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POSTERIOR INSTRUMENTATION AND SPINAL FUSION RESULTS IN SURGICAL TREATMENT OF ADOLESCENT IDIOPATHIC SCOLIOSIS

Mehmet Kürşad BAYRAKTAR[1]
Ali Akın UĞRAŞ[2]
Mustafa Fehmi AKYILDIZ[3]
Mücahit GÖRGEÇ[4]

[1]*Okmeydani Training and Research Hospital, Department of Orthopaedics and Traumatology, Istanbul, Turkey.*
[2]*Private practice, Sisli, Istanbul, Turkey.*
[3]*Haseki Training and Research Hospital, Department of Orthopaedics and Traumatology, Istanbul, Turkey.*
[4]*Private practice, Kadıkoy, Istanbul, Turkey.*

ORCID Numbers:
Mehmet Kürşad BAYRAKTAR:
0000-0003-3860-7847
Ali Akın UĞRAŞ:
0000-0001-6534-9201
Mustafa Fehmi AKYILDIZ:
0000-0003-3393-411X
Mücahit GÖRGEÇ:
0000-0003-0104-6636

Address: Mehmet Kürşad BAYRAKTAR, Okmeydanı Eğitim ve Araştırma Hastanesi, Ortopedi ve Travmatoloji Kliniği, Darulaceze Cad., No:25, Şişli, İstanbul, Turkey.
Phone: +90 535 924 69 76
E-mail: mk_bayraktar@yahoo.com
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ABSTRACT

Objective: To define the relationship between radiological and functional outcomes of AIS more than10 years follow-up.

Methods: 22 AIS patients were reviewed retrospectively. Cobb angles were measured from full-length spinal radiography at preoperative, postoperative, mid-term and long-term follow-up.

Correction rate and correction loss rate were calculated. The SRS-30 questionnaire form was filled by the patients at the final follow-up examination. Results were compared with the Mann Whitney U test and unpaired t-test. Non-parametric correlation analytical test was performed with the Spearman test. $p<0.05$ considered as statistically significant.

Results: There were 15 female and 7 male with the mean age of 14.5. The mean follow-up was 35.8 and 134 months for mid-term and final follow-up. The mean fusion levels were 10.4 and the average of last instrumented vertebra was L 1.8. Major curvatures were corrected from 53.1° to 19.7° with a 63.6% correction rate. According to the SRS-30 questionnaire form, the mean pain, function and activity, self-image appearance, mental health, and satisfaction scores were 4.16 ± 0.29, 4.43 ± 0.28, 4.15 ± 0.31, 3.84 ± 0.30, and 4.15 ± 0.44 at mid-term and 3.96 ± 0.52, 4.22 ± 0.38, 4.35 ± 0.22, 4.14 ± 0.36, and 4.10 ± 0.34 at final follow-up, respectively. While the mental health scores improved statistically (p=0.0214), the pain (p=0,043) and the activity (p=0.038) scores deteriorated and the satisfaction score (p=0.64) remained stable in time. A significant relationship was found between the final cobb angle and pain (p = 0.044, Rho = -0.407). When the SRS-30 results were evaluated among themselves, there was a significant correlation between function and self-image (p= 0.005, Rho = 0.547), also function and pain (p= 0.038, Rho = 0.532).

Conclusion: For the surgical treatment of adolescent idiopathic scoliosis, posterior instrumentation and spinal fusion surgery is an efficient and successful method with patient satisfaction, curvature correction, and low complication rates after more than ten years follow-up.

Keywords: Adolescent idiopathic scoliosis; SRS-30; functional results; long-term

Level of evidence: Retrospective clinical study, Level III

INTRODUCTION

Adolescent idiopathic scoliosis is determined as the most common type of scoliosis. In this three-dimensional deformity lateral shift, axial rotation and sagittal lordosis occur. The most common symptoms are a cosmetic deformity, rib hump, shoulder, hip and breast asymmetries [17,19,21].

Treatment options are observation, conservative treatment or surgical treatment according to the magnitude of the curvature, flexibility, progression and patient age. Surgical indications are generally considered to be curvature more than 45°, rapid progression between follow-up, severe back pain, pulmonary, cardiac and psychological serious complaints [10,15].

The goals of the surgical treatment are to correct the three-dimensional deformity, to provide solid fusion, and to balance the head and body on the pelvis [21]. In recent years segmental pedicle screw fixation technique is commonly used to provide a more rigid fixation. With this method,

compression, distraction, translation and rotation forces can be applied intersegmentally, and control of curvature in each segment is possible [8-9,14,21]. Technological advances have much improved the ability of surgeons to safely correct the deformity while maintaining sagittal and coronal balance [12,17,21].

Radiological and functional outcomes of the patients may change over time on extended follow-up. Especially the SRS-30 form is beneficial for monitoring functional results and measuring patient satisfaction [6,20].

Which radiological parameter that most affect the functional results is not a subject that is studied widely in the current literature. However, notice and interest in the parameter that can change patient satisfaction might improve treatment success.

This study aimed to define the relationship between radiological and functional outcomes of AIS more than10 years follow-up.

MATERIALS and METHODS

Adolescent idiopathic scoliosis (AIS) patients who underwent posterior instrumentation and spinal fusion surgery from 1999 to 2006 at Department of Orthopedics and Traumatology clinic were evaluated in this retrospective study (Table-1). Inclusion criteria were **(1)** diagnosed adolescent idiopathic scoliosis and received acceptable correction surgery, **(2)** minimum ten years follow up period after surgery, **(3)** no previous surgery, **(4)** adequate documentation before and after surgery. Twenty-five patients were collected from the thesis study [3] of the first author and twenty-two of 25 patients who met all the criteria were included in this study. We referred to the results of the previously mentioned thesis study as the mid-term (minimum 2 years follow-up). In July and June 2018, 15 female and seven male with the mean age of 14.55 ± 1.53 were examined for last control visit. The mean follow-ups at the mid-term and the final were 35.8 ± 20.58, and 134 ± 11.98 months, respectively. Demographic characteristic of the patients is determined (Table-2).

Table-1. The age, sex, Risser stage, King classification type, follow-up period, Cobb angles, correction ratio, correction loss and SRS-30 results of each patients.

No	Age	Sex	Risser	King Type	Folow-up (month)	Preop Cobb (°)	Postop Cobb (°)	Last Cobb (°)	Correction Ratio (%)	Correction Lost (%)	Pain	Function / Activity	Self Image Appearance	Mental Health	Satisfaction
1	15	K	5	2	20	54	22	24	59,2	3,7	3,8	4	4	3,4	5
2	13	E	2	3	12	50	9	10	82	2	4,2	4,2	4	4,2	4,4
3	15	E	4	5	13	56	20	20	64,2	0	4,6	3,8	4	4	4
4	12	K	2	2	16	60	16	16	73,3	0	4,2	4,2	4	4,2	4,4
5	13	K	3	3	30	48	14	16	70,8	4,1	4,4	4,8	4,6	4,2	4
6	16	E	4	3	40	50	15	16	70	2	4,2	4,6	4,2	4	4,4
7	15	K	3	2	18	52	22	25	57,6	5,7	4,5	4,8	4	4	4
8	17	E	4	2	46	49	14	17	71,4	6,2	4,6	4,2	4,4	4	4,4
9	18	K	5	2	64	54	20	22	62,9	3,7	4	4,4	3,8	3,4	3,6
10	16	E	4	3	78	53	22	23	58,5	1,8	4,2	4,8	4,8	4,2	4
11	14	K	4	2	36	60	32	32	46,6	0	3,8	4,6	4	3,6	4,4
12	15	K	4	1	65	79	30	34	62,5	4,9	4	4,4	4,2	4	5
13	14	K	3	4	90	50	19	23	62	8	3,5	4,2	3,6	3,4	3,6
14	13	K	3	3	26	54	28	28	48,1	0	4,2	4,8	4,4	4	4,4
15	13	K	3	5	20	46	16	18	65,2	4,3	4,6	4,6	4,2	3,8	4
16	15	K	4	1	22	48	20	21	58,3	2,1	4,5	4,8	4,4	4	4,4
17	18	E	4	4	20	52	24	24	53,8	0	4,2	4,6	4,2	3,8	3,6
18	14	K	4	2	24	52	20	22	61,5	3,8	4	4,4	3,8	3,2	3,6
19	21	K	5	2	54	58	40	44	31,1	6,8	3,8	4,2	3,6	3,4	3,6
20	15	E	3	1	46	54	24	26	55,5	3,7	4	4,2	4,4	4	4
21	12	K	2	1	32	50	18	19	64	2	4,2	4,6	4,2	4	4,4
22	16	E	4	2	38	58	20	22	65,5	3,5	4,6	4,8	4,8	4,2	5
23	18	K	5	2	34	54	30	32	44,4	3,7	4,2	4,4	4	3,6	3,6
24	14	K	4	1	24	45	16	18	64,4	4,4	3,8	4,2	4,2	3,8	4
25	15	K	4	2	27	48	18	19	62,5	2,1	4	4,2	4	3,8	4

Table-2. Demographic characteristic of the patients.

Age	14.55 ± 1.53
Female	15 (68.2%)
Male	7 (31.8%)
Age of onset of symptoms	13.1 ±1.82
Risser sign	3.55 ± 0.85
Mid-term follow-up (months)	5.8 ± 20.58
Final (long term) follow-up (months)	134 ± 11.98

All surgeries were performed in the prone position by the same two attending spinal surgeons. Titanium segmental pedicle screws, 6 mm titanium rods and transverse connectors were used in all cases. The stable vertebra was determined to be the last instrumented vertebra. Instrumentation extended proximally to the neutral vertebra. The mean fusion levels were 10.4 (range 8 to 13) while the longest fusion level was between T2 and L3. The last instrumented vertebra level ranged between T12 and L4, with an average of L 1.8.

To correct scoliotic curvature, facetectomies, apical derotation, convex side compression, and concave side distraction maneuvers were applied respectively. In all cases, a wake-up test was performed during surgery. Only posterior segmental spinal instrumentation was applied to all of the cases.

Thoracolumbosacral orthosis (TLSO) was used from postoperative second day to the fourth month to reduce pain and maintain fusion. All patients were mobilized with TLSO on the second day.

The radiographic evaluation of these patients was obtained preoperatively, immediately after surgery, at the mid-term and final follow-up examination by full-length spinal radiography (Figure-1).

Preoperatively, the apical, neutral and stable vertebrae were determined, and the size of curvatures was measured by Cobb method. Nash Moe method was used to measure apical vertebral rotation. Also, pre-operative curvatures were distributed according to the Lenke classification system (Table-3).

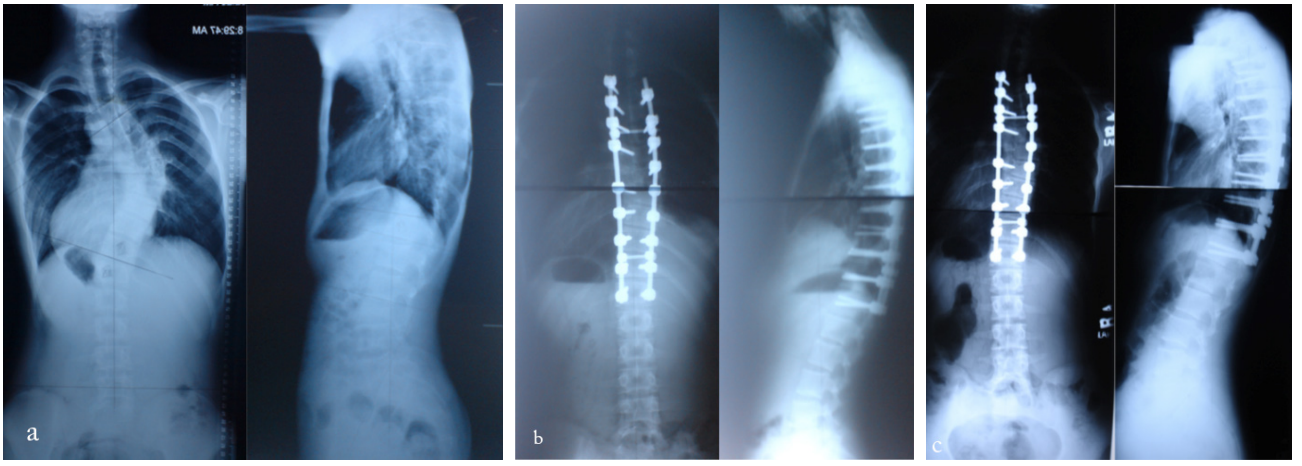

Figure 1 : a) preoperative, **b)** postoperative, and **c)** last follow-up radiographies of 13 years old male. Thoracic major curvature was corrected from 50° to 9° with a 82% correction rate. At the final follow-up on 125th month, 2 % correction loss was seen.

Table-3. Distribution of the all cases according to Lenke classification system.

Curve Type	No (%)	Lomber Spine Modifier			Thoracic Sagittal Profile		
		A	B	C	(-)	N	(+)
I	13 (59.2)	7	5	1	-	13	-
II	2 (9.1)	2	-	-	-	2	-
III	4 (18.2)	-	1	3	-	3	1
IV	1 (4.5)	-	1	-	-	1	-
V	**1 (4.5)**	-	-	**1**	-	**1**	-
VI	**1 (4.5)**	-	-	**1**	-	**1**	-

Correction rate was calculated from the early postoperative radiographs by using the following formula:

Correction rate % = (Pre-op Cobb - Post-op Cobb)*100 / Pre-Op Cobb

From the last follow-up radiographs, the correction loss percentage ratio was calculated:

Correction loss % = (Last Cobb - Post-op Cobb)*100 / Pre-Op Cobb

The Scoliosis Research Society form (SRS-30) was filled by the patients at the final follow-up examination. SRS-30 questionnaire form (encompasses Versions 22 and 24 consists of the five groups and 30 questions with the addition of 6 questions to the SRS-24 after treatment: **(1)** Pain, **(2)** Function and Activity, **(3)** Self Image Appearance, **(4)** Mental Health, **(5)** Satisfaction. Each answer was evaluated out of 5 points (e.g., 5 points for the excellent result while 1 point for poor results), and the average of the groups was recorded (Table-4).

Preoperative, postoperative and follow-up results were compared with the Mann Whitney U test and unpaired t-test. A non-parametric analytical correlation test was performed with the Spearman test by using SPSS software (Version 17.0, SPSS, Inc, Chicago, IL, USA). $p<0.05$ was considered statistically significant.

Table-4. SRS-30 questionnaire

SECTION 1 (All patients)		
1.Which one of the following best describes the amount of pain ou have experienced during the past 6 months?	5-None 4-Mild 3-Moderate 2-Moderate to severe 1-Severe	P
2.Which one of the following best describes the amount of pain you have experienced over the last month?	5-None 4-Mild 3-Moderate 2-Moderate to severe 1-Severe	P
3. During the past 6 months have you been a very nervous person?	5-None of the time 4-A little of the time 3-Some of the time 2-Most of the time 1-All of the time	MH
4. If you had to spend the rest of your life with your back shape as it is right now, how would you feel about it?	5-Very happy 4-Somewhat happy 3-Neither happy nor unhappy 2-Somewhat unhappy 1-Very unhappy	SA
5.What is your current level of activity?	1-Bedridden/wheelchair 2-Primarily no activity 3-Light labor, such as household chores 4-Moderate manual labor and moderate sports, such as walking and biking 5-Full activities without restriction	FA
6.How do you look in clothes?	5-Very good 4-Good 3-Fair 2-Bad 1-Very bad	SA
7. In the past 6 months have you felt so down in the dumps that nothing could cheer you up?	1-Very often 2-often 3-Sometimes 4-Rarely 5-Never	MH
8. Do you experience back pain when at rest?	1-Very often 2-often 3-Sometimes 4-Rarely 5-Never	P
9.What is your current level of work/school activity?	5-100% normal 4-75% normal 3-50% normal 2-25% normal 1-0% normal	FA
10.Which of the following best describes the appearance of your trunk; defined as the human body except for the head and extremities?	5-Very good 4-Good 3-Fair 2-Poor 1-Very poor	SA
11. Which one of the following best describes your medication usage for your back?	5-None 4-Non-narcotics weekly or less 3-Non-narcotics daily 2-Narcotics weekly or less 1-Narcotics daily	P
12. Does your back limit your ability to do things around the house?	5-Never 4-Rarely 3-Sometimes 2-Often 1-Very often	FA
13. Have you felt calm and peaceful during the past 6 months?	5-All of the time 4-Most of the time 3-Some of the time 2-A little of the time 1-None of the time	MH
14. Do you feel that your back condition affects your personal relationships?	5-None 4-Slightly 3-Mildly 2-Moderately 1-Severely	SA
15.Are you and/or your family experiencing financial difficulties because of your back?	1-Severely 2-Moderately 3-Mildly 4-Slightly 5-None	FA
16.In the past 6 months have you felt downhearted and blue?	5-Never 4-Rarely 3-Sometimes 2-Often 1-Very often	MH

17.In the last 3 months have you taken any sick days from work/ school due to back pain, and if so, how many?	5-0 4-1 3-2 2-3 1-4 or more	P
18.Do you go out more or less than your friends?	5-Much more 4-More 3-Same 2-Less 1-Much less	FA
19.Do you feel attractive with your current back condition?	5-Yes, very 4-Yes, somewhat 3-Neither attractive nor unattractive 2-No, not very much 1-No, not at all	SA
20.Have you been a happy person during the past 6 months?	1-None of the time 2-A little of the time 3-Some of the time 4-Most of the time 5-All of the time	MH
21.Are you satisfied with the results of your back management?	5-Very satisfied 4-Satisfied 3-Neither satisfied nor unsatisfied 2-Unsatisfied 1-Very unsatisfied	S
22.Would you have the same management again if you had the same condition?	5-Definitely yes 4-Probably yes 3-Not sure 2-Probably not 1-Definitely not	S
23.On a scale of 1 to 9 , with 1 being very low and 9 being extremely high, how would you rate your self-image? (1 to9)	1-1,2 2-3,4 3-5,6 4-7,8 5-9	SA
SECTION 2 (Postoperative patients)		
24.Compared with before treatment, how do you feel you now look?	5-Much better 4-Better 3-Same 2-Worse 1-Much worse	S
25.Has your back treatment changed your function and daily activity?	5-Increased 3-Not changed 1-Decreased	FA
26.Has your back treatment changed your ability to enjoy sports/ hobbies?	5-Increased 3-Not changed 1-Decreased	FA
27.Has your back treatment _____ your back pain?	1-Increased 3-Not changed 5-Decreased	P
28.Has your treatment changed your confidence in personal relationships with others?	5-Increased 3-Not changed 1-Decreased	SA
29. Has your treatment changed the way others view you?	5-Much better 4-Better 3-Same 2-Worse 1-Much worse	SA
30.Has your treatment changed your self-image?	5-Increased 3-Not changed 1-Decreased	SA

RESULTS

Preoperative major curvatures were measured as a mean of 53.1° ± 7.1 (range 45°-79°) according to Cobb method. The mean postoperative Cobb angle was 19.7° ± 5.3 with a 63.6 % ± 7.8 correction. At the mid-term follow up, the mean correction loss was 3.09 % ± 2.1 and finally 5.06 % ± 2.88 (range 0-12%) for more than 10 years. Preoperative, postoperative and follow-up measurements of the major curvatures, coronal balance and sagittal parameters are compared. In frontal plan, correction of the major curves was important statistically ($p<0.05$), but there was no difference between the postoperative, minimum 2 years follow –up and long-term follow up values. In the other words, loss of correction of the Cobb angles of the major curves were same in the minimum two years and long-term follow-up controls, statistically ($p>0.05$). In all patients physiological normal sagittal contours was obtained postoperatively, in the midterm and long-term follow-up visits. (Table-5).

According to the SRS-30 questionnaire form, at mid-term follow-up the mean pain, function and activity, self-image appearance, mental health, and satisfaction scores were 4.16 ± 0.29, 4.43 ± 0.28, 4.15 ± 0.31, 3.84 ± 0.30, and 4.15 ± 0.44, respectively. At the final follow-up SRS outcomes were 3.96 ± 0.52, 4.22 ± 0.38, 4.35 ± 0.22, 4.14 ± 0.36, and 4.10 ± 0.34, respectively. While the mental health scores improved statistically (p=0.0214), the pain (p=0,043) and the activity (p=0.038) scores deteriorated and the satisfaction score (p=0.64) remained stable in time.

Correlation of the radiological and functional with the Spearman test demonstrated significant relationship was found between cobb angle and pain (p = 0.044, Rho = -0.407). When the SRS-30 results were evaluated among themselves, there was a significant correlation between function and self-image (p= 0.005, correlation coeffective = 0.547), also function and pain (p=0.038, correlation coeffective = 0.417). Comparison of statistically significant data was determined (Table-6).

In the clinical examination, shoulder asymmetry more than 20 mm was detected in 9 patients preoperatively, and 2 cases postoperatively. In these patients self-image and satisfaction scores were statistically lower (p=0.015 and p=0,02).

Table-5. Measurements of the major curvatures, coronal balance and sagittal parameters, and results of the SRS-30 questionnaire.

	Pre-operative	Post-operative	Mid-term follow-up	Final follow-up
Cobb Angle	53.1°	19.7°	21.41°	22.64°
Correction Rate		63.6%		
Correction Loss			3.09 %	5.06 %
Coronal Balance	2.22	1.14	0.98	0.92
Thoracic Kyphosis	14.86	23.6	25.5	26.2
Lumbar Lordosis	44.54	52.18	50.27	49.54
Pain			4.16	3.96
Function and Activity			4.43	4.22
Self-image Appearance			4.15	4.35
Mental Health			3.84	4.14
Satisfaction			4.15	4.10

Table-6. Statistical analysis and results.

Statistical Analysis	Data	Result
Difference	Cobb angle; pre vs post-op	p < 0.001
	Cobb angle; post-op vs mid-term	p =0.24
	Correction loss; mid-term vs final	p = 0.83
	SRS pain; mid-term vs final	p =0.043 (-)
	SRS function and activity; mid-term vs final	p =0.038 (-)
	SRS mental health; mid-term vs final	p = 0.021 (+)
	SRS satisfaction; mid-term vs final	p = 0.64
Correlations	Final Cobb and Pain	p = 0.044 (Rho = - 0.407)
	Final Cobb and Mental Health	p = 0.032 (Rho = - 0.430)
	Correction Ratio and Mental Health	p = 0.080 (Rho = 0.498)
	Function and Self Image	p = 0.005 (Rho = 0.547)
	Function and Pain	p = 0.038 (Rho = 0.417)
	Satisfaction and Self Image	p = 0.024 (Rho = 0.451)
	Satisfaction and Mental Health	p = 0.008 (Rho = 0.521)
	Pain and Self Image	p = 0.006 (Rho = 0.532)
	Self Image and Mental Health	p = 0.001 (Rho = 0.684)

DISCUSSION

The primary goal of the surgical treatment of AIS is to achieve a stable, well-balanced spine with a solid fusion. With the new generation instrumentation systems, surgeons can do more correction with segmenter pedicle screws. Most of the studies with long-term results are related to anterior instrumentation, Harrington, and CD systems [4,19,21].

In many studies, the frontal plane correction results were close to each other. In literature, the first study of long-term results of the TSRH instrumentation, Benli et al. published an average of 64% correction using the TSRH system [4]. Suk et al. reported the mean correction rate as 55% with hooks and 72% with segmental pedicle screws (18,20). In our study, major curvatures were corrected from 53.1° ± 7.1 to 19.7° ± 5.3 with a 63.6% ± 7.8 correction rate.

In a study by King et al., the relationship between the last instrumented vertebra and the postoperative pain was examined [11]. Accordingly, 25% lower back pain was

observed when the last instrumented vertebrae L1 while 82 % in cases where L5 level was included in the instrumentation. They concluded that maintaining the motion segment in the lumbar region as much as possible was critically important [17,22]. In our study, the last instrumented vertebra level ranged between T12 and L4, with an average of L 1.8.

Bartie et al. studied 171 surgically-treated AIS patients with a mean follow-up of 19 years and compared to a control group with the same age and gender [1]. They reported, patients fused to L2, L3, and L4 had slightly more low back pain than controls, but the SF-36 outcomes were equal in patients and controls. Nohara et al. reported 48 % disk degeneration after the 154 months average follow-up time, and L5/S1 was the most common location [14]. However, a relation between low back pain and degeneration was not found. Similar results were reported in the literature [7-9].

The SRS-30 questionnaire form was suggested from Scoliosis Research Society to follow functional outcomes of AIS patients [13]. This form consists of 30 questions and five groups. In the current study, while the mental health scores improved statistically (p=0.0214), the pain (p=0,043) and the activity (p=0.038) scores deteriorated, and the satisfaction score (p=0.64) remained stable in time. Statistically, a significant relationship was found inversely proportional between the final Cobb angles and the pain scores (p = 0.044). A significant correlation between function and self-image (p= 0.005), also function and pain (p=0.038) was evaluated.

Controversies about SRS outcomes and radiologic correlation continue in the current literature. Carreon reported that patient satisfaction with treatment did not change, and other SRS parameters increased significantly [5]. Some studies as the current study found a relationship between pain and Cobb angle, while others showed no significant relation [4-5,8]. However, in these studies, the current conception is satisfaction score generally tends to remain constant or increase with treatment on mid-term and long-term follow-up [4-5,7-8,12].

Bastrom et al reported major complications impact SRS scores [2]. Rodrigues et al evaluated no correlation between functional outcomes and the presence of minor perioperative complications [16]. In our study superficial wound infection was detected in 2 cases and on follow-up functional outcomes were not different from the others. However, in two patients shoulder asymmetry more than 20 mm was detected postoperatively. In these patients self-image and satisfaction scores were statistically lower (p=0.015 and p=0,02).

Limitations of the study were a small patient group, the absence of functional results preoperative and immediate after surgery and retrospective study design. However, most of the cases are still under follow-up and it is planned to publish results more than 20 years.

In conclusion, for the surgical treatment of adolescent idiopathic scoliosis, posterior instrumentation and spinal fusion surgery is an efficient and successful method with patient satisfaction, curvature correction, and low complication rates after more than ten years follow-up.

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