Turk Neurosurg 33(1):118-125, 2023

Original Investigation

Received: 07.12.2021
Accepted: 16.06.2022

DOI: 10.5137/1019-5149.JTN.37313-21.4

Published Online: 08.08.2022

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

Gokhan KARADEMIR[1,2], Kerim SARIYILMAZ[2], Mehmet DEMIREL[3], Okan OZKUNT[4], Fatih DIKICI[2], Unsal DOMANIC[3]

[1]Acibadem Maslak Hospital, Department of Orthopaedics and Traumatology, Istanbul, Turkey
[2]Acibadem MAA University, School of Medicine, Department of Orthopaedics and Traumatology, Istanbul, Turkey
[3]Istanbul University, Istanbul Faculty of Medicine, Department of Orthopedics and Traumatology, Istanbul, Turkey
[4]Medicana Bahcelievler Hospital, Clinics of Orthopaedics and Traumatology, Istanbul, Turkey

Corresponding author: Mehmet DEMIREL ✉ dr88.mehmet.demirel@gmail.com

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° ± 13.52° (range, 29–27°) in SF group and 28.46° ± 15.05° (range, –4°–°47°) in NSF group (p=0.001), and LL angle was 0.88° ± 14.23° (range, –21°–32°) in SF group and 11.54° ± 17.79° (range, –31°–34°) 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

Gokhan KARADEMIR : 0000-0002-0894-9785
Kerim SARIYILMAZ : 0000-0002-8680-1428
Mehmet DEMIREL : 0000-0003-1131-7719
Okan OZKUNT : 0000-0002-6768-959X
Fatih DIKICI : 0000-0003-2681-0098
Unsal DOMANIC : 0000-0002-9210-8080

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§	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-Main Thoracic

*Major = Largest Cobb measurement, always structural
Minor = All other curves with structural criteria applied
§*Type 4 - Main thoracic or thoracolumbar/lumbar can be major curve*

STRUCTURAL CRITERIA

Proximal Thoracic	- Side Bending Cobb ≥ 25 degrees T2-T5 Kyphosis ≥ 20 degrees
Main Thoracic	- Side Bending Cobb ≥ 25 degrees T10-L2 Kyphosis ≥ 20 degrees
Thoracolumbar/lumbar	- Side Bending Cobb ≥ 20 degrees T10-L2 Kyphosis ≥ 20 degrees

MODIFIERS

Lumbar Spine Modifier	Center Sacral Vertical Line to Lumbar Apex
A	Between pedicles
B	Touches spinal body
C	Completely medial

Thoracic Sagittal Profile T5-T12	
Modifier	*Cobb angle*
- (Hypo)	*< 10°*
N (Normal)	*10° - 40°*
+ (Hyper)	*> 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°. Three of the patients in the group SF and two of the patients in the group NSF demonstrating TL/L Cobb angle of <35° 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° to 40° of thoracic convexity and thoracic hyperkyphosis as >40° (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

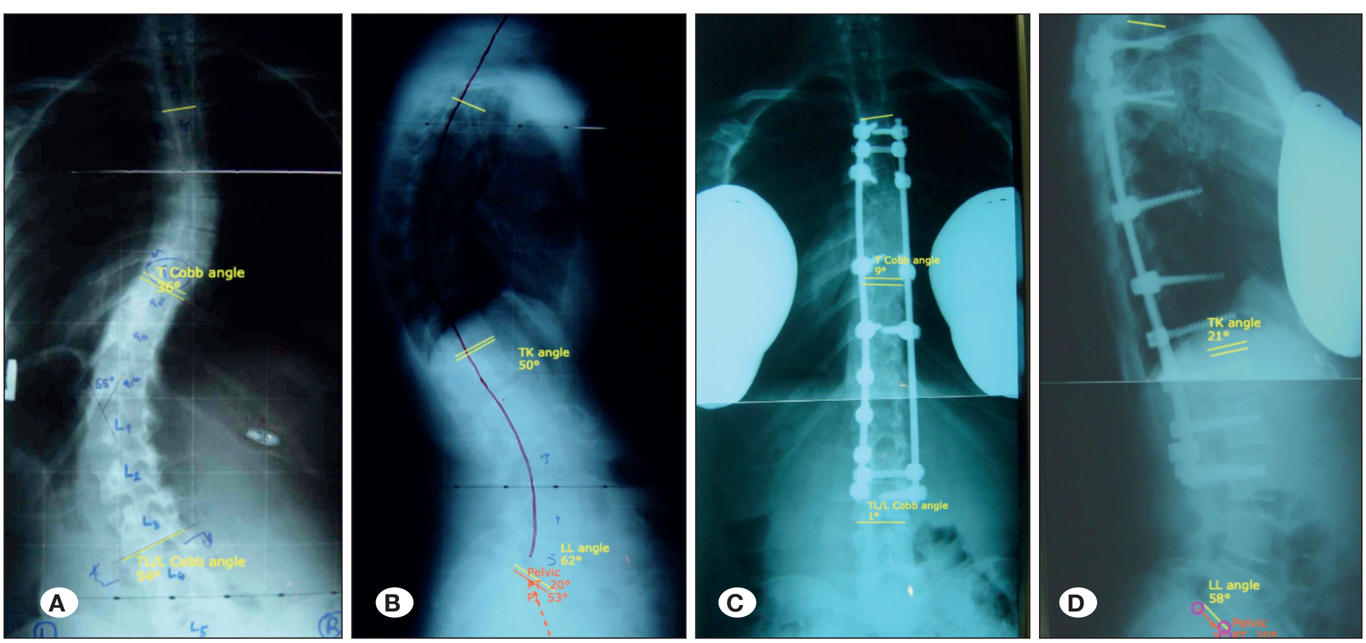

Figure 1: Preoperative **(A,B)** and 37-month follow-up radiographs **(C,D)** of a 25-yr-old female patient with a 54° TL/L Cobb angle, 36° T Cobb angle, and 50° T hyperkyphosis were corrected by nonselective fusion procedure. TL/L Cobb, T Cobb, and T kyphosis were 1°, 9°, and 21°, respectively.

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)	p*
Gender	14F, 2M	9F, 4M	0,364[a]
Mean age at surgery (year)	15.56 (range, 14–18)	15.54 (range, 13–18)	0.968[b]
Follow-up duration (month)	39.13 (range, 24–77)	43.23 (range, 24–65)	0,313[b]

*[a] Fisher's exact test; [b] Mann-Whitney U test. *The significance level was set at 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	p	Group SF	Group NSF	p*
TL/L Cobb angle	Mean ± SD Range	38.75 ± 9.83 27–61	41.77 ± 10.6 27–66	0.434	10.25 ± 10.31 1–36	12.38 ± 7.73 3–32	0.542
T Cobb angle	Mean ± SD Range	16.31 ± 7.2 6–29	25.08 ± 11.54 8–45	0.019	5.5 ± 4.63 0–17	7.38 ± 5.39 1–15	0.32
TK angle	Mean ± SD Range	29.19 ± 6.88 16–40	51.77 ± 8.77 41–66	**0.001***	31.31 ± 9.47 12–57	23.31 ± 10.3 4–47	**0.001**
LL angle	Mean ± SD Range	53.81 ± 13.85 28–84	58.54 ± 12.54 31–69	0.349	52.94 ± 9.79 31–68	47 ± 8.28 32–62	0.094
PI	Mean ± SD Range	53.13 ± 17.51 24–93	53.62 ± 15 37–82	0.937	50.56 ± 13.45 34–77	50.23 ± 16.61 29–75	0.953
PT	Mean ± SD Range	14.81 ± 10.47 -4–30	15.77 ± 10.4 -5–35	0.808	17.19 ± 10.38 2–38	17.92 ± 10.49 2–39	0.852
SS	Mean ± SD Range	38.44 ± 9.71 21–63	37.46 ± 8.97 27–50	0.783	32.94 ± 9.21 12–43	35 ± 5.07 27–45	0.476

**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 Range	74.58 ± 24.98 7.69–97.5	70.02 ± 16.18 39.62–90.9	0.313
T Cobb angle CR (%)	Mean ± SD Range	66.76 ± 23.4 9.09–100	70.25 ± 19.17 40–92	0.444
Difference in TK angle**	Mean ± SD Range	-2.13 ± 13.52 -29–27	28.46 ± 15.05 -4–47	**0.001**
Difference in LL angle	Mean ± SD Range	0.88 ± 14.23 -21–32	11.54 ± 17.79 -31–34	**0.016**
Difference in PI	Mean ± SD Range	2.56 ± 14.67 -27–26	3.38 ± 11.18 -11–23	0.51
Difference in PT	Mean ± SD Range	-2.38 ± 10.75 -22–14	-2.15 ± 10.62 -23–14	0.472
Difference in SS	Mean ± SD Range	5.5 ± 10.36 -19–20	2.46 ± 5.72 -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° ± 6° in SF group, and it was 13° ± 6° in NSF group, $p<0.001$; mean T Cobb was 22° ± 9° in SF, and it was 12° ± 6° 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° ± 10.31° in the SF group and 12.38° ± 7.73° in the NSF group [p=0.542]; the mean T Cobb angle was 5.5° ± 4.63° in the SF group and 7.38° ± 5.39° 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° ± 13.52°) and decreased in the NSF group (28.46° ± 15.05°) in our study (p=0.001). Contrary to reported postoperative hypokphosis (mean: 18° ± 6°) by Lark et al. in the NSF group, 12 patients had normokyphosis, and one patient had hypokphosis 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° ± 13°, 36° ± 9°, 12° ± 7°, and 50° ± 12° 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°) compared with the SF group (T Cobb = 16.31°). 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.

REFERENCES

1. Abelin-Genevois K, Sassi D, Verdun S, Roussouly P: Sagittal classification in adolescent idiopathic scoliosis: Original description and therapeutic implications. Eur Spine J 27:2192-2202, 2018
2. Barrey C, Roussouly P, Le Huec JC, D'Acunzi G, Perrin G: Compensatory mechanisms contributing to keep the sagittal balance of the spine. Eur Spine J 22:834-841, 2013
3. Clements DH, Marks M, Newton PO, Betz RR, Lenke L, Shufflebarger H, Harms Study Group: Did the Lenke classification change scoliosis treatment? Spine 36:1142-1145, 2011
4. Connolly PJ, Von Schroeder HP, Johnson GE, Kostuik JP: Adolescent idiopathic scoliosis. Long-term effect of instrumentation extending to the lumbar spine. J Bone Joint Surg Am 77(8):1210-1216, 1995
5. Cummings RJ, Loveless EA, Campbell J, Samelson S, Mazur JM: Interobserver reliability and intraobserver reproducibility of the system of King et al. for the classification of adolescent idiopathic scoliosis. J Bone Joint Surg Am 80(8):1107-1111, 1998
6. Edwards 2nd CC, Lenke LG, Peelle M, Sides B, Rinella A, Bridwell KH: Selective thoracic fusion for adolescent idiopathic scoliosis with C modifier lumbar curves: 2-to 16-year radiographic and clinical results. Spine 29(5):536-546, 2004
7. Farshad M, Catanzaro S, Schmid SL: The spinopelvic geometry in different Lenke curve types of adolescent idiopathic scoliosis. Spine Deform 4:425-431, 2016
8. Ilharreborde B: Sagittal balance and idiopathic scoliosis: does final sagittal alignment influence outcomes, degeneration rate or failure rate? Eur Spine J 27:48-58, 2018
9. Karademir G, Sariyilmaz K, Ozkunt O, Demirel M, Dikici F, Domanic U: Does thoracic kyphosis have any importance in selective versus nonselective fusion preference in patients with lenke type 5C adolescent idiopathic scoliosis? A contribution to the guidance of the lenke classification. Research Square, Version 1, posted 30 March 2021. Available from: https://doi.org/10.21203/rs.3.rs-340655/v1
10. Lark RK, Yaszay B, Bastrom TP, Newton PO, Harms Study Group: Adding thoracic fusion levels in Lenke 5 curves: Risks and benefits. Spine 38(2):195-200, 2013
11. Lenke LG, Betz RR, Harms J, Bridwell KH, Clements DH, Lowe TG, Blanke K: Adolescent idiopathic scoliosis: A new classification to determine extent of spinal arthrodesis. J Bone Joint Surg Am 83:1169-1181, 2001
12. Lonner BS, Ren Y, Newton PO, Shah SA, Samdani AF, Shufflebarger HL, Asghar J, Sponseller P, Betz RR, Yaszay B: Risk factors of proximal junctional kyphosis in adolescent idiopathic scoliosis-the pelvis and other considerations. Spine Deform 5(3):181-188, 2017
13. McCance SE, Denis F, Lonstein JE, Winter RB: Coronal and sagittal balance in surgically treated adolescent idiopathic scoliosis with the King II curve pattern: A review of 67 consecutive cases having selective thoracic arthrodesis. Spine 23:2063-2073, 1998
14. Pasha S, Ilharreborde B, Baldwin K: Sagittal Spinopelvic Alignment After Posterior Spinal Fusion in Adolescent Idiopathic Scoliosis: A Systematic Review and Meta-analysis. Spine (Phila Pa 1976) 44:41-52, 2019
15. Puno RM, An KC, Puno RL, Jacob A, Chung SS: Treatment recommendations for idiopathic scoliosis: An assessment of the Lenke classification. Spine 28:2102-2115, 2003
16. Qiu G, Zhang J, Wang Y, Xu H, Zhang J, Weng X, Lin J, Zhao Y, Shen J, Yang X, Luk KDK, Lu D, Lu WW: A new operative classification of idiopathic scoliosis: A peking union medical college method. Spine 30:1419-1426, 2005
17. Roussouly P, Labelle H, Rouissi J, Bodin A: Pre-and post-operative sagittal balance in idiopathic scoliosis: A comparison over the ages of two cohorts of 132 adolescents and 52 adults. Eur Spine J 22 Suppl 2:S203-215, 2013
18. Schulz J, Asghar J, Bastrom T, Shufflebarger H, Newton PO, Sturm P, Betz RR, Samdani AF, Yaszay B, Harms Study Group: Optimal radiographical criteria after selective thoracic fusion for patients with adolescent idiopathic scoliosis with a C lumbar modifier: Does adherence to current guidelines predict success? Spine 39:E1368-E1373, 2014
19. Schwab F, Lafage V, Patel A, Farcy JP: Sagittal plane considerations and the pelvis in the adult patient. Spine 34:1828-1833, 2009
20. Senkoylu A, Luk KDK, Wong YW, Cheung KMC: Prognosis of spontaneous thoracic curve correction after the selective anterior fusion of thoracolumbar/lumbar (Lenke 5C) curves in idiopathic scoliosis. Spine J 14(7):1117-1124, 2014

21. Suk SI, Kim WJ, Kim JH, Lee SM: Restoration of thoracic kyphosis in the hypokyphotic spine: A comparison between multiple-hook and segmental pedicle screw fixation in adolescent idiopathic scoliosis. J Spinal Disord 12:489-495, 1999
22. Takayama K, Nakamura H, Matsuda H: Low back pain in patients treated surgically for scoliosis: Longer than sixteen-year follow-up. Spine 34:2198-2204, 2009
23. Von Elm E, Altman DG, Egger M, Pocock SJ, Gøtzsche PC, Vandenbroucke JP: The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement: Guidelines for reporting observational studies. Ann Int Med 147:573-577, 2007
24. Wang F, Xu XM, Wei XZ, Zhu XD, Li M: Spontaneous thoracic curve correction after selective posterior fusion of thoracolumbar/lumbar curves in Lenke 5C adolescent idiopathic scoliosis. Medicine 94(29):e1155, 2015
25. Weinstein SL, Dolan LA, Cheng JCY, Danielsson A, Morcuende JA: Adolescent idiopathic scoliosis. Lancet 371:1527-1537, 2008
26. Yang X, Liu L, Song Y, Zhou C, Zhou Z, Wang L, Wang L: Pre- and postoperative spinopelvic sagittal balance in adolescent patients with lenke type 5 idiopathic scoliosis. Spine 40:102-108, 2015