

Minimum 2-Year Analysis of S2-Alar-Iliac Screw Fixation for Adult Spinal Deformity

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Abstract

Study Design: Retrospective cohort.

Objective: Determine the rate and risk factors for S2AI screw-related pain after adult spinal deformity surgery with a minimum 2-year follow-up.

Methods: A consecutive 83 spinal deformity patients undergoing surgical treatment between August 2015 and December 2017 with minimum 2-year follow-up for S2AI screw complication and screw-related pain were included. Linear regression was performed on various risk factors and postoperative S2AI screw-related pain. Subset analysis of 53 patients was performed on preoperative and postoperative SRS and ODI scores, operative data, and radiographic data.

Results: The overall proportion of S2AI screw-related pain was 9.6%. An S2AI screw complication was identified radiographically in 10.8% of patients; among these, 22.2% experienced S2AI screw-related pain. 3.4% of all patients underwent S2AI screw removal. The SRS, ODI, sagittal vertical axis (SVA), and coronal alignment scores/measurements improved following treatment in all patients. However, the mean difference for the pre and postoperative SRS function score (1.2 ± 0.5 vs 0.9 ± 0.8) and SVA (4.0 ± 4.9 cm vs 2.1 ± 4.8 cm) were higher for the pain group.

Conclusions: A minimum 2-year analysis of S2AI screw fixation in adult spinal deformity patients showed that 9.6% of patients experienced S2AI screw-related pain and 3.4% of patients had S2AI screws removed. The size and the number of S2AI screws did not predict postoperative pain, nor were radiographic findings correlated with clinical outcomes. The patient outcome scores, coronal alignment, and SVA improved for all patients, but within the pain group there was an overall larger change in the SVA and SRS function score.

Keywords

adult spine deformity, spine surgery, S2AI screws, pelvic fixation, complications

Introduction

In adult spinal deformity surgery, achieving adequate deformity correction and avoiding postoperative complications is challenging.¹ One common complication is pseudarthrosis at the distal end of the long fusion construct; this often requires subsequent surgeries. Given that these pseudarthroses occur at the lumbosacral junction due to the high lever arm of the proximally fused segments and the ensuing cantilevering effects, pelvic fixation has become a mainstay in adult deformity correction to provide additional distal fixation and stability.²

Currently multiple options exist for pelvic fixation such as iliac screws and bolts to protect the S1 pedicle screws and enhance fusion rates.^{3,4} However, these are technically difficult

to connect with the proximal screw fixation unless a connector is present to connect the more laterally based iliac fixation to the S1 pedicle screws, which is another variable for instrumentation failure. Also, the iliac screws are anatomically prominent since they are inserted slightly deep to the posterior superior

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iliac spine (PSIS).⁵ The reported rates of clinically significant prominent iliac screws have been reported up to 20%.⁴

The S2-alar-iliac (S2AI) screw is a recently developed surgical technique for pelvic fixation that avoids prominent instrumentation by having a deeper and more medial starting point compared to traditional iliac screw fixation.⁶ There has been a large amount of research comparing the efficacy of the traditional iliac screw and S2AI screw.⁷⁻⁹ However, there are few studies with long-term postoperative S2AI outcome data that evaluate potential pain due to S2AI screws. This study aims to prove that S2AI pelvic fixation in adult spinal deformity patients has low rates of postoperative screw pain and reoperation and attempt to identify risk factors for postoperative S2AI screw-related pain.

Methods

Patient Population

This study was approved by the hospital Institutional Review Board (IRB-AAAS0556). A retrospective chart review of adult spinal deformity patients who underwent a long fusion (defined as over 5 levels) with pelvic S2AI screw fixation by a single surgeon (LGL) was performed. We identified 160 patients with pelvic fixation operated on by LGL from August 2015 to December 2017 by using the CPT code 22848. Inclusion criteria were age over 18 years old, pelvic fixation with S2AI screws, and a minimum of 2-year clinical and radiographic follow-up. Patients were excluded if they were under 18 years old, had previous iliac screw fixation, did not have S2AI screws used for pelvic fixation, or for inadequate follow-up. Following application of inclusion/exclusion criteria there were 83 patients in the present analysis.

Data Collection

Demographic data included age, sex, BMI, history of osteoporosis, and history of psychiatric conditions. Primary variables of interest collected from patient operative notes included number of levels fused, screw size, intraoperative complications, number of screws, and intraoperative screw exchange. Standing full-body radiographs were evaluated at 1-year and 2-year follow-up visits. One senior orthopedic resident (ASH) evaluated the radiographs for evidence of screw loosening, breakage, non-union, or other hardware complications. Screw loosening was defined on radiographs as presence of radiolucent areas greater than 1 mm around the screw (otherwise known as a “halo” sign). Clinic notes were reviewed for postoperative pain related to the S2AI screws. SI joint pain was determined from patient reported subjective pain via questioning by the senior author during postoperative clinic visits without SI joint specific exams.

Patient-Reported Outcomes Data

The patient-reported outcome (PRO) questionnaires collected for sub-analysis were the Scoliosis Research Society-22 (SRS) and Oswestry Disability Index (ODI). The specific domains of

Table 1. Patient Demographics.

Variables	No pain (N = 75), Mean ± SD or n (%)	Pain (N = 8), Mean ± SD or n (%)	P-value
Age (years)	56.8 ± 12.3	54.6 ± 4.7	0.34
Female	57 (76.0)	5 (62.5)	0.19
BMI	26.5 ± 7.1	24.2 ± 3.2	0.12

interest from the SRS-22 questionnaire included the function score, pain score, and total score. Only patients that completed the SRS-22 and ODI questionnaires at the preoperative and 2-year postoperative visit were used for sub-analyses. For patients who had complete PRO data, operative data was then obtained; variables of interest included osteotomies performed [posterior column osteotomy (PCO), pedicle subtraction osteotomy (PSO), vertebral column resection (VCR)] and the number of rods used. Radiographs from preoperative and 2-year postoperative visit were then analyzed, and sagittal vertical axis (SVA) and central sacral vertical line (CSVL) were measured.

Statistical Analysis

Demographic and operative variables were compared between patients who did or did not have S2AI screw-related pain at 2-year follow-up. Differences were evaluated using chi-square tests for categorical variables and Wilcoxon rank-sum tests for continuous variables. Linear regression of all variables was performed for association of S2AI pain using SAS software. Both independent and paired t-tests were used in the sub-analysis of patients with complete PRO data for the preoperative and postoperative SRS/ODI scores, operative data, and radiographic data. $P < 0.05$ was considered statistically significant.

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Results

Of the 83 patients that met study inclusion criteria, 8 (9.6%) experienced S2AI screw-related pain. 62 (74.7%) of the included patients were female and 21 (25.3%) were male (Table 1). The average body mass index of included patients was 26.3 (± 6.9) and the average age was 56.6 (± 11.7) years. At baseline, there were no demographic differences between those patients with and without S2AI screw-related pain.

There were 41 (49.4%) primary and 42 (50.6%) revision surgeries (Table 2). The average length of fusion was 13.5 (± 5.0) levels, and the average number of S2AI screws placed was 2.13 (± 0.5). Two S2AI screws were placed in 76 (91.6%) patients, 3 S2AI screws were placed in 2 (2.4%) patients, and 4 S2AI screws were placed in 5 (6.0%) patients, with 8.5 × 90 mm (47 patients, 56.6%) being the most frequently selected size. An OLIF or TLIF was performed in 79 (95.2%) patients, with TLIF (73 patients, 85.9%) being more frequently performed than OLIF (6 patients, 7.2%). L5-S1 (63 patients, 75.9%) was the most frequently selected level. Three (3.8%)

Table 2. Operative Information.

Variables	No pain (N = 75), Mean ± SD or n (%)	Pain (N = 8), Mean ± SD or n (%)	P-value
Prior Spinal Instrumentation	36 (48%)	5 (62.5%)	0.44
Levels Fused (#)	13.3 ± 5.0	15.5 ± 11.8	0.25
Operative Time (min)	500 ± 132	613 ± 115	0.10
EBL (mL)	1557 ± 945	1825 ± 1022	0.47
OLIF/TLIF	71 (94.67%)	8 (100%)	0.56
TLIF	65 (86.67%)	8 (100%)	0.27
OLIF	6 (7.1%)	0 (0%)	0.41
OLIF/TLIF Level			
L1-L2	5 (6.67%)	0 (0%)	0.45
L2-L3	5 (6.67%)	0 (0%)	0.45
L3-L4	12 (16%)	2 (25%)	0.52
L4-L5	19 (25.3%)	3 (37.5%)	0.46
L5-S1	55 (73.3%)	8 (100%)	0.094
Intraoperative Screw Repositioning	3 (4%)	0 (0%)	0.56
Supplemental Iliac Screw Placement	12 (16%)	2 (25%)	0.52
Screw Diameter (mm)	8.53 ± 0.26	8.5 ± 0	0.73
Screw Length (mm)	85.1 ± 6.46	87.5 ± 4.63	0.31
S2AI Screw Size			
7.5 × 60	2 (2.67%)	0 (0%)	0.64
7.5 × 70	2 (2.67%)	0 (0%)	0.64
8.5 × 70	8 (10.67%)	0 (0%)	0.33
8.5 × 80	31 (41.33%)	2 (25%)	0.37
8.5 × 90	41 (54.67%)	6 (75%)	0.27
9.5 × 90	3 (4%)	0 (0%)	0.56
9.5 × 100	1 (1.3%)	0 (0%)	0.74
Total # S2AI Screws			
2	69 (92.0%)	7 (87.5%)	0.57
3	2 (2.67%)	0 (0%)	0.64
4	4 (5.33%)	1 (12.5%)	0.42

patients had S2AI screws repositioned intraoperatively. For 14 (17.5%) patients, one or more iliac screws were placed in addition to S2AI screws. There were no differences in operative variables between those patients with and without S2AI screw-related pain.

Overall, intraoperative complication rate was 27.7%, postoperative complication rate was 19.3%, and reoperation rate was 18.1% (Table 3). Dural tear (22.9%) and loss of intraoperative neuromonitoring (7.2%) were the most common intraoperative complications. There were no patients with postoperative paralysis. There was no difference in the intraoperative complication rate between patients with and without S2AI screw-related pain. Radiographic S2AI screw-related findings (10.8%) were the most common postoperative complication, with S2AI screw loosening identified in 5 (6.0%) patients, S2AI screw breakage identified in 3 (3.6%) patients, and S2AI screw bending identified in 1 (1.2%) patient. Patients who experienced S2AI screw-related pain had a significantly higher rate of S2AI screw bending (12.5%) than those who did not (0%) ($p = 0.002$).

Pseudarthrosis was the most common reason for reoperation (6%). S2AI screw removal was the most common reoperation

Table 3. Complications and Reoperations.

Variables	No pain (N = 75), Mean ± SD or n (%)	Pain (N = 8), Mean ± SD or n (%)	P-value
Intraoperative Complication	20 (26.67%)	3 (37.5%)	0.52
Dural tear	17 (22.67%)	2 (25%)	0.88
Loss of Signals	5 (6.67%)	1 (12.5%)	0.544
Postoperative Complication	15 (20%)	1 (12.5%)	0.61
S2AI Screw-Related	7 (9.3%)	2 (25%)	0.176
Radiographic Findings			
Screw Loosening	5 (6.67%)	0 (0%)	0.45
Screw Fracture	2 (2.67%)	1 (12.5%)	0.16
Screw Bending	0 (0%)	1 (12.5%)	0.002
Wound Complication	4 (5.33%)	1 (12.5%)	0.42
Gastrointestinal	3 (4%)	0 (0%)	0.56
Ileus	2 (2.67%)	0 (0%)	0.64
Vomiting	1 (1.33%)	0 (0%)	0.74
Cardiac	6 (8%)	0 (0%)	0.41
Tachycardic/Hypotensive	2 (2.67%)	0 (0%)	0.64
Edema	1 (1.33%)	0 (0%)	0.74
Cardiac/Respiratory Arrest	1 (1.33%)	0 (0%)	0.74
Pulmonary	4 (5.33%)	0 (0%)	0.42
Respiratory Distress	2 (2.67%)	0 (0%)	0.64
Pleural Effusion	2 (2.67%)	0 (0%)	0.64
Neurological	1 (1.33%)	0 (0%)	0.74
DVT/PE ¹	2 (2.67%)	0 (0%)	0.64
Anemia	2 (2.67%)	0 (0%)	0.64
Reoperation	11 (14.67%)	4 (50%)	0.01
Pseudarthrosis	4 (5.33%)	1 (12.5%)	0.42
PJK ²	2 (2.67%)	0 (0%)	0.64
Implant Failure	2 (2.67%)	1 (12.5%)	0.15
Wound Complication	4 (5.33%)	1 (12.5%)	0.42
Radiculopathy	1 (1.33%)	0 (0%)	0.74
UE/LE Weakness ³	1 (1.33%)	0 (0%)	0.74
Flat Back Syndrome	2 (2.67%)	0 (0%)	0.64
Removal S2AI Screws	0 (0%)	3 (37.5%)	<0.001

¹ DVT = Deep Venous Thrombosis, PE = Pulmonary Embolism.

² PJK = Proximal Junctional Kyphosis.

³ UE = Upper Extremity, LE = Lower Extremity.

in patients with S2AI screw-related pain (25%), while pseudarthrosis and wound complications were the most common reasons for reoperation in patients without S2AI screw-related pain (5.33% each). The reoperation rate was significantly higher in patients who experienced S2AI screw-related pain (50%) than in those who did not (14.67%) ($p = 0.01$). The rate of S2AI screw removal was significantly higher in patients who experienced S2AI screw-related pain (25%) than in those who did not (0%) ($p < 0.001$).

In patients who experienced S2AI screw-related pain, 5 (62.5%) were revision surgeries and 8 (100%) included TLIFs at L5-S1 (Table 4). Radiographic S2AI screw-related findings were identified in 2 (25%) of the 8 patients who developed S2AI screw-related pain (1 had S2AI screw fracture and 1 had S2AI screw bending). Three (37.5%) of the 8 patients underwent subsequent revision surgery, with 2 (25%) patients electing for removal of the S2AI screws. Overall, the rate of S2AI screw removal was 3.4% (3/87 patients).

Table 4. Patients With Painful S2AI Screws.

Patient	Age	Diagnosis	Index surgery	Radiographic findings	Revision surgery
1	50	DJK s/p T8-L3 Fusion for Adult Idiopathic Scoliosis	Revision T3-Pelvis Fusion, TLIF at L4-S1	No	No
2	57	Thoracic Kyphosis Secondary to Compression Fractures at T5-T7, L2	C5-Pelvis Fusion, TLIF at L5-S1, Corpectomy at T6, T7	No	No
3	56	Adult Idiopathic Scoliosis, s/p T10-L5 Fusion	Revision L2-Pelvis Fusion, TLIF at L5-S1	No	Bilateral S2AI Screw Removal at 43 months for Painful S2AI Screws
4	60	DJK s/p T4-L3 Fusion for Adult Idiopathic Scoliosis	Revision T3-Pelvis Fusion, TLIF at L3-S1	No	No
5	54	PJK and Implant Failure with Subsequent Fixed Sagittal Imbalance s/p T4-L4 Fusion for Adult Idiopathic Scoliosis	Revision T2-Pelvis Fusion, TLIF at L4-S1	No	No
6	51	PJK and Lumbar Hypolordosis s/p T6-L4 Fusion for Adult Idiopathic Scoliosis	Revision T3-Pelvis Fusion, TLIF at L4-S1,	No	Bilateral S2AI Screw Removal at 20 months for Painful S2AI Screws
7	48	Adult Degenerative Scoliosis	T4-Pelvis Fusion, TLIF at L5-S1	S2AI Screw Fracture	Revision Fusion from T10-Pelvis at 24 Months for Pseudoarthrosis
8	61	Adult Degenerative Scoliosis	T2-Pelvis Fusion, TLIF at L5-S1	S2AI Screw Bending	No

In the subgroup analysis of 53 patient, the no pain group demonstrated significant improvements in the total SRS (63.1 ± 58.7 vs 88.0 ± 16.0 ; $p < 0.0001$), SRS pain (2.8 ± 0.9 vs 3.9 ± 1.0 ; $p < 0.0001$), SRS function (2.9 ± 0.9 vs 3.9 ± 0.8 ; $p < 0.0001$), and ODI (38.6 ± 18.5 vs 18.7 ± 16.8 ; $p < 0.001$) scores following treatment (Table 5). Similarly, in the pain group, the SRS total (58.7 ± 13.8 vs 80.3 ± 14.6 ; $p = 0.03$), SRS pain (2.4 ± 0.4 vs 3.4 ± 0.9 ; $p = 0.51$), SRS function (2.8 ± 0.6 vs 4.1 ± 0.8 ; $p = 0.0007$), and the ODI (44.6 ± 13.7 vs 26.0 ± 11.0 ; $p = 0.08$) scores improved following treatment. Both SVA (5.3 ± 5.7 vs 3.2 ± 2.5 ; $p < 0.0001$) and CSVL (3.1 ± 2.9 vs 1.6 ± 1.5 ; $p < 0.0001$) decreased following treatment in the no pain group; this was similar in the pain group (SVA: 8.2 ± 5.2 vs 4.2 ± 4.4 $p = 0.12$; CSVL: 2.6 ± 1.7 vs 1.5 ± 1.2 $p = 0.03$). Within the no pain group, 60.9% of the patients had 3-rod fixation; 100% of the pain group had 3-rod fixation. Both groups were similar in regard to operative treatment; 85.7% of the pain group had PCO and 14.3% had VCR while 80% of the no pain group had PCO and 7.5% had VCR ($p = 0.18$).

Discussion

The S2AI screw fixation is a recently described technique that could reduce pelvic screw fixation pain while maintaining a high fusion rate and lower reoperation rate in adult spinal deformity surgery.¹⁰ The more medial and deeper starting point of the S2AI screws allow the screw to be in a direct line with the S1 screw, making the rod placement technically easier.¹¹ The concerns of this technique stems from potential prominent instrumentation and SI joint pain coming from the inherent S2AI screw design that starts from the sacrum and crosses the SI joint into the ilium. Our results show that S2AI screws led to 9.6% of patients experiencing S2AI screw-related pain with no radiographic findings to correlate with this clinical pain.

The S2AI screw related pain after a minimum 2-year follow-up was lower than the previously reported rates of pain due to

Table 5. Patient-Reported Outcomes, Radiographic Measurements, and Operative Variables.

Variables	No pain (N = 46), Mean \pm SD or n (%)	Pain (N = 7), mean \pm SD or n (%)	P-value*
Osteotomy			0.18
PCO	32 (80)	6 (85.7)	
PSO	5 (12.5)	0 (0)	
VCR	3 (7.5)	1 (14.3)	
Total # Rods			-
2	2 (4.4)	0 (0)	
3	28 (60.9)	7 (100)	
4	15 (32.6)	0 (0)	
5	1 (2.2)	0 (0)	
Pre SVA (cm)	5.3 ± 5.7	8.2 ± 5.2	0.21
Post SVA (cm)	3.2 ± 2.5	4.2 ± 4.4	0.34
Mean difference (cm)	2.1 ± 4.8	4.0 ± 4.9	-
p-value [§]	0.005	0.12	-
Pre CSVL (cm)	3.1 ± 2.9	2.6 ± 1.7	0.61
Post CSVL (cm)	1.6 ± 1.5	1.5 ± 1.2	0.85
Mean difference (cm)	1.5 ± 2.3	1.1 ± 1.0	-
p-value [§]	<0.0001	0.033	-
Pre ODI	38.6 ± 18.5	44.6 ± 13.7	0.42
Post ODI	18.7 ± 16.8	26.0 ± 11.0	0.29
Mean difference	19.9 ± 16.9	18.6 ± 23.8	-
p-value [§]	<0.0001	0.084	-
Pre SRS total	63.1 ± 58.7	58.7 ± 13.8	0.48
Post SRS total	88.0 ± 16.0	80.3 ± 14.6	0.24
Mean difference	24.9 ± 15.4	21.6 ± 19.2	-
p-value [§]	<0.0001	0.025	-
Pre SRS pain	2.8 ± 0.9	2.4 ± 0.4	0.32
Post SRS pain	3.9 ± 1.0	3.4 ± 0.9	0.20
Mean Difference	1.4 ± 1.1	1.0 ± 1.1	-
p-value [§]	<0.0001	0.51	-
Pre SRS function	2.9 ± 0.9	2.8 ± 0.6	0.75
Post SRS function	3.9 ± 0.8	4.1 ± 0.8	0.57
Mean difference	0.9 ± 0.8	1.2 ± 0.5	-
p-value [§]	<0.0001	0.0007	-

*=independent t-test; [§]=paired t-test.

iliac screws, which was reported at 20%.¹² The medial and deeper starting point of S2AI screws obviate prominent instrumentation and does not sacrifice screw length and thickness.

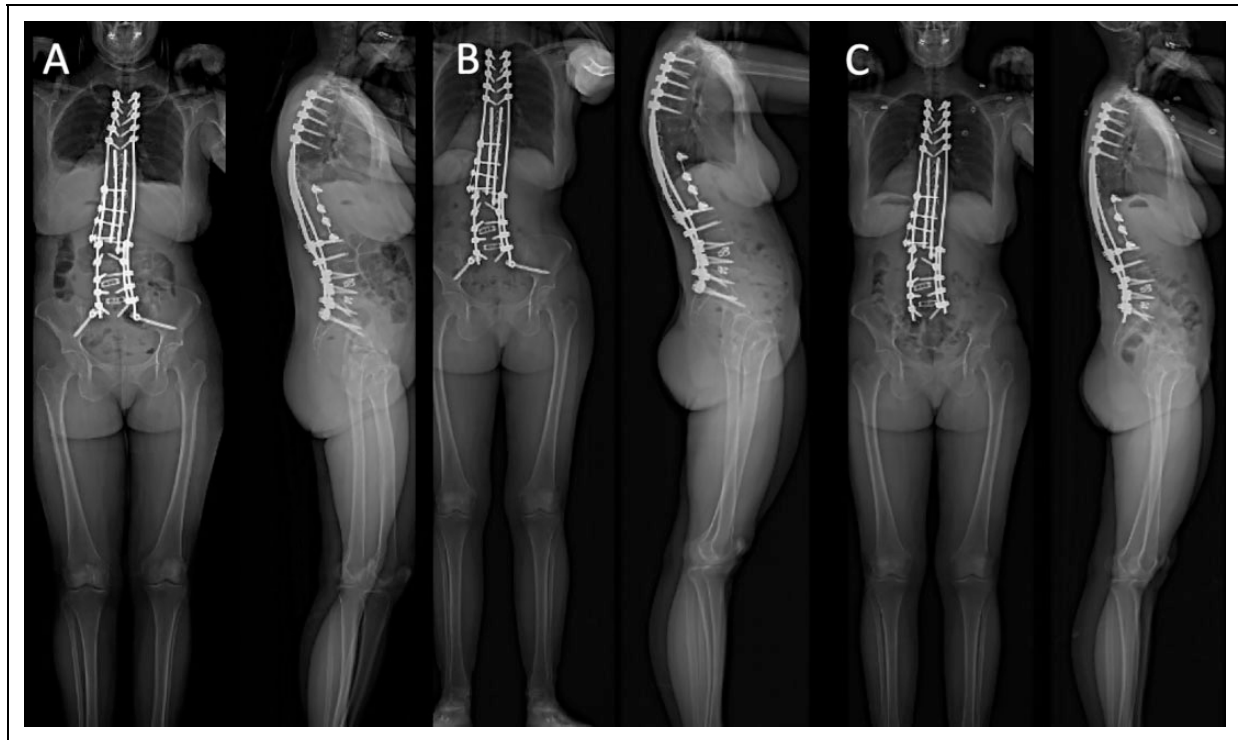


Figure 1. Radiographs of Patient 1. A, AP and lateral radiographs taken 6 days postoperatively from index procedure. B, AP and lateral radiographs taken 20 months postoperatively from index procedure. C, AP and lateral radiographs taken 20 months postoperatively from index procedure and one day postoperatively from S2AI screw removal.

The risk of prominent instrumentation is further mitigated for patients with higher average BMIs in the no pain group compared to the pain group (26.5 ± 7.1 vs 24.2 ± 3.2) (Table 1). Female were more likely to report pain, although this was not statistically significant. The majority of S2AI screws used in the study were 8.5×90 mm, which is sturdier than most pelvic fixation screws reported in literature.^{5,12,13} Interestingly, the size and number of the screws showed no statistically significant correlation with S2AI screw related pain. However, the presence of supplementary iliac screw led to pain in 25% of the patients in the S2AI screw related pain group, which further implies the propensity of the iliac screws to be pain generators.

The presence of L5-S1 anterior column fusion with the use of interbody cages was correlated with developing S2AI screw-related pain in our cohort. All 8 patients in the pain group had L5-S1 interbody fusion, while 73.3% had L5-S1 interbody fusion in the no pain group. L5-S1 interbody fusion and S2AI screw-related pain may be correlated secondary to having rigid fixation at the distal end of the construct in the lumbosacral junction, leading to higher cantilevering forces being transmitted to the SI joints. The cantilevering forces may have contributed to excess motion at the SI joints, promoting SI joint pain, arthritis, and/or instrumentation failure.

Intriguingly, there was no statistically significant difference between the number of levels fused between the no pain (13.3 ± 5.0) and pain (15.5 ± 11.8) groups (Table 2). The pain group had roughly one extra level in the construct, but that should not significantly increase the force on the SI joint.

Similarly, Ha et al have shown that there is no relationship between the number of fused segments and SI joint degeneration for patients who underwent fusion to the sacrum.¹⁴ Although their study did not show any relationship between the number of fused segments and SI joint degeneration, 75% of their patients developed SI joint degeneration, which supports the belief that there is increased stress at SI joint with an increase in the number of fused segments.^{15,16} However, there are minimal reports on the relationship between radiographic findings of degeneration and clinically significant pain.

The reoperation rate between the no pain and pain group differed significantly. Overall, the rate of S2AI screw removal was 3.4% (3/87 patients). The pain group required revision surgery in 50% of cases and 37.5% required S2AI screw removal (Table 3). The 3 cases of S2AI screw removal and revision were done 20, 24 and 43 months postoperatively (Table 4), and pain improved after revision. 14.7% of the no pain group required revision surgery; none required revision for the S2AI screw. There was poor correlation between clinical pain and radiographic S2AI screw complications within the pain group. Of the 8 patients with S2AI screw-related pain, only 2 patients had any radiographic findings (S2AI screw fracture and bent screw). Only 1 of these 2 patients had revision surgery for the fractured screw (Table 4). The total reoperation rate was 18.1% (15/83) in our cohort of patients, which is around the previously reported revision rates of 8.8-23%.^{17,18}

Unexpectedly, radiographic complications and postoperative pain were poorly correlated (Figure 1). 9 total patients had

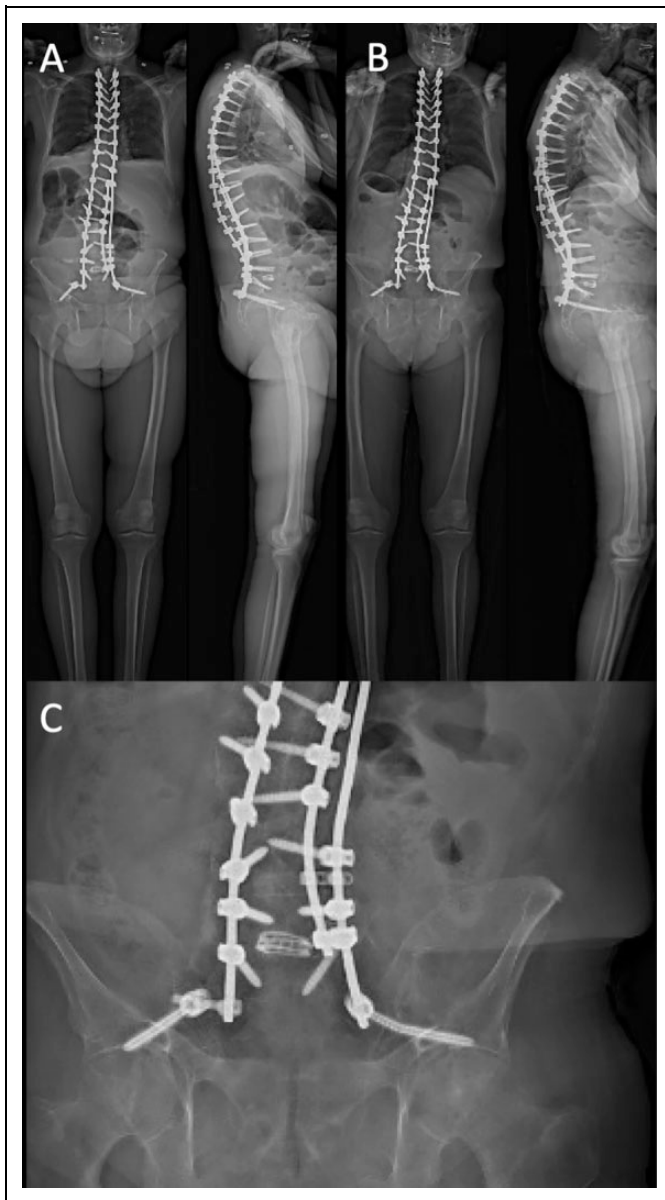


Figure 2. Radiographs of Patient 8. A, AP and lateral radiographs taken 8 days postoperatively from index procedure. B, AP and lateral radiographs taken 26 months postoperatively from index procedure depicting bent screw. C, Zoomed view of AP radiograph taken 26 months postoperatively from index procedure depicting bent screw.

radiographic findings, and only 2 of these patients had pain (22.2%, Table 3). The only radiographic findings associated with pain were screw fracture and bending (Figure 2). Smith et al have shown evidence of mostly asymptomatic S2AI screw lucencies in 10.4% of cases.¹⁸ Similarly, Mazur et al reported 27% of patients with partial periscrew lucency, but none of these patients had S2AI screw-related complications.¹⁹ Thus, the emphasis on proper S2AI screw postoperative evaluation should be based more on clinical examination rather than radiographic findings.

Patient reported outcomes improved postoperatively in both the pain and no pain group with variable statistical significance (Table 5). The pain group showed less of a mean difference in

the ODI, SRS total, and SRS pain scores compared to the no pain group, which implies that S2AI screw related pain negatively impacts these patients despite an otherwise successful deformity correction. The higher mean difference for the SRS function score in the pain group may reflect a higher degree of activity in these patients that led to increased motion at the SI joint. In the pain group, 100% had 3 rods in their construct, which corresponds with the finding by Banno et al who reported a higher incidence of iliac screw loosening in deformity patients with multi-rod constructs.²⁰ They suggested that the multi-rod constructs concentrates mechanical stress on the distal junctional segments; however, there was no significant influence of iliac screw loosening on postoperative spinopelvic parameters or ODI scores in their study. The discrepancy between our results and theirs may be secondary to their shorter duration of follow-up (1 year) and use of different type of pelvic screw fixation.

Both the pre SVA and mean difference in the SVA were higher for the pain group (Table 5). The higher degree of change in sagittal alignment most likely caused a higher concentration of stress in the distal end of the construct at the S2AI screws. The coronal alignment seemed to not influence postoperative S2AI pain within this subset group of patients (1.5 ± 1.2 cm vs 1.6 ± 1.5 cm; $p = 0.85$). However, given the small difference of less than 1 cm for most coronal plane parameters and relatively high standard deviation, these findings may need more power to have a meaningful impact.

There was no specific physical examination performed to evaluate for SI joint specific pain; however, these exams historically have low sensitivity and specificity.²¹ Our method of diagnosis consisted of manual palpation or compression around the SI joints in order to reproduce the patient's pain. Another method for SI joint pain diagnosis could be CT-guided injection for diagnostic and therapeutic purposes. Although, given the low number of patients (8/83) who expressed pain around the SI joint and an even lower number of patients (3/8) that required S2AI screw removal, we did not perform any diagnostic injections. Since the history and physical exam palpation successfully reproduced patient's S2AI screw related pain, we did not use any diagnostic imaging for this select group of patients were specific to S2AI screw related pain.

The limitations in our study comes from the retrospective nature of our patient cohort. There was difficulty assessing SI joint pain in clinical follow-up; this was mostly dependent on the patient's subjective feelings of lumbosacral pain or prominent instrumentation. There was no specific physical examinations performed to evaluate for SI joint specific pain; however, these have low sensitivity and specificity.²¹ The postoperative radiographic analysis of the S2AI screws is also subjective, and subtle haloing around the S2AI screws may have been missed. Finally, we only assessed patients with no prior iliac screw fixation thus reducing the amount of patients eligible for this analysis. Further prospective assessments in a large cohort of patients with or without previous iliac screw fixation for S2AI screw related SI joint pain is warranted.

Conclusion

A minimum 2-year follow-up analysis of S2AI screw fixation in adult spinal deformity patients demonstrated that 9.6% of patients experienced S2AI screw-related pain and 3.4% had S2AI screw removal. Anterior column fusion at L5-S1 had a strong correlation with S2AI screw-related pain. The size and the number of S2AI screws did not predict postoperative pain. There was minimal correlation between radiographic findings with clinical outcomes. The CSVL, SVA, ODI, SRS total, SRS pain, and SRS function scores improved for all patients postoperatively, but the pain group experienced larger changes in the SVA and SRS function score.

Authors' Note

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