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LITERATURE REVIEW

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Iliac screw versus S2 alar-iliac screw fixation in adults: a meta-analysis

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OBJECTIVE In a meta-analysis, the authors sought to compare outcomes after iliac screw (IS) versus S2 alar-iliac (S2AI) screw fixation in adult patients.

METHODS A PubMed/MEDLINE database search was performed for studies comparing IS and S2AI screw fixation techniques in adults. Levels of evidence were assigned based on the North American Spine Society guidelines. Three outcomes were examined: 1) revision surgery rate secondary to mechanical failure or wound complications, 2) surgical site infection rate, and 3) screw prominence/pain. Data were pooled and outcomes compared between techniques. Absolute risk reductions (ARRs) were also calculated for outcome measures.

RESULTS Five retrospective cohort studies (all level III evidence) were included in our analysis. A total of 323 adult patients were included—147 in the IS group (45.5%) and 176 in the S2AI group (54.5%). Overall, revision surgery due to mechanical failure or wound complications was needed in 66 of 323 patients (revision surgery rate 20.4%)—27.9% in the IS group and 14.2% in the S2AI group (13.7% ARR; $p < 0.001$). Four studies reported wound infections among 278 total patients, with an infection rate of 12.6% (35/278)—25.4% in the IS group and 2.6% in the S2AI group (22.8% ARR; $p < 0.001$). Three studies examined development of screw prominence/pain; combined, these studies reported screw prominence/pain in 21 of 215 cases (9.8%)—18.1% in the IS group and 1.8% in the S2AI group (16.3% ARR; $p < 0.001$).

CONCLUSIONS S2AI screw fixation in adults has a significantly lower mechanical failure and complication rate than IS fixation based on the current best available evidence.

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KEYWORDS iliac screw; S2 alar-iliac screw; spinopelvic; adult; deformity; meta-analysis; sacral

Spinopelvic fixation can be used in the correction of high-grade spondylolisthesis or pelvic obliquity; in cases of lumbopelvic trauma or after a sacrectomy/lumbar spondylectomy in tumors or infection; and after long-segment fusion procedures for pediatric or adult spinal deformity.[14] Advantages of fixation to the pelvis include greater construct strength, which is particularly useful given the high biomechanical forces in lumbosacral zone.[10] A variety of techniques have been described throughout the years,[10] but currently iliac screw (IS) fixation and S2 alar-iliac (S2AI) screw fixation are two of the most commonly used procedures.

In IS fixation iliac bolts are placed at the level of the posterior superior iliac spine with a trajectory targeting the superior acetabular notch or the anterior superior iliac spine. This technique has been shown to be biomechanically superior to the use of Galveston rods and has relatively high fusion rates.[18] Nonetheless, concerns include the need for more extensive soft-tissue dissection, need for complex connector systems, instrumentation pain/prominence, and others.[10] On the other hand, S2AI screws were first described for use in pediatric patients with scoliosis[19] but have gained popularity in adult patients given recently reported favorable outcomes,[5,9] including lower complication rates and no need for connectors (given that they are placed in line with lumbar and S1 pedicle screws), among others.[10]

The purpose of the present study was to conduct a me-

ABBREVIATIONS ARR = absolute risk reduction; IS = iliac screw; NASS = North American Spine Society; S2AI = S2 alar-iliac.

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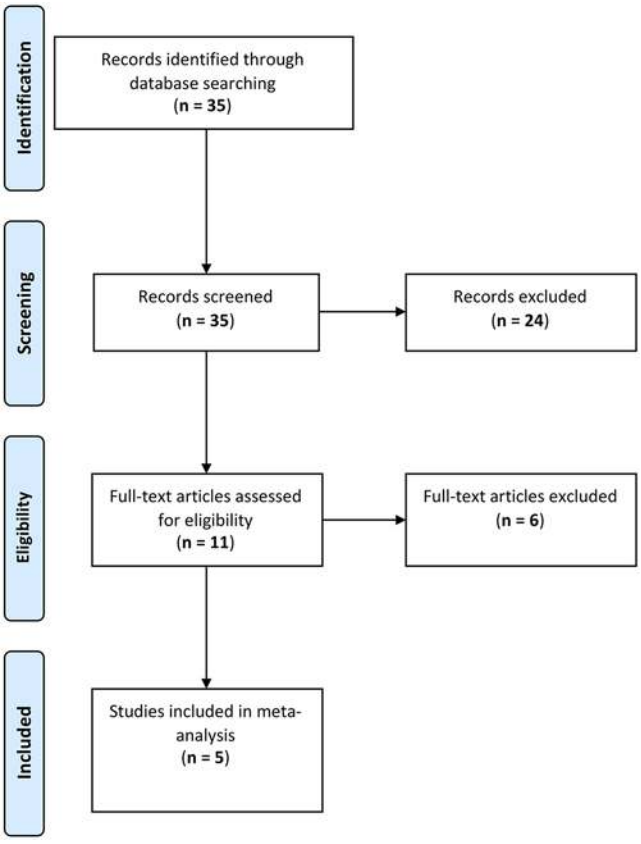

FIG. 1. Flowchart of literature search and study selection. Figure is available in color online only.

ta-analysis comparing IS fixation and S2AI screw fixation techniques in adults, with an emphasis on rates of revision surgery and wound complications.

Methods

Literature Review and Study Selection

PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines were followed in preparation of this paper. A comprehensive online database search was performed on PubMed and MEDLINE. The search algorithm "(S2AI) OR (S2 alar iliac) AND (adult)" was used. Inclusion criteria were studies published in English up to April 2018.

This meta-analysis only included cohort or case-control studies directly comparing the IS and S2AI screw fixation techniques in patients over 18 years of age. Case series and studies only involving pediatric patients were excluded. Larger studies examining outcomes of adult patients but without direct comparisons between IS and S2AI screw fixation methods, cadaveric studies, and technical notes were also excluded from our analysis. References from articles were also reviewed to identify any additional potential manuscripts to be included in our analysis.

Data Collection

Each study was assessed by total number of included patients, number of patients who received IS or S2AI screws, mean age, sex, indications for surgery (tumor, trauma, deformity, etc.), use of anterior column support (i.e., interbody graft at L5–S1), average follow-up time, and level of evidence. The latter was assigned to studies based on the North American Spine Society (NASS) guidelines (https://www.spine.org/Documents/ResearchClinicalCare/LevelsOfEvidence.pdf). Risk of bias was also assessed for each study.

Three primary outcomes were examined: 1) revision surgery rate secondary to mechanical failure (pseudarthrosis, proximal junctional failure, distal device failure, or pelvic screw loosening, among others) or wound complications (including infection, dehiscence, or breakdown), 2) surgical site infection rate, and 3) screw prominence/pain.

Statistical Analysis

For the meta-analysis, STATA SE 12 (StataCorp) and Review Manager v5.3 (Nordic Cochrane Centre, the Cochrane Collaboration) were used. Frequencies were calculated and compared via chi-square tests or Fisher's exact test (for occurrences < 5). The effect measure was calculated using the Mantel-Haenszel test for dichotomous variables and is expressed as an odds ratio, comparing IS and S2AI screw fixation groups. These results are represented in graphics with corresponding 95% CI. Absolute risk reductions (ARRs) were also calculated for outcome measures. Statistical significance was defined as $p < 0.05$.

Results

Literature Review and Study Quality

The literature search of the PubMed and MEDLINE databases yielded a total of 35 unique manuscripts (Fig. 1). All article titles were manually screened to select potential candidates for inclusion in our analysis. Eleven potential articles were reviewed, and 5 were selected for inclusion and the meta-analysis; 6 articles were excluded given that they were biomechanical analyses, technical notes, or noncomparative studies. The 5 selected studies were all retrospective cohort studies comparing outcomes of IS fixation and S2AI screw fixation techniques in adults.[5,7–9,13] Based on the NASS guidelines, all studies were graded as level III evidence (retrospective comparative studies). After risk-of-bias analysis, it was found that all studies had a high risk of selection and performance bias given their nonrandomized and nonblinded nature (Fig. 2). Detection, attrition, and reporting bias were lower compared to selection and performance biases, but they were also present given that the studies did not blind outcomes (except for the study by Ishida et al.[9]) and tended to inconsistently report outcomes.

Patient Characteristics and Outcomes

As summarized in Table 1, all 5 studies were published between 2015 and 2017.[5,7–9,13] Cumulatively, a total of 323 adult patients were included in the analysis—147 in the IS group (45.5%) and 176 in the S2AI group (54.5%). The average age of patients was between 59 and 64 years and 21%–44% were male. The most common indication for spinopelvic fixation was spinal deformity in 91.3% of all

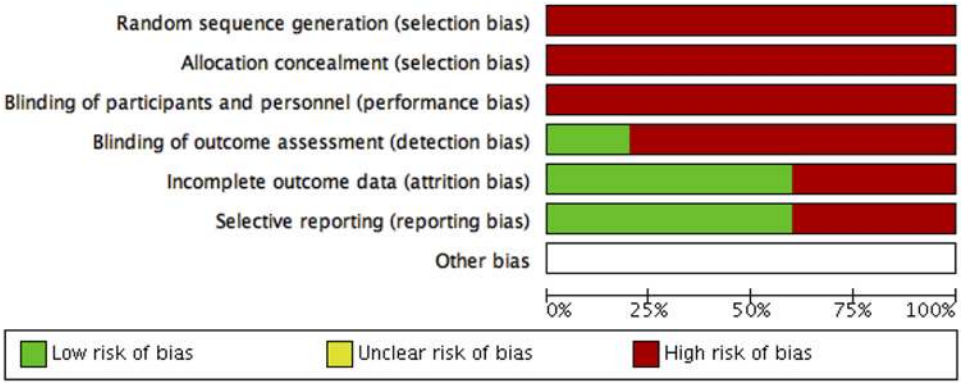

FIG. 2. Risk of bias in individual studies. Figure is available in color online only.

patients. Use of anterior column support at the L5–S1 level also varied from 0% of cases in the series by Guler et al. to 100% of cases in the series by Ishida et al.[7,9] Average follow-up time ranged from 17.6 to 29.6 months.

The cumulative revision surgery rate due to mechanical failure or wound complications for all patients was 20.4% (66/323)—27.9% in the IS group and 14.2% in the S2AI group (13.7% ARR; $p = 0.010$). As shown in Fig. 3, use of S2AI screws significantly reduced the odds of revision surgery (OR 0.32; 95% CI 0.18–0.58; $p < 0.001$) compared to the IS fixation technique. Four studies favored the S2AI fixation technique,[5,8,9,13] while Guler et al. were the only authors who reported a higher rate of mechanical failure in the S2AI group.[7] In their study, they reported polyaxial screw head/shaft disengagement (breakage) and set screw dislodgement as cases of mechanical failure.[7]

Four studies reported wound infections among 278 total patients,[5,8,9,13] with a cumulative rate of 12.6% (35/278)—25.4% in the IS group and 2.6% in the S2AI group (22.8% ARR; $p < 0.001$). Figure 4 illustrates the significantly lower odds of wound infection in the S2AI fixation group compared to the IS fixation group (OR 0.09; 95% CI 0.03–0.26; $p < 0.001$). Three studies showed significantly lower rates of wound infection in the S2AI group,[5,8,9] while only Mazur et al. reported a higher rate of infection in the S2AI fixation group, although the rate was not statistically significant.[13]

Three studies examined development of screw prominence/pain.[5,8,13] Combined, these studies reported 21/215 cases (9.8%)—18.1% in the IS group and 1.8% in the S2AI group (16.3% ARR; $p < 0.001$), corresponding to an OR of 0.17 (95% CI 0.05–0.60; $p = 0.006$) (Fig. 5).

Discussion

Spinopelvic fixation can be achieved through a variety of methods, but currently IS fixation and S2AI screw fixation techniques are among the most popular. Instrumentation down to the pelvic ring provides increased biomechanical strength to the lumbosacral construct and is useful for long fusions extending to the sacrum, deformities requiring 3-column osteotomies in the lumbar spine, high-grade spondylolisthesis, sacrectomies, severe osteoporosis, revisions of previous fusions, and other cases.[10] The S2AI screw fixation technique has gained popularity in adult patients because of its decreased tissue dissection (given a more medial screw entry point compared to iliac bolts), decreased implant prominence compared to IS fixation, and omission of the need for additional connectors given that a single rod can be used in line with the lumbar and S1 pedicle screws, among other reasons.[10] Moreover, recent reports have suggested that S2AI screw fixation has lower rates of revision surgery and wound infection.[5,13]

In the present meta-analysis, we combined results from 5 cohort studies comparing the IS and S2AI fixation techniques in adult patients,[5,7–9,13] and we found a significantly

TABLE 1. General characteristics of studies included in the meta-analysis

Authors & Year	IS vs S2AI Screw Fixation	Mean Age (IS vs S2AI) in Yrs	Male Sex (IS vs S2AI)	Indication	Ant Support (IS vs S2AI)	FU (mos)	Level of Evidence
Guler et al., 2015	25 vs 20	NR	NR	45 deformity patients	0.0% vs 0.0%	17.6	III
Ilyas et al., 2015	43 vs 22	64.3 vs 66.4	20.9% vs 36.4%	65 deformity patients	NR	22.3–29.6	III
Mazur et al., 2015	37 vs 23	64 vs 58	24% vs 43%	55 deformity patients, 4 infection, 1 tumor	65% vs 78%	22	III
Ishida et al., 2017	17 vs 46	64.3 vs 61.5	29.4% vs 22.6%	63 deformity patients	100.0% vs 100.0%	21.1	III
Elder et al., 2017	25 vs 65	59.2 vs 62	44% vs 36.9%	67 deformity patients, 10 spondylolisthesis, 9 tumor, 8 trauma, 1 infection*	52% vs 64.7%	21.1–21.8	III

Ant = anterior; FU = follow-up; NR = not reported.
* Numbers do not add to total IS + S2AI groups given multiple diagnoses in some patients.

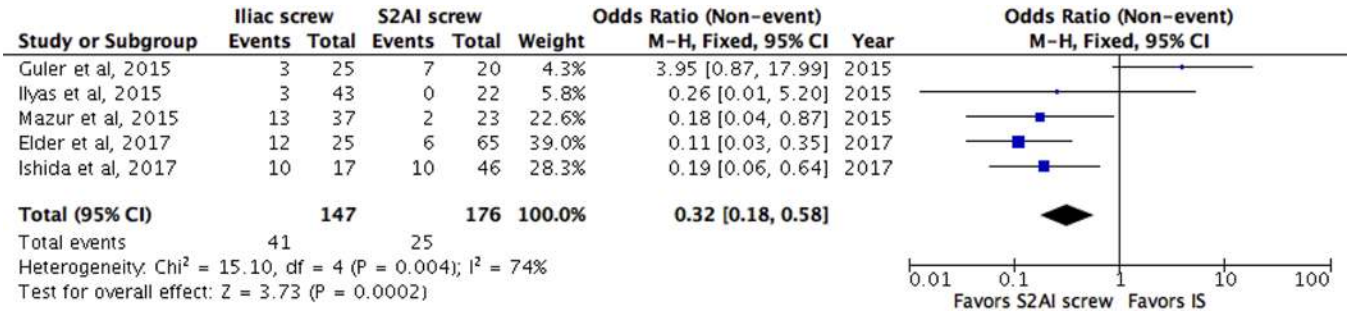

FIG. 3. Forest plot showing rates of revision surgery across studies. The meta-analysis revealed a significantly lower risk of reoperation in patients receiving S2AI screws ($p < 0.001$). Figure is available in color online only.

lower rate of revision surgery, wound infection, and screw prominence/pain associated with S2AI screw fixation. Nevertheless, there was variation in the indications for spinopelvic fixation, the proportion of patients in which anterior support (i.e., an interbody graft) was used, and the follow-up periods. Additionally, all studies were classified as level III evidence and had important biases.

After pooling data from all 5 studies, the rate of revision surgery for mechanical failure or wound complications was 13.7% lower in the S2AI group. Some of the mechanical advantages of S2AI screws over ISs include obviation of the offset connector (thus eliminating a potential point of failure) and greater cortical purchase.[13] O'Brien et al. compared the strength afforded by IS and S2AI screw fixation in 7 human cadaveric spines instrumented from L3 to the pelvis and found that S2AI screws were biomechanically "as stable" as the ISs in all loading modes.[15] Additionally, 65-mm S2AI screws were shown to be equivalent in strength to 90-mm ISs and 80-mm S2AI screws.[15] In another study, Burns et al. compared spinopelvic techniques in 8 specimens with L5–pelvis instrumentation, finding that IS fixation and S2AI screw fixation models showed no significant differences for torsional stiffness in flexion, extension, lateral bending, failure torque, or yield torque.[2]

The addition of anterior support is an important consideration when performing spinopelvic fixation. In our meta-analysis, there was variation in the usage of anterior interbody support, but all studies, except for that by Guler et al. (in which no patient received anterior instrumentation), included a high proportion of patients in whom anterior column support was added to the construct.[7] Kebaish suggested that anterior fusion be considered in long-segment constructs to relieve stress from the posterior elements and to enhance bony fusion.[10] Over the past years, several studies have shown that anterior support improves segmental sagittal alignment, allows for direct decompression of the foramina, and allows for intervertebral height restoration.[6,12,16] In our experience, we also recommend interbody cages (via an anterior, posterior, or lateral approach), particularly at the L5–S1 level, to improve fusion rates and overall sagittal balance.

The rate of wound infection was also noted to be significantly lower in patients who received S2AI screws compared to those who received ISs (overall risk reduction of 22.8%). This difference is not entirely surprising, given that the IS technique requires dissection of the subcutaneous tissue off the lumbosacral fascia to the level of the posterior superior iliac spine.[14] In our meta-analysis, the infection rate in the IS group was 25.4%, compared to only 2.6% in the S2AI group. Though future studies are needed, potential strategies to reduce complications in complex spine cases include an alternative subcutaneous route for IS fixation (vs a conventional open dissection)[22] and use of vancomycin powder,[21] among other considerations.

Screw prominence causing pain is a known complication of adult spinal deformity surgery, particularly cases involving IS fixation.[13] In our present review, S2AI screw fixation was associated with a 16.3% risk reduction for this occurrence. Instrumentation-related pain usually occurs months to years after the index surgery.[3] Although revision surgery may provide pain relief in 12%–70% of patients,[1,3,4,20] instrumentation removal does entail an additional procedure with its own attendant risks.

Overall, the findings of our study suggest that S2AI

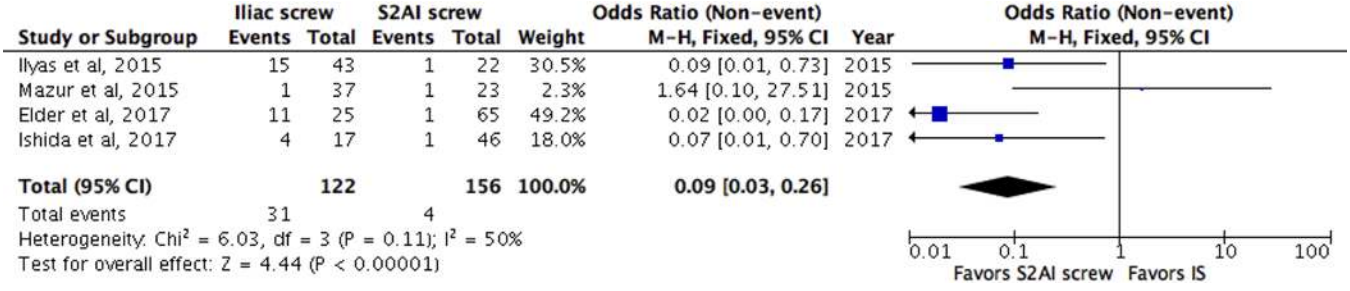

FIG. 4. Forest plot showing rates of wound infection across studies. The meta-analysis revealed a significantly lower risk of infection in patients receiving S2AI screws ($p < 0.0001$). Figure is available in color online only.

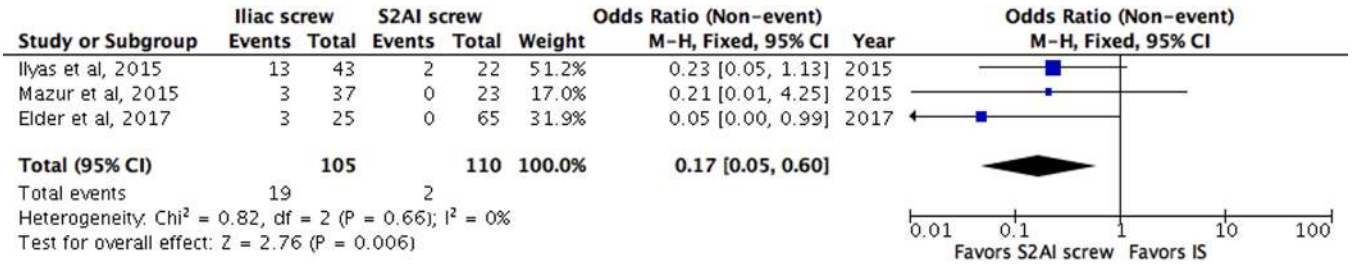

FIG. 5. Forest plot showing rates of screw prominence/pain across studies. The meta-analysis revealed a significantly lower risk of screw prominence/pain in patients receiving S2AI screws (p = 0.006). Figure is available in color online only.

screw fixation is associated with significantly lower risks of revision surgery, wound infection, and screw prominence/pain compared to IS fixation. Furthermore, biomechanical tests have shown that similar fixation strengths are achieved with S2AI fixation compared to IS fixation, which suggests that S2AI screws may be a better option than ISs in select patients.

Nonetheless, it is important to acknowledge that the present meta-analysis also stemmed from studies comprising level III evidence, each with its own biases and limitations. Although most studies favored the use of S2AI screws, there was some variability in patient demographics and operative technique, which carries the risk of confounding. The S2AI screw fixation technique is a newer technique than that for IS fixation, and it is possible that the improved results from the former method reflect a global improvement in surgical technique over time (including improved screw placement accuracy, lower rates of infection, and reduced operative time). Lee et al. reported a decrease in wound infection rate after spinal deformity surgery between 2010 and 2014, from 3.3% to 2.4%.[11] Likewise, Passias et al. found a significant decrease in postoperative complications (from 26.7% to 8.6%; $p < 0.001$) for patients over 75 years of age undergoing deformity surgery between 2003 and 2012, even though the case complexity was found to actually have increased.[17] Another potential important bias results from the studies by Elder et al.[5] and Ishida et al.,[9] both stemming from the same institution. Although the impact of this bias is unclear, an important number of patients are from this single hospital and may present a difficulty with generalization of the results found in our study. Future randomized trials with matching cohorts may further corroborate the present findings favoring the S2AI screw technique.

Conclusions

IS fixation and S2AI screw fixation are currently two of the most popular techniques for spinopelvic fusion. Although the latter technique was developed initially for pediatric patients, recent studies in adults have shown favorable outcomes. In the present meta-analysis, 5 retrospective studies were examined, and we found a significantly lower rate of revision surgery, wound infection, and painful instrumentation in patients who received S2AI screws versus those who received iliac bolts. In addition, biomechanical studies of S2AI screw fixation have shown equivalent results to IS fixation. Nevertheless, the studies included in this the present analysis were all retrospective cohort studies, each with its own important limitations. The findings of the present study suggest that S2AI screws may be superior to ISs in adults, but future randomized trials may be helpful to further corroborate these findings.

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Disclosures

Daniel M. Sciubba has consulting agreements with DePuy Synthes, Medtronic, Stryker, NuVasive, K2M, and Baxter. Reza Yassari has a consulting agreement with Stryker.

Author Contributions

Conception and design: all authors. Acquisition of data: De la Garza Ramos, Yassari, Nakhla. Analysis and interpretation of data: De la Garza Ramos, Nakhla, Sciubba. Drafting the article: all authors. Critically revising the article: Yassari, De la Garza Ramos, Sciubba. Reviewed submitted version of manuscript: Yassari, Nakhla, Sciubba. Approved the final version of the manuscript on behalf of all authors: Yassari. Statistical analysis: De la Garza Ramos. Study supervision: Yassari, Sciubba.

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