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RADIOGRAPHIC AND CLINICAL OUTCOMES IN ADOLESCENT IDIOPATHIC SCOLIOSIS CORRECTIVE FUSION SURGERY: A ONE YEAR FOLLOW UP.

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LIST OF ABBREVIATIONS

Abbreviation	Definition
AIS	Adolescent Idiopathic Scoliosis
HRQL	Health Related quality of Life Score
MCID	Minimum Clinical Important Difference
MT	Main Thoracic Curve
PROM	Patient Reported Outcome Measure
PT	Proximal Thoracic Curve
SC7PL	Sagittal C7 Plumbline
SD	Standard Deviation
SRS 22	Scoliosis Research Society 22 score
TL/L	Thoraco-Lumbar/Lumbar Curve
TPS	Thoracic Pedicle Screw

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AUTHORS' CONTRIBUTION

RD is the senior surgeon and lead researcher whose database was used. He provided the topic, reviewed all stages of the project including data analysis and critically appraising the work prior to final submission.

LN helped with data collection and assisted with the write up of the project proposal.

BB has been involved in all stages of the project and is responsible for the final write up of the research paper. He submits this in fulfillment of his Master of Medicine in Orthopaedics (MMed (Orth) UCT) degree.

CONFLICT OF INTEREST

The authors have no conflict of interest to declare in the execution of this project.

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ABSTRACT

Introduction
Adolescent idiopathic scoliosis (AIS) is a complex three-dimensional deformity of the spine, characterized by a Cobb angle of at least 10 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 post-operative patient reported outcome measures, 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 post-operative PROMs. The average age at surgery was 15yrs with 84% being female. 38% had a Lenke 1 curve and 3 patients had Lenke 6 curves. 73% had posterior approach surgery.

Results
There was a total improvement in SRS-22 scores by 7.8% with 75% achieving MCID. Patients reported significant satisfaction with treatment 4.8/5 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 24^0 to 11^0 (**$p<0.05$),** Main Thoracic (MT) curve from 55^0 to 19^0 and Thoracolumbar/Lumbar curves (TL/L) from 45^0 to 11^0. Pre-operative flexibility and post-operative correction for PT curve were 40% and 41%, respectively. MT was 32% and 67%. 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 total SRS-22 score yielded a 7.8% improvement, sub-analysis of self-image showed the most significant improvement of 4.5/5 **($p<0.05$)**.

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 characterized by a Cobb angle of at least 10 degrees(1). It is the most common type of scoliosis affecting 2-4% of adolescents, mainly 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 main stay of diagnosis in scoliosis. The most common method of measuring the magnitude of the curve is utilizing the Cobb angle on standing radiographs in the postero-anterior, 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 improve 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.* (2005) showed that posterior spinal fusion (PSF) with thoracic pedicle screws (TPS) provided a superior instrumented correction of main thoracic (MT) curves and spontaneous correction of thoraco-lumbar/lumbar (TL/L) curves(7). Davis *et al.* (2013) 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*. (2015) found that surgery was associated with improved patient's 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.* (2018) 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 outcomes (PROMs), using the SRS-22 in patients with AIS in a South African context.

METHODS AND MATERIALS

Study design and Data collection

The senior author's prospectively maintained database (UCT HREC REF: R039/2013) from 2003 - 2022 was retrospectively analyzed in terms of pre- and one-year post-operative patient reported outcome measures (SRS-22) as well as radiological parameters.
Forty-four patients with AIS were identified with pre- and post-operative PROMS. The average age at surgery was 15±2.1yrs with 84% being female. 38% had a Lenke 1 curve and 3 patients had Lenke 6 curves. 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**.

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

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

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 post-op 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 center of the C7 vertebral body vertically downward and assessing the distance of this line in millimeters (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 and 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(12–14).

Data and statistical analysis:

The extracted data was coded, entered, cleaned and analyzed using Microsoft Excel version 16.66.1. Demographic data was summarized using descriptive statistics including frequency and percentage. T-test was used to compare PROMs (SRS-22) pre- and post-operative 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 7 males in our patient cohort. The curve characteristics described according to Lenke are summarized in **Table 1.** Majority of them were Lenke 1 (17 out of 44) and only 7% were Lenke 6.

Table 1. 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 summarized in **Table 2.**

Table 2. 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 (range;96-295) minutes and average blood loss of 739±525.94 (range;100-3000) milliliters. Patients who had the anterior or the posterior approach had similar operative times. However, the blood loss disparity was significant. Average blood loss for anterior approach surgery was 292± 246.64 (range;100-1000) milliliters and that for the posterior approach was 906±505.73 (range;250-3000) milliliters **($p<0.05$). Table 3.** summarizes the number of patients who either

underwent anterior or posterior approach surgery according to their curve morphology (Lenke Classification).

Table 3. 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 summarized in **Table 4.** The main thoracic curve (MT) was corrected from 55^0 to 19^0 after surgery and this correction was maintained at one year post surgery. Though average curve flexibility was 32%, a statistically significant curve correction of 67% was maintained at one year post surgery **($p<0.05$).** Similar average corrections of 71% and 41% were obtained for the thoraco-lumbar/lumbar (TL/L) and proximal thoracic (PT) curves respectively. An average SC7PL of 23.80 millimeters (mm) improved to 20.84 millimeters (mm) post-surgery but this was not statistically significant **($p>0.05$).**

Table 4. Radiological parameters of patients with AIS

Coronal Parameters	Cobb Angle Measurement(degrees)		Flexibility (%)	Correction (%)	p-value
Curve Type	Pre-op Mean±SD (range)	0ne year post-Op Mean±SD (range)	Mean±SD (range)	Mean±SD (range)	
Proximal Thoracic	$24^0 \pm 15.1$ $(1-58)$	$11^0 \pm 8.0$ (1-33)	40±35 (0-90)	41±63 (0-94)	**< 0.001**
Main Thoracic	$55^0 \pm 20.21$ $(12-96)$	$19^0 \pm 11.25$ (1-57)	32±20 (0-73)	67±13 (31-92)	**< 0.001**
Thoraco-Lumbar/Lumbar	$45^0 \pm 17.16$ $(9-88)$	$11^0 \pm 6.89$ (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

Clinical Outcomes

There was a total improvement in SRS-22 scores by 7.8%. Patients reported significant satisfaction with treatment 4.8 out of 5 and improvement in self-image with a change of 1.1**(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 5.** provides an in-depth summary of these findings.

Table 5. Patient-reported Outcome Measure (PROM)- SRS 22

SRS -22	Visit	Mean (range)	Change from Baseline	P value
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

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 6**.

Table 6. Patients meeting Minimum Clinical Important Difference (MCID) between baseline and 1 year postop

SRS -22	Reaches MCID n	Do not Reach MCID n	% of patients Reaching MCID
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
Total (n=44)	33	11	75

Table 7. summarizes SRS scores according to surgical approach. Of note, patients who had the posterior approach had a poorer self-image, but this improved post operatively. 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 7. 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
Total	Preop	15.6 (10.4-18.8)	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 3 cases of surgery-related complications. One was a superficial surgical site infection and the other was a misplaced L4 screw in the disc which were both treated nonoperatively.
One patient had a dislodged T2 transverse process hook requiring revision surgery to reposition the hook and rod.

DISCUSSION

Patient-reported outcomes measures (PROMs) are a useful tool for reporting levels of outcome and analyzing patient recovery but are both under-utilized and non-standardized in spine surgery(15). In the case of AIS, the SRS-22 score is known to be a reliable tool to determine changes in the postoperative period(14,16). Responses are noted to plateau from the twelfth to twenty-fourth month with no statistical difference beyond this time point(12,13). This informed our decision to interrogate our findings after the 1-year post-operative 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.

Clinical Outcomes
In our cohort, we report a significant improvement in total SRS-22 score of 7.8% 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. 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 Kashan *et al.* in 2015, patient's 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 percent of patients achieved a MCID for pain but the mean scores of both pain and function didn't 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(10,17,18). Danielsson and Nachemson (2003) also reported that surgically treated patients with AIS showed no change in activity and function(18).

In terms of surgical approach, the patients who had the posterior approach had poorer self-image scores (3.2/5) compared to those who had surgery via the anterior approach (3.7/5). This leveled 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 3), 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 prominent rib hump making their deformity more obvious which may explain why they had poor self-image scores to begin with. Watanabe *et al.* (2007) (19) and Wang *et al.* (2014)(20) confirmed that, a greater Cobb angle or rotation in the thoracic curve had a negative correlation with self-image(19,20).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(19). 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.* (2019), all the cases presented a higher level of satisfaction postoperatively, when compared to the pre-operative period(21).

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, Ali *et al.* (2018) and Davis *et al.* (2013) 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 23.8mm to 20.84mm **($p>0.05$)**, although this was not statistically significant. A review of 76 patients with AIS by La Maida *et al.* (2013) reported similar findings. Their SC7PL improved from 24.47mm to 23.46mm post-operatively and found no statistical significance(22).

Demographic and surgical parameters

Our female to male ratio is approximately 5:1 which is lesser 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(3,7,8,21). Average blood loss in the anterior approach surgery was significantly less than that of the posterior approach. A multicenter 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 (23)

Limitations

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 utilized 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 will be needed.

CONCLUSION

Surgery yields significant main curve correction which corresponds to high patient reported satisfaction rate. Although total SRS-22 score yielded 7.8% improvement, sub-analysis of self-image showed the most significant improvement. Patients who had surgery via posterior approach were more satisfied with the outcomes although they started off with a lower self-image.

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