Selective versus nonselective thoracic fusion in Lenke 1C curves: a meta-analysis of baseline characteristics and postoperative outcomes

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OBJECT Lenke 1C curves are challenging to manage surgically due to the structural thoracic deformity and nonstructural lumbar curve. Selective thoracic fusion (STF) is considered the standard of care because it preserves motion of the lumbar segment, yet nonselective STF (NSTF) remains prevalent. This study aims to identify baseline patient characteristics that drive treatment and to compare postoperative outcomes for both procedures.

METHODS Studies that compared baseline and postoperative demographic data, health-related quality of life (HRQL) questionnaires, and radiographic parameters of patients with Lenke 1C curves undergoing STF or NSTF were identified for meta-analysis. The effect measure is expressed as a mean difference (MD) with 95% CI. A positive MD signifies a greater STF value, or a mean increase within the group.

RESULTS One prospective and 6 retrospective case-control studies with sample size of 488 patients (344 STF and 144 NSTF) were identified. Baseline age, sex, and HRQLs were equivalent, except for better scores in the STF group for the Scoliosis Appearance Questionnaire (SAQ): Unrelated to Deformity item (3.47 vs 3.88, $p = 0.01$) and the Spine Research Society questionnaire, Item 22: Pain (4.13 vs 3.92, $p = 0.04$). Radiographic findings were significantly worse in NSTF, as measured by the thoracolumbar/lumbar (TL/L) Cobb angle (MD: -4.29° , $p < 0.01$) and TL/L apical vertebral translation (AVT) (MD: -6.08 , $p < 0.01$). Radiographic findings significantly improved in STF, as measured in the main thoracic (MT) Cobb angle (MD: -27.78° , $p < 0.01$), TL/L Cobb angle (MD: -16.24° , $p < 0.01$), MT:TL/L Cobb ratio (MD: -0.21 , $p < 0.01$), coronal balance (MD: 0.47 , $p = 0.02$), and thoracic kyphosis (MD: 7.87° , $p < 0.01$); and in NSTF in proximal thoracic (PT) Cobb angle (24° vs 14.1° , $p < 0.01$), MT Cobb angle (53.5° vs 20.5° , $p < 0.01$), and TL/L Cobb angle (41.6° vs 16.6° , $p < 0.01$). Postoperative TL/L Cobb angle (23.1° vs 16.6° , $p < 0.01$) was significantly higher in STF; but PT Cobb angle, MT Cobb angle, and MT:TL/L Cobb ratio are equivalent.

CONCLUSIONS Patients with larger lumbar compensatory curves displaying a larger degree of coronal translation, as measured by the TL/L AVT, are more likely to undergo an NSTF. Contrary to established guidelines, larger MT curve magnitudes and MT:TL/L Cobb angle ratios have not been found to influence the decision to pursue a selective thoracic fusion. Although overall both STF and NSTF groups are found to have effective postoperative coronal balance, the STF group has only modest improvements in the lumbar curve position as determined by a relatively unchanged TL/L AVT. Furthermore, surgeons may prefer NSTF in patients who may have a worse overall perception of their spinal deformity as measured by HRQL measures of pain and desire for appearance change.

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KEY WORDS scoliosis; Lenke 1C curve; thoracic fusion; outcomes; spine

ABBREVIATIONS AIS = adolescent idiopathic scoliosis; AVR = apical vertebral rotation; AVT = apical vertebral translation; HRQL = health-related quality of life; LIV = lowest instrumented vertebra; MD = mean difference; MT = main thoracic; NSTF = nonselective thoracic fusion; PT = proximal thoracic; SAQ = Scoliosis Appearance Questionnaire; SRS-22, -24, -30 = Scoliosis Research Society (questionnaires); STF = selective thoracic fusion; TL/L = thoracolumbar/lumbar.

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THE Lenke Classification System for adolescent idiopathic scoliosis (AIS) was developed in response to several limitations of the King Classification System, including poor interobserver and intraobserver reliability. It is widely used by surgeons as a guide to differentiate between primary and compensatory curves, to determine the extent of fusion needed in various AIS spinal deformities.²⁵ The Lenke 1C/King Type II curve, also known as the “false double major” curve, is characterized by a structural thoracic curve with a significant compensatory nonstructural lumbar curve. Surgical correction focuses on stabilization of significant curves to halt curve progression and attain global spinal balance, while sparing motion segments above and below the fusion construct. However, the optimal surgical strategy for Lenke 1C curves remains controversial.

The concept of selective fusion in spinal deformity surgery was first introduced by Moe in 1958,³⁰ and refined by King and colleagues in their analysis of patients undergoing selective thoracic fusion (STF) for King Type II curves.²¹ The results of this study show successful STF performed using Harrington instrumentation with spontaneous correction of the lumbar compensatory curve in patients when the lowest instrumented vertebra (LIV) of the thoracic fusion is centered over the sacrum. Despite the initially promising experiences with STF, postoperative spinal imbalance and progression of the unfused lumbar curve is nevertheless reported.^{3,20,38,43}

With the evolution of spinal instrumentation and surgical techniques, STF has been shown to provide successful correction of the thoracic curve with spontaneous correction of the uninstrumented lumbar curve to allow for a well-balanced postoperative spinal column;^{5,6,23,32,34,36,40,42} however, the risk for coronal decompensation remains a concern.^{1,13,14,24,28,29,31,32,43} The decision to include the lumbar compensatory curve by performing a nonselective thoracic fusion (NSTF) may provide a “safer” option in the context of preventing revision surgery for coronal decompensation.³² However, it must be weighed against the risk of an increased likelihood of back pain and degenerative changes with a more distal fusion into the mid- and lower lumbar spine.^{7,8}

Recent interest in determining risk factors for postoperative decompensation after STF has led to research attempting to elucidate criteria for predicting the optimal surgical strategy. Factors such as proper selection of the LIV,^{1,3,4,24,29,31,37,41–43} the main thoracic to thoracolumbar/lumbar (MT:TL/L) ratio,^{25,28,34} thoracic “overcorrection,”^{9,5,6,12,13,16,17,19,25,45} and surgical approach have been correlated with risk of postoperative decompensation. Despite guidelines for performing STF, NSTF is still commonly performed, with one study showing only 49% of patients with Lenke 1C curves being treated with an STF.⁹

Given the heterogeneity in the literature with regard to baseline radiographic parameters and health-related quality of life (HRQL) scores between STF and NSTF, the current study used a meta-analysis to elucidate trends to provide a better understanding of treatment patterns for Lenke 1C curves. The goals of this meta-analysis were to determine the drivers of STF versus NSTF and to assess the impact of demographic data and radiographic parameters

on the decision to perform NSTF over STF. Additionally, we sought to provide descriptive radiographic parameters for STF and NSTF and to compare radiographic findings and HRQL scores between both groups postoperatively.

Methods

Using an electronic and manual literature search of the PubMed database, studies were identified that report on STF and/or NSTF treatment modalities for Lenke 1C-type curves. Studies were identified for meta-analysis that compared baseline and postoperative demographic data, HRQLs, and radiographic parameters of patients with Lenke 1C curves undergoing STF or NSTF. The following search query was used for this review study: Lenke 1C. Studies were eliminated based on title, abstract, and manuscript review with regard to inclusion and exclusion criteria (Table 1). If the study included a subset of patients that met inclusion criteria from which data of interest could be extracted, the subset was included. Baseline patient demographic characteristics, such as age and sex, were included for analysis, as well as pre- and postoperative HRQL questionnaire scores, and radiographic parameters.

To establish inconsistency in the study results, a test for heterogeneity was performed. However, all models include fixed-effects modeling. For statistical analysis, Review Manager version 5.2 (Cochrane) was used. We reported the pooled mean difference (MD) comparing STF with NSTF. Variables reported in only one study, and therefore not using meta-statistics, were compared with a Student t-test. These one-study variables are not a part of the meta-analyses currently conducted; however, they do represent important findings that warrant discussion. We have noted that the findings in just one study are not part of the meta-analyses when presented.

In some studies in which standard deviations were not reported, the standard deviation was estimated based on the reported p value.¹⁵ Results are presented graphically, as well as the actual estimated MD with 95% CIs. The effect measures for continuous variables were calculated using the inverse variance test and expressed as the MD between STF and NSTF treatments. Results are displayed graphically, as well as the actual estimated pooled MD with 95% CIs. An MD of 0 within the 95% CI indicates no significant difference between the two treatment options. A positive MD signifies a greater STF value, or a mean increase within the group.

Results

Using an electronic and manual literature search, 7 studies with a total of 488 patients (344 STF, 144 NSTF) are included (Fig. 1, Table 2). Inclusion into the STF group was defined as LIV at or cephalad to L-1, whereas the NSTF included the LIV at or caudal to L-3. A comparison of baseline demographic characteristics between STF and NSTF cohorts is provided only by Demura et al. (Table 3).¹⁰ Baseline HRQL scores show a significantly lower score on the Scoliosis Appearance Questionnaire (SAQ): Unrelated to Deformity ($p = 0.010$) and a significantly lower score on the Scoliosis Research Society (SRS) questionnaire, Item 22: Pain in the STF group ($p = 0.038$). These

TABLE 1. Inclusion and exclusion criteria for STF and NSTF articles

Inclusion Criteria	Exclusion Criteria
Articles published after January 2004	Less than 24 mos follow-up
Patients w/ Lenke 1C curves	Case report or series w/ less than 10 patients
Surgically treated	Published before January 2004
Clinical follow-up >24 mos	Animal studies
English language	Meta-analysis, biomechanical or kinematic studies, review articles, or in vitro studies
Use of validated health-related outcome measures	Single-site results as part of a multi-center trial
Reporting of complication rates	Published in languages other than English
Reporting of radiographic parameters	Study w/ patient overlap from other qualifying studies

finding show that there may be a tendency for surgeons to choose NSTF based on increased baseline pain scores and greater patient desire for change in appearance related to the scoliosis. A comparison of baseline characteristics shows that age was similar between STF patients in all 4 papers (Table 4).

A preoperative comparison between STF and NSTF cohorts is shown in Fig. 2. The MT Cobb angle in STF and NSTF cohorts is equivalent (MD: -1.01° [-5.59° , 3.57°], $p = 0.66$). The proximal thoracic (PT) Cobb angle in STF and NSTF cohorts is also equivalent (MD: -0.90° [-4.37° , 2.57°], $p = 0.61$). The TL/L Cobb angle in STF is significantly less than in NSTF (MD: -4.29° [-6.15° , -2.42°], $p < 0.01$). The MT:TL/L ratio of Cobb angles in STF and NSTF cohorts is equivalent (MD: 0.09 [-0.08 , 0.26], $p = 0.28$). The MT apical vertical translation (AVT) in STF is significantly larger than in NSTF (MD: 5.58 [1.42 , 9.74], $p < 0.01$). The TL/L AVT in NSTF is significantly greater than in STF (MD: -6.08 [-9.66 , -2.50], $p < 0.01$).

The lowest most frequently fused vertebra with instrumentation is L-3 (Fig. 3). A comparison between pre- and

postoperative radiographic parameters for the STF group is shown in Fig. 4. The MT Cobb angle in STF significantly decreased when compared preoperatively (MD: -27.78° [-30.71° , -24.85°], $p < 0.01$), and the coronal balance (in centimeters) significantly improved in STF (MD: 0.47 [0.07 , 0.87], $p = 0.02$). The TL/L Cobb angle in STF significantly decreased from preoperative measurements (MD: -16.24° [-17.99° , -14.48°], $p < 0.01$). The MT:TL/L ratio in STF significantly decreased from baseline (MD: -0.21 [-0.29 , -0.12], $p < 0.01$). The TL/L AVT did not significantly change (MD: -0.42 [-2.81 , 1.97], $p = 0.36$). In the STF approach, the TL/L apical vertebral rotation (AVR) decrease was insignificant compared with preoperative measurements (MD: -1.45 [-3.74 , 0.85], $p = 0.22$). The thoracic kyphosis in STF significantly increased from preoperative measurements (MD: 7.87° [3.36° , 12.39°], $p < 0.01$). Lumbar lordosis in STF did not significantly decrease from baseline (MD: -1.43° [-5.59° , 2.73°], $p = 0.50$).

A comparison between pre- and postoperative radiographic parameters for the NSTF group is provided by Demura et al. only and therefore is not a part of the present meta-analyses. Those authors' original findings are summarized in Table 5. The PT Cobb angle, MT Cobb angle, and TL/L Cobb angle all showed a significant postoperative decrease ($p < 0.01$). However, the Cobb ratio (MT:TL/L) is equivalent ($p = 0.21$). A comparison between postoperative radiographic parameters between NSTF and STF is provided by Demura et al. only and is therefore not a part of the present meta-analyses. Those authors' original findings are summarized in Table 6. The TL/L Cobb angle is significantly less in NSTF postoperatively ($p < 0.01$). However, the PT Cobb angle ($p = 0.58$), MT Cobb angle ($p = 0.42$), and Cobb ratio (MT:TL/L; $p = 0.29$) are equivalent between the two groups.

Discussion

The basic objective of deformity correction for AIS is to maximize 3D correction by recapitulating coronal and sagittal balance while sparing motion segments above and below the fusion construct to optimize spinal flexibility. The concept of STF was born out of the necessity to accomplish these objectives in all curves amenable to

FIG. 1. Flow chart showing study selection process. Studies were eliminated based on title, abstract, and manuscript review based on inclusion and exclusion criteria. Figure is available in color online only.

TABLE 2. Summary of articles included in the meta-analysis

Authors & Year	Title	Type	No. of Centers	Level of Evidence	Total Patients	Follow-Up (mos)	Notes
Crawford et al., 2013	Selective thoracic fusion in Lenke 1C curves: prevalence & criteria	Multicenter, retrospective review of prospectively collected data	23	III	264	NA	STF vs NSTF: preop radiographic parameters & HRQLs (SRS-30, SAQ)
Demura et al., 2013	Is decompensation preoperatively a risk in Lenke 1C curves?	Multicenter, retrospective review of prospectively collected data	8	III	71	24	STF vs NSTF: preop & postop radiographic parameters; rates of preop & postop decompensation
Edwards et al., 2004	Selective thoracic fusion for adolescent idiopathic scoliosis w/ C modifier lumbar curves: 2- to 16-yr radiographic & clinical results	Retrospective case series	1	III	35	24–192, mean 55.2	STF only: preop & postop radiographic parameters
Ilgenfritz et al., 2013	Lenke 1C & 5C spinal deformities fused selectively: 5-yr outcomes of the uninstrumented compensatory curves	Multicenter, retrospective review of prospectively collected data	NR	III	24	12, 24, 60	STF only: preop & postop radiographic parameters; focuses on compensatory curves
Liljenqvist et al., 2013	Spontaneous lumbar curve correction in selective anterior instrumentation & fusion of idiopathic thoracic scoliosis of Lenke type C	Retrospective case series	1	III	26	range 24–84	STF only (anterior only): preop & postop radiographic parameters; has each data point for all individuals, includes global compensatory/compensatory curves/LL
Wang et al., 2012 ⁴⁶	Postoperative trunk shift in Lenke 1C scoliosis: what causes it? How can it be prevented?	Retrospective case series	1	III	44	24	STF only (posterior only): preop & postop radiographic parameters
Yong et al., 2012	Secondary curve behavior in Lenke type 1C adolescent idiopathic scoliosis after thoracoscopic selective anterior thoracic fusion	Prospective cohort study	1	III	24	24	STF only (anterior only): preop & postop radiographic compensatory, postop HRQL only (SRS-24)

LL = lumbar lordosis; NA = not applicable; NR = not reported.

TABLE 3. Preoperative demographic data: STF versus NSTF*

Variable	STF Mean (SD)	NSTF Mean (SD)	p Values
No. of patients	138	126	
Age in yrs	14.7	14.8	0.377
Female (%)	89.8	86.4	0.379
SAQ			
Severity of deformity	2.49 (0.58)	2.56 (0.55)	0.36
Unrelated to deformity	3.47 (1.18)	3.88 (1.04)	0.010†
Related to deformity	1.97 (1.02)	1.83 (0.94)	0.286
SRS-22			
Total	3.86 (0.48)	3.81 (0.49)	0.426
Pain	4.13 (0.77)	3.92 (0.79)	0.038†
Appearance	3.31 (0.62)	3.32 (0.63)	0.933
Activity	4.17 (0.50)	4.13 (0.64)	0.553
Mental	3.93 (0.73)	3.92 (0.69)	0.874
Satisfaction	3.61 (0.97)	3.69 (0.90)	0.519

* Data are exclusively from Crawford et al., 2013. The p value from a paired Student t-test is displayed.

† Statistically significant.

this surgical strategy. Although there is an abundance of literature regarding STF with respect to outcomes, the guidelines for use and reports of complications are less prevalent; studies are varied and heterogeneous in terms of surgical approaches,^{23,33,35} instrumentation,^{23,27,35,41,43} degree of correction,^{18,34,36,42–44} curve types,^{17,24,28,37,41,44} LIV,^{29,31,34,42} and radiographic parameters analyzed. Additionally, with more modern instrumentation and surgical correction techniques, many of the guidelines developed from the earlier literature may be outdated. By performing a meta-analysis using recent literature pertaining to the Lenke 1C subgroup, we have elucidated current treatment patterns and radiographic parameters that may serve as drivers for selecting STF versus NSTF.

When comparing pre- and postoperative radiographic parameters for STF, expected improvements are seen in the MT Cobb angle, TL/L Cobb angle, MT:TL/L Cobb angle ratios, coronal balance, and TL/L AVR, signifying overall improved balance and correction, with spontaneous lumbar compensatory curve correction. However, it is interesting to note that there are no significant changes in pre- and postoperative TL/L AVT in patients undergoing STF. This is probably secondary to only modest improvements in the lumbar curve position with STF. The cause of the relatively unchanged position of the lumbar curve in the STF can be possibly attributed to undercorrection of the thoracic curve to avoid coronal decompensation, resulting in only modest curve correction in the lumbar spine. The concept of avoiding overcorrection of the thoracic curve to prevent decompensation is an example of dogma that may not be applicable to modern instrumentation techniques.

Early positive experiences with Harrington rod instrumentation for STF are underscored with reports of postoperative coronal decompensation with the introduction of Cotrel-Dubousset instrumentation, which many studies attribute to thoracic overcorrection.^{2,6,31,43} Imrie et al.¹⁸

TABLE 4. Baseline comparison between characteristics within the STF group

Authors & Year	Mean Age (yrs)	SD	No.
Liljenqvist et al., 2013	15.2	2.3	26
Yong et al., 2012	14.8	2.1	24
Edwards et al., 2004	14.2	1.9	35
Ilgenfritz et al., 2013*	NR	NR	24
Overall average	14.7	2.1	85

* Only the Risser grade (a measure of skeletal maturity) was reported in this study, which is why the article was not included in the paper.

report high correction rates with modern instrumentation without increased rates of decompensation in Lenke 1C curves. When patients with an MT curve correction greater than 80% are compared with patients with correction less than 40%, the high correction group is able to achieve a lumbar correction that approaches what is seen on the lateral-bending film, resulting in a more balanced spine. The low correction group only obtains a spontaneous lumbar correction that is half of what is obtained on the lateral-bending film. Another study¹¹ shows comparable clinical and radiographic results of posterior STF performed using hooks versus pedicle screws, and finds the pedicle-screw group allows for a higher degree of correction but with a lower incidence of postoperative coronal decompensation.

However, the literature still varies on whether the goal of STF should be to achieve a straighter spine or a more balanced one. Dobbs et al.¹² showed excellent postoperative coronal balance with spontaneous lumbar curve correction in a cohort of 100 patients by using modern instrumentation techniques, with thoracic correction approximating what is achieved on preoperative thoracic push-prone radiographs. Additionally, it is notable that there is a significant increase in thoracic kyphosis and no change in lumbar lordosis in the pre- and postoperative comparisons of the STF group. Hence, patients undergoing STF did not encounter sagittal imbalance secondary to thoracic overcorrection, which is expected given the principle previously mentioned.

When comparing baseline preoperative radiographic parameters between the groups in the current study, patients chosen for NSTF have higher TL/L Cobb angles and TL/L AVT than patients who undergo STF. These data correlate with the results published by McCall and Bronson,²⁸ who found that patients with lumbar curves greater than 45° and with a low flexibility index are significantly more likely to develop postoperative progression of the uninstrumented lumbar curve with resultant spinal decompensation. Similarly, other studies suggest that larger, stiffer lumbar curves might be a contraindication for STF.^{25,28}

The increased TL/L AVT seen in patients who ultimately receive an NSTF represents a greater degree of preoperative coronal translation. Dobbs et al.¹² show that the presence of preoperative coronal translation places patients at significant risk of postoperative imbalance. In their cohort of patients with Lenke 1C curves, Demura et al. reported that those treated with STF had a 57% incidence of 2-year

Main Thoracic (MT) Cobb Angle

Proximal Thoracic Cobb Angle

Thoracolumbar/Lumbar (TL/L) Cobb Angle

(MT:TL/L) Cobb Angle

MT Apical Vertebral Translation (AVT) (mm)*

TL/L AVT (mm)*

FIG. 2. Preoperative radiographic comparison between STF and NSTF. Asterisk denotes standard deviation used in Crawford et al., 2013, estimated from p value presented by Demura et al., 2013. IV = inverse variance. Figure is available in color online only.

decompensation if they are decompensated preoperatively (C-7 to central sacral vertical line > 2 cm), versus a 31% decompensation rate if they are balanced preoperatively. Whether this amount of coronal translation is clinically significant and merits a role in the decision-making process remains to be seen.

When comparing pre- and postoperative radiographic parameters for the NSTF group, significant correction is achieved with respect to both MT and TL/L Cobb angles, as is expected with a longer fusion. When compar-

ing postoperative radiographic parameters between STF and NSTF, the overall correction is similar with respect to MT Cobb angles and MT:TL/L ratios. Given the trend seen in the literature,^{17,20} it is expected that the STF group has a correction of the TL/L curve that mirrors that of the MT curve. Unfortunately, due to the limited sample data available, additional radiographic parameters were not analyzed.

Surprisingly, larger magnitudes of the MT Cobb angle and the MT:TL/L Cobb angle ratios are not significantly

FIG. 3. Bar graph showing the LIV. Data were derived exclusively from two studies (Demura et al., 2013, and Liljenqvist et al., 2013). Figure is available in color online only.

associated with any specific treatment group. This is contrary to well-established guidelines recommended by Lenke et al.,²⁴ who recommend STF when the MT:TL/L and AVT values and the coronal translation ratios of the major curve intended for selective fusion to the minor compensatory curve are 1.2 or more. The reason for this deviation from traditional guidelines is unclear; perhaps surgeon choice may be more directly related to radiographic parameters as they relate to the lumbar compensatory curve. This finding may highlight the limitations of radiographic guidelines, because the clinical examination is an important component of determining the extent of instrumentation in patients undergoing spine surgery. Even if radiographic criteria are established in this patient population, the clinical examination, in conjunction with numerous other variables including patient preference and comorbidities, may alter decisions on treatment modalities.

Although HQRL scores were only collected in one study in our meta-analysis, it is important to note that patients who ultimately underwent STF have lower pain scores as well as less of a desire for appearance change, as measured by the SAQ: Unrelated to Deformity score. The SAQ is a modification of the Walter Reed Visual Assessment Scale and is used to assess the patient's perception of their spinal deformity.⁴⁰ These trends may signify surgeon preference for NSTF in patients who may have a worse

TABLE 6. Comparison of mean postoperative STF and NSTF values*

Variable	STF Mean (SD)	NSTF Mean (SD)	p Value
No. of patients	53	18	
Cobb angle†			
PT	13.1 (6.1)	14.1 (6.9)	0.58
MT	22.3 (6.8)	20.5 (8.6)	0.42
TL/L	23.1 (5.5)	16.6 (7.6)	<0.01‡
Cobb ratio; MT:TL/L	1.0 (0.3)	1.5 (1.0)	0.29

* Data are exclusively from Demura et al. and therefore are not a part of the present meta-analyses. The p value from a paired Student t-test is displayed.

† Values for Cobb angles are expressed as degrees.

‡ Statistically significant.

overall perception of their spinal deformity. The ultimate goal of the surgeon and the patient can differ, and may not always necessarily correlate to radiographic parameters, as postulated by Newton et al. in their description of the deformity-flexibility quotient as a tool to guide patient satisfaction and surgeon preference.³³ Larson et al. performed a retrospective cohort study comparing long-term clinical and radiographic outcomes for STF versus long fusion for AIS.²² Interestingly, their results suggest that the long-fusion patients are more pleased with the cosmetic results of having both curves fused, although there is no measurable difference between groups with respect to scolionometer measurements or SRS-24 domains related to postsurgical function and image.

This report is limited by the small number of studies that met inclusion criteria for meta-analysis. Furthermore, none of the studies that met inclusion criteria reported on results between surgical approaches, surgical technique, and instrumentation used. The current study's findings highlight the possibility that current treatment guidelines in this patient population may not be the main drivers of treatment. In light of the lack of universally accepted treatment guidelines for modern surgical techniques in this patient population, further research is needed to address this paucity of knowledge. Prospective, randomized studies or large database studies may be best suited to answer these questions.

Conclusions

Patients with larger lumbar compensatory curves with a larger degree of coronal translation as measured by the TL/L AVT are more likely to undergo an NSTF. Contrary to established guidelines, larger MT curve magnitudes and MT:TL/L Cobb angle ratios have not been found to influence the decision to pursue an STF. Although overall both STF and NSTF groups are found to display postoperative balance in the coronal plane, the STF group has only modest improvements in the lumbar curve position, as determined by a relatively unchanged TL/L AVT. Furthermore, surgeons may prefer NSTF in patients who may have a worse overall perception of their spinal deformity as measured by HQRL measures of pain and desire for appearance change.

TABLE 5. Change in pre- to postoperative radiographic values for the NSTF group*

Variable	Preop Mean (SD)	Postop Mean (SD)	p Value
No. of patients	18	18	
Cobb angle†			
PT	24 (6.8)	14.1 (6.9)	<0.01‡
MT	53.5 (12.0)	20.5 (8.6)	<0.01‡
TL/L	41.6 (7.8)	16.6 (7.6)	<0.01‡
Cobb ratio; MT:TL/L	1.2 (0.2)	1.5 (1.0)	0.21

* Data are exclusively from Demura et al. and therefore are not a part of the present meta-analyses. The p value from a paired Student t-test is displayed.

† Values for Cobb angles are expressed as degrees.

‡ Statistically significant.

Main Thoracic (MT) Cobb Angle

Thoracolumbar/Lumbar (TL/L) Cobb Angle

Ratio (MT:TL/L) Cobb Angle

TL/L Apical Vertebral Translation (AVT) (mm)

Coronal Balance (cm)

TL/L Apical Vertebral Rotation (AVR)

Thoracic Kyphosis Angle

Lumbar Lordosis

FIG. 4. Comparison between pre- and postoperative values for STF radiographic parameters. Figure is available in color online only.

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Disclosure

The authors report no conflict of interest concerning the materials or methods used in this study or the findings specified in this paper.

Author Contributions

Conception and design: all authors. Acquisition of data: all authors. Analysis and interpretation of data: all authors. Drafting the article: all authors. Critically revising the article: all authors. Reviewed submitted version of manuscript: all authors. Approved the final version of the manuscript on behalf of all authors: Passias. Statistical analysis: all authors. Administrative/technical/material support: all authors. Study supervision: Passias.

Supplemental Information

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