

MONOAXIAL PEDICLE SCREWS WITH SUBLAMINAR FIXATIONS IN THE CORRECTION OF ADOLESCENT IDIOPATHIC SCOLIOSIS

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ABSTRACT

Objective: To evaluate the radiological outcomes of posterior spinal instrumentation by using monoaxial pedicle screws with sublaminar fixations for the treatment adolescent idiopathic scoliosis (AIS).

Materials and Methods: The data of 14 patients who underwent posterior instrumentation by using monoaxial pedicle screws with sublaminar fixations for the treatment of AIS between 2010 and 2019 were retrospectively analyzed. Patients' age, gender, preoperative Risser classification, preoperative Lenke classification, and operative data were recorded through our medical records. Proximal thoracic (PT), main thoracic (MT), thoracolumbar/lumbar (TL/L) curve Cobb angles as well as thoracic kyphosis (TK) and lumbar lordosis (LL) Cobb angles were measured through preoperative and postoperative standing full spine X-rays.

Results: The mean preoperative PT curve Cobb angle was 33.7 degrees, and it was 4 degrees postoperatively ($p=0.068$). The mean preoperative MT curve Cobb angle was 53.3 degrees and it was 8.7 degrees postoperatively ($p=0.008$). The mean preoperative TL/L curve Cobb angle was 43 degrees and it was 9.2 degrees postoperatively ($p=0.005$). The overall mean coronal plane correction ratio was 84%. The mean preoperative TK Cobb angle was 25.2 ± 17.8 degrees and it was 32.9 ± 8.9 postoperatively ($p=0.101$).

Conclusion: According to the results acquired from this study, monoaxial pedicle screws with sublaminar fixations demonstrated an efficient correction in both PT, MT, and TL/L curves and restoration of TK in AIS surgery.

Keywords: Adolescent idiopathic scoliosis, pedicle screw, monoaxial, sublaminar fixation, correction

INTRODUCTION

Posterior spinal instrumentation is the standard method for the surgical correction of adolescent idiopathic scoliosis (AIS) ⁽¹⁾. From the first introduction of pedicle screws by Roy-Camille in 1979 pedicle screw design evolved over the years ⁽²⁾. Recently, pedicle screw instrumentation has become the most commonly preferred method for the treatment of scoliosis ⁽³⁾. However, there is still debate about the choice of fixation method regarding using either a hybrid system, which consists of laminar wires/tapes, hooks, and pedicle screws, or using only mono/polyaxial pedicle screws ⁽⁴⁾.

Monoaxial pedicle screws were the first introduced pedicle screw and reported as having the advantage of the better correction

of vertebral rotation compared to polyaxial screws ^(3,4). However, it can be difficult to achieve complete seating of the screw into the rod which may result in an inadequate connection between the rod and the screw and it can cause fixation failure ⁽⁵⁾. A recent study also remarked the difficulty of surgical correction among junior surgeons and mentioned that senior surgeons used significantly more monoaxial screws and achieved better correction in the treatment of AIS ⁽⁶⁾. In their study comparing monoaxial and polyaxial pedicle screw in the treatment of AIS, Kuklo et al. ⁽³⁾ also reported greater correction of rotational and thoracic torsion deformities compared to polyaxial screws; however, the authors did not find any significant difference between monoaxial and polyaxial screws in terms of fixation stability and coronal plane deformity correction.



In the literature, many studies exist reporting the outcomes of monoaxial screws in the treatment of thoracolumbar burst fractures. There are also studies comparing the biomechanical properties of monoaxial and polyaxial pedicle screws. Previously, Kuklo et al.⁽³⁾ and Lonner et al.⁽⁴⁾ compared monoaxial and polyaxial thoracic pedicle screws in the treatment of thoracic scoliosis. However, to date, we could not find any study evaluating the outcomes of monoaxial pedicle screw fixation with sublaminar fixation in the correction of AIS. In the current study, we aimed to evaluate the radiological outcomes of posterior spinal instrumentation by using monoaxial pedicle screws with sublaminar fixations for the surgical treatment of AIS.

MATERIALS AND METHODS

We hypothesized that monoaxial pedicle screws with sublaminar fixations resulted in an efficient coronal plane deformity correction and restoration of hypokyphosis compared to the reported studies in the literature.

Study Population

This retrospective study was performed in accordance with the "Declaration of Helsinki". Ethics committee approval was received from İstanbul Atlas University Non-Interventional Scientific Research Ethics Committee (25.06.2021-4758). Informed consent was obtained for each patient. We retrospectively reviewed the prospectively collected clinical and radiological data of 14 consecutive patients who underwent posterior spinal instrumentation for the treatment of AIS between 2010 and 2019. Patients who underwent surgical correction of AIS by using monoaxial pedicle screw and sublaminar tape fixation with a minimum follow-up of 1 year were included in the study. There was no patient with incomplete follow-up and medical records. Fourteen patients (11 females, 3 males) with the mean age of 14.2 ± 2.2 years (ranges, 12 to 18 years) participated in the study. The mean follow-up time was 17 months (ranges, 12 to 36 months).

Operative Technique

All surgeries were performed by the senior author of this study (UA) on a radiolucent table in the prone position. A standard midline approach was used for the posterior spinal instrumentation. Monoaxial pedicle screws were placed either unilaterally or bilaterally according to the fusion levels detected preoperatively. The deformity was corrected by connecting screw and pre-contoured rods gradually by clamps. Depending to the thoracic deformity, 3 or 4 sublaminar fixations were performed in all patients from the convex side of the deformity. A combination of autologous spinous processes autograft and cortico-spongious bone allografts were used for grafting. All patients received prophylactic first-generation cephalosporin 30 minutes prior to the procedure. Postoperative intravenous antibiotics were continued for 24 hours. No postoperative bracing was used in any patients and all patients were mobilized at postoperative 1st day.

Data Evaluation

Patients' age, gender, preoperative Risser classification, preoperative Lenke classification, and instrumentation levels were recorded through our medical records. Patients' preoperative and postoperative full spine posterior-anterior and lateral radiographs were assessed by the senior author (UA) (Figure 1 and 2). Coronal Cobb angles were measured for the proximal thoracic (PT), main thoracic (MT), thoracolumbar/lumbar (TL/L) curves. Sagittal Cobb angles were measured for thoracic kyphosis (TK) and lumbar lordosis (LL). The instrumentation ratio which defined the ratio of screw fixation at the fusion levels was calculated. Bilateral monoaxial screw fixation at all levels was considered as a 100% instrumentation. The correction ratio was also calculated according to the preoperative and postoperative Cobb angles.

Statistical Analysis

Statistical analysis was performed by using SPSS 25.0 (SPSS Inc., IBM, NY, USA). Continuous data were given as means and standard deviations, whereas categorical data were given as frequencies and percentages. Comparison of preoperative



Figure 1. A) Preoperative standing posterior-anterior and lateral radiographs of a Lenke 1B patient (Patient 10) with 45 degrees MT, 40 degrees TL, and 25 degrees TK Cobb angles. B) The patient underwent posterior instrumentation between T4 and T11 levels, an 85% correction rate was achieved in the MT curve and a 63% correction rate was achieved in the TL curve

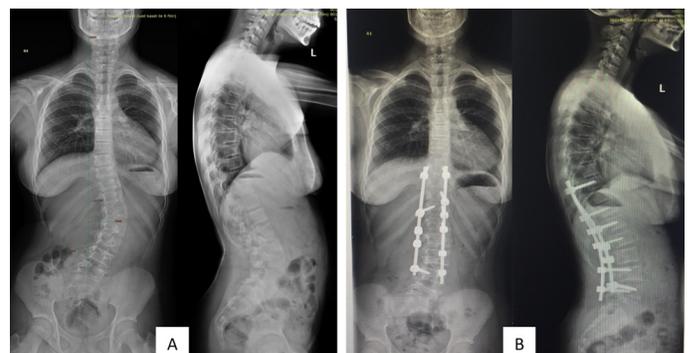


Figure 2. A) Preoperative standing posterior-anterior and lateral radiographs of a Lenke 5C patient (Patient 8) with 43 TL, and 46 degrees TK Cobb angles. B) The patient underwent posterior instrumentation between T9 and L4 levels, a 91% correction rate was achieved in the TL curve

and postoperative mean Cobb angles was performed by the Wilcoxon test. P-values lower than 0.05 were considered as statistically significant.

RESULTS

The preoperative clinical data of the patients were demonstrated in Table 1. The mean preoperative PT curve Cobb angle was 33.7±2.5 degrees, and it was 4±5.3 degrees postoperatively (p=0.068). The mean preoperative MT curve Cobb angle was 53.3±7.5 degrees and it was 8.7±4.4 degrees postoperatively (p=0.008). The mean preoperative TL/L curve Cobb angle was 43±9.8 degrees and it was 9.2±7.7 degrees postoperatively (p=0.005).

The postoperative data were summarized in Table 2. The mean preoperative TK Cobb angle was 25.2±17.8 degrees and it was 32.9±8.9 postoperatively (p=0.101). The mean LL angle was 47.9±13.9 degrees and it was 46.8±10.5 postoperatively (p=0.850).

The overall mean curve correction ratio was 84%±14% and the mean monoaxial screw instrumentation ratio through all fusion levels was 72%±10%. No complication occurred during the follow-up time.

DISCUSSION

The most important finding of this was that we achieved a mean 88% correction ratio in the PT curve, a mean 84% correction ratio in the MT curve, and a mean 79% correction ratio in the TL/L curve. Our correction ratio can easily be accepted as a higher ratio in comparison to the reported studies in the literature about the treatment of AIS by monoaxial screws^(3,4,7).

In their study comparing monoaxial and polyaxial screws in the treatment of Lenke type 1 AIS, Kuklo et al.⁽³⁾ achieved a mean 41% PT correction, 65% MT correction, and 55% TL/L correction with monoaxial screws. Lonner et al.⁽⁴⁾ reported a better MT correction by monoaxial screws (69%) in their study comparing monoaxial, polyaxial, and hybrid constructs. Blondel et al.⁽⁷⁾ mentioned that the decrease in the thoracic Cobb angle was 72% in their monoaxial screw hybrid group.

Our results also demonstrated an increase in thoracic hypokyphosis and restoration of TK. We detected a relative hypokyphosis in our patients preoperatively (25.2 degrees) and it was corrected to normal values postoperatively (32.9 degrees). Kuklo et al.⁽³⁾ reported a mean 28.2 TK preoperatively and it was decreased to the mean 24.5 degrees postoperatively in their monoaxial screw fixation group. In their monoaxial screw group, Lonner et al.⁽⁴⁾ reported a preoperative mean 32 degrees TK and it was decreased to the mean 30 degrees postoperatively. Blondel et al.⁽⁷⁾ achieved a better TK restoration in their hybrid polyaxial screw group compared to their hybrid monoaxial screw group. Acaroglu et al.⁽⁸⁾ also remarked the difficulty of 3D deformity in AIS correction surgery and mentioned that TK is decreased as the lengthening of the spinal column while correcting the coronal plane deformity. The authors reported an overall 0.5-degree increase in thoracic hypokyphosis, in their study evaluating 53 articles about the treatment of AIS by various instruments. In our study, we achieved a mean 7.5 degrees correction in thoracic hypokyphosis. This finding can be explained by the augmentation of monoaxial screw fixation with sublaminar fixation. Acaroglu et al.⁽⁸⁾ also mentioned that increase in TK angle was highest in hybrid constructs. We also achieved a better increase in the TK angle by our monoaxial

Table 1. Preoperative data of the patients

Patient	Age	Gender	Risser grade	Lenke curve type	Preop PT curve	Preop MT curve	Preop TL/L curve	Preop thoracic kyphosis	Preop lumbar lordosis
1	15	Female	4	5 C	*	*	46	23	44
2	16	Female	4	5 C	*	*	42	53	64
3	16	Male	4	2 A	33	56	35	27	38
4	14	Female	4	1 B	36	48	*	32	52
5	17	Female	5	1 C	*	*	43	20	57
6	16	Female	5	5 C	*	*	41	5	24
7	12	Female	3	1 B	*	46	32	11	36
8	12	Female	0	5 C	*	*	43	46	60
9	18	Male	5	2 A	36	49	*	32	48
10	13	Female	4	1 B	*	45	40	25	60
11	12	Female	3	1 A	*	53	*	20	46
12	14	Female	3	6 C	30	70	70	59	76
13	13	Female	4	1 B	*	53	*	6	32
14	18	Male	5	1 B	*	60	38	-6	34

*Cobb angles <25 degree were not taken into consideration

PT: Proximal thoracic, MT: Main thoracic, TL/L: Thoraco lumbar/lumbar, Preop: Preoperative

Table 2. Postoperative data of the patients.

Patient	Fusion levels	Instrument ratio**	Neutral vertebrae	Stable vertebrae	Postop PT curve	Postop MT curve	Postop TL/L curve	Postop thoracic kyphosis	Postop lumbar lordosis	Correction ratio***
1	T8-L4	77%	L5	L4	*	*	24	49	66	48%
2	T10-L4	71%	L5	L5	*	*	2	28	48	95%
3	T2-L1	58%	L1	L1	0	3	0	30	20	95%
4	T2-T11	70%	T11	T10	0	3	*	24	46	94%
5	T11-L3	91%	L5	L4	*	*	11	35	44	75%
6	T6-L4	77%	L4	L4	*	*	6	42	42	85%
7	T2-T11	65%	T10-L5	T11-L4	*	11	12	27	43	76-62%
8	T9-L4	68%	L5	L5	*	*	4	40	56	91%
9	T2-L1	62%	L1	L1	13	15	*	32	44	64-69%
10	T4-T11	68%	T11-L4	T11-L4	*	7	15	26	54	85-63%
11	T4-L2	63%	L3	L3	*	12	*	30	38	77%
12	T2-L4	66%	L5	L5	3	10	0	50	60	90-86%
13	T5-T12	87%	T12	L1	*	4	*	18	49	92%
14	T4-T11	87%	T11-L4	T11-L3	*	14	18	30	45	77-52%

*Cobb angles <25 degree were not taken into consideration
**Bilateral screw placement in all fusion levels considered as 100% instrumentation
***Correction ratio=[(Preop-Postop Cobb angle/Preop Cobb angle)×100]. 100% correction was not taken into consideration
PT: Proximal thoracic, MT: Main thoracic, TL/L: Thoraco-lumbar/lumbar

screw and sublaminar fixation constructs. This issue should be investigated by further studies.

The choice of proper implant is still on debate. Some authors favor the use of hybrid constructs, which consists of hooks and wires, in thoracic curves in addition to pedicle screws; whereas, some authors recommended the use of all pedicle screw constructs⁽⁹⁻¹²⁾. Aubin et al.⁽¹³⁾ evaluated the implant selection of spine surgeons in the treatment of AIS through a spine surgery simulator, and they remarked the large variability between six surgeons in terms of implant selection, implant numbers, fusion levels, and rod rotation maneuvers. The authors concluded that this variability may be dependent on the surgeon's experiences⁽¹³⁾. This difference also exists between senior and junior spine surgeons. Qiao et al.⁽⁶⁾ remarked that senior surgeons used more monoaxial screws and achieved better thoracic correction compared to junior counterparts in the treatment of AIS. With monoaxial screws, it can be difficult to achieve a perpendicular axis between the screw and rod, which may cause a gap between the rod and screw interference during tightening by a nut⁽¹⁴⁾. This situation can be challenging for the surgeons and provoke them to use polyaxial screws due to the freedom of the screw head in all axis. Wang et al.⁽¹⁵⁾ also mentioned that extra forces to ensure proper rod setting is more needed with screws that have less freedom. Many biomechanical studies compared different designs of pedicle screws to evaluate the stability of fixation as well as the efficacy of correction. Liu et al.⁽¹⁴⁾ performed a biomechanical investigation of direct vertebral derotation

comparing monoaxial, uniplanar, and polyaxial pedicle screws. The authors achieved superior direct vertebral derotation by monoaxial screws compared to polyaxial and uniplanar screws⁽¹⁴⁾. In another study, Schroerlucke et al.⁽¹⁶⁾ showed that monoaxial and uniplanar screws resisted higher loads than polyaxial screws. Authors reported that polyaxial screws failed mostly by screw-head slippage while monoaxial and uniplanar screws mostly failed by breakage from screw or rod⁽¹⁶⁾. On the other hand, some authors recommended the use of polyaxial screws at the distal ends of long spinal fusion constructs in order to increase screw-rod interface strength^(17,18).

Low-density versus high-density instrumentation in the correction of AIS is another controversial issue in the literature. Some surgeons prefer to use fewer pedicle screws in order to decrease cost and implant-related complications while other surgeons favor using more pedicle screws to achieve a stronger construct⁽¹⁹⁾. A pedicle density ratio of 100% means that the pedicle screw is used bilaterally in all levels of fusion. In their study that evaluated high versus low pedicle screw density in Lenke 5 AIS, Sariyilmaz et al.⁽¹⁹⁾ mentioned that high pedicle screw density (96.6%) and low pedicle screw density (75.4%) did not significantly differ in terms of curve correction in early postoperative and mean 40 months follow-up. de Kleuver et al.⁽²⁰⁾ reported that <80% pedicle screw density can be recommended in deformities up to 70 degrees according to a survey gathered from experienced spine surgeons. Our mean pedicle screw density was 72% which can be considered as low-density, and we achieved a mean 84% correction despite

low-density. The relationship between low-density pedicle screws and types of screws should also be investigated by further studies.

Study Limitations

The main limitation of this study is its retrospective design. However, we evaluated a prospectively collected patient population. Besides, the retrospective design of the study prevented potential patient selection bias. The other important limitation of our study is its small and heterogeneous patient population. Nevertheless, our cohort is relatively similar to previous studies in the literature comparing the radiographic outcomes of different constructs in the treatment of AIS. The main strength of our study is being the first study in the literature individually evaluating the radiographic outcomes of posterior instrumentation by using only monoaxial pedicle screws in the treatment of AIS performed by the same surgeon.

CONCLUSION

According to the results acquired from this study, monoaxial pedicle screws with sublaminar fixations demonstrated an efficient correction in both PT, MT, and TL/L curves and restoration of TK in AIS surgery.

Ethics

Ethics Committee Approval: Ethics committee approval was received from İstanbul Atlas University Non-Interventional Scientific Research Ethics Committee (25.06.2021-4758).

Informed Consent: Informed consent was obtained from each participant.

Peer-review: Internally peer-reviewed.

Authorship Contributions

Concept: K.T., U.A., Design: K.T., U.A., Data Collection or Processing: G.K.K., Y.O.K., Y.U., Analysis or Interpretation: G.K.K., Y.O.K., Literature Search: Y.Ç., Y.U., Writing: K.T., Y.Ç.

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Conflict of Interest: The authors have no conflicts of interest to declare.

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