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Surgical Outcome of Three-Dimensional Correction of Adolescent Idiopathic Scoliosis

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ABSTRACT

Background: Adolescent idiopathic scoliosis is an abnormal curvature of the spine that appears in late childhood or adolescence. Instead of growing straight, the spine develops a side-to-side curvature, usually in an elongated "S" or "C" shape; the bones of the spine are also slightly twisted or rotated. To prevent further curve progression and obtain a balanced spine, surgery remains the mainstay of treatment for idiopathic scoliosis (IS).

Objective: This study aimed to discuss three dimensional surgical techniques used for correction of adolescent idiopathic scoliosis, evaluating their feasibility, efficacy and safety.

Patients and methods: This study was conducted in Mansoura University Hospital and Alexandria University Hospitals between September 2018 and April 2021. 3D surgical correction was performed for 91 patients complaining of idiopathic scoliosis, and not responding to conservative measures and not associated with neurological affection.

Results: According to Lenke classification, there were 56 patients (61.5%) with type 1 curve type , 9 patients (9.9%) with type 2, 7 patients (7.7%) with type 3, 7 patients (7.7%) with type 5 and 12 patients (13.2%) with type 6. Mean preoperative height was 1.60 m while mean postoperative height was 1.66 m. with significant increase in height postoperatively ($p < 0.001$). Mean percentage height gain was 3.91%.

Conclusion: We do believe that the posterior only approach 3D correction is an effective method in management of AIS concerning correction of Cobb angle, shoulder balance and spinopelvic parameters and recommend it as the best way nowadays to treat this disease.

Keywords: Three dimensional surgical techniques, adolescent idiopathic scoliosis.

INTRODUCTION

Scoliosis comes from the Greek Word “skoliosis” meaning crooked. It is a complex three dimensional deformity of the spine characterized by a lateral deviation of at least 10 degrees with a rotation of the vertebra and usually associated with reduction of normal kyphotic curvature of the spine [(1)]. The overall prevalence of AIS is 0.47% to 5.2% in the current literature [(2, 3)]. AIS commonly affect girls with a female to male ratio of 1.5:1 to 3:1. This ratio increases substantially with increasing age, 90% of the presentation will show a right-sided thoracic curve [(3, 4)].

There are several classifications for scoliosis used by professionals to help in management and to predict outcomes for patients. The one that is currently used for surgical planning is the Lenke classification [(1)]. The Lenke classification has three components: (1) Curve patterns (2) Lumbar spine modifiers (3) Sagittal thoracic modifier [(5)]. This classification was introduced to help surgeons in determining the extent of spinal instrumentation. The vast majority of patients initially present due to a deformity. This may be a perception of asymmetry about the shoulders, waist, or rib cage noticed by the patient, a family member, the primary care physician or a school nurse. Asymmetry of breasts might be the first thing noticed by female patients [(5)].

X-ray imaging includes standing posterior-anterior to measure the degree of the curve using the Cobb method. Standardized lateral radiograph appreciates any sagittal abnormality. These whole spine x-rays should include pelvis to assess the ossification of iliac crest in order to evaluate the Risser’s sign (growth status). Obtain bending films to assess the flexibility of the curve [(1)].

The main treatment options for scoliosis can be summarized by the three Os: Observation, Orthosis (bracing), and Operative treatment. The selection of the best treatment is based on the maturity of the patient (age, menarchal status and Risser grading of iliac epiphysis), location, severity and risk of progression of the curvature [(6)]. A common protocol used to guide treatment is: to observe patients with curves of less than 25 degrees, to brace patients between 25-45 degrees, and to consider surgery on patients with curves of greater than 45 degrees [(6)].

Over the past years, several articles have been published on the evaluation and potential classification of adolescent idiopathic scoliosis (AIS) using three-dimensional (3D) terminology and techniques. CT scan and MRI could be used to assess the spine in 3D [(7)].

The aim of the present study was to discuss three dimensional surgical techniques used for correction of adolescent idiopathic scoliosis, evaluating their feasibility, efficacy and safety.

PATIENTS AND METHODS

This study was conducted in Mansoura University Hospital and Alexandria University Hospitals between September 2018 and April 2021. 3D surgical correction was performed for 91 patients

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complaining of idiopathic scoliosis, and not responding to conservative measures and not associated with neurological affection.

Inclusion criteria: Age between ten and eighteen years, and Cobb angle > 40°.

Exclusion criteria: Age less than ten or more than eighteen years, Cobb Angle < 40°, associated congenital anomalies, contraindication of anasaethia, coagulopathy, and osteoporosis.

Pre-operative evaluation:

1. History taking and Clinical examination:

A complete history including family history of scoliosis is obtained. Patients were assessed *clinically* especially with neurological examination including all cranial nerves, motor strength, reflexes (including abdominal reflexes, often associated with Chiari malformations), sensory modalities, and gait. *Locally* in standing position and by Adam forward bending test figure (1) to detect the abnormal curve rotation, rib hump, shoulder and hip asymmetry, symptoms of pain and/or weakness and how the patient perceives her or his appearance relative to the deformity are especially important and *generally* for detection of associated medical or surgical co-morbidities. During the examination, height, weight, and age are recorded.

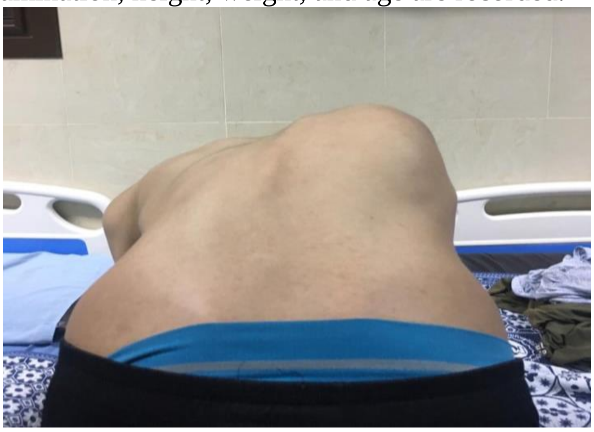

Figure (1): Adam forward bending test for our patients.

2. Imaging studies:

Plain X-ray radiography is the main radiologic tool used for evaluation of AIS cases. Initial posteroanterior and lateral 36- × 14-inch standing long cassette views from occiput to mid-femur are obtained. Once a patient was determined to be an operative candidate, updated standing AP and lateral scoliosis radiographs and lateral bending radiographs were obtained to assess curve progression and flexibility of the curve to differentiate structural from non-structural curves for classification and operative planning. AP view was used to identify the type and apex of the curve, measuring Cobb angle of the abnormal curves and shoulder level by calculating clavicular angle (CA). Also, age-related skeletal maturity was determined by hand and iliac bones radiographs. Lateral view for measuring thoracic kyphosis and spino-pelvic parameters mainly lumbar lordosis.

CT scan: To assess the degree of vertebral rotation, measuring pedicle size and vertebral body length in axial view for screw selection. This was done for all cases. ***MRI*** was indicated with presence of neurologic symptoms present in patients with idiopathic scoliosis and let-sided, sharp angular or irregular curve patterns.

3. Classification system:

We used the three-dimensional Lenke classification system.

4. Routine investigation:

These were ordered for all patients undergoing the procedure including: pulmonary function test (FVC), CBC, liver function, kidney function, blood glucose and INR.

All patients were instructed to fast at the night before the operation and receive an enema to evacuate the colon and take antiflatulant for a better fluoroscopic image. All patients were informed about the operative details and the possible complications. All patients were placed in either the Pediatric or Neurologic Intensive Care Unit after surgery. On the first day after the procedure, all patients were encouraged to ambulate or at least be up into a chair for meals. A physical therapist worked with every patient to determine any needs on discharge. Drains were removed 2-5 days after the patient's last procedure.

Standing anteroposterior and lateral standing scoliosis radiographs, immediate postoperative height and postoperative pulmonary function test (FVC) were obtained for every patient before discharge. Standing radiographs were then repeated at 6 weeks, 3 months, 6 months and 1 year after surgery to assess alignment, preservation of curve correction and hardware placement.

Ethical consent:

An approval of the study was obtained from Mansoura University Academic and Ethical committee. Every patient signed an informed written consent for acceptance of the operation. This work has been carried out in accordance with The Code of Ethics of the World Medical Association (Declaration of Helsinki) for studies involving humans.

Statistical Methods

The collected data were revised, coded, tabulated and introduced to a PC using Statistical package for Social Science (IBM Corp. Released 2017. IBM SPSS Statistics for Windows, Version 25.0. Armonk, NY: IBM Corp.). Data were presented and suitable analysis was done according to the type of data obtained for each parameter. Kolmogorov-Smirnov test was used as a test of normality, if the significance level is greater than 0.05, then normality is assumed. Mean, Standard deviation and range were used for numerical data. Frequency and percentage were used for non-numerical data. Percentage change from baseline was calculated using the formula: (values after treatment-values before treatment)/ values before treatment. Student T Test was used to assess the statistical significance of the difference between two study group means. For the comparison of more than two groups' means, one way analysis of variance (ANOVA) was used. Chi-square and Fisher's exact test were used for comparison of qualitative variables. Paired sample t test was used to assess changes in parameters over time. Correlation analysis was used to assess the strength of association between two quantitative variables. The correlation coefficient defines the strength and direction of the linear relationship between two variables. Linear regression analysis was used for prediction of risk factors, using generalized linear models. Univariate regression examines the effect of a single independent variable on a dependent variable; one variable is analysed at a time. Multivariate regression, more than one variable were analysed together for any possible association or interactions, to explore which of the independent variables are independently associated with the outcome, i.e. they keep a significant p-value in the model despite the inclusion of other independent variables. All reported *p* values were two-tailed and $p \leq 0.05$ was considered to be significant.

RESULTS

This study included 91 cases with mean age of 15.1 ± 2.1 years and ranged between 11 and 18 years. Among the cases, there were 10 males (11%) and 81 females (89%). The mean body weight was 56.8 ± 12.8 kg and ranged between 34 and 121.2 kg. The mean height was 1.60 ± 0.08 m ranged between 1.37 and 1.77 meters (Table 1).

Table (1): Patients' age, sex, weight and height

		Cases (N=91)	
Age (years)	**Mean ± SD**	15.1	±2.1
	range	11	18
Males	**N, %**	10	11%
Females	**N, %**	81	89%
Weight (kg)	**Mean ± SD**	56.8	±12.8
	range	34	121.2
Height (m)	**Mean ± SD**	1.60	±0.08
	range	1.37	1.77

According to Lenke classification, there were 56 patients (61.5%) with type 1 curve type , 9 patients (9.9%) with type 2, 7 patients (7.7%) with type 3, 7 patients (7.7%) with type 5 and 12 patients (13.2%) with type 6 (Table 2).

Table (2): Patients' Risser, Sander and Lenke classification

			Cases (N=91)	
Risser	**0**	**N, %**	4	4.4%
	1	**N, %**	4	4.4%
	2	**N, %**	4	4.4%
	3	**N, %**	8	8.8%
	4	**N, %**	33	36.3%
	5	**N, %**	38	41.8%
Sanders	**2**	**N, %**	4	4.4%
	3	**N, %**	6	6.6%
	4	**N, %**	4	4.4%
	5	**N, %**	4	4.4%
	6	**N, %**	13	14.3%
	7	**N, %**	36	39.6%
	8	**N, %**	24	26.4%
Lenke classification *Curve type*	**1**	**N, %**	56	61.5%
	2	**N, %**	9	9.9%
	3	**N, %**	7	7.7%
	5	**N, %**	7	7.7%
	6	**N, %**	12	13.2%
Lumber modifier	**A**	**N, %**	46	50.5%
	B	**N, %**	8	8.8%
	C	**N, %**	37	40.7%
Sagittal modifier	**Negative**	**N, %**	20	22%
	Normal	**N, %**	71	78%

Preoperative evaluation
***Cobb Angle:** The preoperative Cobb angle of the 91 cases ranged from 40° to 81° and the mean was 51.8 ± 8.4°.
***Shoulder balance:** The clavicular angle (CA) was the measure used to evaluate shoulder balance. It ranged from 4° to 10° and the mean CA was 7.3 ± 1.3°.

***Pulmonary function test (PFT):** Forced Vital Capacity (FVC) was used for PFT evaluation. It ranged from 2.8 to 4.9 litres and the mean FVC was 3.8 ± 0.4 L.
Table (3) showed that LL (lumbar lordsis) ranged from 44° to 68° and the mean was 54.5 ± 6.4º. The PI (pelvic incidence) ranged from 42° to 71° and the mean was 57.4 ±7.4º. The PT (pelvic tilt) ranged from 5° to 30° the mean was 15.6 ± 5.4º (Table 3).

Table (3): Spinopelvic parameters

		Cases N=91	
LL (lumbar lordsis)	Mean ± SD	54.5	±6.4
	range	44	68
PI (pelvic incidence)	Mean ± SD	57.4	±7.4
	range	42	71
PT (pelvic tilt)	Mean ± SD	15.6	±5.4
	range	5	30

Mean preoperative height was 1.60 m ranging from 1.37 to 1.77, while mean postoperative height was 1.66 m ranging from 1.46 to 1.83 m. with significant increase in height postoperatively (p < 0.001). Mean percentage height gain was 3.91%, ranged from 1.16 to 7.59% (Table 4).

Table (4): Comparison of pre and post-operative height

		Preoperative		**Post-operative**		***p***	**Change (%)**	
Height (m)	**Mean ± SD**	1.60	± 0.08	1.66	0.08	**< 0.001**	3.91	1.24
	range	1.37	1.77	1.46	1.83		1.16	7.59

Preoperative and postoperative heights were not affected by Lenke classification. However, there was significant difference in height gain between Lenke curve types. Highest percentage height gain was associated with Lenke II and III, while lowest percentage height gain was associated with Lenke V. There was increase in height postoperatively in each Lenke class (p2 < 0.05 in each Lenke class). It is noticed that Lenke V was least affected regarding height gain (mean height gain= 1.47%) (Table 5).

Table (5): Association of height gain with Lenke classification

		I		**II**		**III**		**V**		**VI**		***P1***
		mean	**SD**	**mean**	**SD**	**mean**	**SD**	**mean**	**SD**	**mean**	**SD**	
Height (m)	**Pre**	1.60	0.08	1.57	0.06	1.60	0.09	1.66	0.07	1.60	0.05	0.293
	post	1.66	0.08	1.65	0.07	1.68	0.09	1.68	0.06	1.67	0.06	0.871
	Change (%)	3.96	0.91	4.59	1.63	4.82	0.77	1.47	0.36	4.05	1.13	**<0.001**
	P2	**<0.001**		**0.008**		**0.017**		**0.015**		**0.002**		

P1, comparison between different classifications; p2, comparison between pre and post-operative data.

Mean preoperative Cobb was 51.8°, ranged from 40° to 81°; while mean postoperative Cobb was 8°, ranging from 3° to 25°, with significant decrease in Cobb immediate and 1 year postoperatively when compared to preoperative level (p < 0.001 for both). Mean percentage Cobb decrease was 84.4%, ranging from 54.3 to 100%. After 1 year Cobb angle was preserved with no significant change from immediate postoperative levels (p3 > 0.05).
Mean preoperative clavicular angle was 7.3°, ranging from 4° to 11°, while mean postoperative clavicular angle was 4.2°, ranging from 2 to 7°, with significant improvement of shoulder balance postoperatively (p < 0.001). Mean percentage decrease in clavicular angle was 42.7%, ranging from -16.7 to 75%.
Mean preoperative FVC was 3.8 litres, ranged from 2.8 to 4.9 L, while mean postoperative FVC was 3.4, ranging from 2.5 to 4.6 with significant decrease in FVC postoperatively (p < 0.001). Mean percentage decrease in FVC was 9.7%, ranging from -15.4 to 16.8%.

Table (6): Comparison of pre and post-operative Cobb, shoulder balance and Forced Vital Capacity (FVC)

		Preoperative		**Post-operative**				***p***	**Immediate Change (%)**	
				Immediate		**After 1 year**				
Cobb	**Mean ± SD**	51.8	8.4	8	6.1	7.9	6.5	**p1<0.001**	84.4	11.8
	range	40	81	3	25	1	26	**P2<0.001** P3=0.824	54.3	100

		Preoperative		**Post-operative**		***p***	**Change (%)**	
Sh.CA	**Mean ± SD**	7.3	±1.3	4.2	±1.3	**<0.001**	42.7	15.3
	range	4	11	2	7		-16.7	75.0
FVC	**Mean ± SD**	3.8	±0.4	3.4	±0.4	**<0.001**	9.7	4.6
	range	2.8	4.9	2.5	4.6		-15.4	16.8

- P1, comparison between pre- and immediate post-operative Cobb. P2, comparison between pre and 1 year post-operative Cobb. P3, comparison between immediate and 1 year post-operative Cobb.

Mean preoperative LL was 54.5°, ranging from 44° to 68°, while mean postoperative LL was 45.7°, ranging from 40° to 58°; with significant decrease in LL postoperatively ($p < 0.001$). Mean percentage decrease in LL was 15.7%, ranging from 8.2 to 24.6%. Mean preoperative PI was 57.4°, ranging from 42° to 71°, while mean postoperative PI was 52.1°, ranging from 40° to 66°; with significant decrease in PI postoperatively ($p < 0.001$). Mean percentage decrease in PI was 8.7%, ranging from -13.5 to 36.9%. Mean preoperative PT was 15.6°, ranging from 5° to 30°, while mean postoperative PT was 15.7°, ranging from 5° to 24°, with no significant difference in PT postoperatively ($p > 0.05$) (Table 7).

Table (7): Comparison of pre and post-operative Spinopelvic parameters

		Preoperative		**Post-operative**		***p***	**Change**	
LL	**Mean ± SD**	54.5	± 6.4	45.7	± 4.1	**<0.001**	15.7	4.5
	range	44	68	40	58		8.2	24.6
PI	**Mean ± SD**	57.4	± 7.4	52.1	± 6.5	**<0.001**	8.7	9.7
	range	42	71	40	66		-13.5	36.9
PT	**Mean ± SD**	15.6	± 5.4	15.7	± 5	0.883	-7.3	38.2
	range	5	30	5	24		-122.2	47.1

Linear regression analysis was conducted for prediction of factors affecting height gain using age, weight, number of fused levels, preoperative Cobb, CA, LL, PI and PT as confounders. Higher number of fused levels and Cobb angle degree were considered as predictors of significant height gain in uni- and multivariable analyses. The contribution from the number of fused levels was significantly greater than any of the other parameters identified ($R2 = 0.259$). **Height gain (%) = [(number of fused levels× 0.337) + 0.051] + [(preoperative Cobb × 0.039)+ 0.0129] +0.3** (Table 8).

Table (8): Regression analysis for prediction of height gain

	Univariable			**Multivariable**		
	B	**SE**	**P**	**B**	**SE**	**P**
Age	-0.001	0.001	0.340			
weight	0.0002	0.0001	0.194			
Number of fused levels	0.337	0.063	**<0.001**	0.337	0.0602	**<0.001**
Preop cobb	0.039	0.015	**0.009**	0.039	0.0129	**0.003**
Pre op CA	0.002	0.002	0.134			
Preop LL	-0.001	0.001	0.216			
Preop PI	0.001	0.0005	0.124			
Preop PT	0.0002	0.001	0.807			

B, regression coefficient; SE, standard error.

DISCUSSION

In this study, there were 10 males (11%) and 79 females (89%) among the cases included. The mean age of the cases was 15.1 years with range between 11 - 18 years. Similar results were obtained by **Yeh *et al.*** [(8)] who included a total of 127 patients (17 males and 110 females) aged 14.4 years old at the time of surgery. Our results are also in accordance with **Tannous and his colleagues**[(9)] who included 35 cases for surgical correction of AIS, the mean patient age at the time of surgery was 14.9 years (range = 12-19 years), with 28 female and 7 male patients.

Lenke curve type

In this study, according to the Lenke type of curves, more than half of the cases (65%) had Lenke type I, 9 patients (9.9%) with type 2, 7 patients (7.7%) with type 3, 7 patients (7.7%) with type 5 and 12 patients (13.2%) with type 6. Lenke type I was the most prevalent type in our study. Most of the studies have reported the same results. **Yeh *et al.*** [(8)] showed that among the cases included in their study, the numbers of

Lenke type 1, 2, 3, 4, 5 and 6 curve patients were 59, 19, 12, 6, 22 and 9, respectively.

Radiological outcomes

In this study, the mean preoperative Cobb was 51.8°, ranging from 40° to 81°, while mean postoperative Cobb was 8°, ranging from 3° to 25°, with significant decrease in Cobb immediate and 1 year postoperatively when compared to preoperative level ($p < 0.001$ for both). Similar results were reported by **Garcia *et al.*** [(10)] who included 79 patients and there was a statistically significant difference in the postoperative Cobb angle as compared to the preoperative Cobb angle (7° vs 53°) respectively. The results of the current study also agree with **Kilinc *et al.*** [(11)] who showed that the preoperative mean main thoracic Cobb angle measured 61.2° and corrected to 25.3° postoperatively, and was 28.5° at 2-year follow-up.

Forced vital capacity (FVC)

In the current study, mean preoperative FVC was 3.8 litres, ranging from 2.8 to 4.9, while mean postoperative FVC was 3.4 L ranging from 2.5 to 4.6 with significant decrease in FVC postoperatively ($p < 0.001$). Mean percentage decrease in FVC was 9.7%, ranging from -15.4 to 16.8%. In accordance with our results, another study reported the impact of thoracoplasty on pulmonary function in adolescent idiopathic scoliosis cases. It included 18 patients who were subjected to posterior spinal fusion and costoplasty. The study evaluated the pulmonary function by forced vital capacity (FVC) prior to and 1 and 2 years after surgery. The average preoperative absolute FVC was 77.15%. One year post-surgery, mean FVC was 79.8%, while the mean FVC was 81.8%, 2 years post-surgery, and it was concluded that the pulmonary function of patients with scoliosis had a progressive improvement of FVC at 1 and 2 years after surgery [(12)]. This comes in consistence with another study that reported decrease in pulmonary function values within 3 months after the operation, but in long-term follow-up, the patients showed significant recovery [(13)].

Height gain

In the current study, mean preoperative height was 1.60 m, ranging from 1.37 to 1.77, while mean postoperative height was 1.66, ranging from 1.46 to 1.83 m. with significant increase in height postoperatively ($p < 0.001$). Mean percentage height gain was 3.91%, ranging from 1.16 to 7.59%. This comes in accordance with **Langlias *et al.*** [(14)] who showed that the mean preoperative clinical height was 160.9 ± 7.5 cm (range 140–179 cm) in the standing position and 82.6 ± 4 cm (range 73–92.5 cm) in the sitting position. The average postoperative clinical height gain in a standing position was 4.2 ± 1.8 cm (range 0–11 cm) ($P < 0.001$).

Shoulder balance

In the current study, the mean preoperative clavicular angle was 7.3°, ranging from 4° to 11°, while mean postoperative clavicular angle was 4.2°, ranging from 2 to 7° with significant improvement of shoulder balance postoperatively ($p < 0.001$). Mean percentage decrease in clavicular angle was 42.7%, ranging from -16.7 to 75%. We agree with **Hong *et al.***[(15)] who noted that there is good balance results after fusion of main and proximal thoracic curves. Besides, **Li *et al.*** [(16)] reported that in 25 patients, 21 (84 %) achieved normal shoulder balance, and 4 (16 %) only minimal imbalance after double fusion of proximal curvature. Moreover, even if the surgeon achieves the successful correction of the proximal thoracic curvature, shoulder imbalance can remain regardless of the amount of coronal curvature correction, which can significantly worsen the outcome of the surgery [(17-19)].

Spino-pelvic parameters

In the current study, there was a significant decrease in LL postoperatively ($p < 0.001$) and there was a significant decrease in PI postoperatively ($p < 0.001$), however, there was no significant difference in PT postoperatively ($p > 0.05$). **Ozkunt *et al.*** [(20)] reported that the mean preoperative lumbar lordosis, pelvic incidence and pelvic tilt were 50.8° ± 7.4°, 48.3° ± 8.5°, and 15.5° ± 4.5°, respectively. Mean postoperative lumbar lordosis, pelvic incidence and pelvic tilt were 46.3° ± 7.1°, °7.7 ± °34.3 and 7°.7 ± °15.2, respectively. Comparison of the preoperative and last follow-up thoracic kyphosis and lumbar lordosis showed that there was a significant difference statistically. However, there was no statistical difference between preoperative and last follow-up pelvic incidence, sacral slope and pelvic tilt. Spinopelvic parameters were investigated by **Farshad *et al.*** [(21)] in different types of AIS curves. They found that the spinopelvic balance was not statistically distinguishable in different Lenke curve types. They found a slight difference of spinopelvic balance only in Lenke type 5 and 6 (major curve at the thoracolumbar/ lumbar region) with a pelvis incidence of 44°, sacral slope of 34° and pelvic tilt of 10°, when compared to normal population values. Different to the literature, in our data, PT following surgery showed no statistically significant difference, however, LL showed a statistically significant decrease.

Regression analysis

In this study, linear regression analysis was conducted for prediction of factors affecting height gain using age, weight, number of fused levels, preoperative Cobb, CA, LL, PI and PT as confounders. Higher number of fused levels and Cobb angle degree were considered as predictors of significant height gain in uni- and multivariable analyses. The model reported by **Spencer *et al.*** [(22)] focuses on the height gain with good reliability ($R^2 = 0.85$) but includes the degree of correction of the frontal Cobb angle, which is a measure taken from postoperative data. The model reported by **Watanabe *et al.*** [(23)] is also based on analysis of the corrected Cobb angle. This model was built to inform the patient quickly and easily in preoperative consultation. it showed a lower adjusted R^2 (0.47), but we can predict the height gain. In the van **Popta *et al.*** **[24]** study, the authors aimed to predict postoperative height but not height gain. This difference makes it possible to obtain a high adjusted R^2 (0.76) because the postoperative height is strongly correlated with the preoperative height. Another study by **Smorgick *et al.*** **[25]** showed that patients with Lenke type 1 and 2 had statistically less height gain compared to patients with Lenke type 3, 4, and 6. **Rentenberger *et al.*** **[26]** showed that the univariate analyses showed that the number of LLIF levels (coefficient=10.9, p=0.03), the absolute coronal vertical axis change (coefficient=0.6, p=0.01), and the absolute Cobb angle change (coefficient=−0.9, p=0.03) were significant predictors for height change.

CONCLUSION

We do believe that the posterior only approach 3D correction is an effective method in management of AIS concerning correction of Cobb angle, shoulder balance and spinopelvic parameters and recommend it as the best way nowadays to treat this disease.

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