FUNCTIONAL AND RADIOGRAPHIC COMPARISON OF ANTERIOR AND POSTERIOR INSTRUMENTATION FOR THE CORRECTION OF ADOLESCENT IDIOPATHIC SCOLIOSIS

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ABSTRACT

Objective: This was a retrospective study to compare the anterior instrumentation (AI) and posterior instrumentation (PI) results among patients diagnosed with adolescent idiopathic scoliosis (Lenke type I) who were treated surgically. Methods: The results from 24 patients aged 11 to 18 years with Lenke type I idiopathic scoliosis who underwent surgery with AI (12 patients) or PI (12 patients) were compared. All the patients were operated by the same surgeon and were followed up for a minimum period of five years. The variables for comparison included: coronal and sagittal correction, distance from apical vertebra to midline, apical vertebral rotation, number of instrumented vertebrae and functional variables (by means of the SRS-22 questionnaire). The data obtained were analyzed using the SAS software, version 9. The two groups were compared using Student's t-test with a significance level of 5% (0.05). Results: The correction of the curve in the frontal plane was higher in the group of patients with the anterior approach, in the immediate (p=0.031) and late (p=0.043) postoperative periods, as was the apical vertebral rotation during the immediate (p=0.002) and late (p=0.019) evaluations. The number of instrumented vertebrae was 7.69 ± 1.38 in the AI group and 11.38 ± 2.92 in the PI group (p = 0.021). Functional assessment (SRS-22) did not show any significant difference (p > 0.05) between the groups. Conclusion: The patients who underwent scoliosis correction with AI presented greater correction in the frontal plane, greater derotation of apical vertebrae and a smaller number of fused vertebrae.

Keywords – Scoliosis; Thoracic; Spine/abnormalities; Surgical Instruments

INTRODUCTION

Surgical treatment for adolescent idiopathic scoliosis is controversial, as are the access route and the type of instrumentation for correction of the curves[1-4]. Treatment by means of a posterior approach was the preferred method, and this became refined through improvements in implants, such that it remained the most used method[5,6]. At the start of surgical treatment, the use of Harrington rods was the standard. In the middle of 1980, a multi-segment rod and hook system became

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popular and, more recently, pedicle fixation has become the preferred technique for correction of scoliosis[5]. The anterior approach was initially used for correction of lumbar and thoracolumbar curves, and later on was also recommended for treating thoracic curves. The advantages of the anterior approach include short arthrodesis, preservation of the posterior musculature of the trunk and greater corrective force applied to the apical vertebra, thereby resulting in greater three-dimensional correction of the deformity. However, the anterior approach is a procedure with higher morbidity, and treatments for the possible complications relating to the implants require solutions of greater complexity[2-4,6].

The aim of the present study was to retrospectively compare the results from patients with adolescent idiopathic scoliosis and Lenke type I curves who were operated by the same surgeon and had a minimum follow-up of five years, through clinical, radiological and functional variables that were prospectively stored in a database.

MATERIAL AND METHODS

The records on 24 patients with adolescent idiopathic scoliosis of Lenke type I who were operated by the same surgeon were analyzed. These data were in the Scolisoft database[7]. The patients were divided into two groups. The first group underwent anterior instrumentation (AI) of the spine using a single rod system, and the second group was treated with posterior instrumentation (PI) using a pedicle screw system. The number of patients in each group was adjusted according to the number of patients who underwent AI, which was smaller than the number of patients who underwent PI. The 12 patients in the PSF group were selected through database randomization, and thus the number of patients compared was the same in each group. Only patients who underwent a single surgical procedure to correct the deformity, without the use of preoperative traction, were included in the groups. The two groups of patients were compared by means of statistical analysis (two-tailed Student's t test with the significance level set at 5%; $p < 0.05$), taking into consideration the number of patients, sex, age, Risser sign, Cobb angle, thoracic kyphosis between T4 and T12, translation of the apical vertebra, distance between the central sacral line and the center of the apical vertebra and rotation of the apical vertebra using the Nash and Moe method[8]. No statistical difference was observed between the two groups ($p > 0.05$) (Table 1).

For both groups, the indication of surgical treatment was based on progression of the curve above 35º in immature patients, above 50º in mature patients, reduction of the thoracic kyphosis or esthetic deformity.

A screw system with lateral fitting (USS Synthes®) was used for anterior or posterior correction, with exclusive use of monoaxial screws and rods of 6 mm in diameter (Figures 1 and 2).

Table 1 – Preoperative values for the parameters evaluated in the anterior instrumentation (AI) and posterior instrumentation (PI) groups and the results from the statistical comparison between the groups. Note that there were no statistical differences among the study parameters ($p > 0.05$).

Cobb angle	Preoperative	51° ± 13.4	62.4° ± 11.9	0.057	
	Immediate postoperative	14.53° ± 10.6	31.46° ± 10.67	0.032	(*)
	Later postoperative	21.76° ± 10.13	36.23° ± 9.09	0.046	(*)
% frontal correction	Immediate postoperative	72.71% ± 19.69	52.76% ± 13.12	0.031	(*)
	Later postoperative	57.59% ± 17.92	40.69% ± 8.92	0.043	(*)
Translation of apical vertebra (mm)	Preoperative	53.7 mm ± 12.1	54.7 mm ± 14.0	0.067	
	Immediate postoperative	9.78 mm ± 9.26	11.7 mm ± 1.18	0.058	
	Later postoperative	10.41 mm ± 6.26	12.6 mm ± 4.3	0.053	
Thoracic kyphosis T4-T12	Preoperative	18.6° ± 11.30	25.60 ± 12.10	0.067	
	Immediate postoperative	22.07° ± 10.07	21.1° ± 7	0.092	
	Later postoperative	23.30° ± 9.44	23.07° ± 6.66	0.099	
Number of vertebra on which arthrodesis was performed		7.69 ± 1.38	11.38 ± 2.92	0.021	(*)
Rotation of apical vertebra	Preoperative	1.5 ± 0.76	1.91 ± 0.75	0.061	
	Immediate postoperative	0.16 ± 0.37	0.66 ± 0.47	0.022	(*)
	Later postoperative	0.21 ± 0.44	0.73 ± 0.52	0.019	(*)

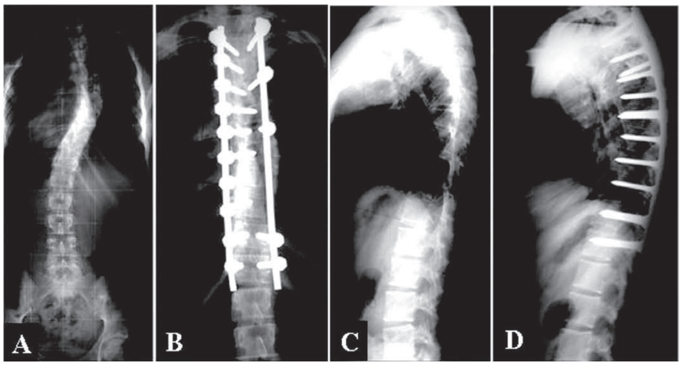

Figure 1 – Preoperative (A and C) and postoperative (B and D) radiographic images from a patient who underwent anterior instrumentation.

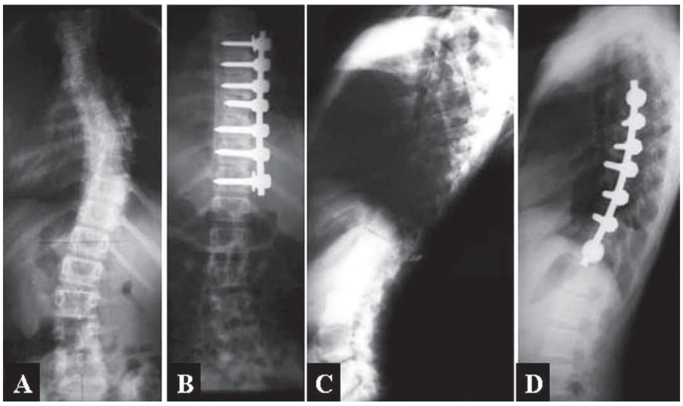

Figure 2 – Preoperative (A and C) and postoperative (B and D) radiographic images from a patient who underwent posterior instrumentation.

In the AI group, the level of arthrodesis included all the vertebrae of the Cobb angle measurement. If two terminal vertebrae were parallel, the more caudal one was selected as the most distal instrumented vertebra (LIV). The surgical access was obtained on the convex side of the curve by means of a single surgical incision and internal double thoracotomy. The intervertebral discs located between the proximal and distal limits of the curve were removed and their spaces were filled with rib bone grafts. A single rigid rod system (6 mm rod) was used for correction and fixation, with screws inserted in the lateral surface of the vertebral bodies.

In the PI group, the upper limit of the instrumentation was the neutral vertebra. The distal limit was defined in accordance with the slope markings. The sagittal plane was also considered in selecting the proximal and distal vertebrae to be instrumented, bearing in mind the presence of proximal kyphosis in determining the proximal extent of the arthrodesis, and the presence of thoracolumbar kyphosis for the distal level. The LIV was considered to be a stable vertebra and the arthrodesis was extended as far as the middle or lower lumbar spine in order to avoid the risk of decompensation in immature patients who presented rotation of the end vertebra.

Instrumentation with a screw was implemented in the PI group in a single or two-pedicle manner at each level. The correction was attained by means of manipulation of the screws in the apical vertebrae and derotation of the rod. Additional correction was obtained by means of compression of the curve on its convexity, relaxation of the concavity or modeling of the rod. Local autologous bone and iliac crest bone were used as bone grafts.

The variables evaluated were the Cobb angle, thoracic kyphosis between T4 and T12, translation of the apical vertebra, distance between the central sacral line and the center of the apical vertebra, rotation of the apical vertebra using the Nash and Moe method[8], number of vertebrae instrumented and the percentage correction of the curve in the frontal and sagittal planes. Evaluations were performed before the operation, during the immediate postoperative period and later on postoperatively.

The functional assessment was made using the SRS-22 questionnaire (Scoliosis Research Society)[9], which takes into account function, pain, self-image, mental health and satisfaction with the treatment, as assessment variables.

The two groups of patients were compared statistically using the two-tailed Student's t test, with equal variation between two samples, taking the significance level to be 5% ($p < 0.05$).

RESULTS

In the AI group, 11 were female and one was male, with ages ranging from 11 to 23 years (mean: 15.9 ± 2.4). The Risser sign was classified as III in five patients (41.6%), IV in five (41.6%) and V in two (16.6%). The apical vertebra was T7 in one patient (8.3%), T8 in six (50%), T9 in three (25%) and T10 in two (16.6%). The distance from the apical vertebra to the midline that went through the center of L5 in the frontal plane, ranged from 28 to 90 mm (mean: 53.73 ± 12.1 mm). Among the patients who underwent anterior correction, the proximal vertebra was T5 in seven patients (58.3%), T6 in four (33.3%) and T7 in one (8.3%). The distal vertebra was L2 in one patient (8.33%), L1 in three (25%), T12 in three (25%) and T11 in five (41.6%). The preoperative Cobb angle ranged from 30º to 70º (mean: 51 ±

13.4º) and the preoperative thoracic kyphosis (measured from T4 to T12) ranged from –4º to 50º (mean: 18.6º ± 11.3º). According to the Lenke classification(10), the lumbar modifier was type A in eight patients (66.6%), type B in three patients (25%) and type C in one patient (8.33%). According to the same classification (16), the thoracic modifier was negative in two patients (16.6%), normal (N) in nine patients (75%) and positive in one patient (8.33%). The vertebral rotation determined using the Nash and Moe method(8) was classified as III in two patients (16.6%), II in two patients (16.6%) and I in eight patients (66.6%) (Table 1).

In the PI group IP, 11 patients were female and one was male, with ages ranging from 11 to 20 years (mean: 14.54 ± 2.57 years). The Risser sign was classified as III in four patients (33.3%), IV in three (25%) and V in five (41.6%). The apical vertebra was T8 in six patients (50%) and T9 in six patients (50%). The distance from the apical vertebra to the midline that went through the center of L5 in the frontal plane ranged from 30 to 94 mm (54.7 ± 14.1). The proximal vertebra was T3 in three patients (25%), T4 in two (16.6%), T5 in six (50%) and T6 in one (8.3%). The distal vertebra was L2 in one patient (8.3%), L1 in five (41.6%), T12 in two (16.6%) and T11 in four (33.3%). The preoperative Cobb angle ranged from 52º to 89º (mean: 62.4 ± 11.9º) and the thoracic kyphosis (measured from T4 to T12) ranged from 6 to 44º (mean: 25.6 ± 12.1º). According to the Lenke classification[10], the lumbar modifier was of type A in eight patients (66.6%), type B in three patients (25%) and type C in one patient (8.33%). According to the same classification (16), the sagittal modifier was negative in one patient (8.33%), normal (N) in nine patients (75%) and positive in two patients (16.6%). The vertebral rotation determined using the Nash and Moe method[8] was classified as III in three patients (25%), II in five (41.6%) and I in four (33.3%) (Table 1).

There was no statistical difference between the AI and PI groups in relation to the number of patients, sex, age, Risser sign, Cobb angle in the frontal plane, thoracic kyphosis, translation of the apical vertebra (distance between the central sacral line and the center of the apical vertebra), rotation of the apical vertebra, lumbar modifier or sagittal modifier (p > 0.05) (Table 1).

The length of the postoperative follow-up ranged from five years to five years and nine months (mean: 65.25 ± 3.05 months) for the patients in the AI group, and from five years to five years and eight months (mean: 65.08 ± 2.87 months) for the patients in the PA group.

The values of the radiological variables that were used to compare the two groups are listed in Table 2. In relation to correction in the frontal plane, a significant difference was observed between the AI and PI groups according to the Cobb angle during the immediate postoperative period (p = 0.032) and later on postoperatively (p = 0.046).

The mean percentage correction of the scoliosis curves in the frontal plane was 72.71 ± 19.69% among the AI patients and 52.76 ± 13.12% among the PI patients. Later on postoperatively, the mean correction was 57.59 ± 17.92% for the AI patients and 40.69 ± 8.92% for the PI patients. The percentage correction of the curve in the frontal plane differed significantly between the AI and PI patients during the immediate postoperative period (p = 0.031) and later on postoperatively (p = 0.043).

The mean translation of the apical vertebra was 9.78 ± 9.26 mm during the immediate postoperative period and 10.41 ± 6.26 mm later on postoperatively, in the AI group, and 11.78 ± 1.18 mm and 12.6 ± 4.3 mm in the PI group, respectively, without any significant difference between the two groups at any time (p = 0.058 and p = 0.053, respectively).

The thoracic kyphosis (T4-T12) was 22.07 ± 10.07° during the immediate postoperative period and 23.30 ± 9.24° later on postoperatively, in the AI patients, and 21.17 ± 7° and 23.07 ± 6.96° in the PI patients, respectively, without any significant difference (p > 0.05) between the two groups.

The mean number of instrumented vertebrae was 7.69 ± 1.38 in the AI patients, with the following proximal vertebrae instrumented: five (38.46%) in T5, two (15.38%) in T6 and T12, and one (7.69%) in T7, T8, T10 and T12, respectively. The distal instrumented vertebra in the AI group was: four (30.76%) in T11 and L3, and one (7.69%) in T12, L1, L2 and L3. In the PI patients, the mean number of vertebrae instrumented was 11.38 ± 2.92, with the following proximal vertebrae instrumented: three (23.07%) in T3, nine (69.23%) in T4 and one (7.69%) in T5. The distal vertebra instrumented in the PI group was: three (23.07%) in T12, one (7.69%) in L1 and L2, six (46.15%) in L3 and two (15.38%) in L4. It was observed that there was a significant difference (p = 0.021) in the number of vertebrae instrumented between the two groups of patients.

The evaluation of rotation of the apical vertebra ac-

Table 2 – Values for the parameters studied in the anterior instrumentation (AI) and posterior instrumentation (PI) groups preoperatively, immediately postoperatively and later postoperatively. An asterisk (*) indicates a significant difference between AI and PI ($p < 0.05$).

Sex	Male	1	1
	Female	11	11
Age		11 to 23 years (15.9 ± 2.4)	11 to 20 years (14.5 ± 2.5)
Risser	III	5 (41.6%)	4 (33.3%)
	IV	5 (41.6%)	3 (25%)
	V	2 (16.6%)	5 (41.6%)
Apical vertebra	T7	1 (8.33%)	xxxxxxxx
	T8	6 (50%)	6 (50%)
	T9	3 (25%)	7 (50%)
	T10	2 (16.6%)	xxxxxxxx
Translation of apical vertebra		28 to 90 mm (53.7 ± 12.1)	30 to 94 mm (54.7 ± 14.1)
Proximal vertebra	T3	xxxxxxxx	3 (25%)
	T4	xxxxxxxx	2 (16.6%)
	T5	7 (58.3%)	6 (50%)
	T6	4 (33.3%)	1 (8.33%)
	T7	1 (8.33%)	xxxxxxxx
Distal vertebra	T11	5 (41.6%)	4 (33.3%)
	T12	2 (25%)	2 (16.6%)
	L1	3 (25%)	5 (41.6%)
	L2	4 (8.33%)	1 (8.33%)
Cobb angle		30° to 70° (51 ± 13.4)	52° to 89° (2.4 ± 11.9)
Thoracic kyphosis (T4-T12)		4° to 50° (18.5 ± 11.3°)	6° to 44° (22.6 ± 12.1)
Lumbar modifier (Lenke)	A	8 (66.6%)	8 (66.6%)
	B	3 (25%)	3 (25%)
	C	1 (8.33%)	1 (16.6%)
Thoracic modifier (Lenke)	Negative	2 (16.6%)	1 (8.33%)
	N	9 (75%)	9 (75%)
	Positive	1 (8.33%)	2 (16.6%)

cording to the Nash and Moe index[8] showed a mean value of 0.16 ± 0.37 during the immediate postoperative period and 0.21 ± 0.44 later on postoperatively in the AI patients and, respectively, values of 0.66 ± 0.47 and 0.73 ± 0.52 in the PI patients, with a significant difference between the groups at the two evaluation times ($p = 0.22$ and $p = 0.019$, respectively).

One patient in the AI group presented a partial neurological deficit in the right leg, which was followed by complete recovery within four months. No surgical complications were observed in the PI patients.

There were no significant differences between the two groups regarding the patients' perceptions in relation to function, pain, self-image, mental function or satisfaction, from the SRS-22 questionnaire (Table 3), thus indicating that both treatment met the patients' expectations.

The AI patients had mean scores of 4.1 ± 0.61 for function; 4 ± 0.77 for pain; 3.9 ± 0.79 for mental function; 4.3 ± 0.66 for satisfaction with the surgical result; and 4.3 ± 0.75 for self-image (Table 3). The PI patients had means scores of 4.03 ± 0.35 for function; 4.12 ± 0.28 for pain; 4.12 ± 0.31 for mental function; 4.31 ± 0.24 for satisfaction with the surgical result; and 3.92 ± 0.17 for self-image ($p < 0.05$ for all the domains).

Table 3 – Results from later functional evaluation using the "SRS 22" questionnaire on the patients in the anterior instrumentation (AI) and posterior instrumentation (PI) groups.

SRS-22	IA	IP	p
Function	4.1 (± 0.61)	4.03 (± 0.35)	0.074
Pain	4 (± 0.77)	4.12 (± 0.28)	0.069
Self-image	4.3 (± 0.75)	3.92 (± 0.17)	0.071
Mental health	3.9 (± 0.79)	4.12 (± 0.31)	0.064
Satisfaction with the treatment	4.3 (± 0.66)	4.31 (± 0.24)	0.089

DISCUSSION

The surgical treatment for adolescent idiopathic scoliosis has undergone changes consequent to improvements in the implants and surgical techniques for correction of the deformity. The improvements in implants have enabled a greater degree of three-dimensional correction of the deformities and greater freedom of movement during the postoperative period, without the need for immobilization with orthoses.

The most recent anterior and posterior instrumentation systems have contributed towards achieving greater correction and early stability, but the basic concept of obtaining solid arthrodesis and a balanced spine has really not changed. Nonetheless, surgery to correct scoliosis, whether using an anterior or a posterior method, does not restore the morphology and normal function of the spine.

The curves of adolescent idiopathic scoliosis, of Lenke type I, can be treated by means of both anterior and posterior instrumentation. The posterior approach is more common, while the anterior approach, which previously was only used for treating lumbar and thoracolumbar curves, has expanded and come to include treatment for thoracic scoliosis, by means of conventional open thoracotomy or by means of a minimally invasive approach.

The present study was retrospective and sought to evaluate and compare the results from two types of surgical treatment that were used by the same surgeon to treat Lenke type I curves. Data from these operations was prospectively stored in a specifically created database for registering patients with deformities. The indication of an anterior or a posterior approach did not obey any criteria of randomization and was influenced by the treatment philosophy prevailing at the time of administering the treatment. Some treatment principles that were used in this group of patients are no longer used, thus reflecting the rapid evolution of surgery for scoliosis and the evolution in its concepts over the last decade.

The present study confirms that it is possible to perform arthrodesis on the thoracic spine using anterior instrumentation and to spare distal levels, as cited in the literature[2,6]. However, the importance of preserving vertebrae in the proximal region of the lumbar spine, in terms of prevention of future lumbar pain, in contrast with the distal lumbar vertebrae, may not be relevant[2]. In theory, for patients with AI only down to T11, T12 and L1, there was no interference with the mobility of the lumbar spine, although the advantages of this shorter arthrodesis have still not been demonstrated. Greater mobility of the lumbar spine may explain the greater correction of the compensatory lumbar curve in patients undergoing AI. The prevalence of lumbar pain has been correlated with the distal level of instrumentation[11,12]. However, there are conflicting reports regarding increases in lumbar pain through arthrodesis of the lower lumbar spine[2,11,13].

The greater number of vertebrae on which arthrodesis is performed with the use of the posterior approach is also related to the selection criteria for the LIV. We used the stable vertebra as the LIV, with the aim of reducing the risk of decompensation[14-17] and in some patients, arthrodesis was extended to the middle of the lumbar spine. Thus, for anterior instrumentation, the LIV was the lower vertebra of the Cobb angle. The risk of coronal decompensation is around 20%, and up to 47% in curves of King type II, when the stable vertebra is the LIV[2,6,15,16]. In some of the patients presented, the LIV was in the middle or lower lumbar spine, to avoid the risk of decompensation. No decompensation of the lumbar curve was observed in any of the AI or PI patients in our study.

The greater correction obtained in the frontal plane by means of AI may have been related to the removal of the intervertebral discs, which enables better realignment of the spine in the frontal plane. Anterior arthrodesis of the spine has been shown to have a greater capacity for correction than posterior arthrodesis with segmental hooks and sublaminar wires[18,19]. Similar results have been reported from other studies[2,4,20,21]. Potter *et al*[6] observed that principal thoracic selective PI using instrumentation with thoracic pedicle screws resulted in better correction of the curves than did ASF with a single rigid rod on Lenke type I curves[6,20,21].

In the present study, correction in the sagittal plane did not present any difference between the AI and PI groups. A more detailed analysis on this variable should divide the groups into patients with hypokyphosis and normal kyphosis, which was not possible here due to the small sample size. The modified Cobb technique was used to evaluate the magnitude of the sagittal curves, and the variability in the level of transition between thoracic kyphosis and lumbar lordosis was not taken into consideration[22]. However, in the report by Betz *et al*[2], AI presented better correction of the sagittal plane in patients with hypokyphosis of less than 20º. Significant hypokyphosis has been considered to be an indication for AI, in order to correct scoliosis[2].

A significant decrease in rotation of the apical vertebra was observed in the ASF group. Similar results were reported by Kotowicki et al(4) following AI using a Pouliquen® anterior plate, compared with posterior instrumentation with Cotrel-Dubousset®. A significant correction of the costal hunch following AI correction has previously been reported, and it is believed that the point of application of the corrective force to the vertebral bodies and the shortening on the anterior side of the spine are essential in obtaining vertebral derotation within the curve[2,3]. Derotation of the apical vertebra is possible with manipulation of different implants, and a significant improvement in vertebral rotation and thoracic torsion has been reported in patients with PI with thoracic pedicle screws, compared with AI[6].

The radiological variables constitute only part of the overall results. Perfect constructions are justified, but should not dominate the objective of the surgical treatment[23].

In the present series, we did not observe any breakage of rods or pseudarthrosis, which have been reported by other authors[2,24]. This may have been due to careful preparation of the surfaces of the vertebral bodies and to the complete removal of the intervertebral discs and end vertebral plate, in order to perform intersomatic arthrodesis, in combination with the use of a rod of greater rigidity. Smith *et al*[25] did not report any cases of pseudarthrosis or implant failure in a small series of patients, thus supporting the role of rigid rods in AI.

The results obtained in the present study showed that both approaches can be used to treat scoliosis of Lenke type I, without difference in the functional results, although some variables from the radiographic assessment differed between the groups. The objectives from surgical treatment of Lenke type I curves can be achieved through both methods, although the aggressiveness of the method, complexity of the instrumentation, quality of the arthrodesis of the spine and cost of the procedure should also be taken into consideration in choosing the therapeutic approach.

CONCLUSION

The group of patients who underwent surgical correction of Lenke type I curves by means of AI presented greater correction in the frontal plane, greater derotation of the apical vertebra and lower numbers of vertebrae on which arthrodesis was performed, in comparison with PI. However, the functional evaluation using the SRS-22 questionnaire did not show any difference between the patients who underwent AI and PI.

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