A Comparison between the Cotrel-Dubousset and the Pedicle Screw-Plate Instrumentations in the Adolescent Idiopathic Scoliosis

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Background: *The Cotrel-Dubousset instrumentation (CD) is one of the standard instrumentations in the scoliosis surgery. Since the pedicle screw-plate system (PSP) was developed, it has resulted in the three-planar and three-dimensional correction with the minimal neurological complications. However, the correction effectiveness between these two methods is still open to question.*
Objective: *To compare the results of using the CD and the PSP in the treatment of adolescent idiopathic scoliosis.*
Material and Method: *A retrospective cohort study was conducted in all patients having an adolescent idiopathic scoliosis who underwent the surgery with either the CD or the PSP instrumentation at the Department of Orthopedics, Ramathibodi Hospital, during 1991 to 1998. The data of the Cobb angle, kyphotic angle, plumb line, rib hump difference and vertebral rotation were collected pre-operatively, post-operatively, and at the last follow-up.*
Results: *Forty-three patients having an adolescent idiopathic scoliosis were included. Eighteen patients: 16 females and 2 males were operated by the CD multiple hooks, and 25 patients: 23 females and 2 males were operated by the PSP instrumentation. The PSP system significantly reduced the Cobb angle and de-rotated the vertebrae in comparison with the CD group (p-value $\leq$ 0.05). The percentage of the correction in King Type III, IV and T-L curve was higher than the other types. Both instrumentations could restore thoracic kyphosis without any major complications.*
Conclusion: *The PSP system was more effective in the sagital correction, vertebral derotation and rib hump compared to the CD instrumentation. Although the PSD is a technically demanded operation, the PSP system is currently one of the most appropriate instrumentation for the adolescent idiopathic scoliosis treatment.*

Keyword: *Adolescent, Bone plates, Bone screws, Instrumentation, Lumbar vertebrae, Orthopedic procedures, Ribs, Rotation, Scoliosis*

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The operative treatment for the adolescent idiopathic scoliosis (AIS) was revolutionized after the introduction of Harrington instrumentation in 1960. This instrumentation was one-planar and two-dimensional correction system. After those treatment periods, problems from using the AIS instrumentation were revealed such as the inability to control sagittal alignment and the need of postoperative

In 1984, the three-planar and three-dimensional systems of Cotrel-Dubousset (CD) was successfully developed and then popularized. Consequently, the CD became one of the standard instrumentation in the scoliosis surgery. This method

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produced a highly good correction of coronal deformity with the Cobb's angle correction within a range of 60 to 85% and some degrees of vertebral derotation[2,3].

Later, the pedicle screw system was gradually developed in the past decade. As a result, these better improvements in a view of the three-planar and three-dimensional correction have been widely accepted. The pedicle screw system has a powerful vertebral derotation and rib cage deformity correction[4]. However, there was very little information that compared the results between the CD instrumentation and the pedicle screw system, especially in the vertebral derotation and rib hump reduction which resulted in better aesthetics and self-image of patients.

The purpose of this study was to compare the results of using the Cotrel-Dubousset and the Pedicle screw-plate (PSP) instrumentation in the treatment of adolescent idiopathic scoliosis.

Material and Method

All patients with AIS who were admitted and operated on the posterior spinal correction and fusion by using either the CD or the PSP instrumentation at the Department of Orthopedics, Ramathibodi Hospital, during 1991-1998 were included in this study. Two senior authors (WW and WL) had performed the operative procedures. All patients had a minimum 2-year follow-up.

The idiopathic juvenile scoliosis and AIS patients who had an indication for the anterior surgical procedure were excluded from the study.

The data of the standing postero-anterior and the lateral radiographs were obtained pre-operatively, postoperatively and at the most recent follow-up. The coronal and sagittal curves were measured by using the Cobb method. The coronal trunk balance was determined by the plumb line drawn from the center of C7 vertebra to the center sacral line. The rib hump difference and the vertebral rotation were also routinely measured by using the standard technique.

The patients were categorized according to the King-Moe classification. The measurement of the coronal deformity was performed by the standard Cobb method. The kyphotic angle was measured on the standing lateral film from the lower end plate of T12 to the upper end plate of T5. The plumb line was drawn from the center of C7 and the horizontal distance between the plumb line and the center sacral line was measured as a coronal balance. The shift of the plumb line to the left is considered as a negative balance while the shift to the right is considered as a positive balance. The rib hump difference was evaluated by forward bending to 90 degrees or until the back parallel to the floor. The point on each side of the back was located and its vertical difference was measured. Regarding to the vertebral rotation, the CT scan measurement using the method of Aaro and Dahlborn was performed[5,6]. The vertebral rotation relative to the midline (RaMl) is defined by the angle formed by the line drawn from the sternum to the most posterior corner of the spinal canal and the line drawn from the same point of the posterior central aspect extending anteriorly to equally bisect the vertebral body (Fig. 1).

Statistical analysis

The baseline characteristics were analyzed and compared within and between the groups. The continuous data were analyzed by using the mean and standard deviation whereas the categorical data were analyzed and described by percentage. The statistical comparison of the continuous variables was carried out by unpaired t-test for the two compared groups, and one-way analysis of variance (ANOVA) for 3 compared groups. Two-way ANOVA was performed to compare the CD group with the PSP by taking into account of variables: pre-operative time and post-operative time. The comparison of categorical data between both groups was analyzed by using Fisher's exact test. P-value ≤ 0.05 was considered as the statistically significant level.

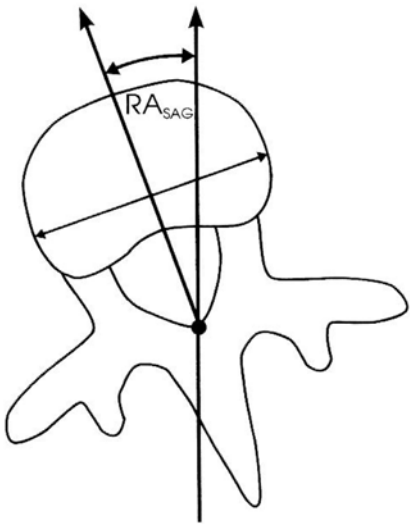

Fig. 1 Axial rotation measurement: Angle of Aaro and Dahlborn

Results

Eighteen patients: 16 females and 2 males having an AIS were operated on the posterior spinal fusion by the Cotrel-Dubousset multiple hooks instrumentation during the year 1991-1996. Twenty-five patients: 23 females and 2 males having an AIS underwent the posterior spinal fusion by using the PSP instrumentation during the time from January to December 1998.

The average age of the patients was 14.7 $\pm$ 3.7 years in the CD group and 14.9 $\pm$ 2.6 years in the PSP group. According to the King-Moe classification, the distribution of curve pattern in both groups was shown in Table 1. There was no statistically significant difference in age and in the curve pattern between the CD and the PSP groups. The average follow-up period was 5.7 years (range 2.5-11.0) in the CD group and 4.1 years (range 2-5) in the PSP group.

The comparison of the outcomes was shown in Table 2. Both groups demonstrated the statistical improvement of the Cobb angle from the pre-operative to postoperative treatments and the last follow-up time

Table 1. The comparison of the baseline characteristics between the CD and the PSP groups

Variables	CD group (n = 18)	PSP group (n = 25)	p-value
Age (year), the mean (SD)	14.7 (3.7)	14.9 (2.6)	0.83
King (%)			0.19
1	0	2 (8.0)	
2	5 (27.8)	8 (32.0)	
3	9 (50.0)	8 (32.0)	
4	1 (5.6)	1 (4.0)	
Double major	2 (11.0)	0	
T-L curve	1 (5.6)	6 (24.0)	

p-value from unpaired t-test

[a] p-value from Fisher exact's test

Table 2. The comparison of overall outcomes between the CD and the PSP groups

Variables	CD group (n = 18)	PSP group (n = 25)	p-value
Cobb angle (degree), the mean (SD)			
Pre-operative	52.9 (7.5)	52.1 (12.1)	0.81
Post-operative	21.8 (7.5)*	14.8 (7.2)*	<0.01
Latest follow-up	24.9 (7.9)*	21.5 (12.7)*	<0.01
p-value[a]	<0.01	<0.01	
Vertebral rotation (degree), the mean (SD)			
Pre-operative	20.5 (2.9)	26.7 (10.7)	0.02
Post-operative	12.9 (4.7)	15.0 (7.6)	0.31
p-value	<0.01	<0.01	
Hypokyphosis (degree), the mean (SD)			
Pre-operative	15.8 (5.6)	22.0 (15.3)	0.11
Post-operative	24.5 (5.6)	24.3 (9.9)	0.93
p-value	<0.01	0.53	
Rib hump (cm), the mean (SD)			
Preoperative	5.2 (5.9)	3.0 (1.5)	0.01
Postoperative	2.3 (2.3)	1.6 (1.0)	0.21
p-value	0.06	<0.01	

p-value from unpaired t-test

* Significant p-value < 0.05 when compared to preoperative data

[a] p-value from one-way analysis of variance

(p-value < 0.01). After controlling the time, two-way ANOVA revealed the significant improvement of the Cobb angle in the PSP group compared to the CD group (p-value = 0.05).

The vertebral rotation was significantly reduced postoperatively in comparison to the pre-operative data of both groups (p-value < 0.01). Although the postoperative vertebral rotation had no statistical difference between these two groups, the pre-operative vertebral rotation was significantly greater in the PSP group than the CD one. Two-way ANOVA showed the significant improvement of vertebral rotation in the PSP group compared to the CD group (p-value = 0.01) after controlling the time.

The sagittal plane correction was only evaluated in the hypokyphotic cases of which the pre-operative sagittal curve from T5-T12 was less than 16 degrees The improvement of the thoracic contour after surgery occurred in the CD groups only (p-value < 0.01). There was no statistical difference of sagittal contour between both instrumentations.

The average rib hump and plumb line in the PSP group was significantly decreased from the pre-operative to postoperative treatments (p-value < 0.01). According to two-way ANOVA, the rib hump was significantly reduced in the PSP group compared to the CD one (p-value = 0.03). The comparison of plumb line between both groups was not performed due to the unavailable data in the CD group.

The analysis was stratified in accordance with the King-Moe classification as in Table 3. In King Type II, III, IV and T-L curve, the PSP instrumentation yielded the better curve correction than the CD instrumentation. However, the loss of curve correction was found in King Type III and IV at the latest follow-up in both groups: 20% in the PSP group compared to 12.1% in the CD group (p-value = 0.17). In T-L scoliosis, the curve correction loss was less in the PSP system: 10.6% compared to 23.2% in the CD (p-value = 0.02).

No postoperative neurological complications or infections have occurred in both groups. In the CD group, one patient had the lower hook dislodgement causing the loss of curve correction at the third month after the surgery. Another patient developed the pseudarthrosis and lost the correction. In the PSP group, there was no implant failure. The loss of curve correction took place in two cases due to the underestimation of the fusion segments.

Table 3. The comparison of the operative results between the CD and the PSP groups according to the King-Moe classification

	Cotrel-Dubousset		Pedicle screw plate	
	Degrees	Percentage of correction (%)	Degrees	Percentage of correction (%)
King II				
Pre-op curve	59.20	51.40	48.88	67.77
Post-op curve	28.60		15.75	
Curve loss	4.85	8.20	4.375	8.90
King III, IV				
Pre-op curve	50.80	65.30	49.33	73.65
Post-op curve	17.60		13.00	
Curve loss	6.90	12.10	9.88	20.00
T-L curve				
Pre-op curve	43.00	30.00	63.00	70.10
Post-op curve	30.00		18.83	
Curve loss	10.00	23.20	6.67	10.60
Sagittal plane				
Pre-op	4.30		8.10	
Post-op	18.30		20.20	
Rotation				
Pre-op	20.50	37.10	26.70	43.80
Post-op	12.90		15.00	

Discussion

The CD instrumentation has become a standard treatment for the adolescent idiopathic scoliosis since 1984. The good correction of coronal deformity and some degrees of vertebral derotation were widely reported[7-9]. Cundy PJ[7] reported the Cobb angle correction at 67% with 26% of improvement in rotation and slightly loss of correction in the first six months.

Labelle et al[8] reported that the average curve correction using the CD instrumentation were 57% and 65% for the thoracic and lumbar curves whereas 40% and 42% improvement were achieved in the thoracic kyphosis and lumbar lordosis, respectively. Furthermore, the orientation of the plane of maximum deformity was shifted onto the average of 45% toward the sagittal plane indicating the significant three-dimensional curve correction.

However, Dansereau et al[9] reported that the rib cage was laterally shifted en bloc with the spine after the correction without any significant changes in the overall shape of the thorax. Moreover, the overall imbalances of the spine and rib cage were improved only 24%. These indicated that the CD did not adequately correct the balance and shape of thorax even though the good correction of the spinal column and some corrections of the apical rib hump were achieved.

Several reports[10-12] revealed that the CD derotation had little effect on the rotational correction. The posterior instrumentation with the hook system could not generate sufficient torque for the vertebral rotation because the axis of hook fixation was posterior to the axis of vertebral rotation[10].

The pedicle screw system has increasingly become the popular instrumentation for the spinal fixation of the adolescent idiopathic scoliosis. In the three-dimensional scoliosis correction, the pedicle screw system has more powerful vertebral derotation and rib cage deformity correction than the hook segmental system does. Regarding to the improvements of the pedicle screw insertion technique and more experiences of the surgeons, neurological complications can be avoided by adherence to the probing technique during the pedicle screw insertion.

Suk SI et al[13] reported that the pedicle screw could be used in the thoracic spine surgery without any neurological complications. The screws provided immediate stability with rigid fixation and yielded the better correction of frontal, sagittal and rotational deformity in comparison with the segmental hook system. There was less loss of correction with a shorter fusion segment.

The segmental pedicle screw fixation reported in another study by Suk SI et al[14] was more effective than the multiple hooks in restoring kyphosis in the patients having a hypokyphotic scoliosis and in creating kyphosis that was similar to the one in the patients having no pre-operative hypokyphosis.

Lee et al[10] found that there was the direct vertebral rotation with the segmental pedicle screw fixation. The average thoracic apical vertebral rotation correction using the CT scan was 42.5%.

The report of using the pedicle screw-plate system by Laohacharoensombat W et al[4] indicated that the apical vertebral rotation correction was 48.4%. There was the significant improvement in the rib hump difference and the coronal trunk balance between the pre-operative and post-operative evaluation.

This study revealed that, under the condition of the same baseline characteristics, the PSP group showed more effectiveness in the scoliosis correction than the CD group (Table 1) The Cobb angle reduction, vertebral derotation, and rib hump were effectively achieved by the PSP system and they obtained significant differences compared to the ones by the CD instrumentation (Table 2) In the thoracic scoliosis, the PSP system was more powerful in correction of scoliosis and in restoration of thoracic kyphosis. These resulted in the rib hump reduction and the plumb line shifted to the midline. The overall balance and sagittal contour of the body were improved.

The explanation is that the pedicle screw system is a three-column fixation. The purchase of the screw into the anterior column of the vertebra increases the lever arm of application which confined to the posterior, middle and anterior column of the vertebral body. In comparison with the posterior instrumentation with the hook system, the axis of pedicle screw fixation was close to the axis of vertebral rotation. Moreover, the PSP system uses the apical dynamic correction during the assembly of the frame and the gradual purchase of the screws which is more effective in both sagittal correction and vertebral de-rotation.

The limitation of this study was that the comparative groups were operated in the different periods of time, *i.e.* historical controls; consequently, the surgical technique, the patient selection and the post-operative care may differ according to the timely fashion. The data of the plumb line were not recorded in the CD group and in the meantime the standing whole spine films were not available. Therefore, they could

not be compared. Additionally, the number of the patients in each subgroup was small which limited the comparative analysis.

Although the posterior instrumentation with the pedicle system is a technically demanded operation, the PSP system should be considered as one of the most appropriate instrumentations for adolescent idiopathic scoliosis treatment by a skillful surgeon.

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การเปรียบเทียบผลการรักษากระดูกสันหลังคดด้วยเครื่องมือ Cotrel-Dubousset และ pedicle screw-plate system

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เครื่องมือ Cotrel-Dubousset (CD) เป็นเครื่องมือผ่าตัดมาตรฐานสำหรับการผ่าตัดรักษาโรคกระดูกสันหลังคด ส่วนเครื่องมือ pedicle screw-plate (PSP) เป็นระบบที่พัฒนาขึ้นใหม่ การศึกษานี้ได้ทำการเปรียบเทียบผลการรักษาระหว่างเครื่องมือทั้งสองชนิด โดยมีผู้ป่วย adolescent idiopathic scoliosis ทั้งหมด 43 ราย โดย 18 ราย ได้รับการผ่าตัดด้วยเครื่องมือ CD multiple hooks และ 25 ราย ได้รับการผ่าตัดด้วยเครื่องมือ PSP ผลการรักษาพบว่าการผ่าตัดด้วยเครื่องมือ PSP สามารถแก้ไข Cobb angle, vertebral rotation และ rib hump ได้ดีกว่าการผ่าตัดด้วยเครื่องมือ CD อย่างมีนัยสำคัญ (p-value ≤ 0.05) โดยเฉพาะผู้ป่วยกลุ่มที่เป็น King type III, IV และ T-L curve นั้นสามารถแก้ไขมุมได้มากกว่ากลุ่มอื่น เครื่องมือทั้ง 2 ชนิดสามารถฟื้นคืน thoracic kyphosis ให้เข้าสู่ปกติได้ โดยไม่มีภาวะแทรกซ้อนรุนแรงจากการผ่าตัด การศึกษานี้สรุปได้ว่าเครื่องมือ PSP สามารถแก้ไขกระดูกสันหลังคดได้ดีกว่าเครื่องมือ CD multiple hooks และ PSP เป็นเครื่องมือที่เหมาะสมสำหรับผ่าตัดรักษากระดูกสันหลังคด