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DEFORMITY

Rates of Loosening, Failure, and Revision of Iliac Fixation in Adult Deformity Surgery

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Study Design. Retrospective cohort review of a prospective multicenter database.

Objective. Identify rates and variations in lumbopelvic fixation failure after adult spinal deformity (ASD) correction.

Summary of Background Data. Traditional iliac (IS) and S2-alar-iliac (S2AI) pelvic fixation methods have unique technical characteristics for their application, and result in varied biomechanical and anatomic impact. These differences may lead to variance in lumbopelvic fixation failure types/rates.

Methods. ASD patients undergoing correction with more than five level fusion and pelvic fixation, separated by pelvic fixation type (IS vs. S2AI). Fixation fracture or loosening assessed radiographically (Figure 1). Multivariate logistic regression, accounting for significant confounders, was used to examine differences between the two groups for screw loosening/fracture, rod fracture, and revision surgery. Level of significance set at $P < 0.05$.

Results. Four hundred eighteen of 1422 patients were included (IS = 287, S2AI = 131). The groups had similar age, body mass index (BMI), baseline comorbidities, number of levels fused

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($P > 0.05$), baseline health related quality of life measures (HRQLs) (short form survey-36, Oswestry Disability Index [ODI], Scoliosis Research Society [SRS-22], numeric rating scale [NRS] leg and back, $P > 0.05$) and deformity (pelvic tilt [PT], pelvic incidence-lumbar lordosis [PI-LL], and sagittal vertical axis [SVA], $P > 0.05$). The IS group had more unilateral fixation *versus* S2AI (12.9% vs. 6%; $P = 0.02$). The overall lumbopelvic fixation failure rate was 23.74%. Pelvic fixation (13.4%) and S1 screw (2.9%) loosening was more likely with S2AI (odds ratio [OR] 2.63, $P = 0.001$; OR 6.05, $P = 0.022$). Pelvic screw (2.3%) and rod fracture (14.1%) rates similar between groups but trended toward less occurrence with S2AI (OR 0.47, $P = 0.06$). Revision surgery occurred in 22.7%, and in 8.5% for iliac fixation specifically, but with no differences between fixation types ($P = 0.55$ and $P = 0.365$). Pelvic fixation failure conferred worse HRQL scores (physical component score [PCS] 36.23 vs. 39.37, $P = 0.04$; ODI 33.81 vs. 27.93, $P = 0.036$), and less 2 years improvement (PCS 7.69 vs. 10.46, $P = 0.028$; SRS 0.83 vs. 1.03, $P = 0.019$; ODI 12.91 vs. 19.77, $P = 0.0016$).

Conclusion. Lumbopelvic fixation failure rates were high following ASD correction, and associated with lesser clinical improvements. S2AI screws were more likely to demonstrate loosening, but less commonly associated with rod fractures at the lumbopelvic region.

Key words: adult deformity, fixation loosening, fracture fixation, iliac fixation, iliac screws, pelvic fixation, S2 alar iliac screws, sacroiliac joint

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The surgical management of spinal deformity involving the lumbosacral junction has evolved toward substantial reliance on pelvic fixation in order to provide for a more secure foundation for the construct, and thus result in greater fusion success as well as a reduction in lumbosacral fixation failure.[1–3] This has been particularly true in the adult deformity population, wherein there is more frequent reconstruction to the sacrum, poorer bone integrity, and higher likelihood of sagittal plane correction. Following the advent of pedicle screw fixation to the spine, iliac bolts were devised and utilized for the purpose of construct attachment to the pelvis. These often required off-set connection to the deformity construct, and prominence of the fixation resulted in an appreciable rate of undesirable symptoms postoperatively.[2,4] In an effort to improve upon these challenges, the S2 alar-iliac screw trajectory has been utilized in both adult and pediatric deformity corrections.[2,4,5] Various studies of this technique have reported a reduction in pain, instrumentation loosening, and surgical revision rates when compared with traditional iliac bolts that do not cross the SI joint.[1,2,6,7] However, concerns about fixation that directly transgresses the sacroiliac joint remain.

Because the sacroiliac joint is essentially constrained by fixation, but not necessarily fused by various methods of sacropelvic fixation during deformity correction, persistent motion at the joint may result in further stress on the lumbopelvic fixation. Cyclical loading of iliac fixation may contribute to loosening or fracture of these implants over time, given the increased stresses incurred at the sacroiliac joint following lumbar and lumbosacral fusion.[8–11] These mechanical failures have shown to result in less desirable clinical and radiographic outcomes. Ultimately, the loss of pelvic fixation at the base of long fusion constructs can potentially lead to pain from loosened fixation, pseudarthrosis at the lumbosacral junction, and loss of deformity correction, amongst other concerns.[2,8,9,11,12] These eventualities have important implications for clinical outcomes, and healthcare economics, of course, should they lead to secondary or revision surgeries. We aimed to characterize and compare the types and rates of radiographic failure related to both traditional iliac and S2-alar iliac sacropelvic fixation within a large group of patients undergoing correction of adult spinal deformity.

MATERIAL AND METHODS

A retrospective cohort study was conducted within a prospectively collected, consecutively enrolled, multicenter adult spinal deformity database through the International Spine Study Group (ISSG). Thirteen centers participated in patient enrollment across the United States, and Institutional Review Board approval was obtained prior to patient enrollment.

Inclusion criteria included adult spinal deformity (ASD) (coronal Cobb $\geq 20°$, sagittal vertical axis [SVA] ≥ 5 cm, pelvic tilt $\geq 25°$, and/or thoracic kyphosis $> 60°$) more than or equal to 18 years old, minimum of 2 years follow up, and more than five level fusion with use of pelvic fixation. Patients with more than one pelvic fixation point per side (three and four screw constructs) were excluded. Patient demographic and clinical data collected for this study were age, sex, body mass index (BMI), and comorbidity severity (Charlson Comorbidity Index [CCI]). In addition, patient reported outcome measures were collected in the form of SRS-22, Oswestry Disability Index (ODI), short formsurvey-36 (SF-36) physical and mental component scores (SF-36 PCS and MCS), and visual analog scales for both back and leg pain. Radiographic alignment data captured included the number of fused levels, pelvic tilt (PT), pelvic incidence-lumbar lordosis (PI-LL), and sagittal vertical axis (SVA).

Additional radiographic analysis was performed by 12 spine surgeons utilizing long-alignment standing plain radiographs to determine the occurrence of iliac or S1 screw loosening, (Figure 1) iliac screw fracture/breakage, rod fracture below L4 (within the lumbopelvic junction region), and to confirm any evidence suggesting revision of iliac fixation had occurred. Loosening was defined as any lucency around the screw shank on radiographs within the sacrum, ilium, or both (Figures 1 and 2). The occurrence of any revision surgery occurrence was noted, including when specifically involving the lumbosacral fixation below L4 and the iliac fixation, specifically.

The cohort was further subdivided by type of pelvic fixation in the forms of traditional iliac screws (IS) *versus* S2 alar-iliac screws (S2AI), in order to ascertain any differential failure frequency and/or mode by fixation type. Univariate

Figure 1. Three years postoperative radiograph with lucency visualized around the left S2-alar iliac screw.

testing was performed using *t* tests and chi-square tests. Multivariate logistic regression, accounting for significant confounders to include unilateral *versus* bilateral iliac fixation, was used to examine differences between the two groups for screw loosening/fracture, rod fracture, and revision surgery. Given that our cohort had a substantial number of patients with unilateral pelvic fixation, and the proportional application of unilateral fixation varied between subgroups (S2AI *vs*. iliac types), we utilized a separate multivariate analysis to control for this potential confounder. Performing multivariate analysis to control for this confounder allowed examining the independent effect of S2AI *versus* iliac screw fixation on our dependent variables, without losing statistical power.

Additionally, the cohort was also subdivided by type of interbody reconstruction at the lumbosacral junction (none,

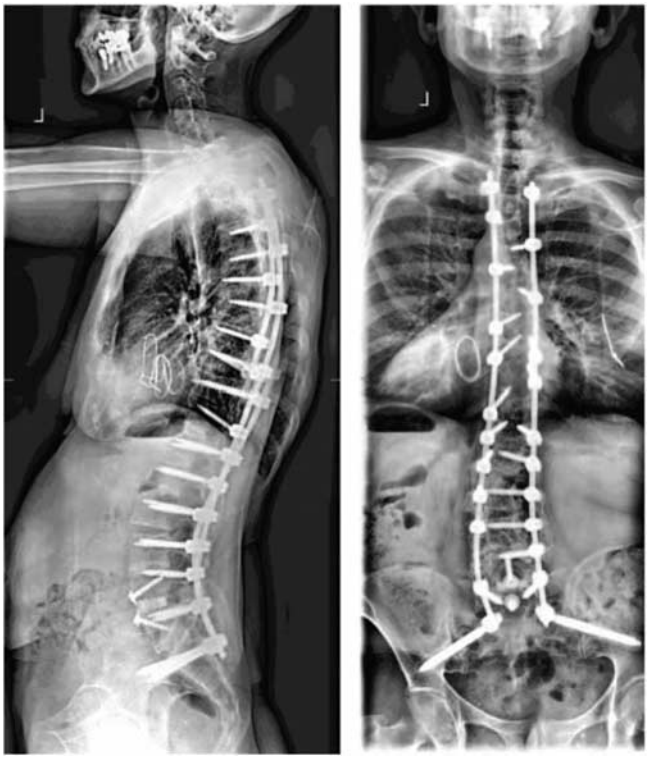

Figure 2. Three years postoperative radiographs demonstrating both lucency around the left S2 iliac screw and a rod fracture on the left above the S1 screw.

Anterior Lumbar Interbody Fusion [ALIF], Transforaminal/Posterior Lumbar Interbody Fusion [TLIF/PLIF]), and those with prior L5-S1 fusions were excluded. Univariate testing via one-way Analysis of Variance and chi^2 tests, and multivariate logistic regression, accounting for significant confounders, were used to examine the difference between the three groups in regard to pseudarthosis (fusion grading utilizing Lenke system criteria), pelvic fixation loosening, rod fracture, and revision surgery. Level of significance was set at $P < 0.05$.

RESULTS

Four hundred and eighteen patients out of 1422 adult spinal deformity patients in the database met inclusion criteria (IS = 287, S2AI = 131). The average follow-up period was 2.65 years with a range from 2 to 9 years. Of the 418 total patients, 228 (54.8%) were revision surgeries, including 168 (40.4%) that underwent prior fusion(s). The two iliac fixation subgroups had similar age, BMI, baseline comorbidities, as well as, similar baseline health-related quality of life measures (Table 1). They also had similar baseline sagittal spinopelvic parameters and number of fused levels (12.62 *vs*. 12.23; $P = 0.3$) (Table 2). Unilateral pelvic fixation was used less commonly in both groups (IS = 37 [12.9%]; S2AI = 7 [5.3%]) than bilateral pelvic fixation (IS = 249; S2AI = 123). There was a notably higher rate of unilateral pelvic fixation within the iliac screw cohort than in the S2AI group (12.93% *vs*. 5.3%; $P = 0.02$). There were differential rates for use of S1 screws (85% *vs*. 71%,

TABLE 1. Baseline Preoperative Characteristics

	Traditional Iliac Screw	S2 Alar Iliac Screw	*P*
Number of patients	287	131	
Age	63.42	64.23	0.43
BMI	28.13	28.06	0.92
CCI	2.01	1.93	0.68
SRS-22	2.65	2.76	0.09
ODI	47.29	46.52	0.65
SF-36 PCS	29.84	30.31	0.61
Back pain NRS	7.3	7.43	0.58
Leg pain NRS	5.03	5.11	0.81

BMI indicates body mass index; CCI, Charleson Comorbidity Index; NRS, numeric rating scale; PCS, physical component score; SF-36, short-form survey 36; SRS-22, Scoliosis Research Society.

$P = 0.001$) and the use of L5-S1 IBE, (51.0% *vs*. 40.0%, $P = 0.04$) when comparing subgroups (IS *vs*. S2AI). Among patients who had an L5-S1 interbody fusion, 49.7% underwent an ALIF and 50.3% underwent a TLIF/PLIF, with no difference between the iliac screws and S2AI groups ($P = 0.39$). There were no differences between iliac fixation types groups with regard to the rate of L4-5 IBE ($P = 0.3$).

The overall lumbopelvic fixation failure rate (screw loosening/screw fracture/rod fracture below L4) was 23.74% with no difference between iliac fixation types (IS 21.68% *vs*. S2AI 28.24%; $P = 0.14$) (Table 3). Loosening of pelvic fixation occurred in 13.4% of patients and was more prevalent in the S2AI fixation group (odds ratio [OR] 2.63, $P = 0.001$). Iliac and S2AI screw fractures (Figure 3) of any type were uncommon in both groups (1.7% and 3.1%, respectively; $P = 0.375$), and after multivariate logistic regression analysis, the OR for occurrence with S2AI was 2.0 ($P = 0.32$) (Table 4). The rate of S1 screw loosening in the overall cohort was 2.9%, and more likely to occur in the S2AI group (OR 6.05, $P = 0.022$). The rate of pelvic fixation fracture in the overall cohort was 2.37%, with no difference between groups ($P = 0.32$). Rod fractures (Figures 2 and 4) below L4 occurred in 14.1% of all subjects, with a trend toward less occurrence in the S2AI group (OR 0.48, $P = 0.06$). Revision surgery for any reason was required in 22.7% of our cohort, with no difference between groups ($P = 0.55$). Revision of iliac fixation occurred in 8.5% of patients, with S2AI screws requiring

TABLE 2. Radiographic Baseline Characteristics

	Traditional Iliac Screw	S2 Alar Iliac Screw	*P*
Number of patients	287	131	
Unilateral pelvic fixation	12.9%	6%	0.02*
Number of levels fused	12.62	12.23	0.3
L4-5 IBF performed	40.7%	35.4%	0.3
L5-S1 IBF performed	51.0%	40.0%	0.04*
Use of S1 screws	85.0%	71.0%	0.001*
Preop PT	26.89	25.13	0.12
Preop SS	28.5	27.9	0.65
Preop PI-LL	21.52	19.28	0.29
Preop SVA	81.12	70.12	0.14

PI-LL indicates pelvic incidence-lumbar lordosis; PT, pelvic tilt; SS, sacral slope; SVA, sagittal vertical axis.
**P < 0.05.*

TABLE 3. Rates of Pelvic Fixation Failure by Type and According to Pelvic Fixation Modality, as Well as Overall Rates

	Overall	Traditional Iliac Screw	S2 Alar Iliac Screw	*P*
Number of patients	418	287	131	
Loosening of IS or S2AI	13.41%	9.09%	21.37%	0.001*
Fracture of IS or S2AI	2.37%	1.75%	3.13%	0.375
Rod fracture (below L4)	11.9%	13.93%	6.52%	0.06*
S1 screw loosening	2.92%	1.64%	6.45%	0.02*
Revision of any type	22.77%	20.91%	25.19%	0.5
Revision of iliac fixation	8.5%	8.74%	6.15%	0.365

IS indicates traditional iliac; S2AI, S2-alar-iliac.
**P < 0.05.*

revision in 6.15% of patients versus 8.74% of those with iliac screws ($P = 0.365$).

The use of unilateral versus bilateral pelvic fixation varied by type of interbody fusion at L5-S1 (no interbody at L5-S1 = 7.36%, ALIF = 19.8%, TLIF = 3.29%; $P = 0.0001$). When evaluating for the impact of lumbosacral IBF type on iliac fixation failure, multivariate logistic regression, with control for unilateral fixation, revealed that type of interbody did not affect rates of pelvic fixation loosening or screw fracture (no interbody OR 0.87, $P = 0.730$; TLIF OR 0.705, $P = 0.393$). ALIF at L5-S1 was associated with lower risk of pseudarthrosis (OR 0.16, $P = 0.026$) and rod fracture (OR 0.19, $P = 0.012$) compared with no interbody fusion, while PLIF/TLIF was no different than using no lumbosacral interbody fusion.

When evaluating for specific factors being related to failure of lumbosacral and pelvic fixation (Table 5), pseudarthrosis at L5-S1 ($P = 0.0001$) was notably associated, as was a longer construct, albeit slightly (13.24 *vs.* 12.25 levels, $P = 0.017$). Interestingly, failures did not occur more commonly with unilateral pelvic fixation ($P = 0.88$), nor with use of L5-S1 IBF at the index ($P = 0.47$) or prior surgery.

Rod material utilization varied by iliac fixation type, with cobalt chromium (CC) used in 57.5% of the IS group and 67.4% of the S2AI group, while titanium alloy (Ti) was used in 13.4% of the IS group and in 37.8% of the S2AI group. There were no stainless-steel rods used in the S2AI group, but they comprised 28.7% of the IS group. Pelvic fixation loosening/failure occurred at similar rates when comparing CC and Ti (16.7% *vs.* 8.9%; $P = 0.09$). In this patient cohort, the rate of pseudarthrosis was not different between those who experienced pelvic fixation failure and those who did not (10.52 *vs.* 14.6%, $P = 0.5$).

There were no differences in postoperative HRQL measures when comparing the iliac screw and S2AI cohorts (Table 6). Notably, however, patients with failure of pelvic fixation had significantly worse HRQL scores (PCS 36.23 *vs.* 39.37 $P = 0.04$; ODI 33.81 *vs.* 27.93 $P = 0.036$), and they had less improvement in their HRQL at 2 years (PCS 7.69 *vs.* 10.46 $P = 0.028$; SRS 0.83 *vs.* 1.03 $P = 0.019$; ODI 12.91 *vs.* 19.77 $P = 0.0016$).

DISCUSSION

In a large cohort of adult spinal deformity patients with pelvic fixation with minimum 2-year follow-up, substantial rates of lumbosacral and pelvic fixation failure (23.74%) were noted across both traditional iliac and S2-alar-iliac screw techniques. S2AI screws were associated with higher rates of loosening, while there was no difference in rates of instrumentation failure between the techniques. Pelvic fixation failure was associated with decreased quality of life.

Sacropelvic fixation in adult spinal deformity correction, typically involving traditional iliac screws or S2-alar iliac screws, has become widespread in an effort to improve radiographic and clinical outcomes. The positional and biomechanical differences between direct iliac and S2AI screws may lead to differences in types and rates of failure. The failure rates in our current series are similar to a smaller series of adult deformity patients reported by Cho *et al*[11] where the overall lumbopelvic fixation failure rate of 34.3%, including major failure requiring surgery in 11.9%. The traditional iliac screws utilized in our series were less likely to loosen than S2-alar iliac screws, which is in contrast to other reports in the literature.[13,14] In the meta-analysis by Guler *et al*,[1] loosening of pelvic fixation was more prevalent after the use of iliac screws, with an iliac screw loosening rate of 17.6% compared with 5.1% with S2-alar iliac screws. Elder *et al* and Ishida *et al* both found similar rates of loosening when comparing types of screws.[15–17] However, Ilyas *et al*[18] found an 18.6% rate of traditional iliac screw loosening, while none was evident in their S2-alar iliac screw cohort. Notably, these studies were generally of shorter follow up duration (1 year minimum), which may have affected both the overall rates, as well as the differences in rates between the types of iliac fixation, given their unique biomechanics.

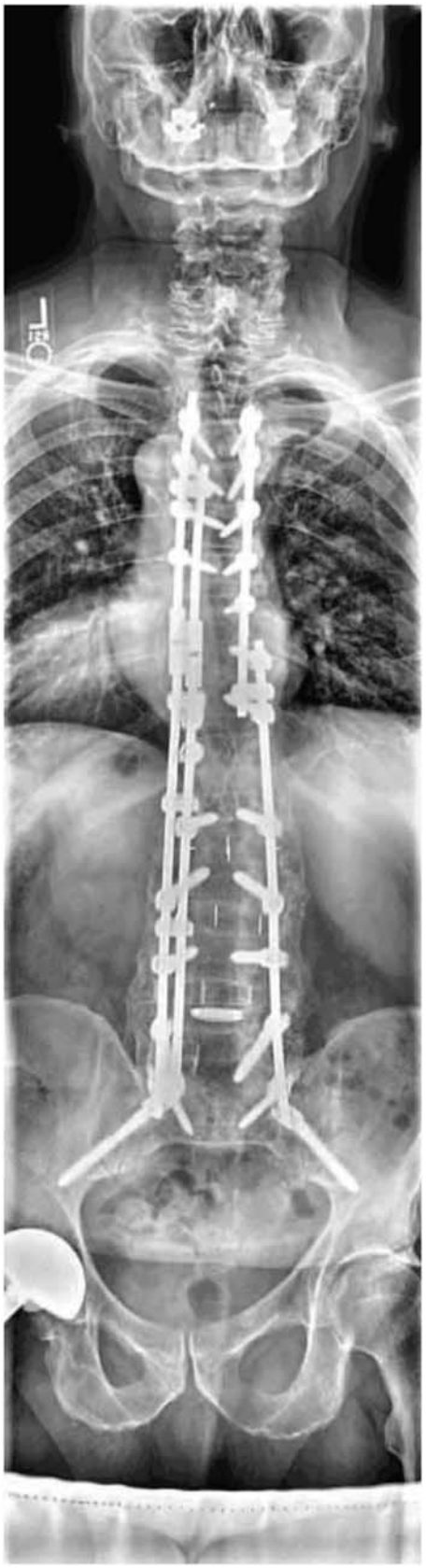

Figure 3. Three years postoperative radiographs demonstrating a left S2 iliac screw fracture within the middle of the shank.

TABLE 4. Odds Ratios for S2AI Outcome *Versus* IS Following Multivariate Logistic Regression Analysis Controlling for Potential Confounders (Unilateral vs. Bilateral Pelvic Fixation Points, Use of S1 Screws, and Use of L5-S1 Interbody)

	OR (for S2Ai)	*P*
Loosening pelvic fixation	2.63	0.001
Fracture of pelvic fixation	2.0	0.32
S1 screw loosening	6.05	0.022
Rod fracture caudal to L4	0.48	0.06
Revision of any type	1.16	0.55
Revision of pelvic fixation	0.62	0.28

Use of S1 screws was not entered as a confounder for the S1 screw loosening outcome (as the outcome only pertains to patients who had S1 screws utilized). IS indicates traditional iliac; S2AI, S2-alar-iliac.
$^{*}P < 0.05$.

Because of the ongoing stress likely appreciated by these iliac fixation points, greater loosening rates may be revealed with longer follow-up durations. Nakashima *et al*[12] evaluated patients undergoing S2-alar iliac screw fixation with a minimum of 2 years in follow-up, found that loosening rates climbed from 24.3% at 6 months to 50% at 2 years postoperatively. Tsuchiya *et al*[19] similarly looked at their experience with standard iliac fixation in 67 patients, and they discovered loosening of the traditional iliac screws in 29 (43%) of their patients. In another larger study looking solely at traditional iliac screw fixation with minimum 2-year follow-up, Nguyen *et al*[20] found a lower rate of 3.6% of loosening. Although details such as screw length and diameter, which may affect fixation durability, at least temporarily, were not captured in these various studies, it is important to note that the overall loosening rate was greater than 10%, even with a predominantly shorter-term follow-up.

Although screw fracture was not specifically identified within many of these prior studies, we scrutinized our cohort radiographically for evidence of screw shank fracture. In our series, we found no difference between iliac screw and S2-alar iliac screw fracture rates at 1.7% and 3.1%, respectively. This was lower than the rate in the Nguyen *et al*[20] study, which found a 4.5% rate of screw fracture. The higher rate of screw fracture in their cohort, while concomitantly seeing a lower rate of loosening, may further support an ongoing cyclical stress appreciated by these fixation points as a result of persistent sacroiliac joint motion, while the failures simply occur in a different manner. Screw diameter likely influences the likelihood of shank fracture, but this information was not provided in their study.

Figure 4. Two years postoperative radiographs with fracture of the rods adjacent to the iliac screw on the left and above S1 on the right.

Sacral (S1) screw fixation was also evaluated in our series, given the known variance in stress and failure appreciated by these screws at the base of deformity corrections.[10,21–23] In our series of patients, there was a 2.9% rate of S1 screw loosening, and such loosening occurred with a greater likelihood in those patients with S2-alar iliac screw fixation. This is a lower rate than was reported by Banno *et al*[21] and Nakashima *et al*[12] who found such loosening in 9.7% and 18.6%, respectively. These variations are difficult to explain, and likely involve a variety of contributions, including bicortical purchase, L5-S1 interbody support, fusion success, screw dimension, osteopenia, and many others.

Rod strain in the lumbosacral junction has been shown to increase as a result of iliac fixation, and there is undoubtedly more stress on the rods at the lumbosacral junction given its transitional and foundational nature.[24] Because of this relationship, we also evaluated our cohort for other fixation failures within the lumbopelvic region, including rod fracture at or below the lumbosacral junction. At nearly 15%, the rate of rod fracture in our series is certainly something to consider, albeit a multifactorial issue. Notably, the rate was slightly higher with the traditional iliac screw group. Because of the lower loosening rate seen with those type of screws, higher sustained levels of rod strain may be appreciated by those same patients. Regardless, this unacceptably high rate of rod failure provokes a deeper analysis of the varied potential contributions, such as metallurgy, increased rod number, rod diameter, interbody support at the lumbosacral junction, and others.

Anterior IBE at L5-S1 provided specific benefits of lower pseudarthrosis and rod fracture rates, but the type and use of IBE at the lumbosacral junction did not result in any differential risk of iliac fixation failure within our cohort. This could be a result of loss of statistical power when dividing the patients into three interbody cohorts, with relatively smaller numbers in each subcohort. However, it may also be the result of continued motion at the sacroiliac joint

TABLE 5. Overall Lumbosacral and Pelvic Fixation Failure Rates Relative to Specific Listed Factors

	No Failure	Failure	*P*
Unilateral pelvic fixation	10.73%	10.20%	0.88
L5-S1 IBF performed at index or prior surgery	47.48%	48.45%	0.87
L5-S1 IBF performed at index procedure	55.51%	51.11%	0.47
BMP2 used in L5-S1 IBF (if performed)	37.09%	32.65%	0.57
Pseudoarthrosis L5-S1 (based on Lenke grade)	0.45%	25.81%	0.0001*
Posterior fusion Lenke grade A&B	74.53%	57.73%	0.01*
Anterior fusion Lenke Grades A&B (if performed)	85.89%	81.33%	0.096
Patient age	63.51	64.25	0.51
Number of levels fused	12.25	13.24	0.017*
Preoperative PT	25.87	27.99	0.08
Preoperative PI-LL	20.17	23.17	0.19
SVA	78.97	73.25	0.48

BMP2, bone morphogenic protein 2; PI-LL indicates pelvic incidence-lumbar lordosis; PT, pelvic tilt; SVA, sagittal vertical axis.
*$P < 0.05$.

TABLE 6. Two-year Postoperative Patient Reported Outcome Measures

	Traditional Iliac Screw	S2 Alar Iliac Screw	*P*	No Failure	Failure	*P*
Number of patients	287	131				
2 years NRS back pain	3.43	3.31	0.73	3.35	3.91	0.19
2 years NRS leg pain	2.57	2.59	0.95	2.45	3.35	0.03*
ODI	28.94	27.85	0.61	27.93	33.81	0.036*
PCS	38.93	39.48	0.64	39.37	36.23	0.04*
MCS	50.66	52.52	0.18	51.33	50.48	0.63
SRS-22	3.61	3.8	0.02	3.68	3.51	0.12

MCS indicates mental component score; NRS, numeric rating scale; ODI, Oswestry Disability Index; PCS, physical component score.
*$P < 0.05$.

after reconstruction being the primary mechanical stressor for the iliac fixation.

In this patient cohort, the rate of pseudarthrosis was not different between those who experienced pelvic fixation failure and those who did not (10.52 *vs.* 14.6%, $P = 0.5$). However, pseudarthrosis was assessed on plain radiographs rather than CT scan, which is a significant limitation. Further studies looking at the relationship between lumbosacral pseudarthrosis and pelvic fixation failure are warranted and should include CT assessment of the fusion rate.

Our study was based on x-ray radiographic assessment alone, and as such, may have underestimated the rate of loosening of fixation, as well as fractures of the same. Previous work evaluating iliac fixation with computed tomography has revealed substantially higher rates of loosening than other analyses utilizing radiographs primarily.[12] By using a team of two reviewers for each case, we attempted to improve the accuracy of assessment in this regard. It is important to note that rod fractures cannot always be visualized, particularly within the screw tulips, nor can screw neck fractures that occur adjacent to the screw tulip. Such failures are often only evident intraoperatively during revision surgery. Ultimately, the retrospective nature of our study challenges our capacity to associate these mechanical failures directly to clinical symptoms or the need for additional surgery. The implications of failed lumbopelvic fixation for diminished clinical outcomes and the requirement for revision surgery suggest that preventive strategies should be considered and investigated further. Future studies are ongoing to prospectively evaluate these relationships, so that we can provide such clarity.

Pelvic fixation in the setting of adult spinal deformity ultimately provides a critical value in preventing failures at the lumbosacral junction, but whether iliac or S2-alar iliac fixation methods are utilized, additional risks related to this fixation are evident.[11,13,23] Some of these risks may be inherent to any spinal fixation and the cyclical loads or stresses occurring during the healing process. However, unique to iliac fixation, the ongoing motion of the sacroiliac joint postoperatively may substantially contribute to these delayed failures of iliac screws, regardless of type. 25,26 This appears to have a modest, but statistically significant negative impact on clinical outcomes, as well as the need for revision surgeries. By better understanding the nature and extent of these failures, we will be better equipped to devise preventive strategies or solutions that allow for an improved effectiveness and durability of the index surgery.

CONCLUSION

Our results demonstrate a substantial rate of lumbosacral and pelvic fixation failure (23.74%) following ASD correction, much of which leads to revision surgery and is associated with smaller improvement in clinical outcome measures following adult deformity correction. S2AI screws were more likely to demonstrate loosening, were more commonly associated with S1 screw loosening, and had a nonsignificant trend toward less rod lumbosacral rod fractures, when compared with traditional iliac fixation.

➢ Key Points

- ❑ Lumbopelvic fixation failure rates and revisions are high following ASD correction.
- ❑ Lumbopelvic fixation failure compromises clinical outcomes after ASD correction.
- ❑ S2AI screws loosened more frequently than iliac screws, but had less frequent rod fracture.

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