Apical Derotation in the Treatment of Idiopathic Scoliosis

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Study Design: *A prospective study of the pedicular screw plate system in the treatment of idiopathic scoliosis.*
Objectives: *To study the efficacy of apical derotation of pedicular screw plate system in idiopathic scoliosis correction and evaluate the feasibility of the technique.*
Summary of Background Data: *In the surgical treatment of idiopathic scoliosis, the standard technique of fixation currently utilized the linkage of the pedicle screws via rods. Alternatively the technique of apical correction of the deformity by sagittally contoured plates found to be a convenient and effective mean of deformity correction and rigid fixation.*
Material and Method: *Twenty-five patients who were diagnosed as idiopathic scoliosis and underwent posterior spinal fusion and fixation with pedicle screws and plates were prospectively analysed. The parameters were compared between preoperative and postoperative by paired t-test. These parameters included Cobb angles, body height, shoulder height difference, coronal trunk balance, hump difference and vertebral rotation.*
Results: *There was statistically significant difference between the pre-op and post-op parameters studied.*
Conclusion: *The instrument can effectively correct the scoliosis of moderately severed deformity in 3 dimensions especially regarding the vertebral derotation and restoration of thoracic kyphosis.*

Keywords: *Vertebral derotation, Scoliosis, Pedicle fixation*

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It has been recently accepted that the posterior segmental spinal system is one of the standard instruments in scoliosis surgery. Since Cotrel has introduced the CD system, the use of this system is widely performed. Most reports verify good correction of coronal deformity with the Cobb's angle correction range from 60% to 85 %. Since then many authors have reported variable degrees of vertebral derotation in various instrumentation[1-10]. Recently the development of posterior pedicular screw fixation system has greatly evolved. Suk reported good results from pedicular screw system especially on vertebral derotation[11,12]. Kao-wha chang[13] utilized the cantilever bending technique for treatment of large and rigid scoliosis. The present study explored the efficacy of the screw-plate system. The apical derotation was studied by CT scan.

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Objective

To evaluate the efficacy of the pedicle screw-plate system in idiopathic scoliosis correction with considering the correction in three planes.

Material and Method

All patients were operated on from Jan 1998 to Dec 1999. There were 25 patients who had a diagnosis of idiopathic scoliosis and underwent the posterior spinal correction and fusion with the pedicle-screw plate system. Inclusion criteria: All patients who had been diagnosed as adolescent idiopathic scoliosis (AIS) and underwent posterior spinal correction and fusion with this technique. Exclusion criteria: Juvenile scoliosis and those who had indication for surgical release either anteriorly or posteriorly. These curves make it difficult to study the rotational deformity (curve >100degree).

The preoperative and postoperative data were collected regarding standing height, Cobb's angle, kyphotic angle (T5 to T12), coronal trunk balance (plumb line), shoulder height difference, rib hump difference, vertebral rotation, alignment index and coronal hump difference. To measure coronal trunk balance, the standard plumb line was routinely used. The shoulder height difference (SHD) was measured by the difference between the highest points of both shoulders. To locate the point of the depressed shoulder, the authors measured the distance from the center of the neck to the highest point of the elevated shoulder and then by the same distance, the point of the depressed shoulder was located. The rib hump difference (RHD) was evaluated by forward bending 90 degrees or until the back was parallel to the floor. In the same manner as SHD measurement, the point on each side of the back was located and its vertical difference was measured.

The measurement of coronal deformity was performed by the standard Cobb's angle technique. The standing film PA and lateral of the whole spine preoperatively and at the last follow up were used. The kyphotic angle was recorded on lateral film between the lower end plate of T12 and upper end plate of T5. In the present study, only 8 patients with hypokyphosis (preoperatively Cobb's angle less than 15 degrees) were analyzed for sagittal contour correction.

Regarding vertebral rotation, the CT scan measurement using the method of Aaro and Dahlborn[14,15] was performed. The RaMl which is defined by the angle formed between the line drawn from the sternum to the most posterior corner of the spinal canal and another drawn from the most posterior aspect of the spinal canal extending anteriorly to equally bisect the vertebral body was measured. The alignment index was calculated by the equation, AI = [apex - (T + B) / 2] where AI = alignment index, apex = average apical RaMl rotational angle, T = average upper end vertebral RaMl rotational angle and B = average lower end vertebral RaMl rotation. This represented the overall segmental vertebral rotation; the closer to zero, the better the alignment. Coronal hump difference was used to evaluate the rib cage deformity and was measured from CT-scan film by first creating the RaMl line and the second line was made perpendicular to the RaMl line and touching the posterior aspect of the more prominent rib cage as shown in the figure. The distance from point B to the rib on the less prominent side is the virtual coronal hump difference which can be converted back to the coronal hump difference by the magnifiying factor (Fig. 1).

Selection of fusion levels

The upper vertebra is one that is in neutral rotation. The lower vertebra is the end vertebra.

Surgical Technique[16]

When the positions of the screws in the pedicle canals are checked by fluoroscopy, any detected malpositions are corrected (Fig. 2).

The spinal plate is then contoured to the normal lordotic and kyphotic curvature. The plates then gather all the screws into their slots on each side. The screws are then further driven to the full depth of the spine. Meanwhile, a bony raw surface between the screws is created so that small longitudinal pieces of bone graft can be inserted under the plate to fill the gap between the proximal part of the transverse processes. Upon tightening of the screw to the plate via the washers and nuts, the spinal segments are gradually realigned and adapted with the contour of the plate. The graft is then compressed under the plates.

Fig. 1 The rotation measurement CT scan by method introduced by Aaro and Dahlborn. Coronal hump difference measurement. The distance between point b and arrow head was measured in milimenters and this can be converted to true coronal hump

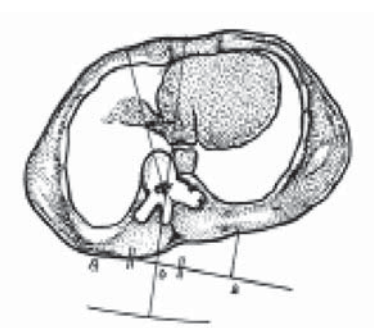

Fig. 2 Orientation of screws at different levels

The mechanics of deformity correction in three-dimensional planes by this instrument works as follows:- (Fig. 3) The first step is derotation of the apical screws by directly forcing the screw shanks into the slot of the plate. Since the screws are partially engaged in the vertebral bodies with different axial planes, it is possible to rotate the screws into the slot of the straight plate. Upon fixing the screws with washers and nuts at appropriate intervals along the plate, the programmed dynamic deformity correction works spontaneously and gradually realigns the deformed spines to the precontoured plates as the surgeon alternately tightens each assembled screw deep into the vertebral body. Part of the mechanics is depicted in Fig. 3. The figure clearly demonstrates that as the surgeon screws in the apical screws on the concave side of the curve, a dynamic distraction is created as the screws gradually sink into the vertebral bodies. Conversely, upon screwing in the peripheral screws on the convex side, dynamic compression occurs spontaneously with gradual shortening of the convex side. As all screws purchase fully in the vertebral bodies, minor readjustment of the screw intervals by either direct compression or distraction would create further static force. Both end vertebra screws on the concave side and the apical screws on the convex side are avoided to prevent late penetration of the screw into the spinal canal.

The muscle flaps are released from the plates and can be sutured without tension. Postopertively, the patient is kept in bed for a few days for medical monitoring and pain control. Gradual ambulation can usually start at day 3 or 4. Generally no support is needed unless in a growing child with the compensatory curve unoperated.

Results

There were 25 patients, 23 were female and the others were male (Table 1). The mean age was 14.9 years (range 11-21 years). The pattern of curve distribution was 8 for King II, 8 for King III, 6 for TL curve, 2 for King I, 1 for King IV and no King V in the present study (Table 1). The means preoperative Cobb's angle is 52.1 degrees and 14.8 degrees postoperatively. At the latest follow up, the mean Cobb angle was 21.5 degrees. Eight patients had hypokyphosis of the thoracic spine (less than 15 degrees). The mean kyphotic angle was 9.6 degrees preoperatively and 22.6 degrees at the last follow up (Fig. 4). The average increase in height was 3.0 cm. The shoulder height difference and coronal trunk balance were markedly improved. The shoulder height difference improved from 1.9 cm to 0.5 cm and the coronal trunk balance improved from 1.4 cm to 0.3 cm. Regarding the vertebral rotation there was significant apical vertebra derotation from 26.7 degrees to 15.0 degrees or 48.4% correction. The rotational angle of the upper end vertebra and the lower end were used to calculate the alignment index, which grossly reflect the overall alignment of the instrumented spinal col-

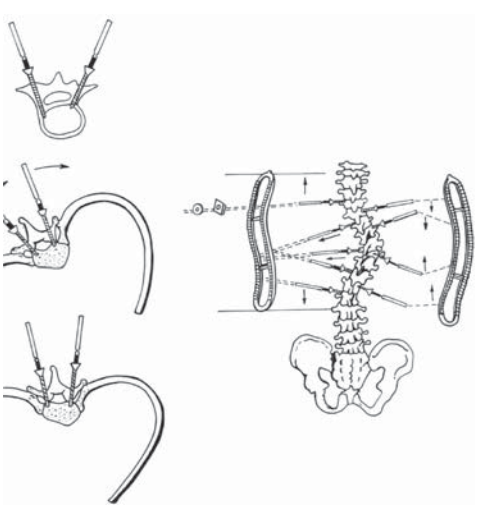

Fig. 3 The mechanics of correction of scoliosis by a double straight contoured plates. The first stage is rotation of the screw shanks so that the screws are aligned in the central slot of the plates. Upon tightening of the screws, spontaneous correction is as depicted by the direction of the arrows

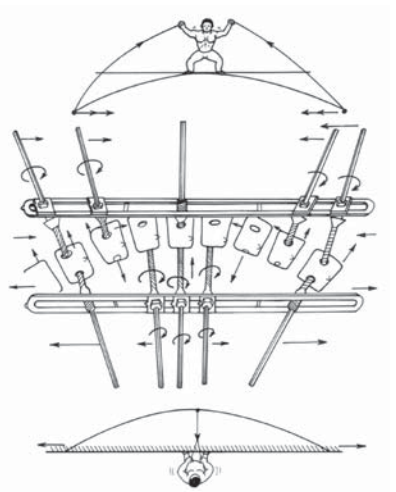

Fig. 4 Pre-operative and post-operative film of a case with thoracic scoliosis. Observe the screws on the concave side are concentrated at the apex whereas the screws on the convex sides are mainly placed on the periphery of the curve (4A). Restoration of kyphosis is shown in the lateral films (4B)

Table 1. Patient's profile

Pt. No	Age (yrs.)	King type	Cobb (degrees)			Rib hump (cm.)		Kyphosis (degrees)		Apex-S1 (degrees)		Plump line (cm.)		Alignment index (degrees)		Last F/U
			Pro-op	Early post	Late post	Pre-op	Post-op	Pre-op	Post-op	Pre-op	Post-op	Pre-op	Post-op	Pre-op	Post-op	
1.	13	1	45	10	13	2	1.5	40	42	22	18	0	0	7	4	4 y 5 m
2.	13	1	45	4	5	1	0.5	20	20	22	1	1	1.5	30.5	8	3 y 11 m
3.	11	2	52	12	20	3	2.6	10	20	20	11	1	0	25	9	5 y
4.	12	2	50	20	25	3	2	4	20	27	19	2	2	20.5	8	4 y 9 m
5.	19	2	55	18	11	3	0.5	4	22	21	14	1	0.5	29	13	4 y 1 m
6.	12	2	48	11	10	2.5	0.5	12	30	19	14	1.5	0	17	7.5	4 y
7.	14	2	38	6	17	2.5	0.5	11	19	25	14	2.5	1.5	15	8	4 y
8.	14	2	40	10	12	2	1.5	22	5	18	10	2.5	0	18.5	7	4 y
9.	21	3	54	25	41	6	3	50	15	39	26	2	1	35	19.5	3 y 10 m
10.	14	3	54	24	25	3.5	2.5	20	30	25	14	1	0	12.5	11	3 y 10 m
11.	14	3	60	21	35	4	2.2	16	20	40	31	2	1	13.5	4	4 y 5 m
12.	17	3	45	10	10	2.5	1.6	10	25	26	7	1.5	0	9	3.5	4 y 4 m
13.	18	3	36	5	10	3	1.6	4	22	29	20	0.5	0	11.5	9	4 y 1 m
14.	20	3	50	22	19	2.5	0.5	28	25	33	18	1	0	11	4	4 y
15.	16	3	43	10	18	3	1.5	26	22	22	7	2.5	0	20	8.5	4 y
16.	14	3	50	5	12	3	1	0	0	25	11	0.5	0	8.5	5.5	4 y 11 m
17.	13	3	45	8	15	3.5	1	60	42	23	14	0	0	13	10	4 y
18.	12	3	60	21	42	2	3	15	30	27	20	3.5	2	37.5	23	4 y
19.	13	4	55	15	45	2.5	2	11	14	28	16	0.5	0	20.5	8	4 y
20.	14	TL	48	8	10	4	2.8	25	35	27	16	0	0	9	9	4 y 1 m
21.	14	TL	60	18	24	3	3	40	27	10	3	2	1.5	1.5	5.5	4 y
22.	16	TL	50	14	20	0.5	0	40	35	12	3	1.5	0	14	0.5	4 y 2 m
23.	17	TL	95	28	54	8	3	20	30	65	27	2	0	42	16.5	2 y 1
24.	15	TL	75	20	20	4	0	30	23	38	26	2.5	0	35.5	19	4 y
25.	17	TL	50	25	25	1.5	2	33	35	24	15	1	0.5	10.5	7.5	4 y
Average	14.9		52.1	14.8	21.5	3.02	1.61	9.6*	22.6*	26.7	15	1.42	0.46	18.68	9.14	4 y 1 m

umn. It was decreased from 20.8 to 10.0 degrees indicating significant improvement in the rotation alignment in those instrumented segments (Fig. 5). Finally the coronal hump difference and rib hump difference was improved significantly from 41.2 to 25.5 mm and 3.2 to 1.4 cm respectively (Fig. 6, 7), indicating some change of the rib case morphology.

Discussion

The anterior instrumentation is the most efficient regarding rotation correction[17]. Suk SI reported the better results of pedicle screw in comparison to the segmental hook system[12]. In the 3D scoliosis correction, the pedicle system has the more powerful vertebral derotation and rib cage deformity correction than the hook segmental system. This is explained by the fact that the pedicle screw system is a three-column fixation, the purchase of the screw into the anterior column increases the lever arm of application from the posterior to the anterior portion of the spinal column.

The screw-plate system is one of the pedicle screw systems. Unlike other systems, it utilizes the apical dynamic correction during the assembly of the plate and screws. The final Cobb's angle correction could be predicted to be about half of the standard bending film in magnitude. In the present study, two cases had outward screw penetration without attempt

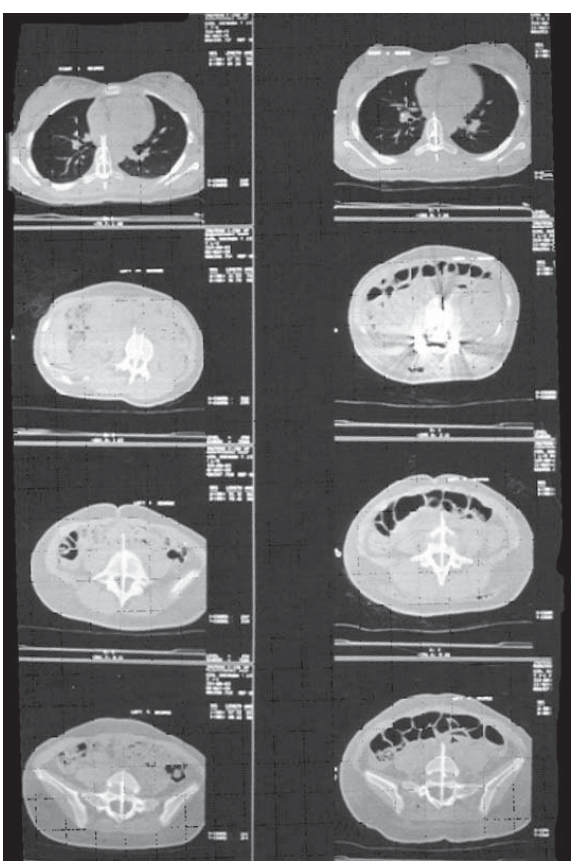

Fig. 5 Pre-operative and post-operative serial CT at upper vertebra, the apex, the lower vertebra and the sacrum of the curve demonstrating apical derotation to the normal position compared with the sacrum

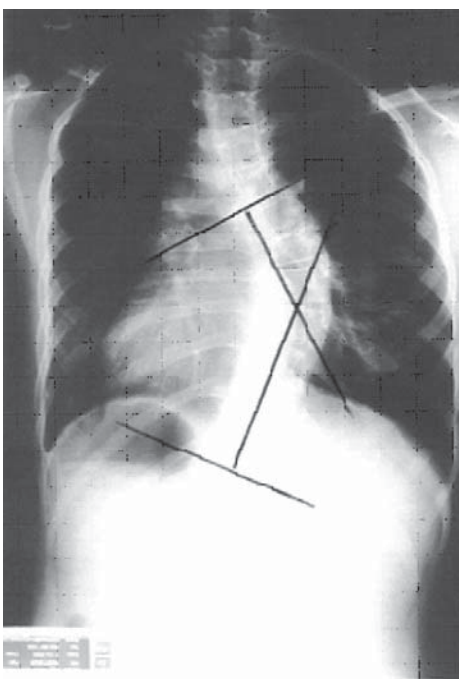

Fig. 6A Contour of the back of a patient demonstrating improvement of the rib cage deformity. 6A (Pre-op), 6B (Post-op)

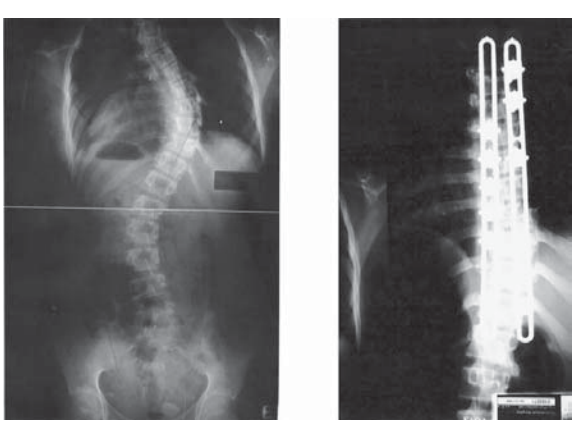

Fig. 6B Too short instrumentation in a case with thoracolumbar curve. This usually leads to late curve progression

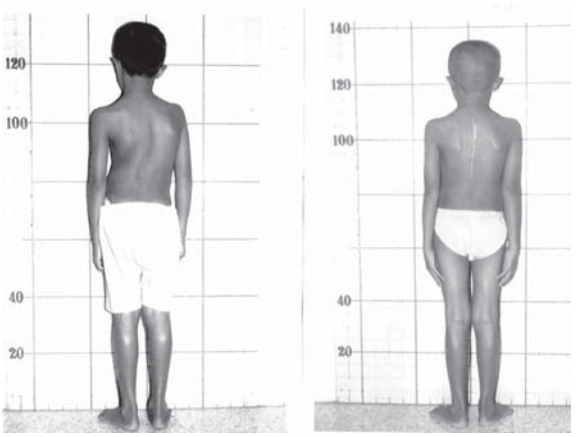

Fig. 7 Contour of the back in a patient with thoracolumbar curve. 7A (Pre-op), 7B (Post-op)

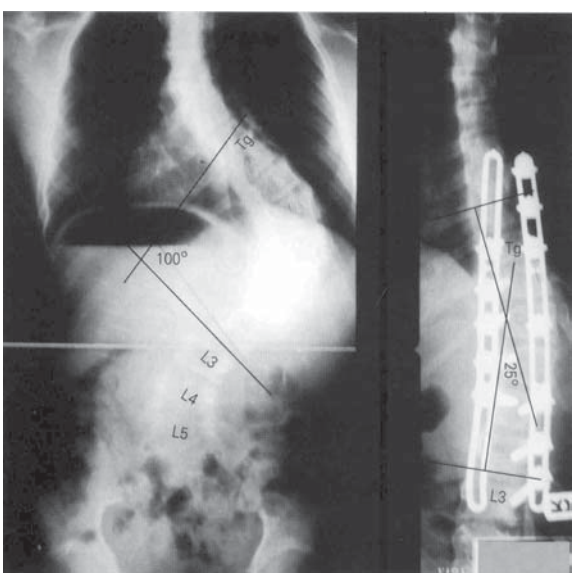

Fig. 8

to re-operate. In one unreported case, the upper most screw on the concave side migrated into the spinal canal post-operatively. This had to be removed. Since then the peripheral screws have been avoided on the concave side of thoracic region. The authors also avoided the apical convex screw for fear of medial migration. In cases of screw migration, the apical screws on the concave side and the peripheral screws on the convex side tend to move outwards away from the spinal canal.

In the present study, the result of Cobb's angle correction by the plates and screws is 71% correction, which was reduced to 59% in late follow up, which is comparable to the other systems. Some loss in two cases were due to too short in fusion segments (Fig. 8). Regarding the vertebral derotation, the degrees of derotation is 45.4%. The authors concluded that the plates and screws can correct the scoliotic deformity in 3 dimensions. The coronal hump difference which reflects the rib cage deformity by radiographic measurement and clinical rib hump difference (RHD) were satisfactory improved.

The pedicle screw-plate system is one of the pedicle screw fixations which can effectively and safely be done by applying dynamic gradual curve correction. It is nonapplicable to cases with the forced bending Cobb angle of over 60 degrees unless some posterior release is performed, and it is hardly applicable to patients under 10 years of age with the pedicle diameter smaller than 4 mm. Those patients with late progression of the deformity were associated with inappropriate selection of fusion segments and poor correction of the alignment index (Fig. 8) (Table 1). Since the screw fixation is concentrated at the apical region of the concave side, some growth potential might remain on the periphery of the concave side. This is important in a younger child. The Crank-Shaft phenomenon was not observed in a few cases of fusion done at 10-11 years with 5 years follow up (case # 3,4).

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การผ่าตัดแก้หลังคดโดยวิธี Apical derotation

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ติดตามผลการผ่าตัดในโรคกระดูกหลังคดงอโดยไม่ทราบสาเหตุ จำนวน 25 ราย ที่ได้รับตรึงกระดูกหลังด้วยแผ่นโลหะกับสกรูเพ็ดดิคัล ด้วยวิธี Apical derotation of pedicular screw plate system ศึกษาข้อดีโดยใช้ Cobb angles, น้ำหนักตัว ระดับความสูงของไหล่ การบิดหมุนแกนกระดูกหลัง ความโก่งแกนหลัง (hump) เป็นตัวหลักในการพิจารณาเปรียบเทียบ ผลการศึกษาการผ่าตัดแบบนี้แก้ความพิการได้ดีแตกต่างกว่าก่อนผ่าตัดแก้ไขอย่างมีนัยสำคัญทางสถิติ