Original Article

Operative Results of Adolescent Idiopathic Scoliosis Correction using Low-Density Instrumentation with 5-Year Follow-up

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Background: The treatment of idiopathic scoliosis has shifted to pedicle screw fixation. The present study was conducted to assess the intermediate-term effectiveness of posterior correction with low-density all-pedicle-screw constructs.

Objective: To review the intermediate-term outcome of low-density posterior-only pedicle screw constructs for a 5-year minimum follow-up.

Materials and Methods: The retrospective review included 30 patients who underwent posterior correction with low-density all-pedicle-screw constructs during 2004 to 2008. The radiographic measurements at pre-operation, immediate post-operation, 2-years post-operation, and 5-years post-operation were evaluated.

Results: Four males and 26 females were included in the present study. The mean follow-up was 6.1 years (range: 5.0 to 9.0). The average age at operation was 14.2±2.2 years. The pre-operative Cobb angle of the major curve was 55.3±12.8°, which was significantly corrected to 15.6±7.8° immediately post-operation, and significantly increased to 17.2±8.2° and to 18.5±8.7° at 2-years post-operation and 5-years post-operation, respectively. The major curve correction loss rate was 25.2%. In the normal thoracic kyphosis group (range: 10° to 40°), the pre-operative thoracic kyphosis angle was 28.0±12.3°, which was non-significantly decreased to 24.1±9.1°, 25.8±8.1°, and 25.8±8.5° at immediately post-operation, at 2-years post-operation, and 5-years post-operation, respectively. Pre-operative lumbar lordosis non-significantly decreased from 42.7±13.0° to 39.5±10.1°, 40.5±9.1° and 41.2±9.4° at immediately post-operation, 2-years post-operation and 5-years post-operation, respectively. Screw density was 0.9 screw per level or 51%.

Conclusion: The present study reviewed the 5-year post-operative outcome of posterior correction with low-density all-pedicle-screw constructs. The Cobb angle in coronal alignment correction was improved, but was significantly lost at 2- and 5-years post-operation. Thoracic kyphosis and lumbar lordosis were improved but did not significantly change at 2- and 5-years post-operation.

Keywords: Adolescent Idiopathic scoliosis, pedicle screws, posterior spinal fusion all-pedicle-screw constructs, low screw density (Spinal fusion)

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Adolescent idiopathic scoliosis (AIS) is a three-dimensional spinal deformity that occurs between 10 years of age and skeletal maturity[1]. Epidemiologic studies showed that 2 to 3% of the adolescent population is affected; however, less than 10% of these patients required treatment[1]. The exact cause of AIS remains unknown[2]. Consensus opinion suggests that there is a hereditary predisposition, and its actual cause involves multifactorial risk factors[2-4]. Spinal curve progression depends on initial curve size, curve type, peak growth rate, age at onset, and gender. Cobb angle greater than 20°, is usually found in girls. Greater curve size, especially more than 50°, is associated with chronic back pain, disability, poor cosmetic appearance, psychosocial issues, respiratory dysfunction, and increased mortality rate[5,6]. Surgical indications for patients with AIS include curve >50° in a skeletally mature patient, curve 40° to 45° in a skeletally immature patient, curve progression despite bracing, and deformity that is unacceptable to the patient[6,7]. The goals of surgical treatment in AIS patient are to obtain significant curve correction and to prevent progression or recurrence after spinal arthrodesis. Hook constructs were the standard treatment for AIS in the past[8-10]. Use of all-pedicle-screw constructs was initially controversial due to

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safety concerns[11]. Posterior segmental spinal instrumentation with all-pedicle-screw fixation provides multiple points of fixation and shorter fusion levels compared to hook constructs[12,13]. The all-pedicle-screws method achieved a three-dimensional curve correction rate that was superior to the rates achieved by other spinal fixation devices[12,14-16]. Complications related to thoracic screws have been reported in scoliosis treatment, such as screw malposition, pedicle fractures, neurologic complications, and dural tears[17-19]. Although there is no precise clarification regarding low and high screw density, low screw density was found not to correlate with the extent of either coronal or sagittal correction within a 2-year follow-up period. High-density instrumentation also increased the operative time, the blood lost, and the cost[20-23].

The aim of the present study was to review the intermediate-term (5 years) effectiveness and safety of patients that underwent posterior correction with all-pedicle-screw constructs at Siriraj Hospital Thailand's largest national tertiary referral center.

Materials and Methods

The retrospective study included 30 patients who underwent posterior correction with all-pedicle-screw constructs at Siriraj Hospital (Bangkok, Thailand) during 2004 to 2008. All patients were followed for at least 5 years. Pre-operative (Pre-op) and postoperative (PO) radiographic data at immediate postoperation, 2-years, and 5-years were measured including Cobb angle, Thoracic kyphosis and lumbar londosis. Curve correction rate (CR) was defined as pre-operative angle minus immediate postoperative angle then divide by pre-operative angle time 100% ((pre-operative - postoperative)/pre-operative x100%). Curve correction loss rate (CL) was determine by 5-year after operation angle - immediate postoperative angle divided by 5-year after operation angle time 100% ((5 years after operation angle - post-op angle)/post-op angle x100%). Sagittal thorosis curve correction was compared between pre-operative and various postoperative angle classified into 2 groups of thoracic kyphosis angle; $\leq$10 degree and $\geq$40 degree. Clinical outcome evaluation including rotation of the apical vertebra (RAV) was classified as good, fair and poor. Finally, complications were investigated.

Statistical analysis

Descriptive statistics were used to summarize data. Mean and standard deviation and median (minimum and maximum) were described continuous data and frequency distribution and percentage used for categorical data. Repeated measures analysis of variance (ANOVA) and Bonferroni's method were used to analyze the Cobb angle, thoracic kyphosis angle, and the lumbar lordosis angle at pre-operation, immediate post-operation, 2-years post-operation, and 5-years post-operation. A *p*-value less than 0.0167 was considered statistically significant according to the adjustment for three pair comparisons (alpha: 0.05/3). The marginal homogeneity test and McNemar's test were used to analyze rotation of the apical vertebra. Wilcoxon signed-rank test was used to analyze sagittal thoracic curve correction. The data were compiled and analyzed using SPSS Statistics version 18.0 (SPSS, Inc., Chicago, IL, USA).

Results

There were 30 patients, including 4 males and 26 females. The mean age at the time of the operation was 14.2$\pm$2.2 years (range: 11 to 19). The mean follow-up was 6.1$\pm$1.2 years (range: 5.0 to 9.0). The mean number of fusion levels was 8.3$\pm$2.6 (range: 4 to 12) (Table 1). Patients were categorized by Lenke classification[24], as follows: type 1 (n = 18), type 5 (n = 10), and type 6 (n = 2) (Table 2).

In the coronal plane, the preoperative Cobb angle of the major curve was 55.3$\pm$12.8° (range: 29 to 75), which was corrected by 71.8% to 15.6$\pm$7.8° (range: 2 to 30) (*p*<0.001) immediately after surgery. The curve correction loss rate for major curve in all 30 patients at 5 years after surgery was 18.6% (Table 3).

Mean preoperative thoracic kyphosis (T5 to T12) was 28.0$\pm$12.3° (range: 9 to 52), which was decreased to 24.1$\pm$9.1° (range: 10 to 45) (*p*<0.292) immediately after surgery, and to 25.8$\pm$8.5° (range: 12 to 42) (*p*<0.696) at 5 years after surgery. Mean preoperative lumbar lordosis (L1 to L5) was decreased from 42.7$\pm$13.0° (range: 20 to 70) to 39.5$\pm$10.1° (range: 20 to 65) (*p*<0.507) immediately after surgery, and to 41.2$\pm$9.4° (range: 20 to 60) (*p*<0.999) at 5 years after surgery (Table 4).

Rotation of the apical vertebra was improved from 11 poor result patients (36.7%) in the preoperative stage to 0 poor result patients in the immediate postoperative period (*p*<0.001), and these corrections were sustained until the 5-year postoperative follow-up (*p*<0.999). At 5 years after surgery, 26 patients achieved good rotation of the apical vertebra (Table 3).

Four patients had thoracic hypokyphosis ($\leq$10°). The mean pre-operative thoracic kyphosis angle of 9.25$\pm$0.5° was improved to 22.0$\pm$1.41°, and increased to 24.0$\pm$3.27° at 5 years after surgery. Six patients had pre-operative thoracic hyperkyphosis ($\geq$40°). The mean pre-operative thoracic kyphosis angle of 46.67$\pm$6.74° was improved to 23.17$\pm$4.12°,

Table 1. Patient demographics data

Characteristics	Mean $\pm$ SD, n (%)
Patient numbers	30
Gender	
Male	4 (13.3)
Female	26 (86.7)
Risser grade (1: 2: 3: 4: 5)	2: 4: 8: 11: 5
Age at operation (years)	14.2 (11 to 19)
Number of fused segments	9.5 (4 to 12)
Follow-up (years)	6.1 (5 to 9)
No. screws/patient	9.5$\pm$2.3
Screw density (no screws/level)	0.9$\pm$0.2
Screw density (no of pedicle screws/ no of pedicles x2)	51%

Table 2. Lenke classification

Type	Lumbar spine modifier	Thoracic sagittal profile T5 to T12*	Number	Total
1	A	- (Hypo)	4	18
		N (Normal)	6	
		+ (Hyper)	6	
	B	- (Hypo)	0	
		N (Normal)	2	
		+ (Hyper)	0	
5	C	- (Hypo)	1	10
		N (Normal)	9	
		+ (Hyper)	0	
6	C	- (Hypo)	0	2
		N (Normal)	2	
		+ (Hyper)	0	

* Hypo <10°, Normal 10° to 40°, Hyper >40°

Table 3. Coronal and Sagittal Parameters Results

Angle	Pre-op (°)	PO (°)	2 years (°)	5 years (°)	CR	CL
Cobb angle						
Mean ± SD	55.3±12.8	15.6±7.8	17.2±8.2	18.5±8.7	71.8%	18.6%
95% CI	48.6 to 58.1	12.7 to 18.5	14.2 to 20.3	15.2 to 21.8		
p-value		0.001*	0.001**	0.001***		
Thoracic kyphosis						
Mean ± SD	28.0±12.3	24.1±9.1	25.2±8.1	25.8±8.5		
95% CI	23.4 to 32.6	20.7 to 27.5	22.2 to 28.2	22.6 to 29.0		
p-value		0.292*	0.999**	0.696***		
Lumbar lordosis						
Mean ± SD	42.7±13.0	39.5±10.1	40.5±9.1	41.2±9.4		
95% CI	37.9 to 47.6	35.7 to 43.3	37.1 to 43.9	37.6 to 4.70		
p-value		0.507*	0.999**	0.999***		

* PO vs. Pre-op; ** 2 years vs. PO; *** 5 years vs. 2 years

Table 4. Evaluation clinical outcome of Rotation of the apical vertebra (RAV)

RAV	Pre-op	PO	2 years	5 years
Good	2 (6.7%)	26 (86.7%)*	26 (86.7%)	26 (86.7%)
Fair	17 (56.7%)	4 (13.3%)*	4 (13.3%)	4 (13.3%)
Poor	11 (36.7%)	0 (0.0%)*	0 (0.0%)	0 (0.0%)
p-value		0.001	0.999	0.999

* Significantly different from preoperative data

and increased to 26.0±5.02° at 5 years after surgery (Table 5).

One patient had lateral malposition of the right screw at T5 level (concavity of the curve), but it did not cause any clinical symptoms. One patient with unstable hemodynamic status during the first operation underwent operation two days later for placement of a local bone graft. No major or fatal complications were observed.

Discussion

Posterior fusion with instrumentation has been a standard of surgical treatment for scoliosis since first introduced by Paul Harrington[8]. Harrington rod system correction force was applied with distraction along the concavity of the curve. The procedure required post-operative stabilization of the trunk with an orthosis or plaster cast for several months in order to maintain the achieved correction[9]. In the second-generation instrumentation system developed by Cotrel and Dubousset[25], the correction was attempted by a rod-rotation maneuver. This procedure provided better sagittal and frontal correction, and also decreased postoperative immobilization due to greater

Table 5. Sagittal thoracic curve correction

Thoracic kyphosis angle	Pre-op (°)	PO (°)	2 years (°)	5 years (°)
Thoracic kyphosis angle ≤10°	9.25±0.5	22.0±1.41	23.0±2.16	24.0±3.27
		0.125*	0.250**	0.50***
Thoracic kyphosis angle ≥40°	46.67±6.74	23.17±4.12	23.33±3.93	26.0±5.02
		0.031*	0.875**	0.062***

* PO vs. Pre-op; ** 2 years vs. PO; *** 5 years vs. 2 years

primary stability. A segmental pedicle screw concept was first introduced by Suk[26]. They reported that the use of all-pedicle-screw constructs in AIS was safe and effective. In a review of 4,604 thoracic pedicle screws that were placed in 462 patients, 67 screws were malpositioned (1.5%), but none of these screws caused neurologic complications or adversely affected the long-term results. Idiopathic thoracic curves of 51 degrees on average were corrected to 16 degrees (69% correction) during a minimum 5-year follow-up. In 1995, Suk, et al[13] compared hook constructs with screw constructs. They reported major curve correction of 72% with segmental screws compared with 55% correction with hooks. Correction in the second compensatory curve was 70% with segmental pedicle screws, and 57% with hooks. In 2004, Kim, et al[12] reviewed 52 patients treated with either segmental pedicle screws or hooks and reported similar results. At the 2-year follow-up, 76% average major curve correction was achieved in patients treated with screws compared with 50% correction with hooks. Blood loss and surgical time were not significantly different between methods. They also documented a significant improvement in pulmonary function in patients treated with pedicle screws compared to those treated with hooks. In 2005, Cheng, et al[27] compared apical sublaminar wires with pedicle screws. No difference was found regarding initial correction (67.4% vs. 68.1%), operating time (350 minutes vs. 357 minutes), and patient satisfaction, but intraoperative blood loss was greater with wires (1,791 ml vs. 824 ml). Similar results were found in the present study. The correction rate of the Cobb angle of the major curve was 71.8%. The curve correction loss rate at 5 years after surgery was 18.6% higher than previous studies. Although some studies described no difference in Cobb angle change at the 2-year postoperative follow-up between low and high screw density, no previous study has followed and reported 5-year postoperative outcomes. Generally speaking, there is no exact definition of low or high-density pedicle screw number. Shen, et al[20] described low density as less than 1.6 screws per level, or less than 55% (number of pedicle screws/number of pedicle screws x2). Bharucha, et al[21] described less than 1.3 screws per level as defining low density. The present study had an average of 0.9±0.2 screws per level or 51%, which was lower than any previous study[21,23,28,29]. Major cobb angle of coronal at 2 years and 5 years increased a little, but the change was statistically significant. This may be explained by the very low screw density in this study, as shown in Figure 1.

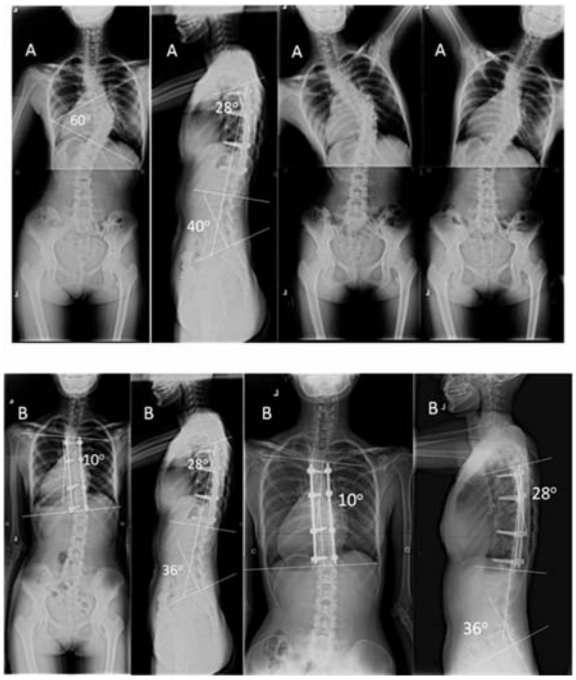

Figure 1. A) Preoperative Standing PA, Lateral, Lateral bending radiographs of a 16 year-old-female with 1AN as Lenke classification. B) The patient underwent posterior correction followed by posterior instrumentation with pedicle screw constructs and posterior fusion from T5 to T12. The major Cobb angle, thoracic kyphosis and lumbar lordosis angle were revealed. C) The major Cobb angle, thoracic kyphosis and lumbar lordosis angle were evaluated at 6 years follow-up. The screw density was 1.14 or 50%.

Many studies reported significant loss of lumbar lordosis (flat-back syndrome) as a complication after AIS correction with Harrington rod instrumentation[30]. In the present study, thoracic kyphosis in the range of 10 to 40 degrees and lumbar lordosis were well-maintained immediately after surgery and at the 5-year follow-up. The pre-operative thoracic hypokyphosis and hyperkyphosis groups were improved to normal kyphosis, but the changes in both groups were not significantly different due to the very small number of patients in each group. This is an acknowledged limitation of the present study. Lumbar lordosis and rotation of the apical vertebra were also well-corrected and maintained for 5 years after surgery.

The present study revealed that it is not necessary to insert pedicle screws in all vertebra that require fusion for many reasons, including cost and technical difficulty associated with insertion of thoracic pedicle screws into deformed and smaller diameter thoracic pedicles, which may endanger vital adjacent structures. In 2007, Di Silvestre[31] reported 18 misplaced screws (1.7%) in 13 patients (11.3%). Other complications included intra-operative pedicle fracture in 15 patients (13%), dural tear (without neurologic complications) in 14 cases (12.1%), and superficial wound infection in 2 patients (1.7%). In the present study, one patient had lateral malposition of the right screw in T5 (concavity of the curves), but it did not cause clinical symptoms. One patient with unstable hemodynamic status during the first operation was reoperated upon 2 days later. There was neither major nor fatal complication. The authors considered placement of thoracic pedicle screws using the free hand technique to be a safe and reliable technique. However, this technique requires an experienced surgeon with a thorough understanding of the anatomy of the deformed spine. In AIS, the concave pedicles are significantly smaller than the convex ones. Therefore, pedicle screw placement on the concavity of scoliotic curves has to be performed with maximum caution[22,23,28,29,32].

The limitations of the present study include its relatively small sample sizes without comparative groups, and the fact that we did not use CT imaging to assess the accuracy of screw placement.

Conclusion

The present study reviewed the intermediate-term (5 years after surgery) curve correction, curve correction loss rate, and safety profile of adolescent idiopathic scoliosis after posterior correction with posterior instrumentation with all-pedicle-screw constructs and posterior fusion at Siriraj Hospital using low instrument density. The all-screw method was proven to be a safe and effective procedure. The spinal curve in each case was well corrected, with no major or fatal complications.

What is already known on this topic?

Posterior spinal correction and fusion with pedicle screws is standard treatment in adolescent idiopathic scoliosis.

What this study adds?

Very low pedicle screw density via posterior spinal correction and fusion could be used in adolescent idiopathic scoliosis according to the results of 5-year post-operative follow-up.

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Potential conflicts of interest

The authors declare no conflicts of interest.

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