COMPARATIVE STUDY OF THE TYPES OF FIXATION IN ADOLESCENT IDIOPATHIC SCOLIOSIS

ESTUDO COMPARATIVO DOS TIPOS DE FIXAÇÃO NA ESCOLIOSE IDIOPÁTICA DO ADOLESCENTE

ESTUDIO COMPARATIVO DE LOS TIPOS DE FIJACIÓN EN LA ESCOLIOSIS IDIOPÁTICA DEL ADOLESCENTE

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ABSTRACT

Objective: To conduct a comparative study of the results obtained in the treatment of adolescent idiopathic scoliosis (AIS) with different types of fixations (traditional, selective and multiple), and to evaluate the correction of angular deformity in the frontal plane by the Cobb and sacral clavicular angle (SCA) methods. Methods: A study of a group of 278 patients with AIS who underwent selective, traditional, and multiple fixation surgeries. Results: Significant corrections of both the Cobb angle and the SCA were observed. Conclusions: In the multiple fixation surgeries there was a 100% correction between the preoperative and postoperative SCA values and a 50% correction in the traditional and selective fixations, a difference considered significant. Regarding the Cobb angle, the three fixations presented corrections between preop and postop with significant differences. ***Level of evidence III; Retrospective Study.***

Keywords: Spine Deformity; Scoliosis; Coronal Malalignment; Global Coronal; Deformity Angle.

RESUMO

*Objetivo: Realizar um estudo comparativo dos resultados obtidos no tratamento da escoliose idiopática do adolescente (EIA) com diferentes tipos de fixação tradicional, seletiva e múltipla e avaliar a correção da deformidade angular no plano frontal pelo método de Cobb e do ângulo sacro clavicular (ASC). Métodos: Estudo de um grupo de 278 pacientes com EIA operados com fixações seletiva, tradicional e múltipla. Resultados: Observou-se correção significativa tanto do ângulo de Cobb quanto do ASC. Conclusões: Nas cirurgias com fixação múltipla constatou-se, entre pré-operatório (pré-op) e pós-operatório (pós-op), uma correção de 100% do ASC, e com as fixações tradicional e seletiva a correção foi de 50%, diferença que se considerou significativa. Com relação ao ângulo de Cobb as três fixações resultaram em correções entre o pré-op e o pós-op com diferença considerada significativa. **Nível de evidência III; Estudo retrospectivo.**

Descritores: Deformidade da Coluna; Escoliose; Desalinhamento Coronal; Coronal Global; Ângulo de Deformidade.

RESUMEN

*Objetivo: Realizar un estudio comparativo de los resultados obtenidos en el tratamiento de la escoliosis idiopática del adolescente (EIA) con diferentes tipos de fijación: tradicional, selectiva y múltiple, y evaluar la corrección de la deformidad angular en el plano frontal mediante el método de Cobb y del ángulo sacro clavicular (ASC). Métodos: Estudio de un grupo de 278 pacientes con EIA operados con fijaciones selectiva, tradicional y múltiple. Resultados: Se observó corrección significativa tanto del ángulo de Cobb como del ASC. Conclusiones: En las cirugías con fijación múltiple se constató, entre preoperatorio (pre-op) y postoperatorio (post-op), una corrección de 100% del ASC, y con las fijaciones tradicional y selectiva la corrección fue de 50%, diferencia que se consideró significativa. Con relación al ángulo de Cobb las tres fijaciones resultaron en correcciones entre pre-op y post-op con diferencia considerada significativa. **Nivel de evidencia III; Estudio Retrospectivo.**

Descriptores: Escoliosis; Deformidad de la Columna; Escoliosis; Desalineación Coronal; Coronal global; Ángulo de Deformación.

INTRODUCTION

Boucher & Vancouver (1959) first described Transpedicular Fixation (TPF),[1] a technique popularized since 1961 by Roy-Camille & Demeulenaere, who published on the subject in 1970.[2]

In 2001, Suk et al. claimed that the third-generation (3G) fixation system was a reliable and safe scoliosis correction method.[3] These other authors agreed that 3G instrumentation was the gold standard for surgeries in AIS of greater magnitude.[4,5]

3G instrumentation began to be used in the treatment of scoliosis, fixing the entire extension of structured scoliotic curves, referred to in

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this article as traditional fixation. Since then, reports about the occurrence of degenerative processes in the discs and facet joints related to overloads and biomechanical changes of the spine have been observed.[6,7] With the introduction of selective fixation (SF), numerous reports can be observed citing the presence of trunk imbalance.[8-13]

In 2019, Beauchamp et al., presented an overall view of the current techniques for the management of idiopathic and early-onset adolescent scoliosis to help provide guidance around the surgical alternatives available for dealing with these conditions.[14]

In 2014, the authors of this article also introduced a new instrumentation principle for the correction of AIS called multiple fixation (MF), which applies short, apical, and multiple fixation.[15] In 2018, the same group published a method for overall measurement of the coronal plane of the spine called the sacral clavicular angle (SCA).[16]

The objective of this article was to conduct a comparative study of the results of corrective treatment for AIS through analysis of preoperative and postoperative data from TF, SF, and MF surgical techniques, as measured by the Cobb method[17] and the SCA.

METHODS

Project: Approved, CAAE: 08122919.9.0000.5138.

A retrospective study was conducted at the Instituto da Coluna Vertebral de Belo Horizonte of 450 patients who underwent 3G instrumentation surgery for AIS performed by the lead author at various city hospitals. Patients with incomplete medical records, operated cases with no image files, only preoperative or postoperative images, poor quality images, such as overly dark images and others not including the upper meeting points of the clavicles with the two second ribs were excluded.

The study refers to the treatment of three groups of patients with AIS submitted to three different fixation approaches: traditional, selective, and multiple. The objective was to analyze and compare the results of the Cobb angle and the SCA.

In the first operated group, most of them at the beginning of the 2000s, the entire extension of the structured curvatures was fixed, known as traditional fixation.

Next, selective fixation was included, in which only the main curve was fixed with the intent of preserving vertebral mobility.

In 2014, the authors of this article introduced the multiple fixation technique, applying short, apical fixation, which can be multiple in scolioses with two or more structured curves. (Figure 1) They considered residual structured curves equal to or greater than 10° in the radiological study of the spine in the posterior anterior incidence, with forced lateral inclination to the right and the left (flexibility test).[15]

Criteria for inclusion of vertebrae in multiple fixation of scoliosis, using the flexibility test: Occurrence of a 75 to 90% correction - two apical vertebra are fixed; correction of 50 to 74% - 2 to 3 vertebrae are fixed; correction of 25 to 49% - 4 to 5 vertebrae are fixed; correction of 0 to 24% - the entire extension of the curve is fixed, studying the possibility of not fixing the terminal vertebrae. The peculiarity of each curvature must be considered, depending on the location, rotation, rigidity, extension, and maturity of the skeleton.

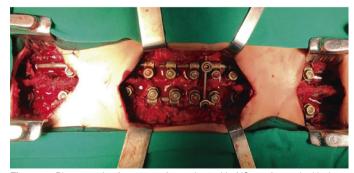Prior to the procedure, all patients were thoroughly informed about the surgery, its indication, the need for it, and its possible complications. All of them signed the informed consent form, including authorization for blood replacement if necessary and the taking of photos, recording of videos, and publication in scientific articles, aimed at an academic and ethical article.

The authors relied on data from the patients' medical records and preoperative and postoperative panoramic spinal X-ray images in posteroanterior and lateral incidences taken in the standing position.

Research variable data were collected, and worksheets were prepared for the biostatistical study.

First, an exploratory analysis was conducted in order to characterize the patient sample, using frequency distributions for the demographic and clinical variables.

A two by two table was used to associate the demographic variables with the traditional, multiple, and selective fixation methods. The Chi-squared test was adopted to test the statistical significance of the association among these variables.

The non-parametric Kruskal-Wallis test was used to evaluate differences between age and the fixation methods, since the assumption of normality was not verified through the Shapiro-Wilk test.

The non-parametric Wilcoxon test was used to evaluate the differences between preoperative and postoperative study patient data because the data did not follow Gaussian distribution.

The study data were processed by the PASW, version 18, statistical program. A significance level of 5% was considered in all the statistical tests performed. Thus, an association is considered statistically significant if its p value is less than 0.05.

RESULTS

Among the patients, there were more females in each of the methods, accounting for 93.5% of the multiple fixations, 89.1% of the traditional fixations, and 83.3% of the selective fixations. White patients were more prevalent in all fixation methods, at 86% of traditional, 88% of multiple, and 96% of selective fixations. No differences between the sexes or races in any of the methods researched were observed. The mean age of the patients was 15 years in all groups with no statistical differences.

In Table 1 and Figure 2, we observe that in patients belonging to the multiple fixation group there was a preoperative median SCA of 3.0°, while the postoperative median was 0°. Comparing these two

Table 1. Frequency distribution of the patients in each method by the Sacral Clavicular Angle (SCA) measurement.

Variable	Method	Descriptive Measurements					P-value
		Operative	1Q	Median	3Q	%Variation	
SCA	Multiple fixation	Pre	2.0	3.00°	6.00	-100%	p<0.001
		Post	0.0	0.00°	2.00		
SCA	Traditional fixation	Pre	0.0	2.00°	5.00	-50%	p<0.001
		Post	0.0	1.00°	2.00		
SCA	Selective fixation	Pre	0.0	2.00°	4.00	-50%	p<0.002
		Post	0.00	1.00°	3.75		

Note: The significance probabilities (p-value) refer to the Wilcoxon test.

Figure 1. Photograph of surgery of a patient with AIS, performed with three approaches for multiple fixation.
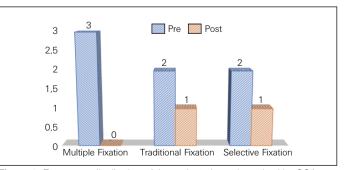

Figure 2. Frequency distribution of the patients in each method by SCA measurement.

moments, there was a postoperative reduction of 100% in relation to the preoperative value. The difference between the preoperative and postoperative values was confirmed as significant by the statistical test.

Also in Table 1 and Figure 2, in patients in the traditional fixation group there was a preoperative median SCA value of 2°, while the postoperative median was 1°. A comparison of these two moments shows a postoperative reduction of 50% in relation to the preoperative value. The difference between the preoperative and postoperative values was confirmed as significant by the statistical test.

Continuing with Table 1 and Figure 2, in patients belonging to the selective fixation group there was a median preoperative SCA of 2°, while the median postoperative value was 1°. A comparison of these two moments shows a postoperative reduction of 50% in relation to the preoperative value. The difference between the preoperative and postoperative values was confirmed as significant by the statistical test.

The results in Table 2 show that, in a comparison of the three methods according to the correction of the SCA, the test identified that the multiple fixation method corrected more (median of 2.00°) than the other methods (traditional and selective), which obtained a median of 0.00°.

In Table 3, we observe that in the patients belonging to the traditional fixation method there was a median preoperative proximal thoracic curve of 44° by the Cobb method, while the postoperative median was 11°. Comparing these two moments, there was a 75% reduction in the postoperative in relation to the preoperative value, a difference which was confirmed by the statistical test and considered significant.

Also in Table 3, patients belonging to the multiple fixation method had a median preoperative proximal thoracic curve of 33° by the Cobb method, while the postoperative median was 7°. Comparing these two moments, there was a 78% reduction in the postoperative in relation to the preoperative value, a difference which was confirmed by the statistical test and considered significant.

Continuing with Table 3, patients belonging to the selective fixation method had a median preoperative proximal thoracic curve of 35° by the Cobb method, while the postoperative median was 14°. Comparing these two moments, there was a 78% reduction in the postoperative in relation to the preoperative value, a difference which was confirmed by the statistical test and considered significant.

The results in Table 4 show that, in comparing the correction of the proximal thoracic curves for the three methods, the test identified that the selective fixation method corrected less (median of 18.00°) than the other methods (traditional and multiple) which obtained medians of 33.00° and 27.00°, respectively.

In Table 5, we observe that for patients belonging to the traditional fixation method there was a median preoperative middle thoracic curve of 55° by the Cobb method, while the postoperative median was 7°. Comparing these two moments, there was an 87% reduction in the postoperative in relation to the preoperative value, a difference which was confirmed by the statistical test and considered significant.

Also in Table 5, patients belonging to the multiple fixation method had a median preoperative middle thoracic curve of 52° by the Cobb method, while the postoperative median was 8°. Comparing these two moments, there was an 84.6% reduction in the postoperative in relation to the preoperative value, a difference which was confirmed by the statistical test and considered significant.

Continuing with Table 5, patients belonging to the selective fixation method had a median preoperative middle thoracic curve of 52° by the Cobb method, while the postoperative median was 8.5°. Comparing these two moments, there was an 83.6% reduction in the postoperative in relation to the preoperative value, a difference which was confirmed by the statistical test and considered significant.

The results in Table 6 show that, in comparing the correction of the middle thoracic curves for the three methods, the test identified that the traditional fixation method corrected more (median of 47.00°) than the other methods (selective and multiple) which obtained medians of 45.00°.

Table 2. Comparison of the patients according to the difference between preoperative and postoperative SCA.

| Method | Descriptive Measurements | | | | | | | | P-value |
	N	Mean	S.D.	Minimum	Maximum	1Q	Median	3Q	
Multiple fixation	93	2.27°	3.37	-7	15	0.00	2.00°	4.50	p<0.001
Traditional fixation	101	1.30°	3.78	-5	20	-1.00	0.00°	3.00	
Selective fixation	84	0.30°	4.89	-10	32	-1.75	0.00°	2.00	

Note: The significance probabilities (p-value) refer to the Kruskal-Wallis test.

Table 3. Frequency distribution of the patients in each method by the proximal thoracic curve variable.

| Variable | Method | Descriptive Measurements | | | | | P-value |
		Operative	1Q	Median	3Q	%Variation	
Proximal thoracic curve	Traditional fixation	Pre	31.25	44.00°	67.75	-75%	p<0.001
		Post	8.00	11.00°	21.00		
Proximal thoracic curve	Multiple fixation	Pre	30.00	33.00°	40.00	-78%	p<0.001
		Post	3.00	7.00°	10.00		
Proximal thoracic curve	Selective fixation	Pre	28.00	35.00°	42.00	-60%	p<0.001
		Post	9.00	14.00°	21.00		

Note: The probability of significance (p-value) refers to the Wilcoxon test.

Table 4. Comparison of the patients by the difference between pre- and postoperative proximal thoracic curves.

| Method | Descriptive Measurements | | | | | | | | P-value |
	N	Mean	S.D.	Minimum	Maximum	1Q	Median	3Q	
Multiple fixation	59	26.36°	7.72	8	44	21.00	27.00°	30.00	p<0.001
Traditional fixation	16	34.25°	16.72	12	78	21.50	33.00°	44.50	p<0.001
Selective fixation	31	18.45°	12.79	0	46	7.00	18.00°	26.00	p<0.001

Note: The probability of significance (p-value) refers to the Kruskal-Wallis test.

Table 5. Frequency distribution of the patients in each method by the middle thoracic curve variable.

| Variable | Method | Descriptive Measurements | | | | | P-value |
		Operative	1Q	Median	3Q	%Variation	
Middle thoracic curve	Traditional fixation	Pre	45.00	55.00°	65.00	-87%	p<0.001
		Post	3.00	7.00°	10.00		
Middle thoracic curve	Multiple fixation	Pre	45.00	52.00°	62.00	-84.6%	p<0.001
		Post	4.50	8.00°	12.00		
Middle thoracic curve	Selective fixation	Pre	40.50	52.00°	61.00	-83.6%	p<0.001
		Post	4.00	8.50°	12.75		

Note: The probability of significance (p-value) refers to the Wilcoxon test.

Table 6. Comparison of the patients by the difference between the preoperative and postoperative middle thoracic curves.

| Method | Descriptive Measurements | | | | | | | | P-value |
	N	Mean	S.D.	Minimum	Maximum	1Q	Median	3Q	
Multiple fixation	93	45.89°	15.0	13	98	36.00	45.00°	52.50	p=0.032
Traditional fixation	95	48.23°	14.09	10	100	40.00	47.00°	56.00	p=0.032
Selective fixation	84	42.00°	17.26	8	82	30.00	45.00°	53.00	p=0.032

Note: The probability of significance (p-value) refers to the *Kruskal-Wallis* test.

In Table 7, we observe that for patients belonging to the traditional fixation method there was a median preoperative lumbosacral curve of 52° by the Cobb method, while the postoperative median was 8°. Comparing these two moments, there was an 85% reduction in the postoperative in relation to the preoperative value, a difference which was confirmed by the statistical test and considered significant.

Also in Table 7, patients belonging to the multiple fixation method had a median preoperative lumbosacral curve of 45° by the Cobb method, while the postoperative median was 7°. Comparing these two moments, there was an 84.4% reduction in the postoperative in relation to the preoperative value, a difference which was confirmed by the statistical test and considered significant.

Continuing with Table 7, patients belonging to the selective fixation method had a median preoperative lumbosacral curve of 46° by the Cobb method, while the postoperative median was 11°. Comparing these two moments, there was a 76% reduction in the postoperative in relation to the preoperative value, a difference which was confirmed by the statistical test and considered significant.

The results in Table 8 show that, in comparing the correction of the lumbosacral curves for the three methods, the test identified that the selective fixation method corrected less (median of 36.00°) than the other methods (traditional and multiple) which obtained medians of 45.00° and 39.00°, respectively.

Table 7. Frequency distribution of the patients in each method by the lumbosacral curve variable.

Variable	Method	Descriptive Measurements					P-value
		Operative	1Q	Median	3Q	%Variation	
Lumbosacral curve	Traditional fixation	Pre	42.25	53.00°	70.25	-85%	p<0.001
		Post	4.25	8.00°	13.75		
Lumbosacral curve	Multiple fixation	Pre	38.00	45.00°	54.00	-84.4%	p<0.001
		Post	4.00	7.00°	10.00		
Lumbosacral curve	Selective fixation	Pre	40.00	46.00°	52.50	-76%	p<0.001
		Post	6.00	11.00°	18.00		

Note: The probability of significance (p-value) refers to the *Wilcoxon* test.

Table 8. Comparison of the patients by the difference between the preoperative and postoperative lumbosacral curves.

Method	Descriptive Measurements							P-value
	N	Mean	S.D.	Minimum	Maximum	1Q	Median	3Q	
Multiple fixation	79	38.44°	12.12	6	62	30.00	39.00°	47.00	p=0.001
Traditional fixation	36	46.64°	15.89	2	75	38.00	45.00°	58.00	p=0.001
Selective fixation	72	37.06°	15.96	12	102	28.25	36.00°	43.00	p=0.001

Note: The probability of significance (p-value) refers to the *Kruskal-Wallis* test.

DISCUSSION

One hundred and thirty-six patients with AIS who underwent selective fixation were studied. A large number of them developed decompensation of the coronal plane in the immediate postoperative period, however, later on most of them improved satisfactorily. In this study, only two patients continued with trunk imbalance until the final follow-up.[18] In 2005, Gaines published a series of 31 patients submitted to short anterior reconstruction for the treatment of AIS and Scheuermann's disease. He claimed it was an alternative that made correction of the deformity and the maximum preservation of whole vertebral segments possible, advising rigorous patient selection and execution of "full" discectomy.[19] In 2019, Jiang et al. operated on adolescent scoliosis due to Chiari malformation type 1. They compared a group of 63 patients with right thoracic scoliosis and another group with left convexity. Both were corrected

successfully through selective thoracic fusion with promising long-term surgical outcomes.[20]

According to Brice Ilharreborde in 2018, the current literature no longer supported the trend to save movement with selective fusion. He prioritized sagittal alignment despite the possible arthrosis resulting from extensive fusions. He stated that customized planning using 3D technology was gaining popularity and might help to reduce complications in the future.[21]

Degenerative junctional spine disorders with dysfunction of the discs and the facet joints have become one of the major challenges of spinal deformity surgery.[6,7] Many articles can also be found in the literature pointing to the frequent imbalance of the trunk with selective fixation.[8-13,22,23] Such occurrences initially encouraged the authors of this article to opt for selective fixation and to later develop multiple fixation to treat scoliosis.

In this case series, we evaluated 278 patients who underwent surgery for AIS. When the 84 patients submitted to selective fixation were compared with the traditional and multiple fixation groups, they showed good correction both in relation to the Cobb angle and the SCA, although slightly less than the others (Tables 1 to 8, Figures 2 and 3).

The 101 patients in this series operated with traditional fixation had a slight improvement in the correction of the Cobb angle as compared to the groups operated using multiple and selective fixation (Tables 4, 5, 6, 7, 8 and Figure 4).

The 93 patients with AIS who underwent multiple fixation presented a one hundred percent correction of the median SCA of the study, while the other two groups operated with traditional and selective fixation resulted in correction of only fifty percent (Tables 1, 2 and Figures 2, 5, and 6).

In 2018, Garcia et al. evaluated the SCA in a group of 46 patients treated for AIS by selective and traditional fixation. They demonstrated in a comparison of preoperative and postoperative SCA median values that no correction occurred. They also measured 46 other individuals who underwent multiple fixation surgery and observed a correction of 83% relative to the median SCA of the study.[16]

Junctional kyphosis (JC) is a common radiographic finding following AIS correction. Therefore, several studies have been conducted about its causes, but no clear definition has been established.[24,25]
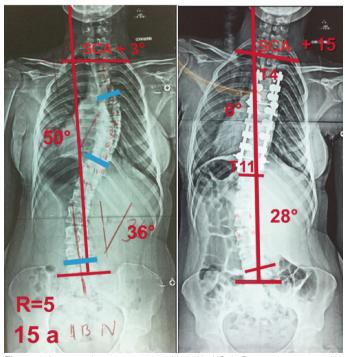

Figure 3. Images of a 15-year-old patient with AIS. In Pre- and postoperative panoramic spinal X-rays the SCA increased from + 3° to + 15° and greater asymmetry of the shoulders is observed after the correction.
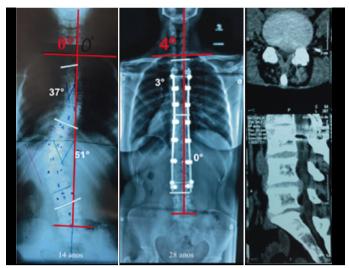
Figure 4. Female patient, 15 years of age. One the left, pre- and postoperative panoramic spinal X-rays of AIS with traditional fixation obtaining excellent correction. The SCA increased from 0° to 4°, right shoulder lower in post-op. On the right, computed tomography of the lumbar spine 15 years after surgery, extensive evidence of the process of disc degeneration.

The authors of the present article are publishing a statistical study conducted with pieces of synthetic spine and call attention to the risk of monoaxial screws positioned divergently to the apex of the curvature at the extremes of the fixation, associated with the distraction force, causing the rotation of the vertebra in kyphosis and triggering JC.[26]

These authors showed that spine surgeries to correct AIS have good results. Neurological damage is the most serious complication, but they also cite infections, problems related to the implant, thrombosis, vision loss, pseudoarthrosis, the crankshaft phenomenon, death, and others.[27] It is noteworthy that the complications that occurred in this case series are in agreement with the literature.

CONCLUSIONS

In conclusion, with the use of multiple fixation in the treatment of AIS there was a 100% correction of the SCA from the preoperative to the postoperative median value and 50% correction using traditional and selective fixations, the difference being considered significant. In relation to the Cobb angle, all three types of fixations resulted in satisfactory preoperative to postoperative corrections with differences considered significant.

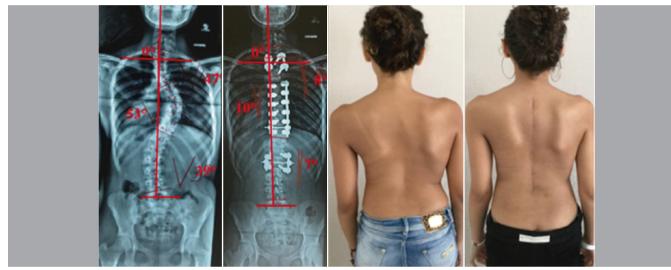All authors declare no potential conflict of interest related to this article.

Figure 5. Female patient, 15 years of age, submitted to multiple fixation for correction of AIS. On the left, preoperative and postoperative panoramic X-rays. The SCA of 0°, remained at 0° postoperatively. On the right, photos before and after surgery.
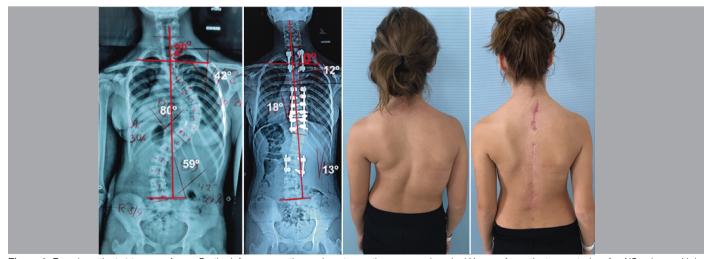

Figure 6. Female patient, 14 years of age. On the left, preoperative and postoperative panoramic spinal X-rays of a patient operated on for AIS using multiple fixation. The SCA went from 2° to 0°. On the right, photos before and after surgery. Note the balanced shoulders.

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