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TRAUMA

Do we need another screw? Sacroiliac screw fixation in open-book pelvic ring injuries (APC type II)

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- *Purpose:* To compare anterior plate fixation (SP fixation) both alone and in combination with an additional posterior sacroiliac screw (SP+SIS fixation) as a treatment for pelvic ring injuries with widening of the pubic symphysis and disruption to the anterior sacroiliac ligaments.
- *Methods:* To find studies with pelvic ring injuries (APC II; B2.3d) and SP or SP+SIS fixation, a systematic literature review was conducted by searching four databases. A protocol was published *a priori* at Open Science Framework (https://doi.org/10.17605/OSF.IO/3YHAV). Exclusion criteria included perineal injuries, chronic instability of the symphysis, complete sacroiliac separation, and pediatric patients (age <18 years). Primary outcomes of interest were defined as implant failure, health-related quality of life, and revision rate.
- *Results:* Altogether, 1861 studies were screened, and 40 studies qualified for full-text analysis. In total, 14 studies (two surveys, six biomechanical studies, and six retrospective clinical studies) were included. The surveys revealed that surgeons who had more recently begun practicing were more likely to use posterior fixation (SP+ISS). The biomechanical studies were heterogenous and did not yield a uniform pattern. In clinical studies, 117 patients (45%) received SP fixation, and 142 patients (55%) received SP+SIS fixation. Complications occurred in 31 SP patients (30%) and in five SP+SIS patients (3.5%).
- *Conclusion:* A high risk of bias was uncovered, and reporting was found to be incomplete. SP+SIS may have the potential to improve outcomes, but the evidence remains too inconclusive to draw reliable recommendations.

Keywords: AO; APC II; B1; B2; bone; disruption; fracture; implant failure; open book; pelvis; rupture; sacroiliac joint; screw symphysis; systematic review

Introduction

Open-book pelvic injuries are often caused by an anterior impact that leads to the external rotation of one or both hemipelves, resulting in the rupture of the symphysis pubis. The sacroiliac joint acts as a fulcrum of rotation and may cause further posterior injury. The degree of pelvic instability increases with the force

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of impact. Current injury classifications are based on the stability of the posterior sacroiliac complex (1, 2, 3). Anterior–posterior compression type II (APC II) injuries show symphysis widening and rupture of the anterior sacroiliac complex. These injuries can be treated with anterior plate fixation (SP fixation) alone or in combination with an additional posterior sacroiliac screw (SP+SIS fixation). Both treatment options are widely debated. APC II injuries are reportedly prone to complications such as fixation failure, reoperation, and malunion when treated with anterior fixation alone (4). Advocates of isolated SP fixation argue that it provides adequate reduction of the anterior pelvic ring and narrows the partially widened sacroiliac joint until the ligamentous injuries have healed. Surgeons who prefer the combined technique often fear implant failure or malunion and consider isolated SP fixation alone to inadequately stabilize APC II injuries. Therefore, they predominately prefer additional posterior fixation using a sacroiliac screw (SP + SIS). The present systematic literature review investigates both treatment options for APC II injuries because no existing study has yet analyzed the available literature.

Materials and methods

This systematic review is in line with PRISMA guidelines (5). The study protocol was published on April7, 2021, at the Open Science Framework digital research repository (https://doi.org/10.17605/OSF.IO/3YHAV).

Eligibility criteria

The population was defined as adult patients (≥18 years) with a pelvic injury that included traumatic disruption of the pubic symphysis and rupture of the anterior sacroiliac ligaments (APC II or B2.3d). The intervention included stabilizing the pubic symphysis using a symphyseal plate and stabilizing the sacroiliac joint using an SI screw. Patients who had been treated with anterior plate fixation alone served as the control group. Outcomes were defined as the rate of implant failure, health-related quality of life, rate of revisions, stability, pain, return to work, and adverse events (both serious and non-serious). We expected to find only very limited evidence and hence included all types of clinical studies (observational and interventional) as well as all types of biomechanical studies and surveys. Eligible studies were limited to those published in English and German. The PICO schema in Table 1 presents the eligibility criteria in detail.

Outcome measures

Prior to the review, we searched the Core Outcome Measures in Effectiveness Trials Initiative database for a possible core outcome set but were unable to identify a set that suited the purpose of our systematic review. Furthermore, the COnsensus-based Standards for the selection of health Measurement INstruments database of systematic reviews was searched for outcome measures; however, available outcome sets focused on gynaecological pelvic conditions or on conditions of chronic pelvic pain. Hence, we based the decision for the selected outcome measures on the clinical expertise of one author in discussion with the research team.

Primary outcomes

- Implant failure was defined as implant loosening, implant fracture, or recurrence of pubic diastasis but was not restricted to this definition. Evidence of implant failure had to be documented either by radiological diagnostics – such as X-ray, CT scan, or MRI – or during revision surgery. The time point for measuring implant failure was defined as weeks or months post-surgery.
- Health-related quality of life (hrQoL) was rated by the patient (but was not restricted to instruments such as SF12 or EQ5D) at least 6 months post-operatively.
- Revision rate was defined as unplanned surgery within the first 24 months post-operatively.

Secondary outcomes

- Fixation success was defined as implant material without clinical or radiological evidence of failure within 24 months post-surgery.
- Return to work was defined as the number of days between discharge from the hospital and return to work.
- Pain was rated by the patient with an instrument such as VAS (1, 2, 3, 4, 5, 6, 7, 8, 9, 10).
- Length of hospital stay (LOS) was defined as the number of days from admission to discharge from the hospital, including in-hospital transfers.
- Other adverse events – such as serious and non-serious events (e.g. pulmonary embolism) – were measured post-operatively.

Search strategy

An electronic search on MEDLINE that included PubMed, Web of Science, Scopus, and the Cochrane Library was conducted on April 14, 2021. The search terms can be found in the Appendix (see section on supplementary materials given at the end of this article). The search strategy was adapted for the other databases. Furthermore, a search for clinical trials was performed on clinicaltrial.gov, and all reference lists of included

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Table 1 Summary of the PICO elements of the present review, with details on inclusion and exclusion criteria.

PICO	Inclusion criteria	Exclusion criteria
Population	Open-book injuries with affection of one or both SI joints and that were classified as APC II or AO: 61-B2.3d in adults. In cases with bilateral instability, both sides needed to be stabilized.	Pediatric injuries in patients <18 years (skeletally immature) Non-related injuries/diseases: • Peripartum pubic symphysis separation • Chronic instability of the pubic symphysis • Instability of the pubic symphysis caused by neoplasia • Complete sacroiliac separation Injury of the posterior sacroiliac ligaments
Intervention	Included operative procedures: • Symphyseal plating Stabilization of the injured SI Joint • Surgical symphysiodesis All types of screws (cannulated, partially, or fully threaded, etc.)	Injuries treated with: • External fixator • Internal fixator • Plate fixation of the SI Joint
Comparator	Open-book pelvic injuries stabilized with symphyseal plating without an SI screw	–
Outcome	Implant failure, health-related quality of life, revision rate, stability, pain, return to work, length of hospital stay (LOS), other adverse events (serious and non-serious)	–

publications were hand-searched for potential further studies.

Selection process

All identified studies were uploaded and screened using Covidence software (Covidence, Melbourne, Australia). Two authors selected the studies independently. Selection was made first based on titles and abstracts and second based on full texts. This study selection was based on the defined inclusion and exclusion criteria as outlined above. Disagreements were resolved via discussion or in consultation with a third reviewer.

Data collection

Data extraction was performed independently by two researchers. Studies were divided into three subgroups: surveys, biomechanical studies, and clinical studies. For every subgroup, a data extraction sheet was developed that contained all relevant information (title, DOI, author information, date of publication, funding source, potential conflicts of interest, type of study, population characteristics, relevant results, limitations, and conclusion). For biomechanical studies, additional data were gathered on the type of intervention, applied forces, number of samples, type of injury, measurements, and whether synthetic or human bones had been used. The diverse nature of the study designs hindered the use of Covidence as intended in the protocol. The data extraction forms were tested on one study each. Two authors extracted the data independently, and any disagreement was resolved via discussion. In cases of missing data, only the available data were used for analysis. No imputation was performed.

Risk of bias assessment

All included clinical studies were independently assessed by two reviewers regarding the risk of bias using the Methodological Index for Non-Randomized Studies (MINORS) tool, in contrast to the study protocol. During data extraction from the included studies, the nature of these studies made it necessary to choose a more suitable tool, and MINORS was thus selected. This tool consists of eight or 12 items (four items are added if the study includes a comparator group). For each item, a score of 0 (not reported), 1 (inadequately reported), or 2 (adequately reported) is assigned. Hence, our ideal study score was either 16 or 24 points (6). Disagreements between the two reviewers were resolved via discussion.

Synthesis methods

We expected that most studies on the topic would be non-comparative (e.g. case studies, case series) or biomechanical studies with small sample sizes. Hence, we did not plan a meta-analysis *a priori*. We focused on mapping the gathered data narratively to create an overview of the evidence on the benefits and harms of the role of additional posterior stabilization in APC II injuries for the two different treatment options (SP vs SP+SIS fixation).

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Publication bias

A funnel plot (e.g. a graph that plots effect size against study size) is used to investigate publication bias in clinical studies. Interpretation of the graph is only possible when more than ten studies of different sizes are included; otherwise, the statistical test is not sufficiently powered (7).

Results

Study selection

The search yielded 2031 hits, 170 of which were duplicates and were removed. A total of 1861 studies were screened for title/abstract, and 40 qualified for full-text screening. Additionally, 14 articles from the manual search were screened for eligibility. Finally, 14 studies met the inclusion criteria. A PRISMA flowchart with reasons for the exclusion of full texts is provided in Fig. 1.

Study characteristics and results

Two surveys (8, 9), six biomechanical studies (10, 11, 12, 13, 14, 15), and six clinical studies (16, 17, 18, 19, 20, 21) met the inclusion criteria. These studies were grouped according to their design and were analyzed separately.

Surveys

The two surveys – one from the UK and one international survey (participants sorted by AO Region: Asia Pacific, Europe, Latin America, Middle East, North America) – included a total of 214 surgeons (8, 9). Both used questionnaires among experienced surgeons that specifically asked about the preferred treatment for APC II injuries. Surgical management varied considerably and revealed two different approaches. Gill *et al.* (9) surveyed 38 experienced surgeons in 2017 and found that combined anterior and posterior fixation was preferred by 64% of surveyed surgeons. A single anterior plate with a single sacroiliac joint screw was the most popular fixation method (SP+ISS). Moed *et al.*'s 2019 survey (8) was conducted among 176 surgeons and revealed that SP fixation was the method of choice for 56% of surgeons. Those who had more recently begun practicing (i.e. those with less clinical experience) were more likely to add a posterior fixation (SP+ISS) (8). In summary, 99 surgeons (53%) preferred SP fixation and 77 (44%) preferred SP+SIS fixation (Table 2).

Biomechanical studies

The six included biomechanical studies consisted of one finite element study (15) and five human cadaver studies (10, 11, 12, 13, 14). The studies were published in France, Germany, the Netherlands, and the USA between 1994 and 2021. A total of 33 pelvises were included in the human cadaver studies (Table 3). Three of the six studies showed improved stability with SP+SIS fixation, and no surgical technique was able to restore the stability of an uninjured, intact pelvis.

Dujardin *et al.* evaluated micromotion of the sacroiliac joint and demonstrated less motion in cadavers with SP+SIS fixation. SP fixation alone did not fully restore the stability of the posterior pelvic ring compared with an uninjured pelvis (11). Metz *et al.* tested ten cadaver specimens, but only seven survived the test protocol of 550 N load and 500 000 test cycles. APC II injuries were induced via complete transection of the pubic symphysis and the sacrospinous, sacrotuberous, and anterior sacroiliac ligaments. A bipedal stance model was used to measure the movement of the pubic symphysis. No significant differences between SP and SP-SIS were detectable (10). Simonian *et al.* used five cadaver specimens and evaluated the stability of intact pelvises with different fixation techniques. A bilateral stance test was performed with a load of up to 1000 N. Gapping motions of the pubic symphysis and the sacroiliac joints as well as flexion of the sacrum was measured. The use of additional SIS fixation improved stability but did not show significant statistical differences to isolated SP fixation and was weaker in uninjured pelvises (12). In another study by Simonian *et al.*, the authors examined the sequence of instability by dissecting the ligaments of the posterior pelvic ring and examining different treatment options for restoring stability. They concluded that SP fixation did not affect sacroiliac motion, that SIS fixation decreased sacroiliac motion, and that the combined treatment yielded the greatest stability (13). Van den Bosch *et al.* directly compared SP and SP+SIS fixation in six cadaver specimens and found no difference between the groups, with both fixation options being unable to restore full pelvic stability (14). In Lipphaus *et al.*'s finite element analysis, a CT-based model of a healthy pelvis was created, and ligaments were modeled as tension strings. Additional SIS fixation improved stability but could not restore full strength (15).

Clinical studies

Of the six included clinical studies, two were retrospective case series (16, 19), and four were retrospective cohort studies (17, 18, 20, 21). All were published between 2004 and 2021 in Germany, India, Pakistan, the UK, and the USA. Only one study was a comparative trial (17), and all others consisted of one study group. The studies investigated a total of 272 patients with a mean age of 38 years, 84% of whom were male. However, only 242 patients had an APC II/B2.3d injury, as illustrated in Table 4. Three studies also included other injuries: Aggarwal *et al.* included APC I ($n = 1$) and APC III ($n = 5$) injuries (16), Putnis *et al.*

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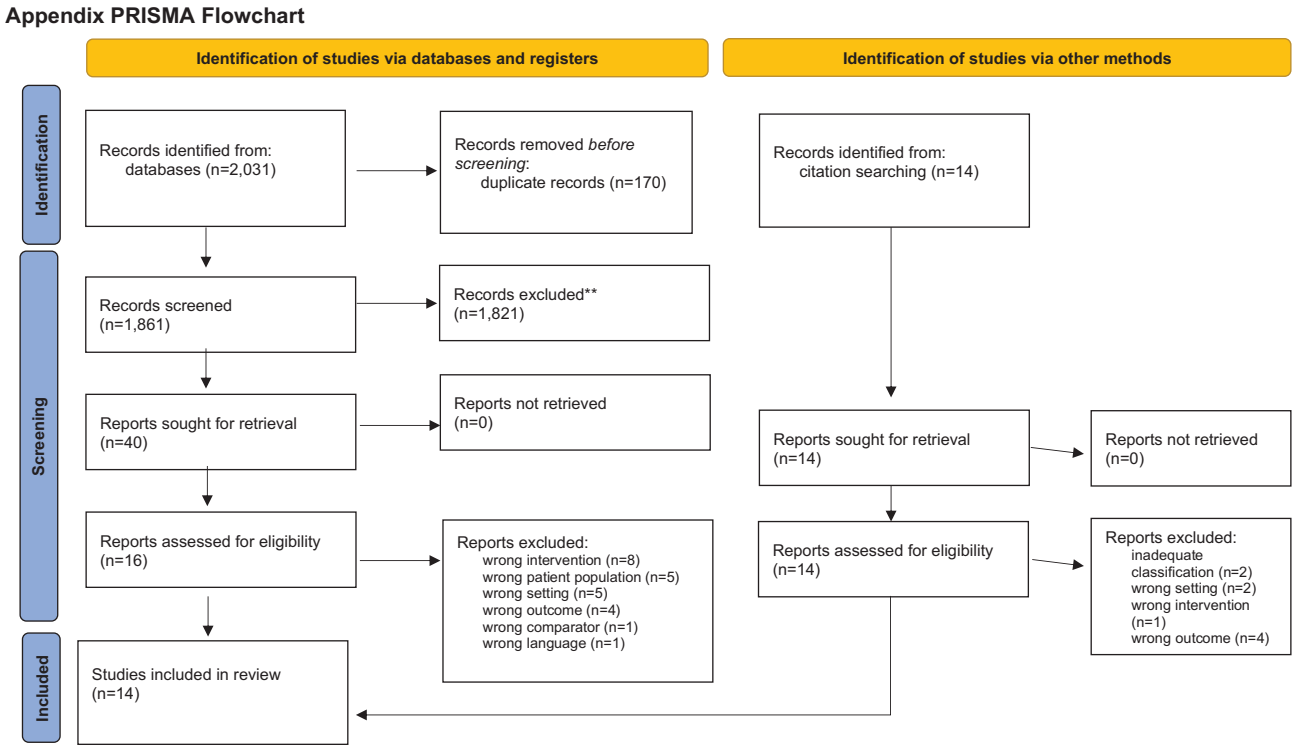

Figure 1

PRISMA flowchart.

included APC III ($n = 11$) and LC ($n = 6$) injuries (18), and van Loon *et al.* included B1.2 injuries ($n = 9$) (20). One hundred twenty-six patients (45%) were treated using SP fixation, and 116 (55%) were treated using SP+SIS fixation. Aggarwal *et al.* analyzed outcome parameters in patients treated with SP fixation ($n = 13$) for APC II injuries (16). In 2016, Avilucea *et al.* published the largest study, which included 134 patients, 92 (69%) of whom received SP+SIS fixation and 42 (31%) of whom received isolated SP fixation (17). Phieffer *et al.* evaluated 13 patients with APC II injuries treated with SP fixation alone. A push–pull test was used to differentiate between APC II and APC III (19). Putnis *et al.* examined 32 patients, and posterior stabilization was used for displacement >1 mm at the sacroiliac (18). Sahito *et al.* evaluated 19 patients with five SP + SIS and 14 SP fixations (21). Van Loon *et al.* identified 31 patients with APC II injuries, 25 (80%) of whom had SP fixation and six (20%) of whom SP+SIS fixation (20). The anterior fixation technique varied in some of the above-mentioned clinical studies. Several studies used two perpendicular plates instead of one, which may also explain some of the observed heterogeneity between studies.

Primary outcomes

Implant failure

All included studies measured implant failure (16, 17, 18, 19, 20, 21). Of the 242 total patients, 6 had plate/implant failures, 23 had screw breakouts, 13 had broken

Table 2 Study characteristics of included surveys.

				Favored treatment	
Survey	**Participants, *n***	**Specification**	**Country**	**SP**	**SP+ISS**
Gill *et al.* (9)	38	63% treated >20 fractures per year	UK	14 (37%)	24 (63%)
Moed *et al.* (8)	176	Surgeons with 3–35 years of practice mostly worked at level 1 trauma centers	International	99 (56%)	77 (44%)
Total	214			113 (53%)	101 (47%)

SP, symphyseal plate; SP + ISS, symphyseal plate and sacroiliac screw.

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Table 3 Characteristics of included biomechanical studies.

Study	Year	Country	Cadavers, *n*	Test setup	Study protocol		SP fixation†	Benefit of SIS fixation
					Load, N	Cycles		
Dujardin *et al.* (11)	2001	France	6	Axial compression, unilateral stance	310	Single	No	Yes
Metz *et al.* (10)	2018	USA	10*	Axial compression, bilateral stance	550	500 000	Ø	No
Simonian *et al.* (12)	1994	USA	5	Axial compression, bilateral stance	Up to 1000	3	No	No
Simonian *et al.* (13)	1994	USA	6	Axial compression, bilateral stance	Up to 400	3	No	Yes
Van den Bosch *et al.* (14)	2003	Netherlands	6	Axial compression, unilateral stance	Up to 900	3	No	No
Lipphaus *et al.* (15)	2021	Germany	None	Finite element study	–		No	Yes
Total			32				No	Yes: 3; No: 3

*Three specimens failed; †SP fixation restored intact pelvic stability (i.e. symphyseal plating restored the stability of pelvic ring adequately in the uninjured pelvis).
SP, symphyseal plate; SIS, sacroiliac screw.

screws, 10 had loose screws, and 19 had broken plates. Two studies with a total of 183 patients compared patients with SP fixation alone with those with SP+SIS (17, 18). Of the 62 patients with SP fixation, 24 (38.7%) and 13 (10.7%) in the group of SP+SIS with a total of 121 patients displayed some form of implant failure. In Avilucea *et al.*'s study, fixation failed in five patients (5.4%) in the SP+SIS group and in 17 patients (40.5%) in the SP group. Malunion occurred in one patient (1%) in the SP + SIS group and in 15 patients (35.7%) in the SP group (17). Aggarwal *et al.* demonstrated excellent quality of reduction in one patient (7.6%), good quality of reduction in six patients (46.2%), fair quality of reduction in four patients (30.8%), and poor quality of reduction in two patients (15.4%), with implant failure in three patients (23.1%) (16). Phieffer *et al.* found one radiographic plate failure, two patients with screw backouts, and one patient with malunion (19).

Health-related quality of lifeTwo studies investigated hrQoL (18, 20). Putnis used the Short Form 12 (SF-12) questionnaire, and van Loon used the Short Form 36 (SF-36) questionnaire. While these instruments were not used to assess hrQoL, both studies used them to assess their patients' function. For the 41 total patients who had completed the questionnaire, Putnis found that their mental health was comparable to that of the average population without injury (49.5 points vs 50 points) and that their physical health was lower than that of the average population (42.5 points vs 50 points) but did not reach statistical significance. The authors also revealed that patients who had undergone revision surgery (*n* = 3) scored significantly lower (physical score: 34.2; mental score: 44.8) than the rest of the cohort. Notably, this included patients with APC III injuries (*n* = 11) and lateral compression injuries (*n* = 6) (18). Van Loon revealed that their patients with B1.1 (now classified as 61-B2.3d) fractures (*n* = 25) had an average general health score of 61 points, an average mental health score of 69 points, and an average physical function score of 70 points. The authors compared these results with those of the general uninjured

Table 4 Characteristics of included clinical studies.

Study	Year	Country	Study type	Patients†, *n*	Patients/treatment		Mean age, years	Average FU*	LOE‡
					SP	SP+SIS			
Aggarwal *et al.* (16)	2011	India	RCS	13	13		42	2.9 years	IV
Avilucea *et al.* (17)	2016	USA	RCH	134	42	92	39	7.2 months	III
Phieffer *et al.* (19)	2004	USA	RCS	13	13		28	Ø	IV
Putnis *et al.* (18)	2011	UK	RCH	32	19	13	Ø	1 year	IV
Sahito *et al.* (21)	2021	Pakistan	RCH	19	14	5	38	6 months	IV
Van Loon *et al.* (20)	2011	Germany	RCH	31	25	6	Ø	7 years	IV
Summary				242	126 (52%)	116 (42%)	38	6 months–7 years	III = 1; IV = 5

Complication = fixation failure. Complications include surgical revision and significant implant failure.
*Follow-up is always reported for the entire cohort and sometimes also includes injuries other than APC II; ‡Oxford Centre for Evidence-Based Medicine 2011 Levels of Evidence; †Patients with APC II / B2.3d injuries.
FU, follow-up; LOE, level of evidence; RCS, retrospective case series; RCH, retrospective cohort; SP, symphyseal plate; SP+SIS, symphyseal plate and sacroiliac screw.

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German population (*n* = 304), who scored 69, 76, and 90 points, respectively (20).

Revision rate

All six studies reported on revision surgeries (16, 17, 18, 19, 20, 21). Of the 242 total patients, 11 (4.3%) had a revision surgery – five due to loss of reduction (18, 19), four due to implant failure (16, 20), and two due to malunion (17). In Sahito *et al.*'s study, no patient required revision surgery (21). In the studies investigating SP and SP+SIS fixations, usually, only patients with sole SP required revision. In Putnis *et al.*'s study, all four patients (12.5%) who required revision had only an SP fixation (18). Van Loon *et al.* reported on one patient (3.2%) who required revision of the SP+SIS fixation (20). In Avilucea *et al.*'s study, the fixation technique of the two patients who required revision is unknown (17).

Secondary outcomes

Fixation success

Only two of the included studies – which included a total of 51 (38 SP+SIS/13 SP) patients – reported successful fixations (16, 20). Of these 51 patients, 36 (70.6%) showed successful fixation. Van Loon *et al.* reported 26 successful fixations in their SP-SIS patients after a mean of 7 years post-operatively. However, it is important to note that for van Loon *et al.*'s study, this number may have included patients with B1.2 injuries with sacral fixation because the authors did not report results for B1.1 injuries separately (20). In Aggarwal *et al.*'s study, ten of 13 patients with SP fixation showed successful fixation after a mean of 2.9 years of follow-up (16).

Return to workOnly van Loon *et al.* reported on their patients' return to work, which included 27 of 38 patients (72%) in the follow-up period. This number also included patients with B1.2 fractures as described above (20).

PainTwo studies – which included a total of 63 patients – reported on pain in their study cohort (18, 20). Van Loon *et al.* reported a median pain level of 1 (range: 0–6.9) on the visual analog scale in the group of B1.1 patients with SP+SIS fixation (20). Putnis *et al.* reported that 37% of their patients were free of pain, but that 7% (three patients) were still experiencing severe pain at 1 year follow-up. However, it is unclear which fixation technique the patients had received because the authors included SP, SP+SIS unilateral, and SP+SIS bilateral fixations but did not report on patients based on the technique used (18).

Length of hospital stayTwo of the included studies reported the LOS (20, 21). Sahito *et al.* reported a mean of 6.57 (±1.89) days of hospital stay (21), whereas van Loon *et al.* reported a median of 18 days, with an interquartile range of 13–34 days. However, this figure also included patients with a B1.2 injury (*n* = 9) (20).

Other adverse events

Five studies – which included a total population of 230 patients (including nine with B1.2 fractures) – reported 24 (8.7%) other adverse events in total (16, 17, 18, 19, 20). Eight general complications occurred, including pneumonia and urinary tract infections. Ten were local complications, such as superficial wound infections. Moreover, van Loon *et al.*'s study reported four men with impotence 2 years post-operatively (20). Both Putnis *et al.*'s and Phieffer *et al.*'s studies reported that none of their patients had a wound infection (18, 19). Furthermore, Phieffer *et al.* reported that none of their patients had deep vein thrombosis (19). Separate information on adverse events by fixation technique was not provided.

MINORS assessment in clinical studies

The MINORS assessment is shown in Fig. 2. Avilucea *et al.*'s comparative study received 13 of 24 possible

	Aggarwal et al.	Avilucea et al.	Phieffer et al.	Putnis et al.	Shaito et al.	Van Loon et al.
1. Clearly stated aim	1	2	1	2	2	2
2. Inclusion of consecutive patients	1	2	1	2	2	2
3. Prospective collection of data	0	1	0	1	1	0
4. Endpoint appropriate for study aim	0	1	0	2	1	2
5. Unbiased assessment of study endpoint	0	0	0	1	1	2
6. Follow-up period appropriate for study aim	0	2	0	2	2	2
7. Loss to follow-up less than 5%	1	0	0	2	0	1
8. Prospective calculation of study size	0	0	0	0	0	0
Additional criteria in case of comparative study						
9. Adequate control group		2				
10. Contemporary group		2				
11. Baseline equivalence of groups		1				
12. Adequate statistical assessment		2				
Total	**3 / 16**	**13 /24**	**2 / 16**	**12 / 16**	**9 / 16**	**11 16**

Legend: low risk of bias = green; moderate risk of bias= yellow; high risk of bias = red

Figure 2

Overview of MINORs assessment (16, 17, 18, 19, 20, 21).

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points and was therefore considered to have a moderate risk of bias (17). In particular, this study had problems with endpoint assessment, the prospective calculation of the study size, and loss to follow-up, which were mostly due to missing information.

All other studies averaged a score of 7.4 out of 16 possible points (range: 2–12 points). Two studies scored three points or fewer and were thus regarded as having a high risk of bias (16, 19). One study was assessed with nine points and regarded as having a moderate risk of bias. The two remaining studies scored 11 and 12 points, respectively, and were regarded as having a low risk of bias (18, 20). The prevailing issue involved insufficient reporting; hence, most studies lost points due to missing information. No study reported on the prospective calculation of study size, and few studies reported on loss to follow-up or on how outcomes were assessed.

Publication bias

Publication bias was not assessed because only six clinical studies could be included, and the statistical power of the funnel plot was therefore insufficient to indicate any such bias.

Discussion

The present systematic review evaluated the evidence of SP and SP+SIS fixation in APC II injuries. The identified evidence was partly at a high risk of bias and low reporting quality. Furthermore, most of the studies were either biomechanical or non-comparative retrospective studies, which hindered our ability to understand the value of SP+SIS or SP in the treatment of APC II injuries. The available studies indicated that SP+SIS may have the potential to improve outcomes related to implant failure, revision surgery, and fixation success. However, the evidence was too weak to draw reliable recommendations. Our systematic review additionally found no reliable evidence for evaluating pain, hrQoL, return to work, LOS, or other adverse events. A comparison of results was also not possible because ours is the first comprehensive systematic review of SP+SIS fixation in APC II injuries.

The two included surveys were helpful in understanding the proportional distribution of the preferred treatment but yielded no further evidence. The different testing methods impeded a comparison of the biomechanical studies. Parameters – including the test setups (unilateral and bilateral stances), applied loads, and number of repetitive cycles – varied. The analyzed biomechanical studies were unable to yield a definitive treatment recommendation.

Limitations of clinical studies were mentioned, and no specific treatment algorithm could be drawn. The choice of fixation technique in the studies was subject to surgeon preference or departmental policy. Reported complications may have indicated various problems (e.g. implant failure, malunion, hematoma, or infection) and were not clearly separated from revision surgery in most studies. It is additionally important to consider the fact that implant failure did not necessarily yield poor functional outcome or poor general health in affected patients (22, 23).

It is imperative that future studies clearly identify APC II injuries. Iliosacral joint disruption should be viewed as a spectrum of instability that affects not only the anterior sacroiliac ligament but also the entire ligamentous sacroiliac complex. Other stabilizing components of the posterior pelvic ring include the iliolumbar, interosseous, and posterior sacroiliac ligaments, as well as pelvic floor components such as the sacrotuberous and sacrospinous ligaments. Rupture of the sacrospinous, sacrotuberous, or interosseous ligaments has been reported to increase instability (11, 13, 24, 25). Initial radiographs and CT scans are static images that do not always reflect the complete ligamentous injury or the degree of instability. Intraoperative stress testing of the pelvis under fluoroscopy may help in identifying the dynamic component of the anterior–posterior compression injury, which can aid in detecting occult instabilities as these instabilities can be missed by radiographs and CT scans. Moreover, push–pull examinations and MRI may help in identifying the injured structures of the sacroiliac complex (26, 27).

Other related clinical studies were excluded because diverse types of posterior ring injuries hindered detailed analysis (24, 25, 26). One biomechanical study was excluded because the posterior pelvic ring had been stabilized with plates instead of with sacroiliac screw fixation (28).

The high number of studies found via hand search suggests a risk according both to Morton *et al.*'s principles and to those outlined in the PRISMA guidelines (5, 29).

Conclusion

Ours is the first systematic review to investigate the treatment of APC II injuries with SP or SP+SIS fixation. No reliable evidence was found to support either SP or SP+SIS as the treatment of choice. The reviewed clinical data suggest that SP+SIS could reduce implant failure, revision surgery rates and could improve fixation success in APC II pelvic ring injuries. However, further studies – particularly comparative ones (interventional and observational) – are needed.

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Key points

The ideal surgical management of APC type II open-book pelvic injuries remains unclear.

Currently, no high-level evidence exists that supports the routine use of additional sacroiliac screw fixation to stabilize the injured posterior pelvic ring.

Prospective randomized clinical trials in a multi-center setting are needed to gain greater insight into the harms and benefits of the existing surgical treatment strategies.

Supplementary materials
This is linked to the online version of the paper at https://doi.org/10.1530/EOR-23-0173.

ICMJE Conflict of Interest Statement
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