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ORIGINAL ARTICLE

Clinical and Radiological Outcome of Surgical Correction of Lenke Type 3 Adolescent Idiopathic Scoliosis Using All-Pedicle Screw Technique

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Abstract

Background: **Adolescent idiopathic scoliosis (AIS) refers to lateral curvature of adolescent spine from body's central line at one or more coronary segments. This condition is frequently associated with spinal rotation, changes in sagittal curvature, rotatory tilt of ribs and pelvis, and paraspinal muscle and ligament malformation.**

Aim and objectives: **To assess clinical and radiological outcomes of employing the all-pedicle screw approach to surgically repair Lenke type 3 AIS.**

Patients and methods: **This prospective research was done on 20 patients of both sexes who presented with Lenke type 3 adolescent scoliosis. This study was carried out at Al-Azhar University Hospitals, Health Insurance Hospitals, Cairo, Egypt.**

Results: **Relation between preoperative, postoperative, and follow-up correction data was assessed. Thoracic curve (degrees) showed a highly statistically significant difference, with *P* value less than or equal to 0.0001. Lateral trunk shift (mm) showed a highly statistically significant difference, with *P* value less than or equal to 0.0001. C7 over the sacrum (mm) showed a highly statistically significant difference, with *P* value less than or equal to 0.0001. Cobb angle 1 showed a highly statistically significant difference, with *P* value less than or equal to 0.0001, and Cobb angle 2 showed a highly statistically significant difference, with *P* value less than or equal to 0.0001.**

Conclusion: **For Lenke type 4 AIS studied cases with curves less than 70° and acceptable flexibility, posterior minimally invasive surgery provides a secure and efficient substitute for the traditional open method.**

Keywords: Adolescent idiopathic, Clinical, Lenke type 3, Pedicle screw, Radiological, Surgical correction

1. Introduction

Adolescent idiopathic scoliosis (AIS) refers to lateral curvature of adolescent spine from body's central line at one or more coronary segments. This situation is frequently associated with spinal rotation, changes in sagittal curvature, rotatory tilt of ribs and pelvis, and paraspinal muscle and ligament malformation.[1]

An increase in the number of implants used in the build has occurred in response to improvements in surgical instruments for the repair of spinal abnormalities. More corrections have been possible thanks to these developments, particularly in difficult instances.[2]

The posterior spinal fusion (PSF) procedure is regarded as hemorrhagic, painful, and contagious as it involves a posterior open midline incision with

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muscle morbidity. Long scars after surgery present teenagers with a difficult-to-ignore esthetic issue and may also be linked to emotional suffering.[3]

In treating individuals with multiple segment scoliosis, minimally invasive surgery (MIS) has been shown to be comparable to PSF, but with less blood and decreased mortality. Adult patients with moderate idiopathic scoliosis, defined as those with a Cobb angle more than 30° but less than 75°, should benefit from MIS in terms of clinical and radiological results.[3]

Because of their better biomechanical qualities, relative ease of insertion, and efficiency in treating complicated abnormalities, pedicle screw instrumentation systems are being employed more often.[4]

Anterior surgery is not necessary to repair scoliotic curves of less than or equal to 100° when pedicle screw instrumentation is used, preventing the accompanying morbidity.[5]

Through a single posterior approach and the placement of pedicle screws at all anatomical levels of spine, intervertebral disc release thoracotomies for significant curves (between 70° and 100°) in the spine have been successfully avoided.[6]

The effect of screw density on the clinical, functional, and radiological outcomes of AIS therapy, however, is debatable. To the authors' knowledge, there has not been a clinical randomized trial comparing the expenses for patients with AIS who had two distinct surgical procedures employing two diverse pedicle screw densities.[7]

This research evaluated the clinical and radiological results of Lenke type 3 AIS surgical repair utilizing an all-pedicle screw method.

2. Patients and methods

This prospective research was conducted on 20 patients who presented with Lenke type 3 adolescent scoliosis; both sexes were included. This study was carried at Al-Azhar University Hospitals, Health Insurance Hospitals, Cairo, Egypt. The study was done after being approved by the ethical committee, and informed written consent was obtained from studied cases involved.

Inclusion criteria were patients diagnosed as having AIS, Lenke type 3 alone, both sexes, and without having had prior surgery.

Exclusion criteria were presence of other types of scoliosis or early onset or adult scoliosis or other causes rather than idiopathic.

All patients were subjected to demographic assessments, including age, sex, level of education, occupation, residence, current general medical and psychiatric history with its type, and family psychiatric history. Preoperative investigations included clinical assessment. The initial evaluation of the patient was done through complete physical examination and examination of the scoliosis. Scoliosis examinations involved overall examination of back in standing position, measurement of shoulder levels from floor to acromioclavicular joints, comparison of levels of anterior superior and posterior superior iliac spines, and measurement of variance in centimeters. Moreover, examination included assessment of the alignment of the head on the spine through anterior chest, which was tested for deformity, pectus ex cavatum, and pectus carinatum. In addition, by watching the studied case from the side, sagittal curve, range of motion, and passive side-bending were assessed. Muscle power was assessed according to MRC scale for assessment of muscle power. Pain assessment was done through visual analog score. Scoliosis Research Society Questionnaire Adapted Arabic Version and body image disturbance questionnaire scoliosis version were also applied.

Investigations: routine laboratory investigations, including radiograph digital images of the whole spine in anteroposterior, lateral, right, and left bending views and MRI in selected cases, were done.

Surgical technique: three top spine surgeons from our facility carried out each operation. A hybrid or pedicle screw construction was employed. Between the primary curve's end-vertebrae were selected to be the levels fused and instrumented. In every instance, local bone grafts were employed instead of autogenous iliac crest bone transplants. No patients received bone morphogenetic protein.

Radiographic assessment after surgery: anteroposterior and lateral standing long-cassette radiographs were evaluated before to, immediately after, and at recent follow-up. All patients had their coronal and sagittal spinal characteristics assessed and documented. To assess the curve's flexibility, preoperative supine side-bending radiographs were taken with studied cases voluntarily bending as much as possible while supine.

According to recommendations from the Spinal Deformity Study Group, the following variables were assessed: main curve's Cobb angles, side-bending Cobb angles, main curve's rate of correction, flexibility, coronal and sagittal vertical axes, the apical vertebral translation and rotation, thoracic kyphosis, and the lumbar lordosis.

Central sacral vertical line and the C-7 plumb line were used as reference points for measuring central vertical alignment (CVA). When C-7 plumb line fell to right of central sacral vertical line, CVA was positive; when it dropped to the left, it was negative.

The sacral vertical alignment (SVA) was calculated as the distance between the upper S1 endplate's rear border and C-7 plumb line. When C-7 plumb line fell anterior to posterior margin of upper S1 endplate, SVA was positive; when it fell posterior, SVA was negative. Both the flexibility rate and the correction rate were calculated.

Both groups had postoperative axial computed tomography (CT) scans of instrumented regions to assess pedicle screw placement.[8] We deemed pedicle screw placement to be adequate in this region when it was placed up to 2-mm medial side and 4-mm lateral side.[9] A single observer conducted measurements using Picture Archiving and Communication System (GE Centricity 3.2, GE Healthcare IT, Barrington, Illinois, USA).

Patients' surgical times, degree of fusion, intraoperative blood loss, blood transfusions, and number of intraoperative C-arm radiation exposures were noted. Based on aspirated blood and the weight of the sponges, intraoperative blood loss was calculated. During the process, mean arterial pressure of around 70 mmHg was maintained. The anesthesiologist decided whether or not to provide transfusions depending on each individual patient's mean arterial pressure and intraoperative blood loss. At the last follow-up, 22-item Scoliosis Research Society questionnaire was used to evaluate health-related quality of life. One researcher who was not engaged in the patients' care independently gathered all of the clinical data.

2.1. Statistical analysis

Mean, median, and SDs were used to analyze continuous variables, whereas the number and percentage of each category were used to evaluate categorical data. The Fisher's exact examination for categorical data was used to compare medication groups at patient level. For continuously varying variables, the Wilcoxon-rank sum examination was used. Generalized estimating equation models were used to compare segment-level data and take into account any possible association between segments from the same patients.

3. Results

Demographic data are shown in Table 1.

Scoliosis examination, thoracic curve correction in frontal plane, and frontal plane balance correction data distribution in all study population is shown in Table 2.

The distribution of screws and radiological assessment data in all study populations are shown in Table 3. The thoracic data in cases of T1–T6 show 3.93 screws, whereas in T7–T10 (at or around scoliotic apex) show 8.43 screws and in T11–T13 show 1.5 screws. In case of lumbar, the data show 3.93 screws. Moreover, radiological assessment data show that the mean misplacement screw was 3, whereas in normal placement was 14.64 and in questionable placement was 0.14 (Table 3).

The previous Table 4 shows the relation between preoperative, postoperative, and follow-up correction data. Thoracic curve (degrees) shows a highly statistically significant difference, with *P* value less than or equal to 0.0001. Lateral trunk shift (mm) shows a highly statistically significant difference, with *P* value less than or equal to 0.0001. C7 over the sacrum (mm) shows a highly statistically significant difference, with *P* value less than or equal to 0.0001. Cobb angle 1 shows a highly statistically significant difference, with *P* value less than or equal to 0.0001,

Table 1. Demographic data.

	All patients $N = 20$
Age	
Mean ± SD	15.14 ± 1.03
Range (minimum–maximum)	14–17
Sex	
Male	1 (5)
Female	19 (95)

Table 2. Scoliosis examination, thoracic curve correction in frontal plane, and frontal plane balance correction data distribution in all study population.

	All patients $N = 20$
Scoliosis examination	
Visible curve in the spine	
Negative	1 (5)
Positive	19 (95)
Asymmetries in the shoulders	
Negative	3 (15)
Positive	17 (85)
Hump or elevation of the rib cage on one side	
Negative	4 (20)
Positive	16 (80)
Thoracic curve correction in frontal plane	
Mean preoperative thoracic curve (deg.)	64.57 ± 5.52
Mean postoperative thoracic curve (deg.)	22.21 ± 2.72
Mean follow-up thoracic curve (deg.)	26.64 ± 7.44
Frontal plane balance correction	
Lateral trunk shift (mm)	
Preoperative	18.43 ± 3.2
Postoperative	13.36 ± 0.84
Follow-up	12.36 ± 1.01
C7 over the sacrum (mm)	
Preoperative	15.93 ± 1.86
Postoperative	12.14 ± 0.66

Table 3. Distribution of screws and radiological assessment data distribution in all study population.

	All patients
	N = 20
Distribution of screws	
Thoracic	
T1–T6	3.93 ± 1.9
T7–T10 (at or around scoliotic apex)	8.43 ± 5.8
T11–T13	1.5 ± 2.41
Lumbar	
Lumbar	3.93 ± 3.15
Radiological assessment	
Misplacement	3 ± 2.08
Normal placement	14.64 ± 5.51
Questionable	0.14 ± 0.36

and Cobb angle 2 shows a highly statistically significant difference, with *P* value less than or equal to 0.000 (Table 4).

3.1. Case presentation

Fig. 1.

3.2. Preoperative

Figs. 2 and 3.

4. Discussion

In a study by Ferguson, obtained improved global balance as regards spinal, shoulder and pelvic balance by about 87%, 73% and 83% respectively which is comparable with other studies as reported by Stephen-Richard et al. Liljenqvist et al. showed that The all-pedicle screw group considerably outperformed hook group in terms of anterior vertebral tethering (AVT) and LIVT correction (AVT sixty four percent vs. fifty four percent and LIVT seventy percent vs. sixty percent).[10]

Godzik, Li et al. reported that after a double fusion of the proximal curvature, 4 (16%) of the 25 patients had only minor imbalances and 21 (84%) had normal shoulder balance. Furthermore, no matter how much the coronal curvature is corrected, shoulder imbalance may still exist even if the surgeon successfully corrects the proximal thoracic curvature, which may greatly affect the result of the procedure.[11]

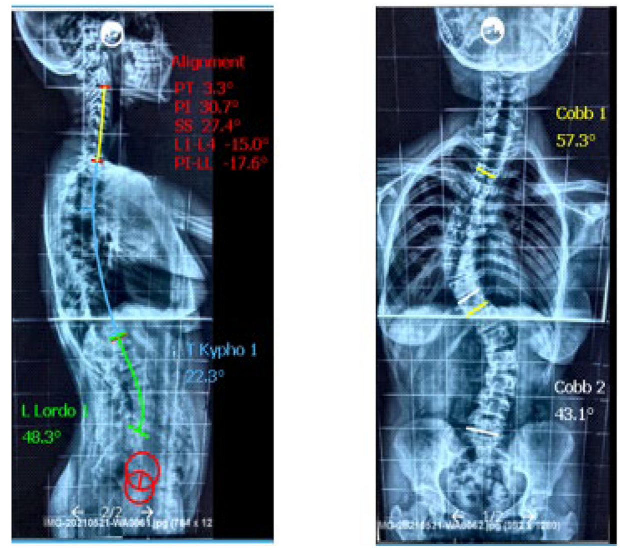

Fig. 1. A 14-year-old female patient presented with AIS deformity with no neurological defects.

Also In this study, The Mean preoperative thoracic curve (degrees) shows 64.57, while in postoperative is 22.21 and in follow up show 26.64.

According to the prevalence of different Lenke types; the present study included six main thoracic curves (type 1) (18.8%), six double thoracic curves (type 2) (18.8%), 10 double major (type 3) (31.3%), six triple major curves (type 4) (18.8%) and four thoracolumbar/thoracic curves (12.5%) (type 6).[12]

On radiographs taken in the sagittal plane after all pedicle screw designs, there has been a decrease in the thoracic kyphosis. Although a few writers link this improvement to the major thoracic curve's stronger angular rectification, this linkage could not be shown in the present dataset.[12]

Tannous et al.[29] reported that by skipping pedicle screw fixation, thoracic curve's correction rate was 69%, with three percent loss of correction at a recent follow-up. However, Yu et al.[13] found a correction rate of 72.7% using the all-screw fixing approach for a major curve.

The Lenke structural thoracic and lumbar curves make up type 3 (double major curve). The increased

Table 4. Relations between demographic data and regarding the dyadic adjustment scale.

	Preoperative	Postoperative	Follow-up	*P* value	Statistically significant
Thoracic curve (deg.)	64.57 ± 5.52	22.21 ± 2.72	26.64 ± 7.44	<0.0001	Significant
Lateral trunk shift (mm)	18.43 ± 3.2	13.36 ± 0.84	12.36 ± 1.01	<0.0001	Significant
C7 over the sacrum (mm)	15.93 ± 1.86	12.14 ± 0.66	–	<0.0001	Significant
Cobb angle 1	62.45 ± 10.36	16.61 ± 5.51	11.31 ± 4.26	<0.0001	Significant
Cobb angle 2	53.66 ± 10.75	11.82 ± 8.15	8.59 ± 4.95	<0.0001	Significant

Statistical test used: one-way analysis of variance.

P value less than or equal to 0.05 was considered statistically significant (95% confidence interval).

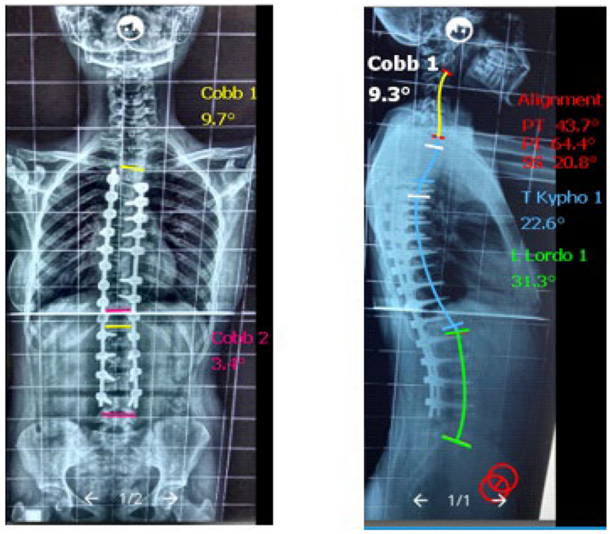

Fig. 2. Immediate post-operative.

occurrence of trunk decompensation in King type 2 curves has been attributed to the difficulties in characterizing them as opposed to double major curves.[14]

To assist surgeons in suggesting the best levels for fusion, Asher and colleagues differentiated among King type 2 (Lenke type 1) and double major curve (Lenke type 3). The thoracic curve adjustment in our data did not reveal any discernible variation among two groups. However, compared with studied cases that had fusion of both curves, those in group II with just fusion of thoracic curve had considerably inferior correction of lumbar curve and a greater incidence of trunk decompensation.[15]

One of major elements of AIS surgery is the repair of axial rotation of damaged vertebrae. No

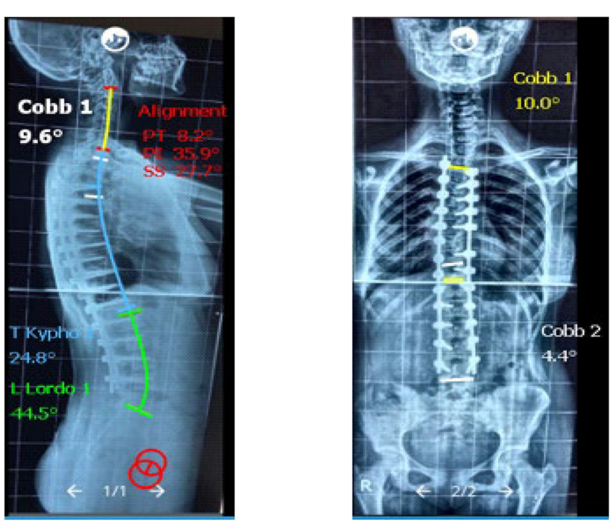

Fig. 3. Follow up post-2Years.

variations in trunk rotation correction among anchor densities above and below 1.3 were observed by Van Popta and colleagues (mean anchor density of ninety one studied cases). However, Ketenci et al.[16] discovered that compared with interval pedicle screw construction, successive pedicle screw construction (anchor density 2.0) significantly improved apical vertebral rotation correction (anchor density 1.14).

In a big series on 619 studied cases with AIS, preoperative T1 tilt raised from −0.10° to 2.42°, clavicle angle from −1.39° to 0.79°, and radiographic shoulder height from −7.04 to 1.63 mm. In 106 studied cases with Lenke type 1A curve, Matsumoto et al.[16] reported clavicle angle and T1 tilt angle as 1.8 ± 2.1° and 3.4 ± 5.5°, respectively, at postoperative follow-up.

Hanee noted that as the distal end of the fusion proceeded from T12 to L4, there was a progressive loss of flexibility that required increased tension in the remaining mobile segments to make up for it. The results of a recent research by Hwang et al.[17] have verified the relationship between higher mobile motion segments and better functional ratings. In a different study, the same researchers found that patients with more mobile motion segments had much better outcome measures of function.

Owing to the fact that all Lenke 1 and 2C curves had LSBC values of less than 25°, all Lenke 1 and 2C curves were exempt from restriction on being treated with STF further, and Lenke 3 and 4C curves with lumbo sacral bending curve (LSBC) values of 35° and less may also be cured with STF.[18]

Selective thiracic fusion (STF) rates climbed to 96, 100, 41, and 36%, respectively, for Lenke 1, 2, 3, and 4C curves. The requirements for STF were subsequently expanded among 2010 and 2012 to include LSBC 45° or less and without T10-L2 20° or more. The rate of STF for Lenke 3 and 4C curves improved to 61 and 50% as a result. Lenke 3 and 4C curves with LSBC less than 35° to LSBC 45° or less might thus be cured extra with STF.[19]

When pedicle density ratio is 100%, all degrees of fusion include bilateral usage of the pedicle screw. It has become quite common to treat AIS using thoracic pedicle screws. According to reports, the risk of screw misplacement in thoracic area differs from 5.7 to 50%, whereas the rate of neurovascular problems is between 0 and 1%. In virtually all studies, there have been no difficulties when the pedicle breach was less than 2 mm, and neurological issues were only thought to be possible when the medial wall perforation was more than 4 mm.[20]

Up to 35 ways have been employed to grade screw placement, according to the grading systems. None of them, however, covered all potential screw positioning errors. According to one study, the thoracic spine's pedicular width is not abnormally less than 3, 2.6 mm, making it smaller than pedicle screws frequently used in scoliosis surgery.[21]

Aberrant pedicle architecture in a scoliotic spine is a significant challenge and raises danger of serious neurological and vascular consequences, particularly near apex of curve on concave side. With all-screw corrective procedures, screw misplacement (1.5−13.6%), dural rips (1.9−6%), vascular damage (0.16%), and neurological impairments (0.8%) have been observed.[8]

Navigation reaches like intraoperative O-arm navigation, isocenter C-arm navigation, preoperative CT navigation, and others were developed to improve accuracy of pedicle screw insertion.[9]

Zhang et al.[30] reported that preoperative CT navigation systems demonstrated precision and safety in pedicle screw placement for AIS surgery, as shown by 5.6% perforation rate of pedicle screws during AIS surgery. In the research by Kotani et al.[22] on 45 studied cases that required posterior corrective surgery, the researchers found that using a CT guidance system significantly decreased the perforation rate. According to earlier research, preoperative CT navigation helped the misplacement rate drop to around 4−6%.

For lumbar spine screw insertion, misplacement rates as low as 2.7% have been observed, and when screw implantation was assessed with plain radiography, those were as low as 1.5%.[23]

However, prior research has found that CT may detect misplacement rate that is 10 times greater than that of conventional radiography. Misplacement rates of up to 50% were reported in a research that used a severe grading system that considered even a 1-mm cortical infraction to be misplaced.[24]

The majority of publications in the literature for patients with scoliosis agree with the previous research's rate of screw misplacement, which was reported to be 14% for the whole study period and 11% for the most recent time (2009). However, as our research found, with a noticeable development in screw placement over last year of research (11%), the overall incidence of misplacement often obscures progressive development over time. Results support both our suggested grading system for evaluation of screw misplacement and our earlier findings on the dependability of low-dose spine CT.[25]

There is no difference between utilizing pedicle screws or hooks to treat specific kinds of AIS, according to a number of studies, and the density of the screws has no effect on the final postoperative SRS score.[26]

Regarding the relationship between the Cobb angle data at preoperative, postoperative, and follow-up times, it is known that Cobb's angle deviation of 50° will continue beyond the point of spinal maturity. Loss of 32% of total lung volume and 45% of normal vital capacity will occur for deviations over Cobb's angle among 60° and 100°. Respiratory failure, recurrent lung infections, and shorter life expectancy are all linked to curves more than 110°. Owing to this, a Cobb's angle more than or equal to 50° is often used to indicate that surgery is preferable over bracing for scoliosis.[27]

Lenke type 1C, 2C, and 5C curves may all be fused selectively. The thoracolumbar curvature, as seen on lumbar bending radiographs, should be slightly rotated, modest, and flexible in type 3 scoliosis to have selective thoracic fusion. Cobb angles, AVT, and apical vertebral rotation are taken into consideration for Lenke types 3C and 6C, for which both thoracic and lumbar curves are structural.[28]

Additionally, a worldwide agreement claimed that for mild curves with Cobb angle of 40°−70°, implant density less than 80% was optimal (73 vs. 27%).[28]

4.1. Conclusion

Posterior MIS offers Lenke type 4 AIS studied cases with curves less than 70° and acceptable flexibility as a secure and efficient alternative to the traditional open method. The effectiveness of MIS and PSF in spine orthopedics was not statistically different at the halfway point of the study; however, MIS had benefits of reduced intraoperative blood loss and less discomfort with more fused segments.

Conflict of interest

There are no conflicts of interest.

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