Outcome of the surgical treatment of adolescent idiopathic scoliosis using the Scoliosis Research Society outcome questionnaire

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Background
Adolescent idiopathic scoliosis (AIS) is a structural deformity of the spine. Posterior deformity correction represents the gold standard of the surgical treatment of AIS. The fixation technique was shifted from hybrid fixation to the all pedicle screw construct, which could produce superior deformity correction. Patient-oriented outcome questionnaires have become an important measure of the success of surgical correction. This study was conducted to assess the outcome of all pedicle screw constructs in treating AIS using the Scoliosis Research Society (SRS)-24 outcome questionnaire.
Patients and methods
Seventy-nine AIS patients were included with a minimum 2-year follow-up. Clinical and radiographic measurements were evaluated at preoperative, postoperative, and final follow-up periods. Complications and results of the SRS-24 questionnaire were analyzed. Sex, Lenke classification, levels of the lowest instrumented vertebra, curve magnitude, and percentage of curve correction were correlated with the SRS-24 questionnaire results.
Results
There were 59 females and 20 males. The mean age of the patients was 14.2±2.5 years. According to Lenke classification, the majority of the curves were type 1 (57 patients), followed by type 5 (11 patients), type 2 (six patients), type 3 (three patients), type 6 (two patients), and no type 4. The mean preoperative major curve Cobb angle was 59.3±9.045° and the mean postoperative Cobb angle was 5.82±5.932°. The average score for SRS-24 was 4.17. The mean preoperative pain score was 3.29, which improved to 4.30 after at least 2 years of follow-up (P<0.005). Statistically significant improvement was seen in the general self-image, function from back condition, and level of activity. After surgery, the mean score for self-image was 4.19, and for function was 3.55. The postoperative function was the lowest, while the postoperative satisfaction score was the best of all domains, with a mean score of 4.55. About 90% of patients were satisfied with the results of their surgical correction. Magnitude of curve and amount of correction did not significantly alter the SRS scores.
Conclusion
All pedicle screw construct is an efficient and safe method in AIS correction. The surgical treatment in our AIS patients has resulted in a perceived benefit in all domains of SRS-24 questionnaire.

Keywords:
adolescent idiopathic scoliosis, all pedicle screws, Scoliosis Research Society-24 questionnaire

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Background

Adolescent idiopathic scoliosis (AIS) is a structural three-dimensional deformity of the spine. AIS is the commonest type of scoliosis, with a prevalence rate of 1–4%. It occurs during adolescence and could have a significant physical and psychological adverse impact on young patients. Surgery for AIS is designed to prevent progression of the curve, achieve solid arthrodesis, and restore the balance of the spine [1].

Posterior deformity correction represents the gold standard of surgical treatment of AIS. Techniques using pedicle screws have been combined with hooks and/or sublaminar wires in hybrid constructs or used alone in all screw constructs. All pedicle screw constructs could

improve deformity correction in the different spinal planes, increasing the ability to perform shorter fusions and save more motion segments. This could lower the risk of pseudoarthrosis, instrumentation failures, and recurrence of the curve [2].

The impact assessment of the surgical treatment of AIS has traditionally been based on radiological measurements, such as the curve correction degree. Patient-oriented outcome questionnaires have become an important measure of the success of surgical correction. Health-related quality of life (HRQoL) is a subjective multidimensional construct that evaluates the disease and treatment impact on three main domains: physical, psychological, and social functioning. HRQoL in spinal deformities could be evaluated by various questionnaires, which could be categorized into general health (e.g. the short form 36) and disease-specific [e.g. the Scoliosis Research Society (SRS) questionnaire] [3]. SRS has developed the SRS-24 questionnaire to evaluate the outcome of surgical treatment for AIS. The SRS-24 questionnaire is a broadly accepted, validated questionnaire that can consistently yield information on pain relief, patient self-image perception, level of activity, and satisfaction for future data analysis [4].

In our retrospective study, we aimed to evaluate the HRQoL outcomes of AIS patients after the surgical treatment with all pedicle screw constructs using the SRS-24 outcome questionnaire.

Patients and methods

Seventy nine patients with AIS were surgically managed with all pedicle screw constructs at the spine unit, orthopedic department, Mansura university hospital by the authors in the years 2013-2020 and were followed up for a minimum of 2 years. Informed consent was obtained from all studied patients.

After approval by the institutional research board, patients aged between 11 and 20 years at presentation were included in our study. Patients with congenital and neuromuscular scoliosis were excluded. Also, patients who were treated conservatively or needed revision surgery were excluded.

All patients were preoperatively evaluated clinically and radiologically. The evaluation started with history taking and paying attention to age, sex, and complaints. All patients underwent a complete general, trunk, and neurological examination. Radiological evaluation consisted of standing plain radiograph posteroanterior, lateral views of the whole spine, and right, and left bending supine views to assess the flexibility of the curves. Curves were classified according to Lenke *et al*. [5] classification and fusion levels were determined.

Pedicle screws were inserted after posterior subperiosteal exposure to the deformed spine. Partial removal of the facets was performed, and we used Ponte osteotomies at the apex of deformity to aid correction in all our cases. The concave side rod was contoured and attached to the screws, then rotated to correct the deformity and recreate the desired sagittal contour, followed by convex rod insertion.

Operative notes were documented, such as operative time, amount of blood loss, and complications. Hospital stay duration was documented. Patients were followed up radiologically and clinically for a minimum of 2 years. Complications encountered during the follow-up visits were documented. At every visit, posteroanterior and lateral views were done; the radiological parameters were measured, documented, and immediately compared to those taken on the previous visit.

The percentage of correction of the major coronal curve at the 6-month follow-up was calculated: the postoperative coronal Cobb angle was subtracted from the preoperative coronal Cobb angle and divided by the preoperative Cobb angle [6].

All patients underwent evaluation using the SRS-24 questionnaire. Patients answered 24 questions, representing seven main patient-based outcome domains (Fig. 1). Trained residents not directly involved in the study applied all the questionnaires translated to the patients.

The following parameters were correlated with the SRS-24 questionnaire results: sex, Lenke classification, levels of lowest instrumented vertebra (LIV), curve magnitude, and percentage of curve correction.

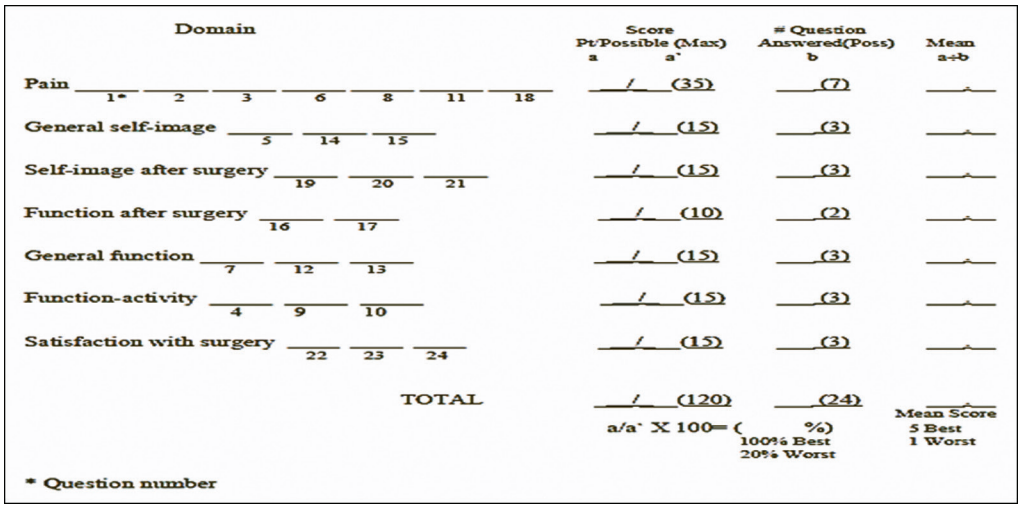
The data collected underwent the analysis using Statistical Package for Social Sciences (SPSS) program (Version 22.0. Armonk, NY: IBM Corp).

The data collected underwent the analysis using Statistical Package for Social Sciences (SPSS) program (Version 22.0. Armonk, NY: IBM Corp). The appropriate statistical tests were used when needed. *P* values less than 0.05 (5%) were considered statistically significant.

Results

The mean age of patients at the presentation was 14.2 ± 2.5 years. Our study consisted of 74.7% (59) females and 25.3% (20) males. The mean follow-up length was 32.2 ± 11 months (Table 1).

Figure 1



SRS-24 patient questionnaire score sheet [7]. SRS, Scoliosis Research Society.

Table 1 Sex, age, and length of follow-up of patients

All patients (*N*=79)					
Sex	Male			25.3 (20)	
	Female			74.7 (59)	
Age	Mean±SD	Median	Minimum	Maximum	*P*
	14.2±2.5	14	13	20	0.911
Length of follow-up (months)	32.2±11	32	26	42	0.922

Table 2 Curve classification according to Lenke and colleagues

	All patients (*N*=79)											
	Curve type						Lumbar modifier			Sagittal modifier		
	I	II	III	IV	V	VI	A	B	C	–	N	+
Number	57	6	3	0	11	2	43	22	14	41	25	13
%	72.2	7.5	3.8	0	14	2.5	54.4	27.8	17.8	51.9	31.6	16.5

According to Lenke and colleagues classification, the majority of the curves were type 1 (57 patients), followed by type 5 (11 patients), type 2 (six patients), type 3 (three patients), type 6 (two patients), and no type 4. The majority of patients had lumbar modifier A (43 patients), B (22 patients), and C (14 patients). The sagittal modifier was hypokyphotic (–) in 41 patients, neutral (N) in 25 patients, and hyperkyphoyic (+) in 13 patients (Table 2).

All patients underwent all pedicle screw instrumentation via posterior approach only (Fig. 2).

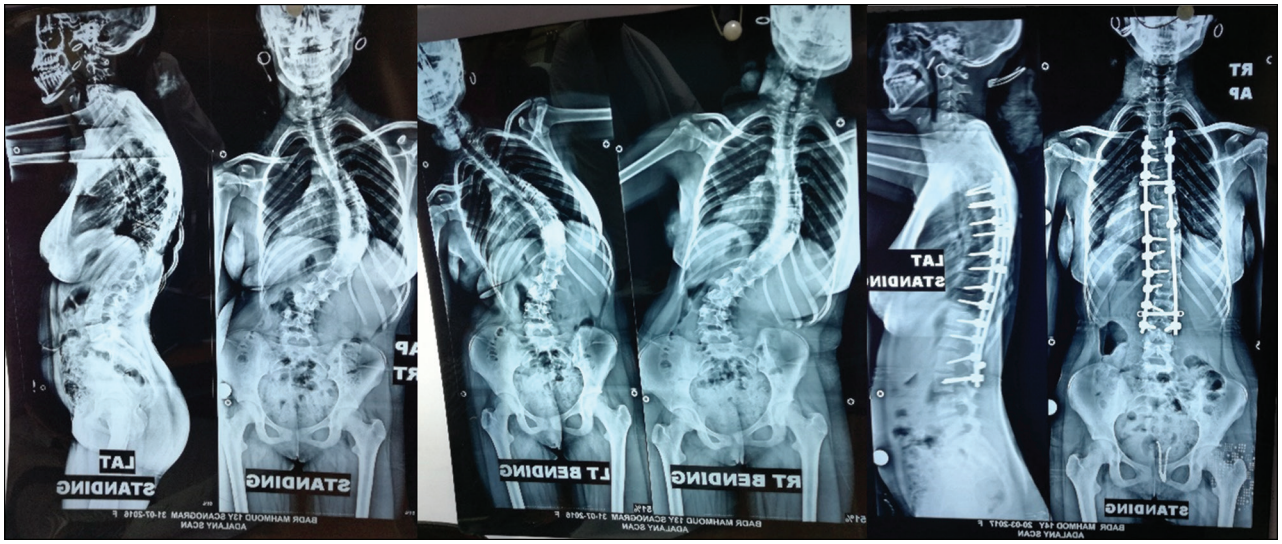
The operative time ranged from 2.5 to 5 h, averaging 3.3±0.7 h. The blood loss (both intraoperative and postoperative) ranged between 650 and 1150 ml, with an average of 475±236 ml. The hospital stay duration ranged between 4 and 18 days with an average of 7.9±62 days. Levels of LIV were D12 in 13 (16.5%) patients, L1 vertebra in 27 (34.2%) patients, L2 in 21 (26.6%) patients, L3 in 10 (12.6%) patients, and L4 in eight (10.1%) patients (Table 3).

Curves ranged preoperatively from 40° to 80°, averaging 59.3±9.045°. Postoperatively, the coronal curve magnitude ranged from 0 to 23°, with an average of 5.82±5.932°. Improvement ranged between 37 and 58° with an average of 46.12±4.839°. Percentage of correction was about 82.8±4.9% (range, 54.3–87.7%). After 2 years, curves ranged 0–30° with an average of 9.52±7.121° (Table 4). The correction loss ranged 0° – 8° with an average of 1.92±2.165 and about 3.6% correction loss. Other radiological measurements are summarized in Table 5.

Functional results

Postoperative pain scores revealed statistically significant improvement when compared with preoperative pain scores. The preoperative range of pain scores was 2–5 and 3–5 postoperative. Preoperative scores of less than 4 were present in 52% of patients.

Figure 2



Preoperative posteroanterior, lateral, and side-bending views of 13-year-old female with one AN curve fused from T4 to L3 demonstrating 87% correction with all pedicle screw construct.

Table 3 Surgical data of the patients

LIV	D12	16.5 (13)
	L1	34.2 (27)
	L2	26.6 (21)
	L3	12.6 (10)
	L4	10.1 (8)
Surgical time	3.3±0.7 h (2.5–5 h)	
Blood loss	472±236 ml (650–1150 ml)	
Hospital stay	7.9±62 (4–18 days)	

LIV, lowest instrumented vertebra.

Table 4 Primary coronal curve magnitude

Cobb's angle	All patients (*N*=79)				
	Mean±SD	Median	Minimum	Maximum	*P*
Preoperative	59.3±9.045	57	40	78	<0.001
Postoperative	5.82±5.932	6.4	0	23	<0.05
Follow-up	9.52±7.121	7.8	0	30	<0.001
Correction %	82.8±4.9	74	54.3	87.7	<0.04

Table 5 Other radiological data of the patients

Range(average)	All patients (*N*=79)		
	Preoperative	Postoperative	Follow-up
Thoracic kyphosis (°)	15–70 (30.5±14.2)	25–37 (29.8±2.7)	27–37 (31.3±2.4)
Lumbar lordosis (°)	35–58 (44.7±6.6)	35–50 (43.7±3)	39–50 (45.2±2.2)
Apical vertebral translation (cm)	2–11 (4.7±2.2)	0–3 (0.7±0.9)	0–3 (0.8±1)
Tilt of LIV (°)	5–32 (18.8±5.9)	0–12 (3.5±4.3)	0–15 (3.8±4.4)
Adjacent disc wedging (°)	0–17 (8.1±4.4)	0–7 (1.7±2.2)	0–6 (1.8±2.3)

LIV, lowest instrumented vertebra.

Postoperative pain scores less than 4 were present in only 10% of patients. The mean preoperative pain score was 3.29±0.582, which improved to 4.30±0.842 after at least 2 years of follow-up ($P<0.005$).

After surgery, general self-image scores demonstrated statistically significant improvement. General self-image scores ranged from preoperative 2–5 while postoperative ranged 3–5. The mean preoperative score

was 3.58 ± 0.744, which improved to 4.12 ± 0.509 after 2 years of follow-up (P<0.01).

Also, the general level of activity scores and function scores were significantly improved after surgery. The mean preoperative general level of activity score was 3.51 ± 0.735 (range, 2–5), which improved to 4.05 ± 0.631 (range, 2–5) after at least 2 years of follow-up (P<0.05). While the mean preoperative function from back condition score was 3.60 ± 0.632 (range, 2–5) improved to 4.16 ± 0.907 (range, 3–5) after 2 years of follow-up (P<0.04).

Results of the only postoperative domains revealed that 90% of patients were satisfied with the results of surgery. The mean satisfaction score was 4.55 ± 0.352 which was the highest among all domains after at least 2 years of follow-up. Postoperative function scores in the studied patients were the lowest among all domains, with a mean score of 3.55 ± 0.615. The mean postoperative self-image score was 4.19 ± 0.546. The mean total SRS-24 score in the studied patients was 4.17 ± 0.352 (range, 3.51–4.30) at 2-year follow-up (P<0.09) (Table 6).

Comparisons between male and female patients didn't yield any significant differences in the scores of all domains (Table 7).

There is no significant correlation between curve types according to the Lenke classification found in all domains. Comparisons between levels of LIV in the different scores of all domains did not show any significant differences (Table 8).

Patients were divided into two groups (Table 9), depending on the coronal Cobb angle of the primary curves. No significant correlation according to preoperative curve magnitude was found in all domains. The percentage of curve correction was also divided into two groups. There was no significant correlation between the percentage of curve correction in both groups and outcome scores in all domains (Table 9).

In our study, two (2.53%) cases had a partial neurological insult due to misplaced screws. One patient developed postoperative unilateral intercostal pain, and the other patient developed incomplete paraplegia. Both patients underwent revision of the misplaced screw position and recovered without affecting their scores. A superficial infection occurred only in two cases and subsided under antibiotic therapy and repeated dressing. There were no postoperative deep wound infections or metal breakages.

Table 6 Scoliosis Research Society-24 scores before and after surgery in the studied patients

Domain	All patients (N=79)				P
	Preoperative		Postoperative		
	Mean±SD	Range	Mean±SD	Range	
Pain	3.29 ± 0.582	2–5	4.30 ± 0.842	3–5	<0.005
General self-image	3.58 ± 0.744	2–5	4.12 ± 0.509	3–5	<0.01
General level of activity	3.51 ± 0.735	2–5	4.05 ± 0.631	2–5	<0.05
Function from back condition	3.60 ± 0.632	2–5	4.16 ± 0.907	3–5	<0.04
			All patients (N=79)		
			Mean±SD		
Postoperative self-image			4.19 ± 0.546		
Postoperative function			3.55 ± 0.615		
Postoperative satisfaction			4.55 ± 0.352		
Total SRS-24 score			All patients (N=79)		
	Mean±SD		Minimum	Maximum	P
	4.17 ± 0.352		3.51	4.30	<0.09

SRS, Scoliosis Research Society.

Table 7 Comparison of scoring items according to sex

SRS domains	Male (N=20)	Female (N=59)	P
Pain difference score	1.06	0.968	0.301
General self-image difference score	0.455	0.644	0.072
Back difference score	0.464	0.585	0.424
Level of activity difference score	0.674	0.614	0.691
Postoperative self-image	4.28	4.12	0.521
Postoperative function	3.65	3.52	0.363
Satisfaction	4.62	4.38	0.213

SRS, Scoliosis Research Society.

Table 8 Comparison of scoring items according to Lenke classification and lowest instrumented vertebra

SRS domains	All patients (*N*=79)					
	Lenke type					
	1	2	3	4	5	6
Pain difference score	1.053	0.967	0.952	0.895	0.885	0.971
General self-image difference score	0.566	0.521	0.533	0.492	0.605	0.542
Back difference score	0.653	0.542	0.624	0.663	0.629	0.637
Level of activity difference score	0.691	0.624	0.635	0.642	0.638	0.645
Postoperative self-image	4.22	4.16	4.05	4.1	3.95	4.06
Postoperative function	3.63	3.54	3.42	3.32	3.38	3.66
Satisfaction	4.71	4.52	4.33	4.42	4.56	4.52
			All patients (*N*=79)			
			LIV			
	D12	L1	L2	L3	L4	
Pain difference score	0.961	0.957	0.882	0.863	0.981	
General self-image difference score	0.534	0.564	0.442	0.604	0.542	
Back difference score	0.565	0.625	0.643	0.629	0.644	
Level of activity difference score	0.628	0.633	0.621	0.629	0.639	
Postoperative self-image	4.05	4.11	4.15	4.09	4.12	
Postoperative function	3.42	3.32	3.24	3.22	3.12	
Satisfaction	4.62	4.43	4.32	4.46	4.56	

LIV, lowest instrumented vertebra; SRS, Scoliosis Research Society.

Table 9 Comparison of scoring items according to curve magnitude and curve correction

SRS domains	All patients (*N*=79)					
	Curve magnitude		*P* value	Percentage of curve correction		*P* value
	≤55° (*N*=37)	>55° (*N*=42)		≤85% (*N*=44)	>85% (*N*=35)	
Pain difference score	0.988	0.875	0.124	0.865	0.978	0.174
General self-image difference score	0.633	0.554	0.325	0.552	0.667	0.256
Back difference score	0.642	0.584	0.429	0.458	0.674	0.364
Level of activity difference score	0.532	0.514	0.608	0.438	0.561	0.264
Postoperative self-image	4.32	4.15	0.120	4.15	4.23	0.237
Postoperative function	3.64	3.33	0.09	3.44	3.58	0.234
Satisfaction	4.71	4.38	0.06	4.65	4.72	0.245

SRS, Scoliosis Research Society.

Discussion

In our study, as regards major coronal curve correction, about 82.8% was achieved, which was comparable with those of other studies on segmental pedicular screws fixation for correction of AIS [8,9]. The goals of surgical treatment for AIS are to improve cosmetic appearance and functional outcomes. Pedicular screws fixation has gained popularity for AIS surgical correction due to its superior biomechanical properties over other instrumentations used for the spine. All pedicle screw constructs have the advantages of fixation of three columns, improved correction, less pseudarthrosis, and fewer instrumentation failures when compared with conventional hooks and wires constructs [10]. Pedicular screws fixation, which provides better-holding power, could lower the rate of correction loss. In our study, the loss of correction averaged 1.92° (3.6%). A good correction of adjacent disc wedging and tilt of LIV were achieved in our patients.

AIS evaluation is no longer viewed alone based on treatment procedures but also requires an assessment of HRQoL. The SRS-24 questionnaire was introduced by SRS with great enthusiasm to evaluate the functional outcomes of AIS patients and later modified to include 22 items (SRS-22, SRS-22r questionnaire). Merola *et al.* [11] evaluated 343 AIS patients with curves between 40 and 80° who completed the questionnaire preoperatively and 2 years after surgery. Preoperative back pain in their study was present with a mean score of 3.68, which improved to a mean of 4.63 after surgery. Also, they demonstrated that their patients had a perceived benefit in all domains. At 2011, Carreon *et al.* [12] diagnosed 745 AIS patients with 14.2 years average age and 54° average curve angle. They found a statistically significant difference in all domain scores between preoperative and 24 months postoperative.

In our study, we found significant improvement in all SRS-24 domains. Our study demonstrated that pain

scores improved after surgery. Our study reported that the mean score for preoperative pain was 3.29, which improved at postoperative follow-up to 4.30 and showed an improvement of one clinical grade for each question answered. After surgery, there were no pain scores in the one response area. The mean preoperative pain score has demonstrated that AIS is associated with baseline back pain before surgery in most patients. Ahonen *et al.* [13] also reported that a considerable amount of pain presented preoperatively in their AIS patients.

In addition to the improvement in back pain in our study, statistically significant improvement was seen in the general self-image by 0.54 points, function from back condition by 0.56 points, and level of activity by 0.49 points. This demonstrated that our AIS patients had a perceived benefit in all domains.

After surgery, the mean score for self-image was 4.19, and for function was 3.55. The postoperative function was the lowest, while the postoperative satisfaction score was the best, with a mean score of 4.55. About 90% of our patients were satisfied with the results of their surgical correction. These results matched the results evaluating HRQoL in AIS patients after surgical correction in Egypt [14].

Correlations between sex and SRS-24 outcome scores were evaluated in our study and did not yield any significant differences in preoperative and postoperative domains. There were no statistical differences in postoperative-only domains between males and females. However, Roberts *et al.* [15] evaluated 744 patients (621 females and 123 males) and concluded that male patients had better preoperative scores for self-image/appearance with less postoperative pain. Also, males had better mental health and total scores preoperative and at 2 years after surgery, while both sexes were similarly satisfied with surgery.

Patients in our study were divided into two groups according to the curve magnitude (≤55° and >55°), and we found no significant correlation between the curve magnitude and the outcome scores in all domains. These results were consistent with Ahonen *et al.*'s [13] results. They stated no correlation was found between the SRS pain domain or total score and the preoperative major curve.

The percentage of the curve correction was assessed, and we found, according to the analysis of our data, that there was no significant correlation between the percentage of the curve correction and outcome scores. This finding was consistent with the Carreon *et al.* [12] study, which observed no statistically significant correlation between the percentage of curve correction and 2-year postoperative SRS satisfaction score. However, Ng *et al.* [16] found in their 104 Chinese AIS patients that postoperative curve correction magnitude was a significant predictor of function/activity scores, self-image/appearance, and satisfaction. The magnitude of curve correction alone is not the only way to assess the surgery's success. Surgeons should give more importance to balancing the spine, the shoulders, and the pelvis than absolute correction magnitude alone. They should restore the waistline, eliminate the rib hump, and improve overall self-image.

Selection of the LIV plays an important role in the fusion of AIS. The commonly selected LIV includes end, neutral, last substantially touched, or stable vertebra. One of the advantages of all pedicle screw fixation in AIS correction is short-segment posterior fusions to preserve more motion segments without impairing balance after surgery [17]. In our study, we selected LIV according to the Lenke classification. After analyzing our data and studying correlations according to LIV, no significant difference was found after at least 2 years of follow-up. That may be due to short period of follow-up and fewer cases of LIV at L3 or L4, so it needs further assessment. However, Ahonen and colleagues found that pain, satisfaction, and total SRS-24 scores were significantly higher in patients fused to L2 or higher when compared with patients fused to L3 or lower with longer follow-up. They selected LIV according to the Lenke classification and stated that the curve type itself (structural thoracolumbar curve) has a different HRQoL in the long term. Also, leaving fewer discs distal to the fusion could increase the risk of developing low back pain in the future [13]. In our study, there is no significant correlation between curve types according to Lenke classification found in all domains. This was consistent with the results of Spanyer *et al.* [18].

The greatest concern in AIS surgeries is the risk of neural complications. SRS estimated its incidence by 1%. The risk of neural complications increases with complex procedures, including osteotomies and kyphosis correction [19]. In our study, two cases only developed partial neurological deficits, which later improved completely.

Our study was a retrospective and needed a longer follow-up period. To our knowledge, there was not a validated Arabic version of SRS-24 present. We continued to translate the questionnaire for the patients. There were new versions of SRS questionnaires, like SRS-22 or SRS-22r questionnaire. Also, our study excluded revision surgeries, which could impact the findings. We may gather these cases in the future and assess the affection through revision surgeries along

with their scores. However, we evaluated only cases of AIS that underwent surgeries by one approach (posterior approach) and all pedicle screw constructs.

In conclusion, all pedicle screw constructs for the treatment of AIS have been shown to be safe and effective, as well as having a correction power for all curve patterns. All patients were evaluated by the SRS-24 questionnaire, which reported statistically significant improvement and perceived benefits in all domains. Our results did not show any significant correlation between patient outcome scores and the magnitude of the curve, percentage of correction, curve type according to Lenke classification, or level of LIV. Also, there was no significant difference between males and females.

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Conflicts of interest
No conflict of interest to be declared.

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