<br>§Type 4 - Main thoracic or thoracolumbar/lumbar can be major curve |  |
| <b>STRUCTURAL CRITERIA</b>  |  |
| Proximal Thoracic   | - Side Bending Cobb ≥ 25 degrees<br>T2-T5 Kyphosis ≥ 20 degrees  |
| Main Thoracic   | - Side Bending Cobb ≥ 25 degrees<br>T10-L2 Kyphosis ≥ 20 degrees |
| Thoracolumbar/lumbar  | - Side Bending Cobb ≥ 20 degrees<br>T10-L2 Kyphosis ≥ 20 degrees |

| <b>MODIFIERS</b>      |  |
|-----------------------|--|
| Lumbar Spine Modifier | Center Sacral Vertical Line to Lumbar Apex |
| <b>A</b>              | Between pedicles                           |
| <b>B</b>              | Touches spinal body                        |
| <b>C</b>              | Completely medial                          |

| <b>Thoracic Sagittal Profile T5-T12</b> |            |
|---|------------|
| Modifier                                | Cobb angle |
| <b>- (Hypo)</b>                         | < 10°      |
| <b>N (Normal)</b>                       | 10° - 40°  |
| <b>+ (Hyper)</b>                        | > 40°      |

2. lost to follow-up;
3. concomitant neuromuscular or congenital disorders;
4. being unwilling to participate in the study.

**Patients**

A total of 37 patients were evaluated based on the above eligibility criteria. Four patients who were lost during follow-up, two patients treated with spinal surgery previously, and two patients with neuromuscular disorder were excluded. After excluding eight patients, remaining 29 patients with Lenke Type 5C AIS who met the inclusion criteria were included in the study and invited to a final follow-up examination for radiographic assessment. The study protocol was approved by local ethical committee (ATADEK ref. number: 2017/17-3; approval issue date: October 27, 2017), and the study was performed in accordance with the ethical standards in the 1964 Declaration of Helsinki.

The main indication for the surgical treatment of AIS patients was having a TL/L Cobb angle of  $>35^\circ$ . Three of the patients in the group SF and two of the patients in the group NSF demonstrating TL/L Cobb angle of  $<35^\circ$  were operated due to rapid progression of their deformity before skeletal maturity, truncal shift, and cosmetic reasons. Patients included in the study were categorized into two groups based on the fusion procedure used in the surgical treatment and TK angle: SF group including patients with normal TK and NSF group including patients with thoracic hyperkyphosis (Figure 1). Normal TK is defined as  $10^\circ$  to  $40^\circ$  of thoracic convexity and thoracic hyperkyphosis as  $>40^\circ$  (11). In the SF group, upper-instrumented vertebrae were determined according to the upper-end vertebrae, which are designated by the Cobb method. In the NSF group, it was determined according to the

shoulder asymmetry in the coronal plane and the upper-end vertebra of the TK in the sagittal plane.

**Surgical Technique**

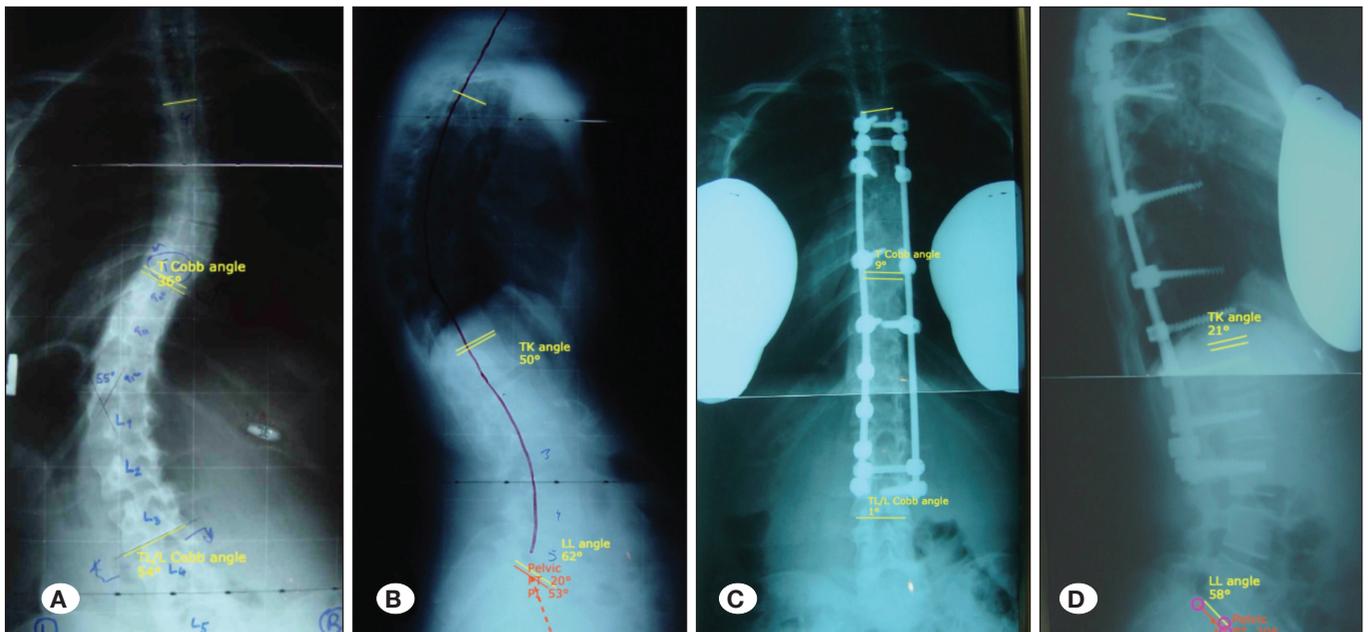
All surgical procedures were performed by the same senior surgeon. All patients underwent general anesthesia and placed in a prone position on a surgical table. After a posterior midline incision was made, subperiosteal paraspinal muscles were dissected to expose the posterior elements of the spinal fusion levels. The pedicle screws were inserted by a free-hand technique and checked with intraoperative fluoroscopy (26). First, a lordotic-shaped titanium rod was placed at the convex side of curvature to obtain lordosis and correct the coronal deformity. The concave rod was given less lordosis than the first rod. Curve correction was achieved using the rod-rotation maneuver with convex rod, followed by slight convex compression and concave distraction. After decortication of the posterior elements and facet excision autogenous and allogenic bone grafts were used for fusion.

**Radiographic Outcome Measures**

Radiological parameters examined in the study were as follows:

- Coronal spinal parameters: 1) thoracolumbar/lumbar (TL/L) Cobb angle and 2) thoracic (T) Cobb angle;
- Sagittal spinal parameters: 3) thoracic kyphosis (TK) angle and 4) lumbar lordosis (LL) angle;
- Pelvic parameters: 5) pelvic incidence (PI), 6) sacral slope (SS), and 7) pelvic tilt (PT).

All radiological measurements were performed on standing AP and lateral radiographs of the entire spine, by a single



**Figure 1:** Preoperative (A,B) and 37-month follow-up radiographs (C,D) of a 25-yr-old female patient with a  $54^\circ$  TL/L Cobb angle,  $36^\circ$  T Cobb angle, and  $50^\circ$  T hyperkyphosis were corrected by nonselective fusion procedure. TL/L Cobb, T Cobb, and T kyphosis were  $1^\circ$ ,  $9^\circ$ , and  $21^\circ$ , respectively.

attending surgeon, who did not participate in the treatment of the patients, using a validated software (Surgimap™, Nemaris Inc, New York), preoperatively and at the final follow-up. TK angle was measured from the superior end plate of T5 vertebra to the inferior end plate of T12 vertebra. LL angle was measured from the superior end plate of L1 vertebra to the superior end plate of S1 vertebra.

The correction rate of each Cobb angle in both groups was calculated using the following equation: (preoperative X angle – final follow-up X angle)/preoperative X angle in the standing film × 100.

**Statistical Analysis**

For statistical analysis, IBM SPSS Statistics software, version 22.0 (IBM Corp., Armonk, New York, NY, USA) was used. Kolmogorov–Smirnov test was used to determine normality tests. Between-group comparisons were performed using the Student *t*-test for parametric variables, Mann–Whitney *U* test for nonparametric variables, and Fisher’s exact test for categorical variables. Statistical significance was set at *p*<0.05. The quality of the current study was assessed using

criteria from the STROBE checklist for observational studies (23).

**RESULTS**

The mean follow-up was 39.13 (range, 24–77) months in the SF group and 43.23 (range, 24–65) months in the NSF group (Table II). The patients’ radiological outcomes in each group are demonstrated in Table III. In the preoperative measurements between the two groups, no significant differences were observed in all radiographic outcome measurements, except TK angle. The mean TK angle was 29.19° ± 6.88° (range, 16°–40°) in SF group and 51.77° ± 8.77° (range, 41°–66°) in NSF group (*p*=0.001).

In the final follow-up measurements, the significant difference was observed in the mean TK angle and LL angle, which were higher in NSF group. TK angle difference was –2.13° ± 13.52° (range, –29° to 27°) in SF group and 28.46° ± 15.05° (range, –4° to 47°) in NSF group (*p*=0.001). LL angle difference was 0.88° ± 14.23° (range, –21° to 32°) in SF group and 11.54° ± 17.79° (range, –31° to 34°) in NSF group (*p*=0.016) (Table IV).

**Table II:** Demographic Characteristics of the Study Participants

|                            | Group SF (16 patients) | Group NSF (13 patients) | <i>p</i> *         |
|----------------------------|------------------------|-------------------------|--------------------|
| Gender                     | 14F, 2M                | 9F, 4M                  | 0,364 <sup>a</sup> |
| Mean age at surgery (year) | 15.56 (range, 14–18)   | 15.54 (range, 13–18)    | 0.968 <sup>b</sup> |
| Follow-up duration (month) | 39.13 (range, 24–77)   | 43.23 (range, 24–65)    | 0,313 <sup>b</sup> |

<sup>a</sup> Fisher’s exact test; <sup>b</sup> Mann-Whitney *U* test; \**p*<0,05  
**SF:** Selective fusion, **NSF:** Non-selective fusion.

**Table III:** Radiographic Outcome Measures at All Study Interval Assessments

| Variables              |           | Preoperative measurements |               |               | Final follow-up measurements |               |              |
|------------------------|-----------|---------------------------|---------------|---------------|------------------------------|---------------|--------------|
|                        |           | Group SF                  | Group NSF     | <i>p</i>      | Group SF                     | Group NSF     | <i>p</i> *   |
| <b>TL/L Cobb angle</b> | Mean ± SD | 38.75 ± 9.83              | 41.77 ± 10.6  | 0.434         | 10.25 ± 10.31                | 12.38 ± 7.73  | 0.542        |
|                        | Range     | 27–61                     | 27–66         |               | 1–36                         | 3–32          |              |
| <b>T Cobb angle</b>    | Mean ± SD | 16.31 ± 7.2               | 25.08 ± 11.54 | 0.019         | 5.5 ± 4.63                   | 7.38 ± 5.39   | 0.32         |
|                        | Range     | 6–29                      | 8–45          |               | 0–17                         | 1–15          |              |
| <b>TK angle</b>        | Mean ± SD | 29.19 ± 6.88              | 51.77 ± 8.77  | <b>0.001*</b> | 31.31 ± 9.47                 | 23.31 ± 10.3  | <b>0.001</b> |
|                        | Range     | 16–40                     | 41–66         |               | 12–57                        | 4–47          |              |
| <b>LL angle</b>        | Mean ± SD | 53.81 ± 13.85             | 58.54 ± 12.54 | 0.349         | 52.94 ± 9.79                 | 47 ± 8.28     | 0.094        |
|                        | Range     | 28–84                     | 31–69         |               | 31–68                        | 32–62         |              |
| <b>PI</b>              | Mean ± SD | 53.13 ± 17.51             | 53.62 ± 15    | 0.937         | 50.56 ± 13.45                | 50.23 ± 16.61 | 0.953        |
|                        | Range     | 24–93                     | 37–82         |               | 34–77                        | 29–75         |              |
| <b>PT</b>              | Mean ± SD | 14.81 ± 10.47             | 15.77 ± 10.4  | 0.808         | 17.19 ± 10.38                | 17.92 ± 10.49 | 0.852        |
|                        | Range     | -4–30                     | -5–35         |               | 2–38                         | 2–39          |              |
| <b>SS</b>              | Mean ± SD | 38.44 ± 9.71              | 37.46 ± 8.97  | 0.783         | 32.94 ± 9.21                 | 35 ± 5.07     | 0.476        |
|                        | Range     | 21–63                     | 27–50         |               | 12–43                        | 27–45         |              |

\*The significance level was set at *p*<0.05.

**TL/L:** Thoracolumbar/Lumbar; **T:** Thoracic; **TK:** Thoracic kyphosis; **LL:** lumbar lordosis; **PI:** Pelvic incidence, **SS:** Sacral slope, **PT:** Pelvic tilt, **SF:** Selective fusion, **NSF:** Non-selective fusion.

**Table IV:** Comparative Results for Correction Rates of Radiographic Parameters Between Both Groups

| Variable                 |                    | Group SF                   | Group NSF                   | p*           |
|--------------------------|--------------------|----------------------------|-----------------------------|--------------|
| TL/L Cobb angle CR (%)   | Mean ± SD<br>Range | 74.58 ± 24.98<br>7.69–97.5 | 70.02 ± 16.18<br>39.62–90.9 | 0.313        |
| T Cobb angle CR (%)      | Mean ± SD<br>Range | 66.76 ± 23.4<br>9.09–100   | 70.25 ± 19.17<br>40–92      | 0.444        |
| Difference** in TK angle | Mean ± SD<br>Range | -2.13 ± 13.52<br>-29–27    | 28.46 ± 15.05<br>-4–47      | <b>0.001</b> |
| Difference in LL angle   | Mean ± SD<br>Range | 0.88 ± 14.23<br>-21–32     | 11.54 ± 17.79<br>-31–34     | <b>0.016</b> |
| Difference in PI         | Mean ± SD<br>Range | 2.56 ± 14.67<br>-27–26     | 3.38 ± 11.18<br>-11–23      | 0.51         |
| Difference in PT         | Mean ± SD<br>Range | -2.38 ± 10.75<br>-22–14    | -2.15 ± 10.62<br>-23–14     | 0.472        |
| Difference in SS         | Mean ± SD<br>Range | 5.5 ± 10.36<br>-19–20      | 2.46 ± 5.72<br>-9–10        | 0.14         |

\*The significance level was set at  $p < 0.05$ .

\*\*Differences were calculated as preoperative measurement – final follow-up measurement

**CR:** Correction rate, **TL/L:** Thoracolumbar/Lumbar, **T:** Thoracic, **TK:** Thoracic kyphosis, **LL:** lumbar lordosis, **PI:** pelvic incidence, **SS:** Sacral slope, **PT:** Pelvic tilt, **SF:** Selective fusion, **NSF:** Non-selective fusion.

The correction rate of TL/L Cobb and T Cobb angles and difference in PI, PT, and SS in both groups is also presented in Table IV. Between the two groups, there were no significant correction rates of TL/L Cobb and T Cobb angles or differences in PI, PT, and SS.

## ■ DISCUSSION

In the surgical treatment of Lenke Type 5 AIS, SF of the structural TL/L curve has been considered to be the leading treatment method (11,16,25). Many studies have reported satisfactory radiological and clinical outcomes, as well as spontaneous T curve correction with SF. However, Lenke Type 5 AIS is unique, and it differentiates from other types as the T kyphosis cannot be controlled by only fusing the structural TL curve. Although Lenke classification identifies the T kyphosis as (+), N, and (-), it made no recommendation regarding kyphosis.

Contrary to the recommendations of the Lenke classification, some spine surgeons have been reported to perform NSF in 27% of patients with Lenke Type 5 AIS (10). The main reason for performing NSF has been to control the T coronal plane deformity (10). However, it has been stated that maintaining sagittal balance is crucial for favorable radiological and clinical outcomes, and it should not be neglected in AIS (8,17). T5-T12 T kyphosis and T1-T4 sagittal alignment were determined as the criterion to be considered in achieving sagittal balance (8,21). In a study by Connolly et al., sagittal plane parameters have been stated to be more substantial in the long-term health of the spine (4). Consistent with this statement, in another study by Takayama et al., it was reported that patients with low functional scores were the ones whose sagittal

balances could not have been restored (22). Considering that the importance of the sagittal plane in the treatment of AIS has been supported by current publications (24), another reason to extending the fusion to T spine may be to control and restore the T kyphosis (24). Accordingly, it was planned to investigate effects of T kyphosis on the treatment choice and radiological outcomes in Lenke Type 5C patients in the current study. Moreover, the importance of the correction of T kyphosis in the hypokyphotic spine was also emphasized in a study by Suk et al. (21). In our study, hypokyphotic patients were not included in the study due to underpowering; thus, only normokyphotic and hyperkyphotic patients were compared.

In a study by Lark et al., 58 Lenke Type 5 patients underwent SF or NSF, and a significant difference was reported in both postoperative TL/L Cobb and T Cobb angles in the matched groups (The mean TL/L Cobb angle was  $19^\circ \pm 6^\circ$  in SF group, and it was  $13^\circ \pm 6^\circ$  in NSF group,  $p < 0.001$ ; mean T Cobb was  $22^\circ \pm 9^\circ$  in SF, and it was  $12^\circ \pm 6^\circ$  in NSF,  $p < 0.001$ ) (10). In our study, there was no significant difference between the groups in terms of postoperative TL/L Cobb and T Cobb angles. (The mean TL/L Cobb angle was  $10.25^\circ \pm 10.31^\circ$  in the SF group and  $12.38^\circ \pm 7.73^\circ$  in the NSF group [ $p = 0.542$ ]; the mean T Cobb angle was  $5.5^\circ \pm 4.63^\circ$  in the SF group and  $7.38^\circ \pm 5.39^\circ$  in the NSF group [ $p = 0.32$ ]). In that study, TK increased in the SF group, and it decreased in the NSF group postoperatively. In parallel, TK increased in the SF group ( $-2.13^\circ \pm 13.52^\circ$ ) and decreased in the NSF group ( $28.46^\circ \pm 15.05^\circ$ ) in our study ( $p = 0.001$ ). Contrary to reported postoperative hypokyphosis (mean:  $18^\circ \pm 6^\circ$ ) by Lark et al. in the NSF group, 12 patients had normokyphosis, and one patient had hypokyphosis in NSF group postoperatively in our study (Table V). The reason for this difference may be that patients who underwent NSF

**Table V:** Results for Kyphotic Status Between Both Groups

| Variable       | Group SF |        | Group NSF |        |
|----------------|----------|--------|-----------|--------|
|                | Preop    | Postop | Preop     | Postop |
| Hypo kyphotic  | 0        | 0      | 0         | 1      |
| Normo kyphotic | 16       | 16     | 0         | 11     |
| Hyper kyphotic | 0        | 0      | 13        | 1      |

**Preop:** Preoperatively, **Postop:** Postoperatively, **SF:** Selective fusion, **NSF:** Non-selective fusion.

were hyperkyphotic ones in our study, whereas they were normokyphotic ones in that study. Another reason for that may be the longer time required for the normalization of the sagittal profile, as stated in a meta-analysis by Pasha et al. (14). The other spinopelvic parameters were also evaluated in our study. Coherent with our findings, in the preoperative evaluation of Lenke Type 5 AIS patients, the mean values of spinopelvic parameters reported by Farshad et al. (7) were as  $48^\circ \pm 13^\circ$ ,  $36^\circ \pm 9^\circ$ ,  $12^\circ \pm 7^\circ$ , and  $50^\circ \pm 12^\circ$  for the PI, SS, PT, and LL, respectively. As reported in the literature, increased sacral slop was present in our patient series as well to probably compensate for increased LL (Table III) (2,7,19). Although PI and SS decreased, and PT increased postoperatively in both groups, the differences were not statistically significant ( $p=0.496$ ,  $p=0.051$ ,  $p=0.391$  for SF group and  $p=0.324$ ,  $p=0.154$ ,  $p=0.479$  for the NSF group, respectively).

Lonner et al. reported that the frequency of complications has been increasing related to AIS surgery (12). In another study, it was reported that post junctional kyphosis (PJK) occurred in 28% of patients with AIS. In a study in which PJK was reported as 8.5% in Lenke Type 5 AIS, hyperkyphosis was defined as the main risk factor. Also, Wang et al. reported that PJK was frequently seen in short-segment instrumentation (24). In our study, it has been demonstrated that SF can be performed in patients with Lenke Type 5 AIS, and T sagittal profile can be restored better with NSF in patients with TK. Contrary to those reported in the literature, the reason for developing PJK in none of the 29 patients in our series with a mean of 39.13 months follow-up might be due to the consideration of the sagittal plane analysis in the preference of surgical treatment method.

Lenke classification does not adequately evaluate the sagittal plane. Based on this shortcoming, Abelin-Genovois et al. described a new classification that evaluates the sagittal plane in more detail in AIS and would aiming contributes to guiding the treatment (1). They described a new AIS sagittal classification system complementary to the Lenke classification. This classification describes three sagittal types based on the location of the sagittal structural curves, independent of the coronal type of curve: Type 1, normal TK; Type 2a, TK with neutral TL junction; Type 2b, TK with kyphotic TL junction; Type 3, cervicothoracic kyphosis with TL lordosis. In our study, hypokyphotic patients were not included in the study; only patients with normokyphosis and hyperkyphosis were compared. All the patients had a Type 1 sagittal profile in the group SF, whereas 53.84% of the patients

had a Type 1 sagittal profile, and 46.16% of the patients had a Type 3 sagittal profile in the group NSF in our study. This can be interpreted that if kyphosis is cervicothoracic and the inflection point shifted to more cranial levels, it may be the reason why NSF is preferred. Additionally, as the authors stated in their treatment recommendations, we concluded that it is beneficial to preserve the harmonious sagittal alignment in Abelin-Genovois Type 1 cases and that SF should be primarily preferred in these cases. In our retrospective case series, the patients with Lenke Type 5 AIS who underwent SF or NSF were compared radiologically. When the Cobb angles are evaluated in both groups, the mean T curves angles were not high, so they can be considered as nonstructural. Whereas SF can be performed for both groups according to the Lenke classification, the surgeon included the T region into the fusion area in those who have high TK based on his own experience. While the sagittal modifier of Lenke remains N in patients undergoing SF, it changed from (+) to N in 12 of the patients who underwent NSF. These findings show us that the sagittal plane evaluation of the Lenke classification system may be insufficient to guide the treatment. In this study, in the midterm to long-term follow-up, it has been shown that SF can be performed for the patients with Lenke Type 5 AIS, additionally the sagittal plane is restored better with NSF in patients with TK.

This study calls attention to the importance of TK, which the Lenke classification does not consider in the treatment recommendation, as a determinant in the choice of SF versus NSF in patients with Lenke Type 5C AIS by evaluating TL/L, T Cobb angles, TK, LL, PI, SS, and PT. It must be noted that the findings of this study should be supported by prospective randomized controlled trials involving a larger number of patients.

This study was retrospective in nature, and it contains similar deficiencies with other retrospective studies. First, the outcomes of the SF and NSF treatments were evaluated only radiologically. The sample size was relatively small. The decision to perform a SF versus NSF was mainly based on TK, and there was no control group. Additionally, T Cobb angles and T kyphosis were higher in the NSF group (T Cobb =  $25.08^\circ$ ) compared with the SF group (T Cobb =  $16.31^\circ$ ). Not only T kyphosis but also the magnitude of the T Cobb angle might have influenced the decision of fusion level preference. The main strength of our study is that the patients in the study were homogeneous in terms of age, gender, follow-up duration, and preoperative sagittal plane parameters except for T5-

T12 TK. All the patients underwent posterior instrumentation and fusion by the same surgeon with the same pedicle screw instrumentation system. Additionally, a considerable length of follow-up duration a mean of 39.13 months is another strength of the study.

## ■ CONCLUSION

The findings of this study support that TK can be a decision-making criterion in the preference of NSF versus SF in patients with Lenke Type 5 AIS. In cases in which Lenke's sagittal modifier is N, SF can be performed efficiently. NSF can be preferred for those with (+) Lenke's sagittal modifiers as it provides better TK control.

## ■ AUTHORSHIP CONTRIBUTION

**Study conception and design:** GK, MD

**Data collection:** GK, MD

**Analysis and interpretation of results:** KS, OO

**Draft manuscript preparation:** GK, MD

**Critical revision of the article:** KS, FD, UD

**Other (study supervision, fundings, materials, etc...):** OO

All authors (GK, KS, MD, OO, FD, UD) reviewed the results and approved the final version of the manuscript.

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