

The posterior pedicle screw construct: 5-year results for thoracolumbar and lumbar curves

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Clinical article

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Object. Several studies of the outcomes of patients with adolescent idiopathic scoliosis (AIS) with thoracolumbar and lumbar curves after treatment with posterior pedicle screws have been reported, but most of these studies reported only 2-year follow-up. The authors analyzed the radiographic and clinical outcomes of patients with thoracolumbar and lumbar curves treated with posterior pedicle screws after 5 years of follow-up.

Methods. A multicenter database was retrospectively queried to identify patients with AIS who underwent spinal fusion for Lenke 3C, 5C, and 6C curves. Radiographs from the following times were compared: preoperative, first follow-up visit, 1-year follow-up visit, 2-year follow-up visit, and 5-year follow-up visit. Chart review included scoliometer measurements, Scoliosis Research Society (SRS)–22 questionnaires, and complications requiring return to the operating room.

Results. Among 26 patients with Lenke 3C, 5C, and 6C curves, the mean (\pm SD) age was 14.6 ± 2.1 years. From the time of the preoperative radiographs to the 5-year follow-up radiographs, there was a statistically significant improvement in the mean coronal lumbar Cobb angles ($p < 0.0001$), and from the time of the first postoperative radiographs to the 5-year follow-up radiographs, the lumbar curve remained stable ($p = 0.14$). From the time of the preoperative radiographs to the 5-year follow-up radiographs, there was a statistically significant improvement in the mean coronal thoracic Cobb angles ($p < 0.0001$), and from the time of the first postoperative radiographs to the 5-year follow-up radiographs, the thoracic curve remained stable ($p = 0.10$). From the first postoperative visit to the 5-year follow-up visit, the thoracic kyphosis (T5–12) remained stable ($p = 0.10$), and from the time of the preoperative radiographs to the 5-year follow-up radiographs, the lumbar lordosis (T-12 to top of sacrum) remained stable ($p = 0.44$). From the preoperative visit to the 5-year follow-up visit, the coronal balance improved significantly ($p < 0.05$) and remained stable from the first postoperative visit to the 5-year follow-up visit ($p = 0.20$). The SRS-22 total scores improved significantly from before surgery to 5 years after surgery ($p < 0.0001$). No patients required reoperation because of complications.

Conclusions. Correction of the coronal, sagittal, and axial planes in this cohort of patients was maintained from the first follow-up measurements to 5 years after surgery. In addition, at 5 years after surgery total SRS-22 scores and inclinometer readings were improved from preoperative scores and measurements.

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KEY WORDS • adolescent idiopathic scoliosis • thoracolumbar and lumbar curves • spinal fusion • posterior pedicle screw • 5-year follow-up • lumbar

Two approaches (anterior and posterior) are used for the treatment of thoracolumbar and lumbar adolescent idiopathic scoliosis (AIS).^{2,6,7,9,12,13,16,20–22} In 1969, Dwyer et al. first proposed the anterior approach for the treatment of thoracolumbar and lumbar curves with use of vertebral body screws and a compression cable. This approach resulted in good coronal correction but also resulted in a kyphosing effect, poor derotation, and a high rate of pseudarthrosis.^{6,7,12,16} Later, to improve derotation, Zielke replaced the wires with an anterior

threaded rod, but the kyphosing effect and high rate of pseudarthrosis remained.^{2,13} Later, dual anterior solid rods were developed and resulted in better coronal correction, improved derotation, and less kyphosis.²¹

The first posterior approach to be accepted for treatment of thoracolumbar and lumbar AIS was the Harrington method, which used posterior hooks and rods.⁹ In 1989, Luk et al. compared the Harrington, Dwyer, and Zielke methods and showed improved correction in the coronal and sagittal planes with posterior hooks and rods.²⁰ In 2004, Shufflebarger et al. showed that using a wide posterior release and posterior pedicle screws to correct lumbar and thoracolumbar idiopathic scoliosis

Abbreviations used in this paper: AIS = adolescent idiopathic scoliosis; SRS = Scoliosis Research Society.

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resulted in a coronal correction of 80% with good sagittal alignment at 2 years after surgery.²² Several studies that compared anterior spinal fusion with pedicle screw fixation for the treatment of thoracolumbar and lumbar AIS reported no statistically significant difference in coronal or sagittal curve correction between the 2 methods at 2 years after surgery.^{10,19,25} However, in 2009, Geck et al. compared patients with Lenke 5C AIS treated with a posterior release and pedicle screws with those who received anterior instrumentation; they found that at 2 years after surgery, the patients with pedicle screws had statistically significantly better curve corrections, better maintenance of corrections over time, and shorter hospital stays.⁸

Although the long-term results for anterior constructs have been reported, clinical and radiographic outcomes of pedicle screw constructs are largely based on short-term follow-up. To our knowledge, no study has examined radiographic findings, progression, and clinical outcomes of patients with thoracolumbar and lumbar AIS curves treated with pedicle screw constructs for a minimum of 5 years after surgery.

Methods

Institutional Review Board approval for the study was obtained locally from each contributing institution's review board, and consent was obtained from each patient before data collection. A prospectively collected multicenter database was retrospectively reviewed to identify 99 patients (younger than 18 years) with AIS treated with pedicle screws from January 2002 to December 2006 and followed for at least 5 years. Patients with Lenke 1, 2, and 4 curves were excluded, leaving 26 patients with Lenke 3C, 5C, and 6C AIS. Lenke 3C curves were included because they have a structural thoracolumbar component.

Standing posteroanterior and lateral radiographs were taken preoperatively and at the first follow-up visit and 1, 2, and 5 years after surgery. The following measurements were recorded from the radiographs: coronal lumbar and thoracic curve magnitudes, percentage flexibility (measured on side-bending radiographs), coronal balance (distance between C-7 and the central sacral vertical line), thoracic kyphosis (T5–12), and lumbar lordosis (T-12 to the top of the sacrum). To reduce radiation exposure and because we did not suspect malpositioned screws or pseudarthrosis, we did not obtain CT scans. Other study variables were Lenke classification, Scoliosis Research Society (SRS)–22 scores, angle of rotation as measured by scoliometer, fusion levels, and postoperative complications. Statistical analyses were performed using the SPSS statistical package (version 12.0.2, SPSS, Inc.). All results are reported as means \pm standard deviations. Descriptive statistical analyses were performed using ANOVA and were used to detect differences between the time periods; significance level was 0.05.

Results

Patient Demographics

The cohort consisted of 26 patients with thoracolumbar or lumbar AIS (6 patients with Lenke 3C, 8 with Lenke

5C, and 12 with Lenke 6C). The mean age of the patients was 14.6 ± 2.1 years, and 24 (92%) were female (Table 1).

Thoracolumbar/Lumbar Curve

The mean (\pm SD) preoperative lumbar coronal Cobb angle was $55.4^\circ \pm 12.1^\circ$, straightening to $27.5^\circ \pm 12.1^\circ$ on side-bending radiographs, for a mean lumbar percentage flexibility of $50.0\% \pm 20.0\%$. From the time of the preoperative radiographs to the 5-year follow-up radiographs, there was a statistically significant improvement of the mean coronal lumbar Cobb angles ($p < 0.0001$), and from the time of the first postoperative radiographs to the 5-year follow-up radiographs, the curve remained stable ($p = 0.14$). Furthermore, at the first postoperative visit, the mean percentage correction of the lumbar curve was $70.0\% \pm 20.0\%$, and it remained the same at the 1-, 2-, and 5-year follow-up visits (Table 2).

Thoracic Curve

The mean preoperative thoracic coronal Cobb angle was $46.4^\circ \pm 19.6^\circ$, straightening to $30.1^\circ \pm 16.4^\circ$ on side-bending radiographs, for a mean thoracic percentage flexibility of $40.0\% \pm 20.0\%$. From the time of the preoperative radiographs to the 5-year follow-up radiographs, there was a statistically significant improvement of the mean coronal thoracic Cobb angles ($p < 0.0001$), and from the time of the first postoperative visit to the 5-year follow-up visit, the curve remained stable ($p = 0.10$). However, the thoracic mean percent curve correction decreased significantly from the first postoperative visit to the 5-year follow-up visit ($p < 0.05$) (Table 2).

Thoracic Kyphosis and Lumbar Lordosis

From the preoperative visit to the 5-year follow-up visit, there was a statistically significant decrease of the mean thoracic kyphosis (T5–12) ($p < 0.05$). However, from the first follow-up visit to the 5-year follow-up visit, the mean thoracic kyphosis (T5–12) remained stable ($p = 0.10$). From the preoperative visit to the 5-year follow-up visit, the mean lumbar lordosis (T-12 to the top of the sacrum) remained stable ($p = 0.44$) (Table 2).

Coronal Balance

From the preoperative visit to the 5-year follow-up visit, the mean coronal balance (C-7 to the central sacral vertical line) improved significantly ($p < 0.05$). From the

TABLE 1: Demographics for the 26 patients*

Characteristic	No. of Patients
sex	
female	24
male	2
Lenke curve (type)	
3C	6
5C	8
6C	12

* Mean age 14.6 ± 2.1 years.

TABLE 2: Radiographic measurements of thoracic and thoracolumbar/lumbar curves*

Measurement*	Preop	1st Postop	1-Yr Postop	2-Yr Postop	5-Yr Postop	p Value†
thoracolumbar/lumbar Cobb	55.4 ± 12.1	14.7 ± 9.4	15.7 ± 8.5	15.7 ± 9.4	17.3 ± 10.0	<0.0001
thoracic Cobb	46.4 ± 19.6	14.4 ± 7.3	16.5 ± 7.5	16.3 ± 7.4	17.4 ± 7.9	<0.0001
thoracic kyphosis (T5–12)	27.7 ± 10.1	24.6 ± 8.4	23.8 ± 8.1	22.8 ± 10.4	23.1 ± 12.7	<0.05
lumbar lordosis (T12–top of sacrum)	-60.0 ± 13.2	-54.7 ± 12.4	-61.3 ± 13.3	-56.7 ± 12.4	-58.2 ± 13.4	0.44
coronal balance (C7–CSVL) (cm ± SD)	-1.7 ± 2.8	-1.3 ± 2.7	-1.3 ± 2.7	-0.7 ± 1.4	-0.8 ± 0.9	<0.05

* All measurements are in degrees ± SD unless otherwise indicated. CSVL = central sacral vertical line.

† Preoperative to 5-year postoperative. Boldface indicates statistical significance.

first postoperative visit to the 5-year follow-up visit, it remained stable ($p = 0.20$) (Table 2).

Inclinometer Readings

From the preoperative visit to the 5-year follow-up visit, the thoracic and lumbar inclinometer measurements revealed significant improvement ($p < 0.0001$). These measurements remained stable from 1 year to 5 years after surgery ($p = 0.19$) (Table 3).

SRS-22 Scores

From the preoperative visit to the 5-year follow-up visit, SRS-22 total scores improved significantly ($p < 0.0001$). In particular, patients experienced statistically significant improvements in self-image and satisfaction ($p < 0.0001$) (Table 4).

Postoperative Complications

Overall, 7 (26.9%) of the 26 patients experienced minor postoperative complications; 5 patients within 60 days of surgery and 2 patients after 60 days of surgery. Among those with early complications, 1 patient experienced a urinary tract infection on postoperative Day 0, which resolved without antibiotic therapy; 1 patient experienced gastrointestinal ileus on postoperative day 6, which resolved after intravenous hydration and an enema; 2 patients experienced postoperative numbness over the right chest on postoperative Days 0 and 46, which resolved without treatment; and 1 patient experienced a small pleural effusion on postoperative Day 24, which resolved without treatment. Among those with late complications, 1 patient experienced pain caused by prominent hardware on postoperative Day 814, which resolved after an injection of bupivacaine and triamcinolone; and 1 patient experienced 2 episodes of sciatica of the right lower extremity on postoperative Day 2274, which resolved after physical therapy. No patients experienced proximal junctional kyphosis, residual deformity, pseudarthrosis, malpositioned instrumentation, hardware

failure, or infection that required a return to the operating room (Table 5).

Discussion

Several studies have reported the outcomes of patients with thoracolumbar and lumbar AIS treated with pedicle screw constructs;^{8,10,17–19,22,25} however, most of these studies reported only 2 years of follow-up. To the best of our knowledge, ours is the first such study to analyze the clinical and radiographic findings of posterior pedicle screw constructs at 5 years after surgery. Overall, our results suggest that from the first follow-up visit to the 5-year follow-up visit, the coronal, sagittal, and axial plane correction measurements were maintained. Furthermore, at the 5-year follow-up visit, SRS-22 total scores and inclinometer readings were improved over preoperative scores and readings.

The long-term outcomes of older posterior spinal fusion constructs and anterior spinal fusions for the treatment of AIS have been well documented.^{1,3,4,11,14,24} However, long-term data on the pedicle screw construct are limited.^{1,3,4,15,23} In 2005, Suk et al. studied 203 patients with AIS who underwent segmental thoracic pedicle screw fixation; they reported a 69% correction of the main thoracic curve and a 66% correction of the compensatory lumbar curve and good maintenance of the sagittal profile at 5 years after surgery.²³ Di Silvestre et al. compared pedicle screw and posterior hybrid constructs among 52 patients with AIS for a mean of 6.7 years of follow-up and found better maintenance of the main thoracic curve correction with pedicle screws (mean loss of 11.3° with hybrid constructs compared with mean loss of 1.9° with pedicle screws).⁵

In 2004, Shufflebarger et al. reported the outcomes of patients with Lenke 3C, 5, and 6 AIS curves after treatment with a wide posterior release and pedicle screw fixation; they reported 80% coronal plane correction with normalization of the sagittal plane, leveling of the lowest

TABLE 3: Inclinometer readings

Location	Degrees ± SD				p Value*
	Preop	1-Yr Postop	2-Yr Postop	5-Yr Postop	
thoracic	10.5 ± 5.3	7.1 ± 4.8	6.8 ± 3.9	5.7 ± 3.9	<0.0001
lumbar	12.6 ± 5.4	3.3 ± 3.1	3.1 ± 3.4	2.6 ± 3.3	<0.0001

* Preoperative to 5-year postoperative. Boldface indicates statistical significance.

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instrumented vertebra, and improved balance parameters at 2 years after surgery.²² Our study shows similar findings at 5 years; thoracolumbar/lumbar percent correction was maintained at $70.0\% \pm 20.0\%$, and the thoracic Cobb angle was maintained, but the thoracic percent correction decreased significantly from the first postoperative visit to the 5-year follow-up visit. Thoracic kyphosis (T5–12) also decreased significantly from the preoperative visit to the first postoperative follow-up visit. However, from the first follow-up visit to the 5-year follow-up visit, the mean thoracic kyphosis values remained stable with excellent preservation of lumbar lordosis (T-12 to the top of the sacrum). These minor differences between our study and

the Shufflebarger et al. study may be the result of the longer follow-up period (5 years vs 2 years), larger preoperative thoracic coronal Cobb angles (mean $46.4^\circ \pm 19.6^\circ$ vs 27° for Lenke 5 and 43° for Lenke 3C and 6 curves), and larger preoperative lumbar mean coronal Cobb angles ($55.4^\circ \pm 12.1^\circ$ vs 52°) found in our study.

Most importantly, from 2 to 5 years after surgery, no significant radiographic changes, including thoracic and thoracolumbar/lumbar coronal Cobb magnitudes, thoracic kyphosis (T5–12), lumbar lordosis (T-12 to the top of the sacrum), and coronal balance, were found (Fig. 1A–H). The inclinometer readings also did not differ significantly from 2 to 5 years after surgery. This finding is

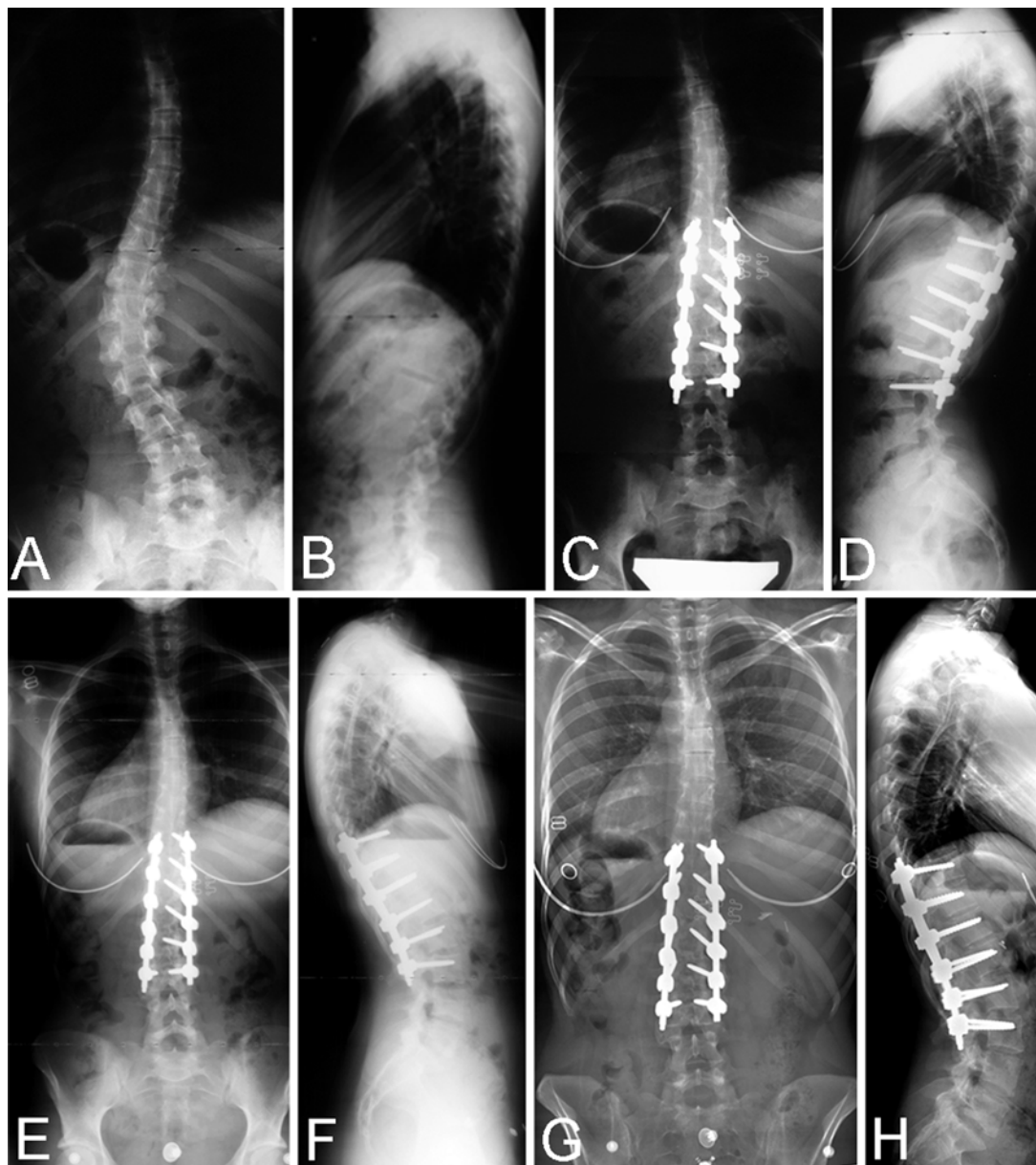


Fig. 1. Preoperative standing posteroanterior (A) and lateral (B) radiographs obtained in a 15-year-old girl with a left 48° main thoracolumbar curve and a 29° compensatory thoracic curve. First erect posteroanterior (C) and lateral (D) radiographs obtained after selective posterior spinal fusion with pedicle screws from T-10 to L-3, showing a 2-cm coronal (C7–central sacral vertical line) imbalance to the left. Two-year follow-up posteroanterior (E) and lateral (F) radiographs showing restoration of coronal balance. Five-year follow-up posteroanterior (G) and lateral (H) radiographs showing maintenance of coronal and sagittal correction.

TABLE 4: SRS-22 scores

Domain	Score ± SD		p Value*
	Preop	5-yr Postop	
pain	4.0 ± 0.7	4.3 ± 0.7	0.069
self-image	3.2 ± 0.6	4.4 ± 0.7	<0.0001
general function	4.5 ± 0.7	4.7 ± 0.5	0.160
mental health	3.9 ± 0.8	4.0 ± 0.9	0.380
satisfaction	3.2 ± 1.1	4.6 ± 0.7	<0.0001
total	3.8 ± 0.5	4.3 ± 0.6	<0.0001

* Boldface indicates statistical significance.

clinically relevant and reassuring, especially when counseling patients about the likelihood that their curve correction will remain stable from 2 to 5 years after surgery.

The study was limited because it had a small sample size (26 patients). Furthermore, the study was a retrospective review of a multicenter database reflecting different surgeons and surgical techniques. However, use of a multicenter database was necessary to obtain the greatest sample size. Although there are some data on 5-year results of thoracolumbar and lumbar AIS treated with posterior pedicle screw constructs, there are no published radiographic or clinical data on 10-year outcomes. For better evaluation of the progression and incidence of long-term clinical outcomes for thoracolumbar and lumbar AIS treated with posterior pedicle screw constructs, longer follow-up is required.

Conclusions

Radiographs obtained in 26 patients with thoracolumbar and lumbar AIS curves treated with posterior pedicle screw constructs revealed that the coronal, sagittal, and axial plane corrections noted at the first postoperative follow-up visit were maintained 5 years later. The SRS-22 total scores and inclinometer readings were better 5 years after surgery than they had been before surgery.

Disclosure

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TABLE 5: Postoperative complications

Complications	No. (%)
total	7 (26.9)
early (<60 days)	5 (19.2)
urinary tract infection	1 (3.8)
neurological	2 (7.7)
gastrointestinal ileus	1 (3.8)
pleural effusion	1 (3.8)
late (≥60 days)	2 (7.7)
prominent hardware	1 (3.8)
neurological	1 (3.8)

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