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RESEARCH ARTICLE

Radiological Outcome of Cotrel-Dubousset Instrumentation in Nineteen Patients with Adolescent Idiopathic Scoliosis

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Abstract

Objective: Adolescent idiopathic scoliosis is a progressive type of scoliosis that may lead to permanent deformity unless prevented and treated effectively. To present radiological outcome of patients with adolescent idiopathic scoliosis treated with the Cotrel-Dubousset (CD) instrumentation in our clinic.

Methods: This was a prospective follow-up study of 19 patients (8 males, 11 females; mean age 18.5 years; age range 12-43 years) who underwent CD instrumentation for late onset idiopathic scoliosis. The CD instrumentation and posterior spinal fusion was performed using the standard technique through either anterior or posterior approach. On average, 13.52 vertebrae (range, 8-16) were included in the spinal fusion. The mean postoperative follow-up duration was 18 months (2-32 months).

Results: Cobb angle on frontal plane was corrected 47.74%±21.73% at thoracic region and 34.52%±15.96% at lumbar region. On sagittal plane, the percentage of correction was 28.61%±20.91% on thoracic kyphosis angle and 38.96%±29.73% lumbar lordosis angle. In general, physiological sagittal contour of spine was obtained in 49.2% of patients after CD instrumentation. The most common postoperative complications were hook dislocation (n=8), bending and dislocation of screw (n=7), broken lamina and pedicule (n=5), and infection (n=3), all of which were effectively treated.

Conclusion: CD instrumentation effectively corrects the late onset idiopathic scoliosis if it is performed after a proper preoperative planning.

Key words: Curl-up exercise, abdominal muscles, sternocleidomastoid, electromyography.

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Introduction

Late onset or adolescent idiopathic scoliosis is the most common spinal deformity in adolescents with an overall prevalence of 0.47-5.2% (Konieczny et al., 2013). It is characterized by a lateral deviation of the spine with unknown etiology, and defined as a spinal curve greater than 10° detected by Cobb method (Cobb, 1948; Shindle et al., 2006). In severe cases, it is associated with severe pain, cardiopulmonary compromise, and social isolation (Weiss et al., 2016). Adolescent idiopathic scoliosis is a progressive type of scoliosis that may lead to permanent deformity unless prevented and treated effectively. Its treatment includes exercise, rehabilitation, and surgery (Weiss and Goodall, 2008). For optimal management, it is important to distinguish the adolescent idiopathic scoliosis from early-onset scoliosis, which occur before the age of

10 and has a higher morbidity and mortality rate (Cunin, 2015; Weiss et al., 2016). The goal in scoliosis surgery is to reduce curvature and to create a stable framework on which vertebral fusion can occur (Gunnoe, 1990). Various instrumentation systems are currently utilized for posterior fusion in adolescent idiopathic scoliosis, such as Harrington rods, Universal Spine System instrumentation, the Cotrel-Dubousset (CD) instrumentation, and all-pedicle screw constructs (Remes et al., 2004; Lykissas et al., 2013). Among these systems, CD instrumentation, which has been used for almost 30 years, is a rigid system of immobilization and allows the most effective correction for all kinds of spinal deformities (Cotrel and Dubousset, 1984; Dubousset and Cotrel, 1991). In comparison to other instrumentation techniques, CD instrumentation has been shown to provide higher degree of correction in the coronal and sagittal planes (Lykissas et al., 2013). Therefore, CD instrumentation became the most preferred technique in the operative treatment of adolescent idiopathic scoliosis. However, some mid- and long-term studies reported higher rate of complications and revision surgery associated with CD instrumentation (Helenius et al., 2003; Lykissas et al., 2013). Therefore, there is still a need for more experience with CD instrumentation to decide on the best technique for surgical treatment of adolescent idiopathic scoliosis.

In this study, we aimed to present radiological outcome of 19 patients with adolescent idiopathic scoliosis treated with CD instrumentation in our clinic.

Methods

Study design and population

This was a prospective follow-up study of 19 patients (8 males, 11 females; mean age 18.5 years; age range 12-43 years) who underwent CD instrumentation for late onset idiopathic scoliosis in the Clinics of Orthopedic Surgery of SSK Okmeydani Hospital. None of the patients had received any treatment for scoliosis before applying to our clinic. On clinical and radiological assessment none of the patients had congenital, neuromuscular, or similar primary etiology for scoliosis.

Surgical procedure

The CD instrumentation and posterior spinal fusion was performed using the standard technique through either anterior or posterior approach (Cotrel and Dubousset, 1984). On average, 13.52 vertebrae (range, 8-16) were included in the spinal fusion. All patients received autologous blood with or without cell saver, and were given intravenous cephalosporin during the operation and for 72 hours postoperatively for prophylaxis. A wake-up test was performed to check the intraoperative neurology after the insertion of the vertical rod on the concave side. All patients were mobilized in seven to ten days after the operation, and discharged after 15 days.

Outcome measures

The patients were evaluated at postoperative 1, 3, 6, 12, and 24 months. In each postoperative visit, the following data were recorded: subjective complaints, physical examination of scoliosis, asymmetry, rib hump, and change in gravity line. On the frontal and lateral radiographs of the spine, the Cobb angles at thoracic and lumbar regions, thoracic kyphosis, lumbar lordosis, and angulation at thoracolumbar junction were measured.

Statistical analysis

Study data were summarized using descriptive statistics (e.g., mean, standard deviation, frequency and percentage). For paired comparisons, Wilcoxon signed tank test was used. Statistical level of significance was set to $p<0.05$.

Results

The clinical characteristics of patients were summarized in Table 1. According to starting age of scoliosis, 13 patients had adolescent, 5 had juveline, and 1 had infantile idiopathic scoliosis. On radiological assessment, majority of patients had either type 2 (n=10) or type 4 (n=6) idiopathic scoliosis according to King Classification (King et al., 1983). In terms of maturity, 6 males (75%) had secondary sex characters, and 9 females (81.8%) had menarche. The Risser sign, which is an indirect measure of skeletal maturity, revealed that most of the patients had either Grade 4 (n=13) or Grade 5 (n=5) maturity, which correspond to an almost cessation of growth and end of growth, respectively (Risser, 1958).

The evaluation of the position of gravity center with respect to intergluteal line showed that gravity line passes exactly through the crease in 10 patients (52.6%), which indicates a balanced curvature, while there was 1-3 cm deviation in seven patients (36.8%) and more than three cm deviation in two patients (10.5%). According to radiological evaluation, one patient had flexible thoracic lordosis, one had thoracic kyphosis, three had double major scoliosis, six had thoracolumbar scoliosis, and eight had rigid thoracic lordosis (Table 1).

Table 1. Demographic and clinical characteristics of study patients

Parameters		Result (n=19) n (%)
Age	10-19 years	16 (84.2%)
	≥20 years	3 (15.8%)
Gender	Male	8 (42.1%)
	Female	11 (57.9%)
Risser sign[a]	Grade 3	2 (10.5%)
	Grade 4	13 (68.4%)
	Grade 5	4 (21.1%)
Type of scoliosis according to starting age	Adolescent	13 (68.4%)
	Juvenile	5 (26.3%)
	Infantile	1 (5.3%)
Radiological classication of scoliosis	Flexible thoracic lordosis	1 (5.3%)
	Rigid thoracic lordosis	8 (42.1%)
	Thoracic kyphosis	1 (5.3%)
	Thoracolumbar scoliosis	6 (31.6%)
	Double major	3 (15.8%)
King classification[b]	Type 1	1 (5.3%)
	Type 2	10 (52.6%)
	Type 3	2 (10.6%)
	Type 4	6 (31.6%)

[a] Grade 3: the ilium (bone) is calcified at a level of 75% corresponding to the slowing of growth. Grade 4: the ilium (bone) is calcified at a level of 100% corresponding to an almost cessation of growth. Grade 5: the ilium (bone) is calcified at a level of 100% and the iliac apophysis is fused to iliac crest corresponding to the end of growth.

[b] Type 1: an "S" shape deformity, in which both curves are structural and cross the central sacral vertical line (CSVL), with the lumbar curve being larger than the thoracic one. Type 2: an "S" shape deformity, in which both curves are structural and cross the CSVL, with the thoracic curve being larger or equal to the lumbar one. Type 3: major thoracic curve in which only the thoracic curve is structural and crosses the CSVL. Type 4: long "C" shape thoracic curve in which the fifth lumbar vertebra is centered over the sacrum and the forth lumbar vertebra is tilted into the thoracic curve.

The spinal correction obtained by CD instrumentation

The average postoperative follow-up duration was 18 months (2-32 months). After this period, the Cobb angle on frontal plane was corrected 47.74%±21.73% at thoracic region and 34.52%±15.96% at lumbar region. On sagittal plane, the percentage of correction was 28.61%±20.91% on thoracic kyphosis angle and 38.96%±29.73% lumbar lordosis angle. The overall percentage of patients having thoracic kyphosis angle within normal limits or 0-10° deviation increased from 80% to 95% with CD instrumentation. Similarly, the rate of lumbar lordosis angle within normal limits or 0-10° deviation increased from 59% to 79%. However, the rate of thoracolumbar angle within normal limits or 0-10° deviation decreased from 89% to 42% (Figure 1). In general, physiological sagittal contour of spine was obtained in 49.2% of patients after CD instrumentation. Sample radiographs of a patient before and after CD instrumentation were presented in Figure 2.

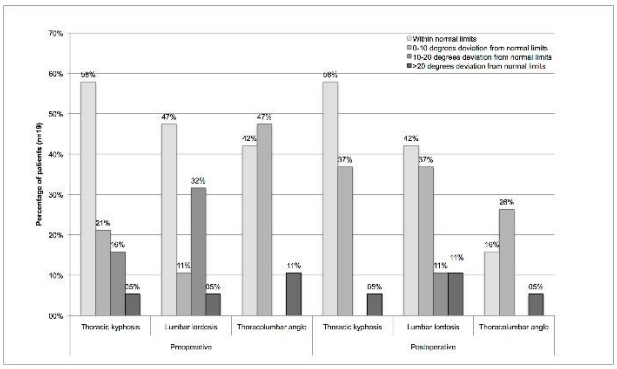

Figure 1. Distribution of patients with respect to sagittal angles before and after CD instrumentation (n=19).

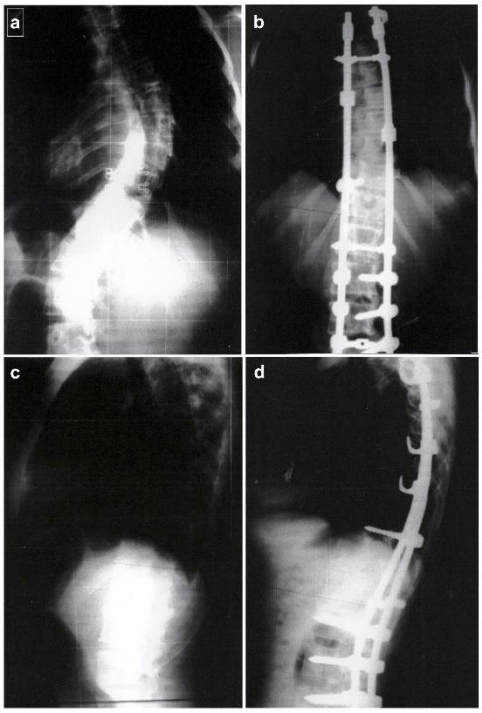

Figure 2. On the frontal plane radiograph of a patient with adolescent idiopathic scoliosis before CD instrumentation (**a**), the Cobb angles at thoracic and lumbar regions were 64° and 50°, which decreased to 23° and 16° after CD instrumentation (**b**), respectively. On the sagittal plane radiograph of the same patient before CD instrumentation (**c**), thoracic kyphosis, lumbar lordosis, and thoracolumbar junction angles were 26°, -40°, and 0°, which changed to 12°, -7°, and -7° (**d**), respectively.

The degree of corrections on frontal plane obtained by CD instrumentation with respect to preoperative King classification was summarized in Table 2. Accordingly, the percentage of correction in the Cobb angles at thoracic and lumbar regions ranged between 11.9% and 64.1% and the degree of correction ranged between 10° and 39.7° on frontal plane, being statistically significant in King Type 2 and 4 scoliosis. The corrections that were obtained in bending Cobb angle were relatively lower (Table 2).

On sagittal plane radiographs, although angles of thoracic kyphosis, lumbar lordosis and thoracolumbar junction were corrected by 26.32%-48.95% after CD instrumentation, none of the corrections reached to the level of statistical significance (Table 3).

With respect to radiological type of scoliosis, the highest correction was obtained in thoralumbar scoliosis, particularly those with kyphosis in both frontal and sagittal planes (Tables 4 and 5).

At last follow-up radiographs, a 7.4° of correction loss (17.1%) in thoracic angle and 8.3° of correction loss (25.5%) in lumbar lordosis was recorded in King Type 2 curves (Table 6). The correction losses in the last follow-up were not statistically significant in other types of curves (Table 6).

The most common postoperative complications were hook dislocation (n=8), bending and dislocation of screw (n=7), broken lamina and pedicule (n=5), and infection (n=3), all of which were effectively treated. None of the patients developed neurological complications and pseudoarthrosis during follow-up.

Table 2. The degree of corrections in the spine obtained by CD instrumentation on frontal plane radiographs with respect to preoperative King classification

King Classification		Preoperative Cobb angle	Postoperative Cobb angle	Degree of correction	Percentage of correction %	p	Preoperative bending Cobb angle	Percentage of correction %	p
Type 1 (n=1)	Thoracic	84°	74°	10°	11.9	-	74°	11.9	-
	Lumbar	100°	82°	18°	18.0	-	88°	12.0	-
Type 2 (n=10)	Thoracic	75.6°±18.52°	43.4°±17.19°	34.3°±10.1°	44.42±17.76	0.0051	60.8°±22.5°	20.98±12.67	0.005
	Lumbar	49.2°±11.18°	31.0°±10.74°	17.9°±9.24°	36.14±15.78	0.0051	30.9°±12.31°	36.72±20.83	0.005
Type 3 (n=2)	Thoracic	66.0°±4.24°	31.0°±5.66°	35.0°±1.42°	53.20±5.52	0.179	56.0°±18.38°	15.18±22.45	0.317
	Lumbar	-	-	-	-	-	-	-	-
Type 4 (n=6)	Thoracic	65.83°±27.64°	26.17°±21.12°	39.7°±17.93°	64.1±20.72	0.027	40.83°±30.16°	40.16±22.94	0.028
	Lumbar	-	-	-	-	-	-	-	-

Table 3. The degree of corrections in the spine obtained by CD instrumentation on sagittal plane radiographs with respect to preoperative King classification

King Classification		Preoperative	Postoperative	Degree of correction	Percentage of correction %	p
Type 1 (n=1)	TK	48°	18°	30°	-	
	LL	11°	0°	11°	-	
	TL	65°	56°	9°	-	
Type 2 (n=10)	TK	31.4°±10.02°	30.2°±8.2°	8.2°±6.37°	26.32±16.60	0.953
	LL	-38.6°±22.27°	-27.4°±23.89°	-14.2°±15.31°	34.39±26.32	0.059
	TL	-3.6°±9.83°	-0.4°±5.58°	7°	-	0.126
Type 3 (n=2)	TK	24.0°±14.14°	24.5°±0.7°	9.5°±0.71°	48.95±31.79	0.654
	LL	-25.0°±14.14°	-19.0°±19.97°	-6.0°±2.83°	32.38±29.63	0.179
	TL	-2.5°±3.54°	1.0°±2.83°	4.5°	-	0.654
Type 4 (n=6)	TK	31.3°±24.3°	34.8°±16.99°	8.5°±9.35°	19.99±19.52	0.500
	LL	-34.0°±17.88°	-23.5°±13.47°	12.83°±13.99°	38.6±30.91	0.225
	TL	-43.0°±12.97°	-3.33°±5.20°	5.7°	-	0.345

TK, thoracic kyphosis; LL, lumbar lordosis; TL, thoracolumbar juntion.

Table 4. The degree of corrections in the spine obtained by CD instrumentation on frontal plane radiographs with respect to type of scoliosis

		n	Preoperative Cobb angle	Postoperative Cobb angle	Degree of correction	Percentage of correction %
Flexible thoracic lordosis		1	68°	41°	25°	36.8
Rigid thoracic lordosis		8	69.5°±9.43°	32.6°±6.32°	36.9°±8.42°	47.53±18.46
Thoracic kyphosis		1	103°	72°	31°	30.1
Thoracolumbar scoliosis	Kyphosis	2	40.0°±25.16°	10.5°±10.61°	29.5°±14.83°	77.7±12.30
	Lordosis	4	78.75°±14.74°	34.0°±21.46°	44.75°±16.72°	57.3±21.91
Double major	First curve	3	81.7°±27.57°	61.0°±21.81°	20.7°±13.61°	25.13±11.56
	Second curve		71.3°±29.01°	48.3°±30.37°	23.0°±7.81°	35.9±15.48

Table 5. The degree of corrections in the spine obtained by CD instrumentation on sagittal plane radiographs with respect to type of scoliosis

			Preoperative			Postoperative			Degree of correction			Percentage of correction		
		n	TK	LL	TL	TK	LL	TL	TK	LL	TL	TK%	LL%	TL%
Flexible thoracic lordosis		1	34°	-39°	-12°	28°	-20°	-2°	6°	19°	10°	17.6	48.7	83.3
Rigid thoracic lordosis		8	27.75°±7.87°	-38.6°±15.78°	-4.1°±9.16°	28.9°±9.63°	-35.4°±16.25°	0.37°±5.18°	7.9°	7°	10.8°	28.4	18.2	60.6
Thoracic kyphosis		1	55°	-45°	-6°	32°	-28°	-3°	23°	17°	9°	41.8	37.8	50
Thoracolumbar scoliosis	Kyphosis	2	52°±7.07°	-27.5°±28.99°	-15.5°±20.51°	52.5°±3.54°	-31°±26.87°	-7°±4.24°	2.5°	3.5°	11.5°	4.8	12.7	54.8
	Lordosis	4	21±23.24°	-37.3±14.32°	1.3±3.95°	26±12.83°	-19.8°±2.86°	-1.5°±5.07°	11.5°	17.5°	2.75°	57.8	46.9	25
Double major		3	3.3±13.75°	-10±41.04°	25±35.16°	26±6.93°	6.7°±14.2°	21°±31.8°	13°	26.7°	4.3°	39.4	25	19.2

TK, thoracic kyphosis; LL, lumbar lordosis; TL, thoracolumbar juntion.

Table 6. The degree and percentage of correction loss at last follow-up radiographs with respect to preoperative King classification

King Classification		Degree of correction loss	Percentage of correction loss	p
Type 2	Frontal plane			
	Thoracic Cobbs	7.4°	17.1%	*0.018*
	Lumbar Cobbs	7.1°	22.9%	0.116
	Sagittal plane			
	Thoracic kyphosis	5.7°	18.9%	0.179
	Lumbar lordosis	8.3°	25.5%	*0.027*
	Thoracolumbar junction	4.4°	-	0.715
Type 3	Sagittal plane			
	Thoracic kyphosis	1.0°	4.1%	0.179
	Lumbar lordosis	4.0°	20.5%	0.317
	Thoracolumbar junction	2.0°	-	0.179
Type 4	Frontal plane			
	Thoracolumbar Cobbs	7.0°	26.8%	0.345
	Sagittal plane			
	Thoracic kyphosis	6.7°	19.2%	0.916
	Lumbar lordosis	6.3°	26.8%	0.345
	Thoracolumbar junction	7.3°	-	0.294

Discussion

Although there is still no consensus on the surgical technique for correction of adolescent idiopathic scoliosis, the CD instrumentation is the most preferred surgical treatment since its introduction in 1984 (Cotrel and Dubousset, 1984; Gunnoe, 1990). It has the advantage of rigid fixation and improved three-dimensional curve correction. In this prospective series of 19 patients with late onset idiopathic scoliosis, we obtained 47.74%±21.73% correction on frontal plane and 28.61%±20.91% correction in thoracic kyphosis and 38.96%±29.73% in lumbar lordosis on sagittal plane with CD type instrumentation.

In a meta-analysis of 1613 patients from 27 studies, Lykissas et al. (2013) reported a correction of 40.3º in thoracic curve and 37.2º in lumbar curve on frontal plane, and a correction of 33.5º in thoracic kyphosis and 46º in lumbar lordosis on sagittal plane. Similarly, in our study, the degree of correction was 39.7° in King Type 4 curves on frontal plane. Additionally, angles of thoracic kyphosis, lumbar lordosis and thoracolumbar junction were corrected by 26.32%-48.95% after CD instrumentation. The overall percentage of patients having thoracic kyphosis angle within normal limits or 0-10° deviation increased from 80% to 95% with CD instrumentation. Similarly, the rate of lumbar lordosis angle within normal limits or 0-10° deviation increased from 59% to 79%. The overall correction degrees and percentages we obtained in our series were in similarity with previous meta-analysis (Lykissas et al., 2013).

The percentage of the correction in thoracic curve and lumbar lordosis was higher in King Type II and IV, and thoracolumbar scoliosis than the other types, as the correction in thoracic kyphosis was highest in Type III scoliosis. Similarly, in previous studies, the greatest correction in adolescent scoliosis was obtained by CD instrumentation in Type III and IV, and thoracolumbar curves (Wajanavisit et al., 2009; Puno et al., 1992).

Although none of the patients developed neurological complications and pseudoarthrosis

during 18-month follow-up, three patients developed infection, which was treated effectively. We also encountered hook dislocation in eight patients, bending and dislocation of screw in seven patients, and broken lamina and pedicule in five patients, all of which may be due to our limited experience with CD instrumentation, which requires greater surgical skill than the Harrington rod with extended surgical time (Ameri et al., 2013).

The main limitation of the present study is the small sample size, which precludes us from reaching to a more definitive conclusion on the effectiveness and safety of CD type instrumentation in surgical correction of adolescent idiopathic scoliosis. Additionally, our limited experience with the surgical technique prevented us to obtain optimal outcome of CD instrumentation. Nevertheless, we think that our series will contribute to the literature of CD instrumentation and clinical practice of the technique.

Based on our experience with the present series of 19 patients, we have some suggestions for CD type instrumentation. For rigid type of scoliosis, anterior relaxation followed by posterior fusion and derotation maneuver increases degree of correction. Since the rods of CD instrumentation were not rigid enough, they should be bended during obtaining lumbar lordosis. The impaired balance, which is the most common complication of CD instrumentation in certain types of scoliosis, can be overcome by choosing correct level of fusion and avoiding excessive correction. The location of distal fusion should be determined by locating stable and neutral vertebrae and mobile disc space. In type 2 scoliosis, lumbar vertebrae should be included into fusion level in order to prevent decompensation in long-term.

Conclusion

In conclusion, CD instrumentation effectively corrects the late onset idiopathic scoliosis if it is performed after an extensive clinical and radiological assessment of spinal deviation preoperatively. We suggest that the high rates of correction loss and complications in our series are due to our inexperience with the technique and insufficient preoperative planning. We believe that with increased experience with CD type instrumentation and better surgical planning, the rates of complications and correction loss will be reduced and optimal correction will be obtained in cases with late onset idiopathic scoliosis.

Ethics Committee Approval: The requirement for the ethics committee approval was waived for the retrospective design and valid legal regulations at the time of the study.
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