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ORIGINAL ARTICLE

Operative Treatment of Sacral Fractures with Traumatic Spino-Pelvic Dissociation: A Systematic Review and Meta-analysis

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ABSTRACT

Background:
The therapy of sacral fractures accompanied by traumatic spino-pelvic dissociation (SPD) poses considerable problems owing to the intricate nature of the injuries and the diverse surgical procedures available. Two principal fixation techniques, iliosacral fixation and posterior pelvic fixation, are frequently utilized. The comparative results and complication rates between various methods remain ambiguous.

Methods: A systematic review and meta-analysis were performed to evaluate outcomes, complication rates, and intraoperative parameters (including blood loss and operation duration) between iliosacral fixation and posterior pelvic fixation. Research conducted from 2001 to 2024 was located by an exhaustive search of databases such as PubMed, Embase, Scopus, and Google Scholar. Data from pertinent studies were retrieved and analyzed utilizing Review Manager (RevMan version 5.4.1). Odds ratios (ORs) and standardized mean differences (SMD) with 95% confidence intervals (CIs) were computed to assess the outcomes.

Results: A total of 13 papers were incorporated in the meta-analysis, contrasting the Ilio-sacral and Posterior pelvic fixation cohorts. The pooled analysis indicated no statistically significant difference in complication rates between the two groups (OR: 0.64 [0.27, 1.51], p = 0.30), exhibiting low to moderate heterogeneity (I^2 = 29%). Furthermore, there was no notable difference in overall outcomes between the two groups (OR: 0.64 [0.27, 1.51], p = 0.30). The results demonstrated that Posterior pelvic fixation resulted in markedly reduced intraoperative blood loss (SMD: −6.11 [−9.32, −2.89], p = 0.0002) in comparison to Ilio-sacral fixation.

Conclusions: Both Ilio-sacral fixation and Posterior pelvic fixation offer comparable outcomes and complication rates in the surgical management of sacral fractures with SPD. Nonetheless, posterior pelvic fixation seems to correlate with markedly decreased intraoperative blood loss. The selection between these two fixation techniques should depend on the therapeutic setting and individual patient characteristics, as no definitive advantage in outcomes was observed.

Key Words: Sacral fractures, Spino-pelvic dissociation, Posterior pelvic fixation, Complications, Blood loss

INTRODUCTION:

Sacral fractures, especially those linked to traumatic spino-pelvic dissociation, pose a considerable problem in orthopedic trauma surgery. The sacrum is essential for the structural stability of the pelvic ring and the transfer of weight between the spine and lower limbs. Injuries in this region, especially with spino-pelvic dissociation, frequently necessitate surgical intervention due to the intricate forces at play and the risk of neurological impairment [1]. Traumatic spino-pelvic dissociation, characterized by the disruption of continuity between the spine and pelvis, requires a specialized therapeutic strategy. The surgical management generally entails spinopelvic fixation, which aids in reinstating stability to the impacted area. Research indicates that percutaneous iliosacral screw fixation is advisable in the absence of spino-pelvic dissociation, offering sufficient stabilization without requiring open surgical intervention. In proven cases of dissociation, spinopelvic fixation is favored for its enhanced efficacy in preserving alignment and guaranteeing long-term stability [2].

Sacral fractures are intricate injuries that frequently necessitate surgical intervention, particularly when linked to pelvic ring disturbances or spino-pelvic dissociation. The treatment strategy differs according to the degree of the fracture, its stability, and any concomitant ailments. Commonly utilized surgical methods for the management of sacral fractures encompass:

Posterior Pelvic Stabilization: This method stabilizes the posterior pelvic ring, essential in instances with considerable instability. It is frequently employed alongside anterior pelvic fixation when the anterior pelvic ring is also impaired [3].Modified Triangular Osteosynthesis: This method employs a rod and pedicle screw system for vertically unstable sacral fractures, ensuring superior post-operative stability. Research indicates that this technique has favorable outcomes, with the majority of patients attaining satisfactory to superior fracture reduction and stable bone union without additional problems [4].

Percutaneous sacroplasty is an efficient minimally invasive procedure for less severe fractures, including sacral insufficiency fractures. This technique substantially reduces pain, typically within 48 hours post-surgery [5].

Sacroiliac arthrodesis can serve as a successful treatment for chronic and substantially displaced fractures, facilitating robust fusion and substantial pain alleviation without the necessity for fracture reduction [6].Sacral fractures accompanied by traumatic spino-pelvic dissociation (SPD) are a distinct and serious class of pelvic injuries. SPD is often defined by the presence of transverse and sagittal fracture lines in the sacrum, leading to a mechanical separation of the spine from the pelvis. These fractures are frequently underdiagnosed due to their intricacy, although they can result in significant functional deficits if not addressed swiftly.Timely identification and diagnosis of SPD are essential, since postponed or overlooked diagnoses might deteriorate the patient's prognosis. Such injuries frequently lead to significant instability, necessitating prompt surgical intervention. Treatment generally entails spinopelvic fixation, which has demonstrated superior results in stabilizing pelvic vertical instability and restoring functionality. Research repeatedly demonstrates that spinopelvic fixation yields favorable to superior radiological and functional outcomes in patients with vertically unstable pelvic fractures accompanied by spino-pelvic dissociation [7].

Notwithstanding the surgical success, complications including infection and wound issues persist as a difficulty. Consequently, appropriate surgical precautions and postoperative management are vital to mitigate these risks and facilitate a good recovery [8].This study aims to evaluate the results of several surgical treatment methods for sacral fractures linked to traumatic spino-pelvic dissociation (SPD) as documented in the English language literature. The study seeks to elucidate significant disputes in the management of these intricate injuries by evaluating the results and measuring treatment efficacy. This study will consolidate existing information to suggest a streamlined treatment strategy, providing doctors with a realistic guidance for surgical decision-making in patients of sacral fractures accompanied by spino-pelvic dissociation.

METHODS

The Institutional Review Board (IRB#10779) of Zagazig University accepted the protocol for this systematic review and meta-analysis in April 2023. The review adheres to known protocols for systematic reviews in surgical operations, assuring ethical compliance.

Eligibility criteria: A comprehensive review of studies published from 2001 to 2022 was undertaken, concentrating on the surgical management of sacral fractures associated with traumatic spino-pelvic dissociation (SPD). The inclusion criteria comprised all case reports, case series, and clinical studies in the English literature pertaining to the operational therapy of SPD. Studies were excluded based on the following criteria: irrelevant topics, duplicate studies, inaccessible full texts (abstract-only papers), animal or biomechanical research, studies involving patients under 18 years, reports addressing non-traumatic fractures or lumbosacral dislocations, non-English publications, and studies on sacral fractures not linked to SPD.

A systematic evaluation was performed to assess and compare different surgical interventions and fixation techniques for sacral fractures associated with sacropelvic dissociation (SPD). Subsequent to data gathering, a meta-analysis was scheduled for studies encompassing randomized controlled trials (RCTs), utilizing the Review Manager software (RevMan version 5.4.1).

Search strategy

The literature search was performed across many databases, including MEDLINE (via PubMed), EMBASE, SCOPUS, and Google Scholar. The subsequent keywords were employed in the search: "Sacral fracture," "Spinopelvic dissociation," "Lumbopelvic dissociation," "Suicidal Jumper's fracture," "U-shaped sacral fractures," "H-shaped sacral fracture," "Lumbopelvic fixation," "Triangular fixation," "Treatment strategy," "Systematic review," and "Meta-analysis."

The study selection process occurred in two phases:

Screening of titles and abstracts: Following the identification of potentially relevant studies from the database search, abstracts were retrieved and evaluated for eligibility according to the inclusion and exclusion criteria.

Comprehensive evaluation: The whole texts of the selected papers were obtained for thorough analysis. Each paper was evaluated independently by multiple reviewers, and any inconsistencies were reconciled through consensus. Supplementary studies were obtained from the references of the included articles, while irrelevant or duplicate research were eliminated.

Data Extraction and Quality Assessment:

Data were systematically extracted utilizing a pre-established data extraction form in Excel.

Data extracted comprised: Author, title, publishing type, and country of origin.

Study attributes: Design, objectives, randomization methods, quality evaluation, and bias risk assessment.

Characteristics of participants: Patient count, age, gender, injury mechanism, concomitant injuries, and neurological impairments.

Intervention and therapeutic modalities: Information regarding surgical interventions, associated complications, follow-up periods, and results.

The quality of the included studies was evaluated using suitable checklists instead of quality scores to guarantee a rigorous methodological assessment. The danger of bias and the quality of the study were rigorously evaluated to ascertain the validity of the findings.

Data synthesis encompassed both qualitative and quantitative analyses:

Qualitative analysis: Systematic reviews lacking adequate data for meta-analysis were subjected to qualitative analysis, summarizing results and deriving conclusions.

Quantitative analysis: A meta-analysis was conducted utilizing standardized statistical methodologies where applicable. Effect sizes were computed to enable comparison across several trials, and outcomes were standardized to maintain consistency.

Results were visually represented through forest plots and funnel plots, facilitating the evaluation of heterogeneity and possible publication bias.

The results were analyzed within a therapeutic framework, yielding evidence-based recommendations for surgical intervention and fixation methods in patients with sacral fractures and sacropelvic dissociation. This phase encompassed the synthesis of results, assessed through intraoperative metrics (e.g., duration of surgery, hemorrhage), complication frequencies (e.g., infection, wound dehiscence), radiological findings (e.g., sacral fracture kyphosis angle, sacro-coccygeal angle, and pelvic incidence), neurological assessments (e.g., Gibbons score) and Clinical outcome (Majeed functional score).

The findings of the meta-analysis are to assist physicians in making informed judgments on surgical procedures and underscore the implications for future research and clinical practice.

RESULTS:

The PRISMA flow chart illustrates the thorough procedure of discovering, screening, and choosing papers for our systematic review and meta-analysis.

Identification Phase: In the initial step, 1,200 records were identified, comprising 1,000 obtained from diverse databases: PubMed (400 records), Embase (200 entries), Google Scholar (150 records), and Scopus (250 records). Furthermore, an additional 200 documents were uncovered from alternative sources. Following the elimination of duplicates (600 records), 1,100 records were retained for screening.

Screening Phase: The screening phase commenced, during which the studies were evaluated for relevance. Following a preliminary assessment, 1,000 studies were removed for being either irrelevant to the research topic, comprising solely abstracts, or lacking accessible full texts. This exclusion reduced the selection to 100 reports designated for further retrieval.

Eligibility Phase: Out of the 100 reports, 80 were effectively retrieved and evaluated for eligibility. Nevertheless, 67 papers were omitted according to defined exclusion criteria. The compilation comprised 10 studies centered on animal and biomechanical research, 12 studies involving patients under 18 years of age, 13 studies investigating non-traumatic sacral fractures, 14 studies published in non-English languages, 10 studies addressing lumbosacral dislocations, and 30 studies concentrating on sacral fractures unrelated to traumatic spino-pelvic dissociation. Furthermore, 20 reports were not obtained for additional examination, presumably due to access issues or absent data.

Inclusion Phase: Following comprehensive screening and assessment, 13 studies were ultimately incorporated into the systematic review and meta-analysis. These studies specifically focused on the surgical management of sacral fractures associated with traumatic spino-pelvic dissociation, in accordance with the study's inclusion criteria.

This meticulous method guaranteed the inclusion of just the most pertinent and high-caliber research in the final analysis, establishing a dependable basis for your systematic review. The flow chart emphasizes the meticulous methodology employed to sift through extensive data while highlighting the deliberate application of inclusion and exclusion criteria, thereby maintaining a concentration on studies pertinent to sacral fractures associated with traumatic spino-pelvic dissociation.

This meta-analysis table consolidates data from various studies examining the surgical management of sacral fractures associated with spino-pelvic dissociation (SPD). The table delineates essential data regarding patient demographics, injury mechanisms, concomitant injuries, and fracture classifications from multiple studies, offering an extensive summary of the affected populations and the characteristics of their injuries.

Patient Demographics

The examined studies encompass the period from 2006 to 2024, with sample sizes varying from 6 to 212 patients. The aggregated data reveal that the mean patient age across studies is 35.76 years (± 10.02). The gender distribution indicates that 59.81% of the patients are male and 40.19% are female, demonstrating a modest male predominance in sacral fractures with SPD. Nonetheless, a study by Katharina et al. [16] concentrated on an older demographic, with a mean age of 62.64 years, in contrast to other studies that included younger participants, potentially indicating divergent research emphases or patient selection procedures.

Injury Mechanism

The injury mechanism in these instances is primarily attributed to Road Traffic Accidents (RTA) and Falls From Height (FFH). In the aggregated investigations, 44.60% of injuries were from road traffic accidents (RTAs), whereas 55.40% were attributed to falls from height (FFH), underscoring the substantial impact of high-energy trauma on these fractures. Certain investigations, such as Tian et al. [19], indicated an even greater prevalence of FFH patients (88.88%), hence underscoring the influence of falls on the occurrence of sacral fractures associated with SPD. This disparity in injury mechanisms may indicate geographical or population-specific trauma patterns.

Complications with Pelvic Ring Fractures

A significant percentage of patients, 61.20%, presented with concomitant injuries, which frequently complicate the clinical care and prognosis of sacral fractures. In Sean et al. [9], an impressive 94.50% of patients exhibited concomitant injuries, highlighting the complexity and severity of the cases analyzed in this study. Furthermore, 88.90% of patients in the aggregated data presented with pelvic ring fractures, typically linked to high-energy traumatic incidents. The prevalence of pelvic ring fractures in a significant proportion of patients complicates the surgical management and long-term rehabilitation of these injuries.

Fracture Distribution and Roy Camille Classification

The table delineates the distribution of sacral fractures among different spinal levels. The most often impacted levels are S1-S2, with 61.50% of patients exhibiting fractures at this site. Conversely, more distal fractures (e.g., S3-S4 or S4-S5) are far rarer, including fewer than 1% of occurrences in the aggregated analysis.

The Roy Camille classification, which categorizes transverse sacral fractures according to displacement, was employed to evaluate the fractures in the research. Type 3 fractures were the most prevalent, accounting for 36.70% of the cases, followed by Type 2 at 28.60%. This classification aids in assessing the degree of the displacement and informs treatment choices, especially with the necessity for surgical intervention.

Morphological Classification

The morphological classification of fractures indicated that U-shaped fractures were the most prevalent, comprising 52.60% of cases. These fractures are frequently intricate, encompassing both vertical and horizontal elements, rendering them very difficult to manage. H-shaped fractures were the second most prevalent kind, occurring in 38.40% of instances. Y, L, and C-shaped fractures were significantly rarer, each constituting less than 7% of the aggregate occurrences. The distribution of various fracture configurations underscores the complexity and variety of sacral fractures associated with SPD, demanding tailored treatment techniques.

Meta-analysis results

Operation times

The forest plot illustrates a comparison of operative durations between two surgical cohorts: Ilio-sacral fixation (LPF group) and Posterior pelvic fixation (PPF group) across multiple trials. This plot assesses if one surgical method necessitates significantly less time than the alternative.

The forest plot indicates that, although individual studies such as Elhabashy et al. [17] demonstrate reduced operation times for the Posterior pelvic fixation group, the comprehensive meta-analysis does not show a statistically significant difference in operation time between the Ilio-sacral fixation and Posterior pelvic fixation techniques. The pooled odds ratio indicates that, on average, both surgical methods exhibit comparable operation durations. The minimal to moderate variation among the studies reinforces the reliability of these findings across various research environments.

Blood loss

The forest plot contrasts blood loss between two surgical techniques: Ilio-sacral fixation and Posterior pelvic fixation across many trials. The objective is to ascertain if there exists a major disparity in blood loss during surgery between these two groups.

The forest plot demonstrates compelling evidence that posterior pelvic fixation is linked to significantly reduced blood loss in comparison to ilio-sacral fixation throughout the trials analyzed. Notwithstanding the considerable variation, the overall effect size is substantial and statistically significant. Bleeding was significantly higher among cases managed by posterior LPF at all studies

Complication

The forest plot juxtaposes the complication rates of the Ilio-sacral fixation group (LPF group) with those of the Posterior pelvic fixation group across multiple studies. The aim is to evaluate if a statistically significant difference exists in the incidence of complications between the two surgical methods.

This forest plot indicates that there is no statistically significant difference in complication rates between the iliosacral fixation and posterior pelvic fixation groups based on the aggregated data. Although isolated studies, such as Elhabashy et al. [17], indicate a markedly reduced complication rate in the Posterior group, the comprehensive study fails to provide a definitive superiority of one surgical method over the other. The low to moderate heterogeneity suggests that the results are very consistent among the research considered. Additional research or larger sample sizes may be required to conclusively determine if one strategy results in fewer issues than the other.

Outcome

The forest plot you provided compares the outcomes of the Ilio-sacral fixation group (LPF group) with those of the Posterior pelvic fixation group across several studies. This investigation seeks to determine whether one surgical treatment produces better outcomes than another.

The forest plot reveals no observable or statistically significant difference in overall outcomes between the Ilio-sacral fixation and Posterior pelvic fixation groups, based on the combined data from the included trials. Although certain studies, such as those by Katharina et al. [16] and Meghan et al. [20], indicate significant inequalities favoring particular groups, the overall analysis does not establish a definitive advantage of one technique over another.

The low to moderate variability indicates that the results throughout the studies are consistent, hence reinforcing the conclusion that both fixation approaches produce equal outcomes. This suggests that the choice between iliosacral fixation and posterior pelvic fixation may be determined by factors such as surgeon preference, patient-specific characteristics, or the therapeutic context, rather than a clear superiority in outcomes.

Table 1: Patient Demographics and Mechanism of Injury data according to 13 studies were deemed suitable for inclusion in the systematic review and meta-analysis

Study	N	AGE	SEX		Mechanism of injury		Associated injuries	Pelvic ring fracture
			Male	Female	RTA	FFH		
Lindahl et al. [9]	36	30.55±5.36	50.00%	50.00%	10%	27.75%	33%	100%
Sean et al. [10]	13	35.96±8.74	50.00%	50.00%	46.10%	53.84%	94.50%	69%
Gribnau et al. [11]	8	29.63±4.85	37.50%	62.50%	0%	100%	100%	62.50%
Jeffrey et al. [12]	31	41.29±9.64	64.50%	35.50%	20%	80%	58%	37.10%
Nonne et al. [13]	28	33.61 ± 8.23	60.70%	39.30%	60.70%	39.30%	51.20%	100%
Mouhsine et al. [14]	6	30.44 ± 6.55	83.30%	16.70%	16.70%	83.30%	NA	57.14%
Schildhauer et al. [15]	18	31.23 ± 8.87	55.60%	44.40%	52.63%	47.36%	63,15 %	52%
Katharina et al. [16]	125	62.64 ± 14.98	62.30%	37.70%	65%	35%	NA	100%
Elhabashy et al. [17]	54	NA	NA	NA	70%	30%	NA	100%
Romoli et al. [18]	20	43.71 ± 13.26	50.00%	50.00%	40%	60%	NA	100%
Tian et al. [19]	18	33.1 ± 1.4	77.77%	22.22%	11.11%	88.88%	83.30%	NA
Meghan et al. [20]	16	46.5 ± 20.4	31.25%	68.75%	31.25%	68.75%	56.00%	63%
Rovere et al. [21]	212	37.66 ±15.5	65.30%	34.70%	65.50%	34.50%	32.00%	86.30%
Pooled		35.76 ± 10.02	59.81%	40.19%	44.60%	55.40%	61.20%	88.90%

Table 2: Fracture Distribution and Roy Camille Classification and Morphological Classification data according to 13 studies were deemed suitable for inclusion in the systematic review and meta-analysis

Study	N	transverse sacral fracture injuries						Roy Camille classification (Trasverse Sacral # displacement)				Morphological Classification				
		S1-2	S2	S2-3	S3	S3-4	S4-5	Type1	Type2	Type3	Type4	U	H	Y	L	C
Lindahl et al. [9]	36	41.60%	44.40%	8.30%	5.50%	0%	0%	0%	41.60%	58.40%	0%	0%	100%	0%	0%	0%
Sean et al. [9]	13	100%	0%	0%	0%	0%	0%	7.60%	61.50%	30.70%	0%	100%	0%	0%	0%	0%
Gribnau et al. [10]	8	75%	0%	25%	0%	0%	0%	12.50%	25%	62.50%	0%	100%	0%	0%	0%	0%
Jeffrey et al. [12]	31	NA	NA	NA	NA	NA	NA	41.90%	0%	0%	58.10%	100%	0%	0%	0%	0%
Nonne et al. [13]	28	67.90%	32.10%	NA	NA	NA	NA	0%	46.50%	53.50%	0%	50%	50%	0%	0%	0%
Mouhsine et al. [14]	6	NA	NA	NA	NA	NA	NA	0%	0%	57.10%	42.90%	0%	42.90%	0%	0%	57.10%
Schildhauer et al. [15]	18	71.50%	28.50%	0%	0%	0%	0%	0%	47.30%	31.50%	20.80%	15.70%	73.6%t	10.70%	0%	0%

Katharina et al. [16]	125	NA	NA	NA	NA	NA	NA	48%	33.70%	0%	18.30%	0%	100%	0%	0%	0%
Elhabashy et al. [17]	54	55.50%	22.25%	22.25%	0%	0%	0%	50%	20%	30%	0%	46.30%	53.70%	0%	0%	0%
Romoli et al. [18]	20	NA	NA	NA	NA	NA	NA	0%	10%	90%	0%	50%	50%	0%	0%	0%
Tian et al. [19]	18	NA	NA	NA	NA	NA	NA	0%	67.70%	33.30%	0%	55.60%	33.30%	11.10%	0%	0%
Meghan et al. [20]	16	NA	NA	NA	NA	NA	NA	31.20%	56.20%	12.50%	0%	50%	50%	0%	0%	0%
Rovere et al. [21]	212	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Pooled		61.50%	30.10%	7.30%	1.10%	0.00%	0.00%	20.50%	28.60%	36.70%	14.20%	52.60%	38.40%	3.50%	0.00%	6.50%

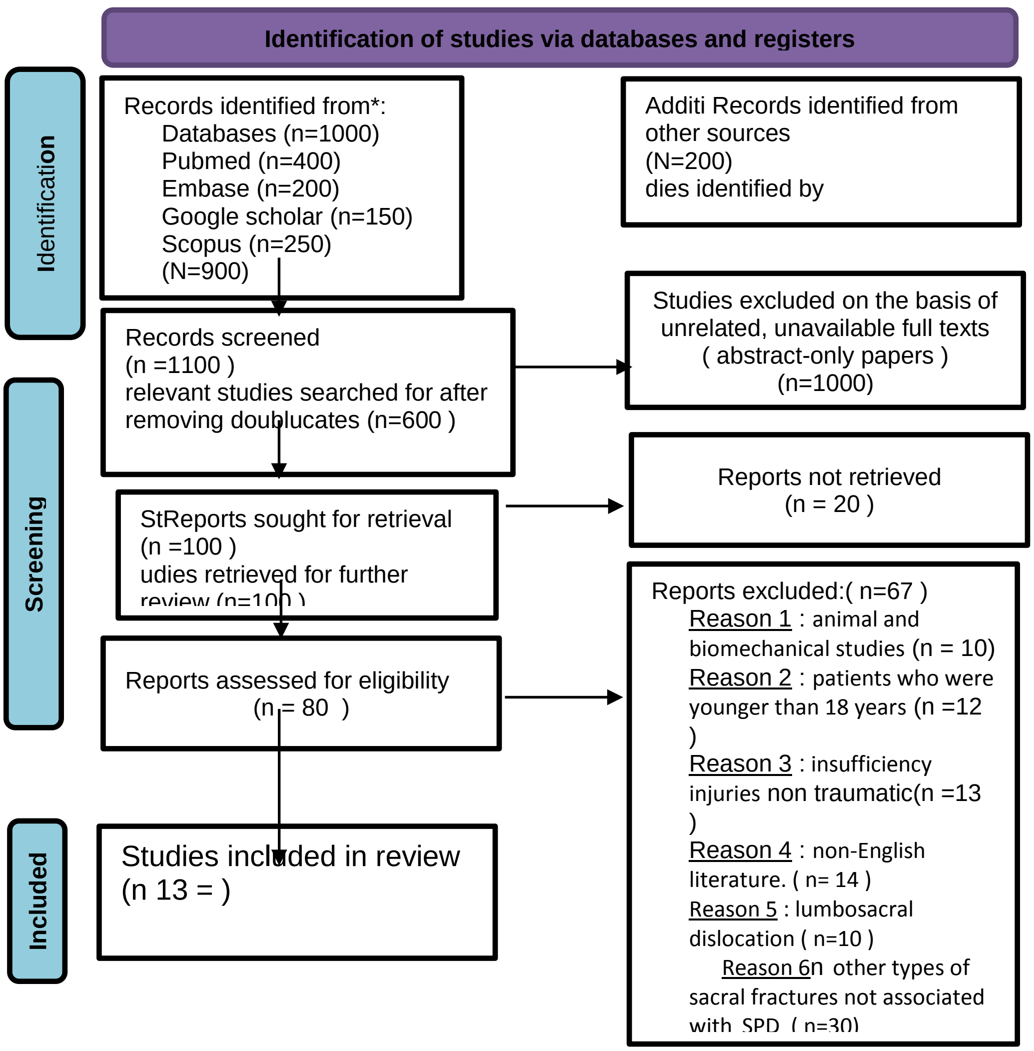


Figure 1: Prisma flow chart

	Ilio-sacral Group		Posterior Group			
Study or Subgroup	**Event**	**total**	**Event**	**total**	**Weight**	**M-H, Random, 95%CI**
Elhabashy et al. [17]	2	30	8	24	19.20%	0.14 [0.03, 0.76]
Rovere et al. [21]	0	0	86	212		Not estimable
Gribnau et al. [10]	0	8	0	0		Not estimable
Jeffrey et al. [12]	13	16	10	15	19.50%	2.17 [0.42, 11.30]
Katharina et al. [16]	8	77	8	48	33.80%	0.58 [0.20, 1.66]
Lindahl et al. [9]	0	36	0	0		Not estimable
Meghan et al. [20]	1	16	0	0		Not estimable
Nonne et al. [13]	0	0	20	28		Not estimable
Mouhsine et al. [14]	2	6	0	0		Not estimable
Romoli et al. [18]	2	6	4	14	14.00%	1.25 [0.16, 9.76]
Schildhauer et al. [15]	2	9	3	9	13.60%	0.57 [0.07, 4.64]
Sean et al. [9]	2	13	0	0		Not estimable
Tian et al. [19]	0	0	0	18		Not estimable
Elhabashy et al. [17]	2	30	8	24	19.20%	0.14 [0.03, 0.76]
Total (95% CI)		138		110	100%	0.64 [0.27, 1.51]
Total Event	27		33			
Heterogeneity: Tau^2= 0.28; Chi^2 = 5.66, df = 4 (P = 0.23); I^2 = 29%						
Test for Overall effect: Z = 1.03 (P = 0.30)						

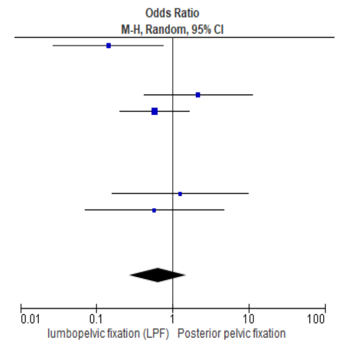


Figure 2: Forest plot of Operation time distribution between Groups among all studies

	Ilio-sacral Group			Posterior Group				
Study or Subgroup	**Mean**	**SD**	**Total**	**Mean**	**SD**	**Total**	**Weight**	**M-H, Random, 95%CI**
Elhabashy et al. [17]	105	21	30	320	86	24	37.20%	-3.60 [-4.48, -2.71]
Jeffrey et al. [12]	165	26	16	550.5	61	15	32.10%	-8.18 [-10.47, -5.89]
Romoli et al. [18]	125.2	25	6	450	50	14	30.70%	-6.98 [-9.58, -4.39]
Total (95% CI)			52			53	100%	-6.11 [-9.32, -2.89]
Heterogeneity: Tau^2 = 7.03; Chi^2 = 17.40, df = 2 (P = 0.0002); I^2 = 89%								
Test for Overall effect: Z = 3.72 (P = 0.0002)								

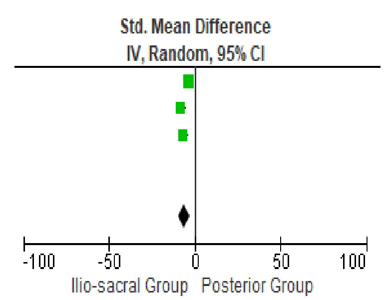


Figure 3: Forest plot of Blood loss distribution between Groups among all studies

	Ilio-sacral Group		Posterior Group			
Study or Subgroup	**Event**	**total**	**Event**	**total**	**Weight**	**M-H, Random, 95%CI**
Elhabashy et al. [17]	2	30	8	24	19.20%	0.14 [0.03, 0.76]
Rovere et al. [21]	0	0	86	212		Not estimable
Gribnau et al. [10]	0	8	0	0		Not estimable
Jeffrey et al. [12]	13	16	10	15	19.50%	2.17 [0.42, 11.30]
Katharina et al. [16]	8	77	8	48	33.80%	0.58 [0.20, 1.66]
Lindahl et al. [9]	0	36	0	0		Not estimable
Meghan et al. [20]	1	16	0	0		Not estimable
Nonne et al. [13]	0	0	20	28		Not estimable
Mouhsine et al. [14]	2	6	0	0		Not estimable
Romoli et al. [18]	2	6	4	14	14.00%	1.25 [0.16, 9.76]
Schildhauer et al. [15]	2	9	3	9	13.60%	0.57 [0.07, 4.64]
Sean et al. [9]	2	13	0	0		Not estimable
Tian et al. [19]	0	0	0	18		Not estimable
Elhabashy et al. [17]	2	30	8	24	19.20%	0.14 [0.03, 0.76]
Total (95% Cl)		138		110	100%	0.64 [0.27, 1.51]
Total Event	27		33			
Heterogeneity: Tau^2= 0.28; Chi^2 = 5.66, df = 4 (P = 0.23); I^2 = 29%						
Test for Overall effect: Z = 1.03 (P = 0.30)						

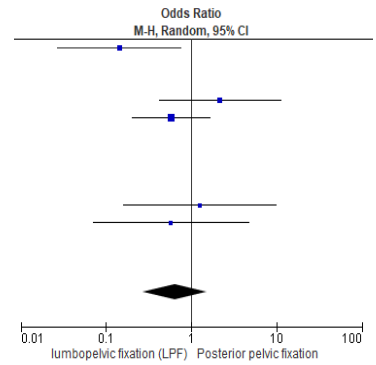
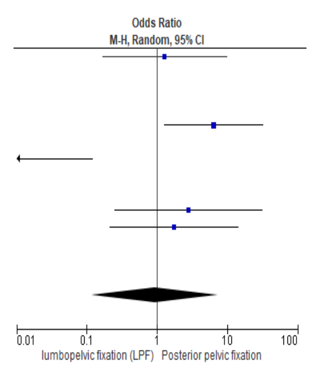


Figure 4: Forest plot of Complication distribution between Groups among all studies

	Ilio-sacral Group		Posterior Group			
Study or Subgroup	**Event**	**total**	**Event**	**total**	**Weight**	**M-H, Random, 95%CI**
Elhabashy et al. [17]	28	30	22	24	20.90%	1.27 [0.17, 9.77]
Rovere et al. [21]	0	0	0	212		Not estimable
Gribnau et al. [10]	4	8	0	0		Not estimable
Jeffrey et al. [12]	0	16	0	15		Not estimable
Katharina et al. [16]	75	77	41	48	22.60%	6.40 [1.27, 32.25]
Lindahl et al. [9]	30	36	0	0		Not estimable
Meghan et al. [20]	0	16	14	16	16.50%	0.01 [0.00, 0.12]
Nonne et al. [13]	0	0	18	28		Not estimable
Mouhsine et al. [14]	4	6	0	0		Not estimable
Romoli et al. [18]	5	6	9	14	19.40%	2.78 [0.25, 30.91]
Schildhauer et al. [15]	7	9	6	9	20.70%	1.75 [0.22, 14.22]



Sean et al. [9]	10	13	0	0		Not estimable
Tian et al. [19]	0	0	0	18		Not estimable
Total (95% CI)		217		384	100.0%	0.92 [0.12, 7.32]
Total events	163		110			
Heterogeneity: Tau² = 4.26; Chi² = 18.13, df = 4 (P = 0.001); I² = 78%						
Test for overall effect: Z = 0.08 (P = 0.94)						

Figure 5: Forest plot of Outcome distribution between Ilio-sacral Group and Posterior Group among all studies

DISCUSSION

Our study aim to review the outcome of operative treatment modalities of sacral fracture with traumatic spino-pelvic dissociation in the English language literature, to discuss critical treatment controversies and to analyze the available literature to propose a simple treatment algorithm.

Our meta-analysis was performed after data extraction process. After application of inclusion and exclusion criteria, thirteen eligible studies were included in this review from 2001 to 2023 to compare the percutaneous SI screw fixation with Traditional L-P fixation open method. After analyzing the included studies, we had pooled the available data to define the appropriate method of fixation.

Nonsurgical Treatment

There is little evidence-based literature to recommend the indications for or to present the outcomes of nonoperative management. [22] recommend nonsurgical management if the patient cannot tolerate surgery or will be non-weight-bearing or bedbound for at least 3 months. In such cases, an inferior vena cava filter should be strongly considered. Furthermore, if the sagittal deformity is,20°, nonoperative treatment may be considered. However, in the majority of cases, the goal is early and stable internal fixation to allow for early weight-bearing to minimize the risks of pulmonary complications and decubitus ulceration associated with prolonged recumbency [22].

By comparing the pooled data from the eligible 13 studies between the two groups ,Group 1 including all cases managed by with (Indirect Reduction +Indirect Decompression + per cutaneous ISS fixation) and Group 2 including all cases managed with (open Direct Reduction +-open Direct Decompression + LP fixation or TOS) regard to blood loss during operation, the overall effect was found to be significant towards the open S-P technique as it had more blood loss than percutaneous IS screw method where $p < 0.0001$ where it is statistically significant. But the pooled data from these different studies showed high heterogeneity and this may be due to the different protocols and strategies used in management in these patients.

This could be explained by the small stabbing incisions, lack of extensive soft tissue dissection and the reduced need for drains postoperatively in the percutaneous SI screw technique. All these factors minimize the need for transfusions and decrease morbidity and economic burdens.

Pearson et al. [12] conducted a comparison between percutaneous fixation and open reduction internal fixation (ORIF) for spinopelvic dissociation, revealing a considerable disparity in blood loss. Percutaneous fixation yielded an average blood loss of 171 cc, while the open method resulted in 538 cc ($p = 0.0013$). Their results corroborate your findings that percutaneous techniques significantly reduce intraoperative blood loss.

Williams and Quinnan [23] indicated that percutaneous lumbopelvic fixation for sacral fractures exhibiting spinopelvic dissociation patterns seeks to mitigate sequelae, including hemorrhage. Their research substantiated the advantages of minimally invasive methods for this category of injury.

Operative time:

By comparing the pooled data from the eligible 13 studies between the two groups with regard to the time taken during operation, the overall effect was found to be significant towards the open S-P Fixation technique as it had more time than percutaneous I-S Screw method where $p < 0.0001$ where it is statistically significant. But the pooled data from these different studies showed high heterogeneity and this may be due to the different protocols and strategies used in management in these patients.

This could be explained on basis of extensive muscle and periosteal dissection, retraction, more time for hemostasis and excess time expenditure to identify anatomical landmarks for proper screw entry point in the open technique. All these causes of long operative time are absent in the percutaneous technique. Fluoroscopy throughout the percutaneous approach also facilitates the identification of ideal landmarks for screw insertion. Nork et al. [10] indicated that the percutaneous I-S screw approach is advantageous for patients who cannot withstand the blood loss associated with a more extensive open treatment or who have significant soft-tissue injury over the sacrum.

Regarding Functional outcome:

By comparing the pooled data from eligible 13 studies between the two groups with regard to neurological outcome (Gibbons Score) and clinical grading (Majeed functional scores), the overall effect was found to be similar between the percutaneous IS screw and L-P fixation where it is statistically significant and there was substantial heterogeneity between these 10 studies

Lindahl et al. [9] identified multiple characteristics that predict the eventual outcome of spinopelvic dissociations treated with a standardized lumbopelvic fixation approach and neural decompression. From the results, the following conclusions can be drawn: The Roy-Camille grading system for transverse sacral fractures is not applicable for assessing the prognosis of neurological damage. Neurological healing and clinical outcomes were correlated with the extent of initial translational displacement of the transverse sacral fracture. Permanent neurological impairments occurred more frequently in patients with complete transverse sacral fracture displacement than in those with partially displaced sacral fractures. The quality of reduction for residual postoperative translational displacement and kyphosis of the transverse sacral fracture was correlated with the clinical outcome.

Elhabashy et al. [17] reported that LPF and ISF exhibit similar safety and efficacy in individuals with sacral fractures. ISF is a superior and secure fixation technique, particularly in the elderly, to mitigate difficulties associated with open surgery. LPF is favored in young, active patients to facilitate quick weight-bearing post-surgery and in instances of unclear sacral anatomy, such as sacral dysmorphism.

Regarding complication rate

By comparing the pooled data from eligible 13 studies between the two groups with regard to post-operative complications the overall effect was found to be similar between the percutaneous IS screw and L-P fixation where it is statistically significant and there was substantial heterogeneity between these 10 studies

Schildhauer et al. [15] observed that complications associated with lumbopelvic fixation included wound-related issues such as infection, hemorrhage, and seroma, as well as complications linked to screw prominence.

CONCLUSIONS

Both Ilio-sacral fixation and Posterior pelvic fixation offer comparable outcomes and complication rates in the surgical management of sacral fractures with SPD. Nonetheless, posterior pelvic fixation seems to correlate with markedly decreased intraoperative blood loss. The selection between these two fixation techniques should depend on the therapeutic setting and individual patient characteristics, as no definitive advantage in outcomes was observed.

At the end of this study, we recommend the following:

Awareness not only of the surgical anatomy but also the radiological and fluoroscopic anatomy of the Lumbosacral Spine is crucial in better outcomes and little complications of any pedicle procedure especially the minimally invasive ones. Early Identification and Fixation of SPD is important to prevent Compilation. Evaluating percutaneous fixation as a minimally invasive procedure in patients with bleeding tendencies (e.g. hemophilia) is essential to try decreasing morbidity and mortality among this critical group of patients. Further studies to evaluate the combination of percutaneous ISS fixation with other procedures are essential e.g. decompression and S-P fixation to have more beneficial clinical outcomes.

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