Radiographic and clinical outcomes in adolescent idiopathic scoliosis corrective fusion surgery: a one-year follow-up

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Abstract

Background

Adolescent idiopathic scoliosis (AIS) is a complex three-dimensional deformity of the spine, characterised by a coronal Cobb angle of at least ten degrees. The goal of surgery is not only to prevent progression, but restoration of sagittal and coronal balance, protection of cardiopulmonary function, and improvement of cosmesis. In this study, we reviewed the impact of deformity correction surgery in terms of radiology and patient-reported outcomes.

Method

Data extracted from a prospectively maintained database (2003–2022) was retrospectively analysed for pre- and postoperative patient-reported outcome measures (PROMs), captured using the Scoliosis Research Society-22 (SRS-22) questionnaire, as well as radiological parameters. Forty-four patients with AIS were identified with pre- and postoperative PROMs. The average age at surgery was 15 years, with 84% female. There were 38% with Lenke 1 curves, and three patients had Lenke 6 curves. Posterior approach surgery was used for 73%.

Results

There was a total improvement in SRS-22 scores by 8%, with 75% achieving minimum clinically important difference (MCID). Patients reported significant satisfaction with treatment of 4.8 out of 5, and improvement in self-image with a change of 1.1 ($p < 0.05$). However, no difference in function and pain were recorded ($p > 0.05$). Overall, proximal thoracic (PT) curves improved from 24–11° ($p < 0.05$), main thoracic (MT) curves from 55–19° ($p < 0.05$), and thoracolumbar/lumbar (TL/L) curves from 45–11° ($p < 0.05$). Preoperative flexibility and postoperative correction for PT curves were 40% and 41%, respectively. MT was 32% and 67%, while that for TL/L was 57% and 71%, respectively.

Conclusion

Surgery yields significant main curve correction, which corresponds to high patient-reported satisfaction rate. Although the total SRS-22 score yielded an 8% improvement, subanalysis of self-image showed the most significant improvement of 4.5/5 ($p < 0.05$).

Level of evidence: Level 3

Keywords: adolescent idiopathic scoliosis, quality of life, SRS-22, anterior and posterior fusion, South Africa

Introduction

Adolescent idiopathic scoliosis (AIS) is a complex three-dimensional deformity of the spine characterised by a coronal Cobb angle of at least ten degrees.[1] It is the most common type of scoliosis affecting 2–4% of adolescents, involving children between 10 and 18 years of age.[2] The overall prevalence of AIS is 0.47–5.2%.[1] The female-to-male ratio ranges from 1.5:1 to 3:1, and increases substantially with age. The two major groups of scoliosis are idiopathic and non-idiopathic, and the diagnosis of idiopathic scoliosis is made if non-idiopathic scoliosis has been excluded.[3]

Clinical evaluation and radiology remain the mainstay of diagnosis in scoliosis. The most common method of measuring the magnitude of the curve is utilising the Cobb angle on standing radiographs in the posteroanterior, lateral and side-bending views.[4,5] In the setting of AIS, the goal of surgery is not only to prevent progression but also to restore sagittal and coronal balance, protecting cardiopulmonary function and improving cosmesis.[6]

Recent advances in surgical technique, such as the use of pedicle screw construct, allow for a good correction.[7,8] Potter et al. showed that posterior spinal fusion with thoracic pedicle screws provided a superior instrumented correction of main thoracic (MT) curves and spontaneous correction of thoracolumbar/lumbar (TL/L) curves.[7] Davis et al., in a retrospective study of 31 patients treated for AIS in South Africa, found that strategic screw placement yields adequate correction and curve maintenance.[8]

In addition to postoperative radiological outcomes, which are a surgeon's traditional measure of successful correction, patient satisfaction has become an important measure of successful reconstruction. To assess health-related quality of life, the

Scoliosis Research Society-22 (SRS-22) questionnaire is widely used, and has been translated and validated in many languages.[9] Using the SRS questionnaire, Kashani et al. found that surgery was associated with improved patient self-image, mental state and satisfaction, while pain and function remained unchanged. In their study, the total SRS score improved significantly after surgery.[10] Ali et al. reported, in a five-year follow-up of patients with AIS treated with instrumentation, that there was good improvement and maintenance of the corrected spine curves in two-thirds of the patients, whereas one-third showed variable minor and major surgery-associated complications.[11]

Our study aims to determine the impact of scoliosis corrective surgery, in terms of radiology and patient-reported outcome measures (PROMs), using the SRS-22 in patients with AIS in a South African context.

Methods

Study design and data collection

The senior author's prospectively maintained database (UCT HREC ref: R039/2013) from 2003–2022 was retrospectively analysed in terms of pre- and one-year postoperative PROMs (SRS-22), as well as radiological parameters.

Demographic data such as age, skeletal maturity using the Risser classification, sex, curve morphology according to Lenke's classification, and complications, among others, were reported.

Risser divided the steps of ossification and fusion of the iliac apophysis into six stages (Risser stages 0–5), with the higher numbers describing advancement towards skeletal maturity. Stage 0 describes an X-ray on which no ossification centre is seen in the apophysis, whereas stage 5 represents complete ossification and fusion of the iliac apophysis.[12]

The Lenke classification system provides surgeons with a simple, accurate and reproducible way to communicate about scoliosis. It relies on measurements taken from standard radiographs (X-rays). Each scoliosis curve is then classified by the curve type based on which three regions of the spine – PT, MT and TL/L – is/are structural. Curve types 1–6 are then defined by the structural curves.[13]

Figure 1. Posterior instrumented fusion for Lenke 2 curve, showing 50% screw density

Patients without a complete set of data and who were not followed up for a minimum of one year were excluded from this study.

Forty-four patients with AIS were identified with pre- and postoperative PROMs. The average age at surgery was 15 ± 2.1 years, with 84% being female. Lenke 1 curves were found in 38%, and three patients had Lenke 6 curves. A total of 73% had posterior approach surgery and the rest anterior only. Largely due to cost, we aimed for a 50% screw density for our patients who had the posterior approach surgery, as shown in *Figure 1*.

Outcome measures

Radiology

Cobb angle measurement: This measurement was obtained by drawing a line along the superior endplate of the upper-end vertebra (vertebra maximally tilted above the apex of the scoliotic curve) and inferior endplate of the lower-end vertebra (vertebra maximally tilted below the apex of the scoliotic curve). This was determined for all three curves, namely PT, MT and TL/L.

Curve flexibility: This measurement was obtained by subtracting the angle obtained per curve on the bending view from that obtained from the erect standing view. The result was then divided by the angle obtained from the erect standing view.

This was computed as: (preop-Cobb angle $_{\text{standing}}$ − Cobb angle $_{\text{in bending view}}$) / preop-Cobb angle $_{\text{standing}}$

Curve correction: This measurement was obtained by subtracting the angle obtained per curve on the postop erect standing view from that obtained from the preop erect standing view. The result was then divided by the angle obtained from the preop erect standing view.

This was computed as: (preop-Cobb angle $_{\text{standing}}$ − postop-Cobb angle $_{\text{standing}}$) / preop-Cobb angle $_{\text{standing}}$

Sagittal C7 plumb line measurement (SC7PL): This was measured on a standard lateral view by dropping a plumb line from the centre of the C7 vertebral body vertically downward and assessing the distance of this line in millimetres (mm) from the posterior superior aspect of the S1 vertebral body.

Clinical

Scoliosis Research Society-22 Score (SRS-22): The SRS-22 is a health-related quality of life (HRQL) questionnaire that consists of five domains, with the following number of questions per domain: function/activity (5), pain (5), self-image/appearance (5), mental health (5), and satisfaction with management (2). Each question is scored from 1 (worst) to 5 (best). Each domain has a total sum score ranging from 5 to 25, except for 'satisfaction with management', which ranges from 2 to 10. The maximum total sum score of 110 and an average score (total sum/22) can be obtained from the cumulative data. A percentage improvement can then be calculated from each domain overall. The following threshold values, used as the minimum clinically important difference (MCID), were taken from previous studies: 0.587 for SRS-pain; 0.375 for SRS-function; 0.800 for SRS-image; 0.420 for SRS-mental; and 0.710 for SRS-total.[14-16]

Data and statistical analysis

The extracted data was coded, entered, cleaned and analysed using Microsoft Excel version 16.66.1. Demographic data was summarised using descriptive statistics including frequency and percentage. The t-test was used to compare PROMs (SRS-22) pre- and postoperative values, as well as radiological parameters. Statistical significance was reported at $p < 0.05$.

Ethical approval (UCT HREC REF: 249/2023), as well as institutional approval was obtained prior to data collection.

Results

Demographic and surgical data

There were 37 females and seven males in our patient cohort. The curve characteristics described according to Lenke are summarised in *Table I*. The majority of them were Lenke 1 (17 out of 44), and only 7% were Lenke 6.

Table I: Curve characteristics according to Lenke classification in patients with AIS

Lenke classification	n	%
Lenke 1	17	38
Lenke 2	6	14
Lenke 3	6	14
Lenke 4	4	9
Lenke 5	8	18
Lenke 6	3	7

Most of our patients were classified as Risser 4 (27%), and the distribution is summarised in *Table II*.

Table II: Skeletal maturity according to the Risser classification in patients with AIS

Risser classification	n	%
Risser 0	6	14
Risser 1	2	5
Risser 2	6	14
Risser 3	9	20
Risser 4	12	27
Risser 5	9	20

Thirty-two (73%) patients underwent posterior approach surgery and the rest anterior only. Average surgical time was 160 ± 39.5 minutes (range 96–295) and average blood loss of 739 ± 525.94 millilitres (ml) (range 100–3 000). Patients who had the anterior or the posterior approach had similar operative times. However, the blood loss disparity was significant. The average blood loss for anterior approach surgery was 292 ± 246.64 ml (range 100–1 000), and that for the posterior approach was 906 ± 505.73 ml (range; 250–3 000) ($p < 0.05$). *Table III* summarises the number of patients who underwent either anterior or posterior approach surgery, according to their curve morphology (Lenke classification).

Table III: Anterior versus posterior surgery according to Lenke classification in patients with AIS

Lenke classification	Anterior surgery		Posterior surgery	
	n	%	n	%
Lenke 1	0	0	17	39
Lenke 2	0	0	6	14
Lenke 3	2	5	4	9
Lenke 4	0	0	4	9
Lenke 5	8	17	0	0
Lenke 6	2	5	1	2
Total	**12**	**27**	**32**	**73**

Radiological parameters

The radiological parameters are summarised in *Table IV*. The MT curve was corrected from 55° to 19° after surgery, and this correction was maintained at one year post surgery. Although average curve flexibility was 32%, a statistically significant curve correction of 67% was achieved following surgery ($p < 0.05$). Similar average corrections of 71% and 41% were obtained for the TL/L and PT curves, respectively. An average SC7PL of 23.8 mm improved to 20.8 mm post surgery, but this was not statistically significant ($p > 0.05$).

Clinical outcomes

There was a total improvement in SRS-22 scores by 8%. Patients reported significant satisfaction with treatment 4.8 out of 5, and improvement in self-image with a change of 0.4 ($p < 0.05$). Also, a statistically significant change in mental health was noted at one year post surgery. However, no difference in function and pain were recorded ($p > 0.05$). *Table V* provides an in-depth summary of these findings.

In total, 75% of our patient cohort achieved MCID at one year post surgery; 41% and 2% achieved MCID for self-image and pain, respectively. These are reported in *Table VI*.

Table VII summarises SRS scores according to surgical approach. Of note, patients who had the posterior approach had a poorer self-image, but this improved postoperatively. At one year, the scores were similar to those of patients who had the anterior approach. Patients who had the posterior approach were more satisfied with their treatment compared to those who had the anterior approach.

Table IV: Radiological parameters of patients with AIS

Coronal parameters	Cobb angle measurement (degrees)		Flexibility (%)	Correction (%)	p-value
Curve type	Preop mean ± SD (range)	One-year postop mean ± SD (range)	Mean ± SD (range)	Mean ± SD (range)	
Proximal thoracic	24 ± 15.1 (1–58)	11 ± 8.0 (1–33)	40 ± 35 (0–90)	41 ± 63 (0–94)	**< 0.001**
Main thoracic	55 ± 20.21 (12–96)	19 ± 11.25 (1–57)	32 ± 20 (0–73)	67 ± 13 (31–92)	**< 0.001**
Thoracolumbar/lumbar	45 ± 17.16 (9–88)	11 ± 6.89 (0–31)	57 ± 27 (9–100)	71 ±17 (21–100)	**< 0.001**
Sagittal parameter					
C7 plumb line	23.80 (18.17–70.40) mm	20.84 (16.47–69.00) mm	N/A	N/A	0.504

$p < 0.05$ highlighted

Table V: Patient-reported outcome measure (PROM)-SRS 22

SRS-22	Visit	Mean (range)	Change from baseline (%)	p-value
SRS total	Preop	15.3 (10.4–18.8)	7.8	**< 0.001**
	1 year postop	16.9 (10.6–19.0)		
Function	Preop	3.9 (2.2–4.6)	0.0	0.792
	1 year postop	4.0 (2.6–5.0)		
Pain	Preop	4.1 (1.6–4.6)	0.1	0.155
	1 year postop	4.3 (2.0–5.0)		
Mental health	Preop	3.9 (2.8–5.0)	0.2	**0.032**
	1 year postop	4.1 (2.8–5.0)		
Self-image	Preop	3.3 (1.6–5.0)	1.1	**< 0.001**
	1 year postop	4.5 (3.0–5.0)		
Satisfaction	Preop	N/A	N/A	N/A
	1 year postop	4.8 (3.0–5.0)		

$p < 0.05$ highlighted

Table VI: Patients meeting minimum clinical important difference (MCID) between baseline and one year postop

SRS-22	Reaches MCID n	Does not reach MCID n	% of patients reaching MCID
SRS total (n = 44)	33	11	75
Function (n = 44)	0	44	0
Pain (n = 44)	1	43	2
Mental health (n = 44)	0	44	0
Self-image (n = 44)	18	26	41

Table VII: Comparing anterior versus posterior approach surgery using patient-reported outcome measure (PROM)-SRS 22

SRS-22	Visit	Anterior surgery mean (range)	Posterior surgery mean (range)	p-value
SRS total	Preop	15.6 (10.4–8.8)	15.2 (12.8–18.2)	0.510
	1 year postop	16.9 (10.6–18.6)	16.9 (13.8–19.0)	0.982
Function	Preop	3.9 (2.2–4.4)	4.0 (2.8–4.6)	0.619
	1 year postop	3.9 (2.6–5.0)	4.0 (3.0–5.0)	0.811
Pain	Preop	4.2 (1.6–5.0)	4.1 (2.4–5.0)	0.893
	1 year postop	4.5 (2.0–5.0)	4.3 (2.8–5.0)	0.517
Mental health	Preop	3.9 (2.8–5.0)	3.9 (2.8–5.0)	0.594
	1 year postop	4.0 (3.0–4.6)	4.2 (2.8–5.0)	0.485
Self-image	Preop	3.7 (2.8–4.4)	3.2 (1.6–4.6)	**0.023**
	1 year postop	4.5 (3.0–5.0)	4.4 (3.0–5.0)	0.898
Satisfaction	Preop	N/A	N/A	N/A
	1 year postop	4.5 (3.0–5.0)	4.9 (3.0–5.0)	0.014

$p < 0.05$ highlighted

Complications

We report three cases of surgery-related complications. One was a superficial surgical site infection, and the other was a misplaced L4 screw in the disc, both of which were treated nonoperatively. One patient had a dislodged T2 transverse process hook requiring revision surgery to reposition the hook and rod.

Discussion

PROMs are a useful tool for reporting levels of outcome and analysing patient recovery, but are both underutilised and non-standardised in spine surgery.[17] In the case of AIS, the SRS-22 score is known to be a reliable tool to determine changes in the postoperative period.[16,18] Responses are noted to plateau from the twelfth to the twenty-fourth month, with no statistical difference beyond this time point.[14,15] This informed our decision to interrogate our findings after the one-year postoperative phase. This, we noted, was about the time most of the patients had recovered from their surgeries and had reintegrated into their various social roles. Hence, this was an appropriate time to determine any changes from baseline.

Using the concept of MCID, the clinical change from baseline relevant for each patient was assessed. This represents a fundamental qualitative difference between a statistically significant difference and a clinically relevant difference. Statistically significant difference is a mathematical term that shows the measured

change is unlikely to be due to chance. This may not translate to a clinically relevant change as this refers to an actual change for the patient that he/she can perceive as relevant. MCID would then be the threshold value for the smallest change in a PROM that is considered meaningful to the patient.[19]

Clinical outcomes

In our cohort, we report a significant improvement in total SRS-22 score of 8% from baseline. This corresponds to 75% of them achieving MCID.

On average most of the patients had a poor self-image, averaging 3.3 out of 5 preoperatively. A year after surgery, this had significantly improved to 4.5 out of 5 ($p < 0.05$). However, only 41% achieved MCID, which is less than the 98% reported by Fernandes et al.[20] This may be due to our population being less sensitive about their body image than that of the developed world, or a difference in expression by our culture. Mental health improved from a score of 3.9 to 4.1 out of 5 ($p < 0.05$), which was equally statistically significant. In a study involving 48 patients by Kashani et al. in 2015, patients' self-image, mental health and satisfaction were significantly improved following surgery. However, no patients had significant back pain before surgery nor throughout their follow-up period.[10]

Two per cent of patients achieved an MCID for pain but the mean scores of both pain and function did not yield a significant difference ($p > 0.05$). This is in keeping with available literature. Most of the patients in this population are healthy and start off with a good functional baseline with minimal to no pain, hence the impact of surgery in this regard is minimal.[10,21,22] Danielsson et al. also reported that surgically treated patients with AIS showed no change in activity and function.[22]

In terms of surgical approach, the patients who had the posterior approach had poorer self-image scores (3.2 out of 5) compared to those who had surgery via the anterior approach (3.7 out of 5). This levelled following surgery to scores of 4.4 and 4.5, respectively. Overall, patients who had a posterior approach surgery expressed greater satisfaction compared to the other patients who had the anterior approach surgery. This may be because most of the patients designated to have posterior surgery were mainly Lenke 1 to 4 curves (as in *Table III*), which meant they predominantly had a structural major thoracic curve. The anterior approach group, on the other hand, had Lenke 5 and 6 curves, which are mainly structural TL/L curves. Patients with structural major thoracic curves usually have a razor/rib hump deformity making their pathology more obvious, which may explain why they had poor self-image scores to begin with. Watanabe et al.[23] and Wang et al.[24] confirmed that a greater Cobb angle, or rotation in the thoracic curve, had a negative correlation with self-image.[23,24] They concluded that a thoracic scoliotic deformity with prominence should be substantially reduced by surgical treatment in order to improve satisfaction rates and self-image.[23] Consequently, we believe it may have accounted for their tremendous expression of satisfaction following posterior approach surgery, since their more prominent deformity was now barely noticeable.

Generally, the patients were satisfied with the treatment they received, with an almost perfect score of 4.8 out of 5. This underlines the value of surgery in the treatment of AIS. In a study by Fernandes et al., all the cases presented a higher level of satisfaction postoperatively, when compared to the preoperative period.[20]

Radiological parameters

One year post surgery, we achieved a significant correction of 67%, 71% and 41% for our MT, TL/L and PT curves, respectively ($p < 0.05$). Similarly, Davis et al. and Ali et al. both reported mean corrections of 74% and 65% for their main structural curves following surgery.[8,11] Davis concluded that strategic screw placement in AIS surgery yields adequate correction and curve maintenance at a dramatically reduced cost, especially in a low-income environment.[8]

Our SC7PL improved from 23.8 mm to 20.8 mm ($p > 0.05$), although this was not statistically significant. A review of 76 patients with AIS by La Maida et al. reported similar findings. Their SC7PL improved from 24.5 mm to 23.5 mm postoperatively, and found no statistical significance.[25]

Demographic and surgical parameters

Our female-to-male ratio is approximately 5:1, which is fewer females than the general reported ratio of 7:1 in patients with curves greater than 40 degrees.[3] However, an average age at surgery of 15 years in our cohort is within the limits stated in the literature.[3,7,8,20] Average blood loss in the anterior approach surgery was significantly less than that of the posterior approach. A multicentre study comparing both approaches in patients with a Lenke 5 curve confirmed that patients who had posterior approach surgery were more likely to receive blood transfusion.[26]

Some limitations should be considered when interpreting the results. The sample size is small, and assessing the potential impact surgical complications may have on these outcome measures is challenging. Also, a few radiological parameters were utilised in this work. As a result, some parameters that may have influenced clinical outcomes have not been fully explored. Further work to investigate radiological parameters that correlate with clinical outcomes extending beyond the use of SRS-22 is needed.

Conclusion

Surgery yields significant main curve correction which corresponds to high patient-reported satisfaction rate. Although the total SRS-22 score yielded an 8% improvement, subanalysis of self-image showed the most significant improvement. Patients who had surgery via the posterior approach were more satisfied with the outcomes, although they started off with a lower self-image.

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Ethics statement

The authors declare that this submission is in accordance with the principles laid down by the Responsible Research Publication Position Statements as developed at the 2nd World Conference on Research Integrity in Singapore, 2010.

Prior to commencement of the study, ethical approval was obtained from the University of Cape Town Human Research Ethics Committee (UCT HREC REF: 249/2023); institutional approval was also obtained prior to data collection. All procedures were in accordance with the ethical standards of the responsible committee on human experimentation (institutional and national) and with the Helsinki Declaration of 1975, as revised in 2008. Informed consent was obtained from all patients for being included in the study.

Declaration

The authors declare authorship of this article and that they have followed sound scientific research practice. This research is original and does not transgress plagiarism policies.

Author contributions

BHB: involved in all stages of the project; responsible for the final write-up of the research paper

LN: data collection; assisted with the write-up of the project proposal

RND: senior surgeon and lead researcher whose database was used; provided the topic, reviewed all stages of the project, including data analysis, and critically appraised the work prior to final submission

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