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S2 Alar Iliac Fixation in Long Segment Constructs, a Two- to Five-Year Follow-up

Evan J. Smith, MD[a,*], Justin Kyhos, MD[b], Robert Dolitsky, MD[c], Warren Yu, MD[a], Joseph O'Brien, MD[a]

[a]*Department of Orthopedic Surgery, George Washington University, 2300 M St. NW 5th Fl., Washington, DC 20037, USA*
[b]*Department of Orthopedic Surgery, Northwestern University, 633 Clark St, Evanston, IL 60208, USA*
[c]*Department of Orthopedic Surgery, Northwell Health, Great Neck, NY, USA*

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Abstract

Study Design: Retrospective review of patients having undergone S2 alar-iliac (S2AI) fixation for long fusions with a minimum two-year follow-up.
Objectives: To report on fusion rates, complications, technique-specific complications of patients having undergone S2AI fixation.
Summary of background data: Sacropelvic fixation continues to be a challenge when performing long fusions to the pelvis. S2AI screws have been found to provide solid biomechanical fixation and have been found to have good clinical results in short-term follow-up for pediatric and adult patients.
Methods: Cases were retrospectively reviewed in patients who had placement of S2AI screws for long fusions with at least a two-year follow-up. Demographic data, complications, and reoperations were reviewed. Complications were broken into minor and major categories similar to previous series on pelvic fixation.
Results: There were 86 cases identified. Minor and major complications occurred in 29% and 24% of patients, respectively, with the majority of minor complications being intraoperative dural tears. Revision surgery for all causes was performed in 23% of the cohort. Fusion rate at L5–S1 for patients without preoperative pseudarthrosis was 95.3%. Preoperative L5–S1 pseudoarthrosis was identified in 20 patients, 17 (95%) of these went onto fusion after one surgery. There was evidence of S2AI screw lucency in 10.4% of cases. However, the majority of these were asymptomatic.
Conclusions: Sacropelvic fixation using the S2AI technique provides safe, durable fixation with low rates of technique-specific complications and limited need for hardware removal. Complication rates in this series were similar to other series on long fusions to the pelvis. Additionally, fusion rates were high at L5–S1 for both patients with and without preoperative L5–S1 pseudarthrosis. It appears that the S2AI technique is a powerful option for patients with previous L5–S1 pseudarthrosis.
Level of Evidence: Level III.

Keywords: Sacropelvic fixation; Pelvic fixation; Pseudarthrosis; Long fusion; Deformity

Introduction

Sacral fixation for long fusions to the spine provides an extra point of distal stability, but also places significant strain on caudal fixation. Ending thoracolumbar fusions at S1 may be indicated for degenerative stenosis; however, S1 screws alone may lead to high pseudarthrosis rates with or without loss of sagittal balance [1,2]. Retrospective studies have shown pseudarthrosis rates as high as 24% in long fusions (greater than four levels) when sacral fixation is used alone [2,3]. Sacropelvic fixation may be used to enhance stability and avoid complications seen when S1 pedicle screws are used alone as distal fixation. There are several accepted indications for use of supplemental sacropelvic fixation: flat-back deformity, correction of pelvic obliquity, high-grade spondylolisthesis, sacrectomy, sacral

IRB Approval: This study was reviewed and approved by the George Washington University research ethics board.

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*Corresponding author. 2300 M St. NW 5th Fl., Washington, DC 20037, USA. Tel.: (215) 407-0144; fax: (202) 741-3313.

E-mail address: ejs5086@gmail.com (E.J. Smith).

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Fig. 1. A computed tomographic scan of the pelvis on a 70-year-old female patient who underwent previous S2AI pelvic fixation. These screws were placed using a percutaneous technique. Figures show the trajectory of the screw beginning lateral to the S2 foramen (A), traversing the sacroiliac joint (B), and safely entering the ilium (C). Because the entry point is in line, there is no need for offset connectors.

fractures, spinopelvic dissociation, and osteoporosis in the setting of lumbosacral fusion.

Currently, several options exist to improve caudal fixation in long constructs. These include iliosacral screws, iliac screws, S2 pedicle screws, sacral alar screws, and S2AI screws. Because of the weak sacral bone stock, alar, S1, and S2 screws alone or in conjunction have had less promising results, with higher rates of failure and pullout [1-3]. Iliac and iliosacral screws have improved rates of success, with lower rates of pseudarthrosis (5%) and failure; however, these techniques require separate incisions, and use of offset connectors adding to surgical time and morbidity [4-6]. In addition, Tsuchiya et al. found a 34% rate of iliac screw removal at 5 years after iliac screw pelvic fixation in a series of adult spinal deformity (ASD) patients [6]. Fusion to the pelvis continues to be a challenge in spine surgery. Much of this is due to the challenging anatomy, biomechanics, and morbidity related to invasive procedures.

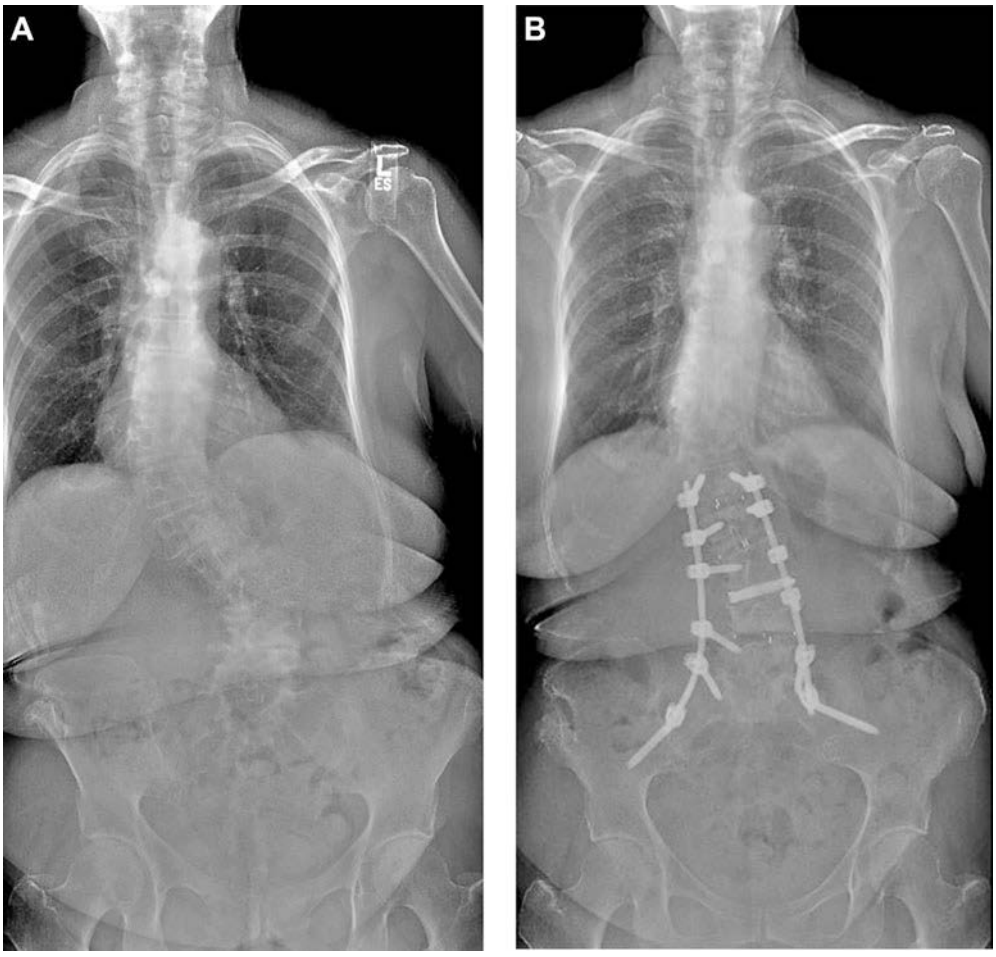

Fig. 2. Images of an 80-year-old woman with a 45° coronal plane deformity underwent surgery for multilevel stenosis (A). She underwent a two-stage procedure beginning with placement of interbody cages from L1 to L5 using the lateral lumbar interbody fusion, transpsoas approach. Two days, later she underwent percutaneous posterior instrumentation from L1 to pelvis using percutaneous S2AI technique. She still has excellent correction at two-year follow-up (B).

Recently, the S2 alar iliac (S2AI) screw has shown promising results for fusion, with low complications rates. S2AI is a low-profile, in-line technique that provides durable distal fixation [7]. Specifically, it is a modified-trajectory S2 alar screw placed across the sacroiliac (SI) joint into the ilium (Fig. 1A−C) [8]. Because the S2AI screw is placed in line with more cephalad instrumentation, there is generally no need for offset connectors. Additionally, the screws can be placed either open or percutaneously (Fig. 2A and B) [9]. The use of S2AI has been present for several years, with groups starting to publish promising results [10-13]. Strike et al. in a prospective review found very low rates of instrumentation complications at 5 years after S2AI screw placement and extremely high fusion rates (98%) from L4 to S1 [13].

Methods IRB approval needs to be added

From 2009 to 2014, all fusions to the sacrum were performed by senior surgeons (WY, JOB) using bilateral S2AI technique as described radiographically by Chang et al. and anatomically evaluated by O'Brien et al. [7,8]. Cases were retrospectively reviewed in patients who had placement of bilateral S2AI screws with at least a two-year follow-up extending over four disc levels: for example, L2−S1 was considered four levels. This was considered a "long segment" construct in accordance with previous descriptions by Kim and Bridwell [3]. Indications for S2AI use was at the discretion of the senior surgeons; all cases were performed open. During this interval, 131 cases were identified with pelvic fixation, and 108 of these cases had bilateral S2AI fixation as the sole method of pelvic fixation. Of these cases, 86 cases reached at least two years of follow-up. Demographic data as well as fusion, complications and reoperations were reviewed. Fusion was identified on plain radiographs using FDA criteria by the senior surgeons and time to fusion as well as presence of pseudarthrosis at the level of L5−S1 and above. Complications were divided into minor and major categories similar to those reported in other series on lumbosacral fixation: minor complications being dural tears, transient neurologic changes, superficial infection, and instrumentation prominence. Major complications included intraoperative vascular complications, neurologic compromise requiring reoperation, deep infections, proximal junctional kyphosis (PJK), adjacent segment degeneration, and instrumentation fracture and loosening requiring reoperation. Instrumentation complications like loosening and fracture were established based on review of postoperative imaging.

Technique

A starting point was identified at the midway point on a line that connects the lateral edge of the S1 and S2 dorsal foramina. A sharp awl was used to mark this entry point. A 2.5-mm pelvic drill or long straight Lenke probe was directed laterally through the sacral ala toward the greater trochanter at an angle of approximately 40° to 50° from the horizontal, and 20° to 30° caudal. The drill path was within 20 mm proximal to the greater sciatic notch aiming toward the AIIS. A 3.2-mm drill is used after crossing the SI joint to avoid breaking the smaller drill in the ilium [8,14].

Results

The mean age at the time of surgery was 63.6 ± 9.2 (range 34−81), 79% of patients were women (68), and 21% were men (18). The average number of levels fused was 8 ± 2.6 (range 4−17) (Table 1). Polyaxial screws were used in all cases, with diameters ranging from 6.5 to 8.5 mm, and average length of 73 mm. There were 29 minor complications in 25 patients (overall rate 34%) (Table 2), with 16 (55%) of these being intraoperative dural tears. The overall rate of dural tears was 18.6%. Eight patients had superficial surgical site infections, which were successfully treated with either oral or intravenous antibiotics. Superficial infections represented 28% of minor complications and were present in 9% of total cases. There was one patient who developed a deep venous thrombosis and one who developed a pulmonary embolism, one patient had a vein tear during revision anterior lumbar interbody fusion, which was repaired at the time of surgery with minor blood loss. Overall, there were 25 major complications (29%) in 21 patients (Table 2). There were three cases of deep infection, which were successfully treated with irrigation and debridement and antibiotics: two with orthopedics for posterior wounds, one with general surgery for an anterior wound. One patient had a chronic wound infection requiring revision and removal of instrumentation. There were 13 patients with radiographic evidence of adjacent segment degeneration, 8 patients had evidence of proximal junctional kyphosis (PJK), and 7 underwent revision surgery. Twenty patients underwent revision surgery for all causes (23.3%) (Table 2). There were no cases of neurologic injury or vascular injury requiring reoperation. Sixty of 86 cases had undergone previous lumbar spine surgery, 70% of cases. Of these cases, there were 27 (45%) minor complications and 21 (35%) major complications.

Specific to sacral fixation, there were no complications related to screw insertion; nine patients (10.4%) had radiographic evidence of screw loosening (Table 2) and one patient (1%) had a broken S2AI screw after a fall. The patient with the broken S2AI screw (7.5 mm × 75 mm) had

Table 1
Patient/instrumentation statistics.

Variable	Value
Patients	86
Average age	63.6 ± 9.2 (range 34−81)
Male/female	18:68
Number of levels fused	8 ± 2.6 (range 4−17)
Average screw diameter	7.8 mm (range 6.5−8.5)
Average screw length	73 mm (range 50−90)

Table 2
Complication events, fusion rates.

Event	n (100 × events/no. of patients)
Minor complications	29 (34%)
Major complications	25 (29%)
S2AI screw loosening on radiograph	9 (10.4%)
Fusion at L5–S1 in patients without preoperative pseudarthrosis	62 (93.9%)
New L5–S1 pseudoarthrosis	4 (6.1%)
New pseudarthrosis above L5–S1	8 (9.3%)
All-cause revision surgery	20 (23.3%)
Removal of S2AI screws	2 (2.3%)
Patients having undergone prior spine surgery	60 (70%)
Minor complications of patients having undergone prior surgery	27 (45%)
Major complications of patients having undergone prior surgery	21 (35%)

S2AI, S2 alar-iliac.

no sequelae or further intervention. Of the nine patients with screw loosening, seven (78%) were identified on plain films and two (22%) were only seen after computed tomographic scans of pelvis were performed for other medical reasons. Neither of these two patients had issues with subsequent fusion, and neither required revision surgery for any reason. Of the remaining seven patients, three were asymptomatic and had no evidence of pseudarthrosis. One patient had persistent low back pain with evidence of lucency around the left SI screw with equivocal, radiographic evidence of fusion. This patient originally underwent a three-column osteotomy and fusion from T8 to the pelvis for sagittal imbalance. She subsequently underwent revision surgery with placement of interbody cages at L4–L5 and L5–S1, exploration of posterior fusion with upsizing of the left-sided S2AI screw, and augmentation with left-sided iliac fixation with later radiographic evidence of fusion. The final three remaining patients all had radiographic evidence of pseudarthrosis at L5–S1; one had evidence of L5–S1 pseudarthrosis preoperatively from a previous procedure. This patient underwent pseudarthrosis takedown and was noted to have a fusion mass on the left side and loose fixation on the right. The right-sided pelvic and pedicle screws were upsized with posterolateral bone grafting, with subsequent fusion noted on follow-up. Of the patients with a new L5–S1 pseudarthrosis, one underwent removal of instrumentation and upsizing of S2AI fixation, which was noted to be loose, and posterolateral fusion with bone morphogenic protein–2. This patient went on to fusion but had continued unilateral SI joint pain and underwent SI joint fusion with improvement in pain. The final patient underwent pseudarthrosis treatment with an anterior approach, an L5–S1 anterior lumbar interbody fusion without revision of posterior instrumentation, and was noted to have radiographic evidence of fusion at 18 months.

The rate of fusion at L5–S1 was 93.9% in patients who did not have a preoperative L5–S1 pseudarthrosis. Four patients had radiographic evidence of pseudarthrosis at L5–S1 (6.1%) (Table 2). All of these patients went on to fusion with revision surgery as described above. Twenty patients had evidence of preoperative L5–S1 pseudarthrosis for which they underwent the indexed procedure (Table 3). None of these patients had previous S2AI fixation. Seventeen of these patients went on to have fusion: 17/20, 85% (Table 3). Of the final three, all underwent pseudoarthrosis takedown with upsizing pedicle screws and S2AI fixation. One of these patients had intraoperative bone morphogenic protein–2 application. All of these went on to have radiographic fusion.

Discussion

Lumbosacral arthrodesis and maintenance of sagittal balance after long fusion to the sacrum remains a challenge in adult spinal deformity surgery. Multiple studies have shown high pseudarthrosis rates when S1 pedicle screws are used without complete lumbosacral fixation [3,15-17]. Complete fixation for long fusions to the sacrum includes iliac fixation as well as interbody support—whether anterior lumbar interbody fusion or transforaminal lumbar interbody fusion [4]. There are multiple options for sacropelvic fixation with a range of results.

S2AI fixation has been used clinically at multiple scoliosis centers with success. Results from previous series have been encouraging, reporting few technique-specific complications and fusion rates of 98% from L4 to S1; additionally, they reported major and minor complication rates of 31% and 28%, respectively [13]. Sponseller et al. reported very low complication rates in a series on the S2AI technique in the pediatric population [10]. Among the reasons for a lower complication rate in pediatric surgery for neuromuscular scoliosis is the increased soft tissue coverage with S2AI screws. Sponseller et al., after CT imaging of S2AI screws, reported an average insertion point 15 mm deeper to the skin than that for PSIS insertions. The S2AI method has been described in open and minimally invasive scenarios [8,9].

In this study, complications for long fusions appear to be similar to those reported by other large series. There were 29 (34%) minor complications in 25 (29%) patients, and

Table 3
Patients treated with S2AI fixation for preoperative L5–S1 pseudoarthrosis.

No. of cases	Average age	Male/female	Levels average/range	BMP use	Previous L5–S1 interbody	New L5–S1 interbody	Arthrodesis
20	63.75	4:16	5.9/4–10	14 (70%)	13 (65%)	4 (20%)	17 (85%)

BMP, bone morphogenic protein; S2AI, S2 alar-iliac.

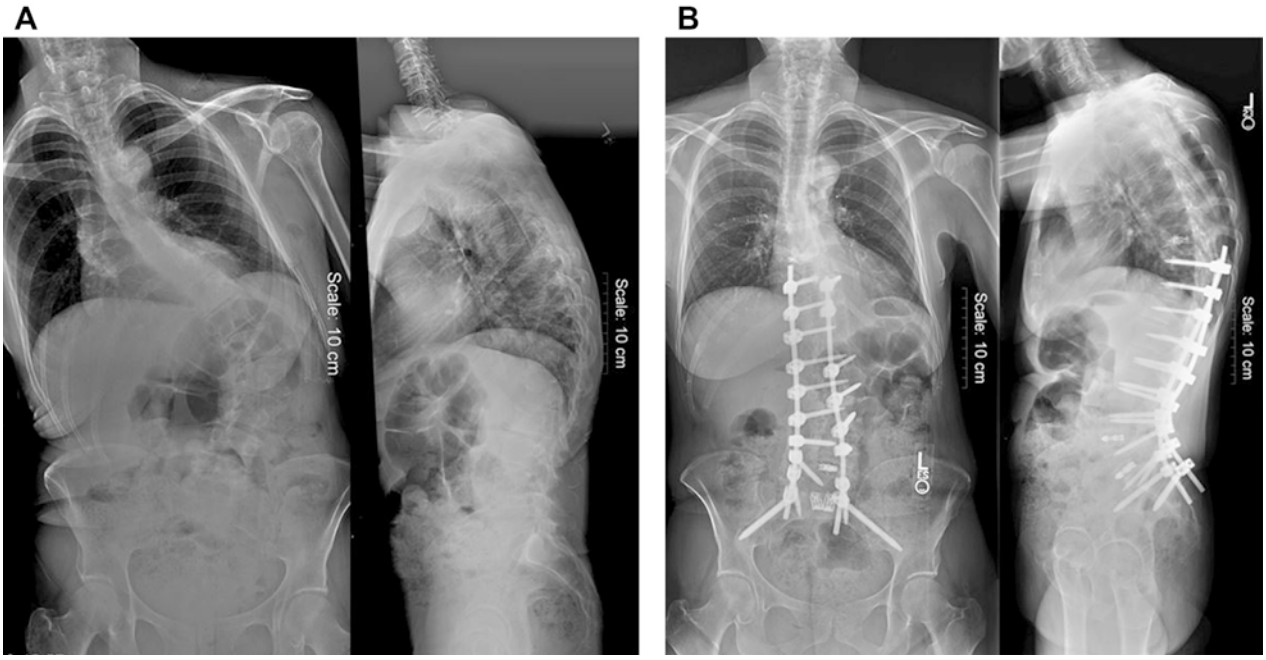

Fig. 3. Images of a 56-year-old woman who underwent deformity surgery for sagittal and coronal imbalance. The latter was measured to 70 degrees (A). She underwent an L3−S1 decompression, placement of interbody cages at L4−L5 and L5−S1 in addition to kyphoplasty at T10 and T11, Smith-Peterson osteotomies from L1 to L5, and placement of instrumentation from T10 to the pelvis using S2AI technique and posterolateral arthrodesis. She had an uncomplicated course, and her balance is well maintained at two-year follow-up (B).

25 (29%) major complications in 21 (24%) patients (Table 2). Cho et al. in their series on patients with multilevel revision deformity surgery reported a 50% overall complication rate, with 34% major complications [18]. They similarly found a late complication rate of around 19%, which included pseudarthrosis and adjacent segment disease. O'Neill et al. in their series on patients requiring extension of long fusion to the sacrum found a major complication rate of 30% [16]. Revision cases have higher reported complication rates ranging from 19% to 58% [18-20]. Of note, 70% of the patients included in this study had previous instrumentation, and an increased minor complication rate of 45% was noted (Table 2). The relatively high rate of dural tears reported here is felt to be a consequence of the quantity of revision procedures. Nevertheless, complications rates in this study are similar to previously reported series and suggest that fusions with pelvic fixation using S2AI technique does not incur additional risks.

Complications specific to S2AI fixation were few in this study. In their series on S2AI in adult deformity surgery, Strike et al. reported S2AI screw fractures in 6.5% of patients and evidence of loosening in 18% of patients [13]. In the pediatric population, Ilyas et al. reported no patients with evidence of S2AI screw loosening [21]. In this study, there were 9 patients (10.4%) who had evidence of S2 loosening on imaging. Two of these patients required hardware removal and revision for L5−S1 pseudarthrosis. One patient had exchange of S2AI instrumentation after pseudarthrosis.

The S2AI technique has decreased screw prominence compared to other procedures, and patients do not experience the same degree of symptomatic instrumentation as compared to iliac fixation. This is probably because the starting point of the screw is roughly 15 mm deeper than the entry point for the PSIS [10]. Additionally, a single rod can be used without the need for bulky connectors. In this study, one patient had complaints of screw prominence, but opted to forego removal. No patients had buttock pain of screw prominence requiring removal of sacral screws. Of note, one patient had continued SI pain requiring removal of S2AI screws and SI joint fusion 18 months after the initial surgery. This patient had previous lumbosacral fusion with L5−S1 pseudarthrosis that fused after S2AI fixation. In contrast, with iliac screws, authors have reported significant buttock pain and removal of instrumentation ranging from 22% to 78% [5,6]. Iliosacral screws require less dissection but have had inconsistent outcomes, with some studies reporting failure rate as high as 28% [22,23]. Similarly, tricortical S1 screws were an attempt to improve fixation but still have had mixed results, with failure rates in long fusions as high as 44% [1,2,22].

Pseudarthrosis continues to be a significant issue after long fusions. Overall reported pseudarthrosis rates have ranged from 8% to 42% in adults with spinal deformity surgery [3,15,16,24]. Evidence seems to suggest that the lumbosacral junction is most at risk. Many strategies have evolved to improve lumbosacral stability; these include

sacro-iliac screws, sacral alar screws, S2 pedicle screws, and foraminal hooks. However, the L5−S1 disc continues to be the level at the highest risk for pseudarthrosis [15,16]. In this study, new L5−S1 pseudarthrosis was identified in 4 patients (6.1%), which is relatively low. A significant portion of the study population was being treated for previous L5−S1 pseudarthrosis (20 patients, 23%). Of these, 17 (85%) went on to have radiographic fusion, and two more went onto have fusion after a revision procedure. These data suggest that S2AI fixation provides a stable construct to resist lumbosacral nonunion comparable, if not improved, as compared to previously reported pseudarthrosis rates [16]. Additionally, S2AI may be a promising strategy to treat previous nonunion at L5−S1.

S2AI fixation does not appear to increase rates of more proximal pseudarthrosis. In this study, there was a total pseudarthrosis rate above L5−S1 of 9.3%. It has been postulated that rigid fusion to the sacrum may increase pseudarthrosis proximally [25]. Edwards et al. in their series found higher pseudarthrosis rates cephalad to L5−S1 when comparing fusion stopping at L5 to those continuing to the sacrum [15]. O'Neill et al. in their series observed similar pseudarthrosis rates at L5−S1 and segments cephalad [16]. They reported a very low pseudarthrosis rate of 8% using iliac or S2AI screws while also using interbody cages and bone morphogenic protein−2in a large majority of patients. Additionally, screws at the proximal end were frequently cemented. Figure 3A and B demonstrate a lower thoracic stopping point with cement augmentation.

There were several limitations to this study. The group of patients was highly heterogeneous, and indications for surgery ranged from failed previous fusion and nonunion revision to primary deformity surgery. A significant proportion of patients had previous pseudarthrosis. Second, the data were retrospectively reviewed and there was likely an underreporting of subjective outcomes particularly related to pelvic pain. Clinical outcome scores were not gathered (eg, Oswestry Disability Index, visual analog scale, Scoliosis Research Society scores). Subjective outcome measures for S2AI would have been useful and therefore could not be compared to other methods of pelvic fixation. There were no data on deformity and spinopelvic harmony measures. While this information would be enlightening, a large percentage of these patients underwent concurrent corrective procedure to improve sagittal alignment, and these values would likely reflect more on deformity correction than S2AI screws. Lastly, follow-up was limited to 2−5 years, and further complications may be appreciated as the cohort is followed.

Conclusions

S2AI fixation appears to provide safe, durable fixation with low rates of technique-specific complications. Additionally, S2AI provides stable fixation during revision surgery for previous pseudarthrosis with a high rate of arthrodesis. Major and minor complication rates are similar to other large series on long fusions to the sacrum. Finally, there were very few reported complications specific to S2AI screws and when comparing to other methods of pelvic fixation, there was an extremely low rate of instrumentation complications and removal. S2AI fixation provides durable fixation comparable to other powerful techniques for sacropelvic fixation without the instrumentation prominence and reoperation rates.

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