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Surgical Management of Unstable Pelvic Fractures in Yemen: A Prospective Cohort Study of Functional Outcomes and Complications

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Abstract

Background: Unstable pelvic fractures are severe injuries resulting from high-energy trauma that often led to significant morbidity and mortality. Surgical management aims to restore stability and improve functional outcomes; however, data from conflict-affected regions such as Yemen are scarce. This study aimed to prospectively evaluate the functional outcomes and complications of the surgical management of unstable pelvic fractures in a Yemeni patient cohort.

Methods: This prospective cohort study was conducted at the Military General Hospital and Al-Thawra Modern General Hospital in Sana'a, Yemen, between April 2019 and April 2023. We enrolled 76 patients aged 16–60 years with unstable pelvic ring fractures that required surgical intervention (Tile type B/C). Data on patient demographics, mechanism of injury, fracture classification (Tile and Young-Burgess), surgical approach, and complications were collected and analyzed. Anatomical reduction was assessed using the Matta and Tornetta criteria, respectively. Functional outcomes were evaluated using the Majeed scoring system at a mean follow-up of four years.

Results: The mean patient age was 34 years, and the majority of patients were male (68.4%). The most frequent mechanisms of injury were motorcycle accidents (30.3%) and car accidents (27.6%), followed by falls from a height (26.3%). According to the Tile classification, the most frequent fracture patterns were C2 (36.8%) and C1 (34.2%). Postoperative radiological assessment revealed excellent reduction in 69.7% of patients. The overall complication rate was 30.3%, with wound infections (9.2%) being the most common. According to the Majeed Functional Outcome Score, 63.2% of the patients achieved excellent results. Statistical analysis revealed a significant positive correlation between the quality of radiological reduction and final functional outcomes ($p < 0.05$).

Conclusion: Surgical management of unstable pelvic fractures in the challenging setting of Yemen can yield good-to-excellent functional outcomes. Despite resource limitations, anatomical reduction and stable fixation lead to satisfactory results, although complication rates remain a concern. This study highlights the feasibility and effectiveness of modern orthopedic trauma care in conflict zones.

Article Info

Keywords:
Pelvic Fractures, Surgical Fixation , Functional Outcome, Trauma, Yemen, Majeed Score

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1. INTRODUCTION

Unstable pelvic ring fractures represent one of the most formidable challenges associated with orthopedic trauma. Typically resulting from high-energy mechanisms such as motor vehicle collisions or falls from a height, these injuries are frequently observed in polytraumatized patients [1]. They are associated with a high risk of life-threatening hemorrhage and multiorgan failure in the acute phase, with mortality rates reported to be between 5% and 16% [2, 3]. Patients who survive an initial in-

sult often face significant long-term morbidity, including chronic pain, limb length discrepancy, gait dysfunction, neurological deficits, and urogenital complications, which can profoundly affect their quality of life and ability to return to work [4]. The cornerstone of the management of unstable pelvic fractures is the restoration of the anatomical integrity and mechanical stability of the pelvic ring [5]. Although stable fractures may be managed nonoperatively, surgical intervention is the established standard of care for rotationally and vertically unstable fractures (Tiles B and C) [6]. The primary goals of operative fixation are to achieve anatomical reduction and provide sufficient stability to allow for early patient mobilization, thereby reducing complications associated with prolonged recumbency, such as thromboembolism and pneumonia [7]. Numerous studies have demonstrated that successful surgical stabilization, particularly with anatomical reduction, leads to superior long-term functional outcomes, reduced pain, and a higher rate of return to pre-injury activities than nonoperative care [8].

Surgical techniques for pelvic stabilization have evolved significantly, with a modern emphasis on methods that minimize soft tissue disruption while providing robust fixation. Techniques such as percutaneous iliosacral screw fixation [9], minimally invasive plate osteosynthesis (MIPO), and the use of anterior subcutaneous internal fixators (INFIX) [10] have been developed to reduce iatrogenic injury, decrease blood loss, and lower infection rates compared to traditional extensive open approaches. However, the success of these procedures relies heavily on advanced imaging, specialized instrumentation, and a highly experienced surgical team.

Despite these advances, a significant disparity exists in the available literature, which is predominantly derived from well-resourced trauma centers in high-income countries (HICs). Prospective data on the outcomes of modern pelvic fracture surgery in low- and middle-income countries (LMICs), a gap that is particularly acute in regions affected by armed conflict [11]. Yemen has endured a prolonged humanitarian crisis that has severely fragmented its healthcare system. Trauma care in this setting is fraught with challenges, including delayed patient presentation, a high burden of complex polytrauma, and significant limitations in the availability of surgical implants, advanced imaging, and postoperative rehabilitation services [12]. These factors can critically influence the feasibility of surgical intervention and the ultimate patient outcome.

Therefore, the primary objective of this study was to prospectively evaluate the functional outcomes, radiological results, and complications of the surgical management of unstable pelvic fractures in a cohort of Yemeni patients. We hypothesized that, despite the austere clinical environment and resource limitations, adherence to established surgical principles could achieve satisfactory functional outcomes and complication rates approaching international benchmarks. This study aimed to provide crucial, context-specific evidence to guide clinical practice and resource allocation for orthopedic trauma care in conflict-affected regions of the world.

2. MATERIALS AND METHODS

2.1. Study Design and Setting

This prospective cohort study evaluated the clinical and radiological outcomes of patients with surgically managed unstable pelvic ring fractures. The study was conducted at two major public trauma referral centers in Sana'a, Yemen: the Military General Hospital and Al-Thawra Modern General Hospital. The recruitment and follow-up periods spanned four years (April 2019–April 2023).

2.2. Study Participants and Eligibility

The target population comprised adult patients with unstable pelvic ring fractures who required surgical stabilization.

2.2.1. Inclusion Criteria:

1. Age between 16 and 60 years
2. Diagnosis of an unstable pelvic ring fracture (classified as Tile Type B or C)
3. Specific fracture patterns requiring stabilization include tetra-pubic rami fractures, superior and inferior pubic rami fractures on one side with posterior pelvic ring disruption, and unilateral vertical unstable/rotationally unstable fractures.

2.2.2. Exclusion Criteria:

1. Age outside the specified range (16–60 years)
2. Non-traumatic pelvic ring instability (e.g., pathological fractures or tumors)
3. Stable pelvic ring fractures (Tile Type A)
4. Penetrating pelvic injuries (e.g., gunshot wounds)
5. Pregnancy
6. Symphyseal disruption was managed nonoperatively in non-emergency cases, and 76 patients who met the inclusion criteria were enrolled in the study.

2.3. Variables and Preoperative Assessment

Data were collected prospectively using standardized forms. The key variables collected were as follows:

- Demographics: Age, sex, and mechanism of injury (e.g., Motor Vehicle Accident, Fall from Height, Pedestrian).
- Clinical Status: Hemodynamic stability on admission (presence of shock), documentation of all associated injuries, and baseline neurological status

- Fracture Classification: Each injury was classified using the Tile classification (to characterize stability: A, B, C) and Young-Burgess classification (to characterize the mechanism: LC, APC, VS, CMI).
- Radiological evaluation included standard plain radiographs (Anteroposterior, Inlet, and Outlet views) and a Computed Tomography (CT) scan with 3D reconstruction for precise assessment of posterior injury.

2.4. Surgical Management Protocol

Initial patient management strictly adhered to the Advanced Trauma Life Support (ATLS) protocols [13]. The mean time from injury to definitive internal fixation was eight days. The choice of surgical approach was individualized based on the fracture pattern.

Anterior pelvic fixation was performed using a modified Stoppa approach in 23 patients and a suprapubic (Pfannenstiel) approach in 9 patients. Posterior pelvic fixation was managed via closed reduction with percutaneous screws (TSIF) in seven patients and open reduction internal fixation (sacroiliac approach) in three patients. A combined anterior and posterior approach was used in 34 patients. All patients received prophylactic broad-spectrum antibiotics and postoperative chemical thromboprophylaxis.

2.5. Outcome Assessment and Follow-up

Patients were followed up clinically and radiographically at 2, 6, 12, and 24 weeks and annually thereafter for up to three years, yielding a mean follow-up of four years.

- **Radiological outcome:** anatomical quality of reduction was assessed using postoperative standard radiographs (AP, inlet, and outlet views). Reduction quality was graded using the Matta and Tornetta criteria based on the maximal residual displacement: excellent ($\leq$ 4 mm), good (4–10 mm), fair (10–20 mm), and poor ($>$ 20 mm).
- **Functional Outcome:** The primary outcome was evaluated at the final follow-up using the validated Majeed Scoring System[14], which assesses five domains: pain, standing, sitting, sexual intercourse, and work/gait performance. The scores were categorized as Excellent, Good, Fair, and Poor.
- **Complications:** Early (e.g., infection, iatrogenic nerve/vessel injury, and DVT/PE) and late (e.g., malunion, post-traumatic arthritis, and hardware failure) complications were meticulously recorded throughout the follow-up period.

2.6. Statistical Analysis

Data were analyzed using IBM SPSS Statistics. Continuous variables are presented as mean $\pm$ standard deviation (SD), and categorical variables are reported as frequencies (n) and percentages (%). Inferential statistics were used to identify prognostic factors. A Chi-square test was performed to analyze the association between the quality of radiological reduction (Matta/Tornetta criteria) and the final functional outcome (Majeed Score). Statistical significance was set at $P < 0.05$.

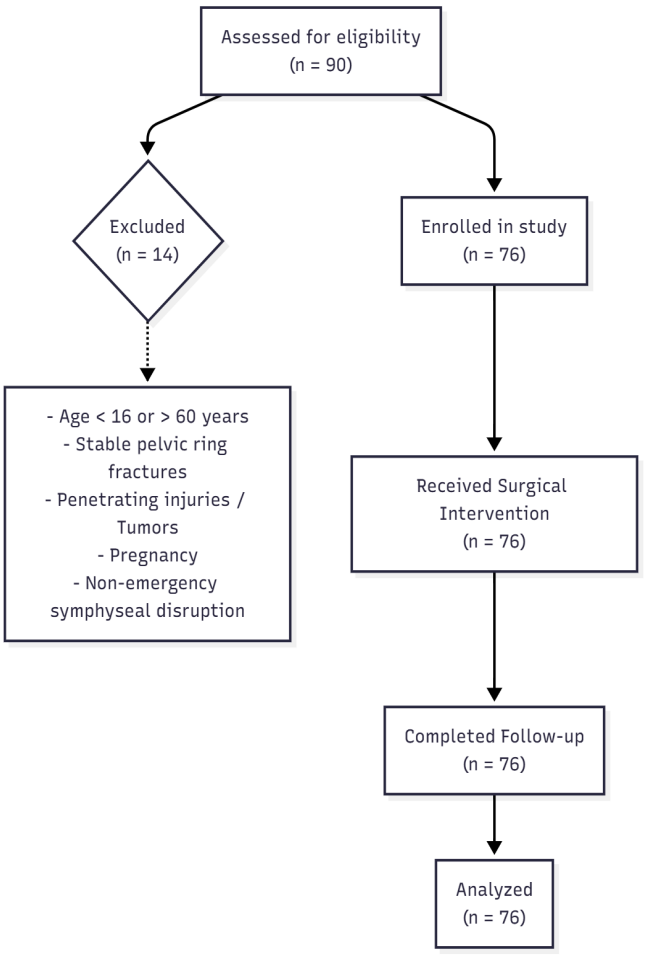

Figure 1. Flow diagram of patient recruitment. (Total assessed: 90; excluded: 14 due to age >60 years, stable fractures, or penetrating injury; enrolled: 76).

3. RESULTS

Of the 90 patients assessed for eligibility, **76** with unstable pelvic ring fractures were enrolled in this study **(Figure 1)**. All patients completed the follow-up period, which averaged over four years.

3.1. Patient Characteristics and Injuries

The average age of the patients was 34 years (range, 16–60 years). The majority of patients were male (52, 68.4%). All injuries were caused by high-energy trauma. The most frequent causes were motorcycle accidents (n=23, 30.3%), car accidents (n=21, 27.6%), and falls

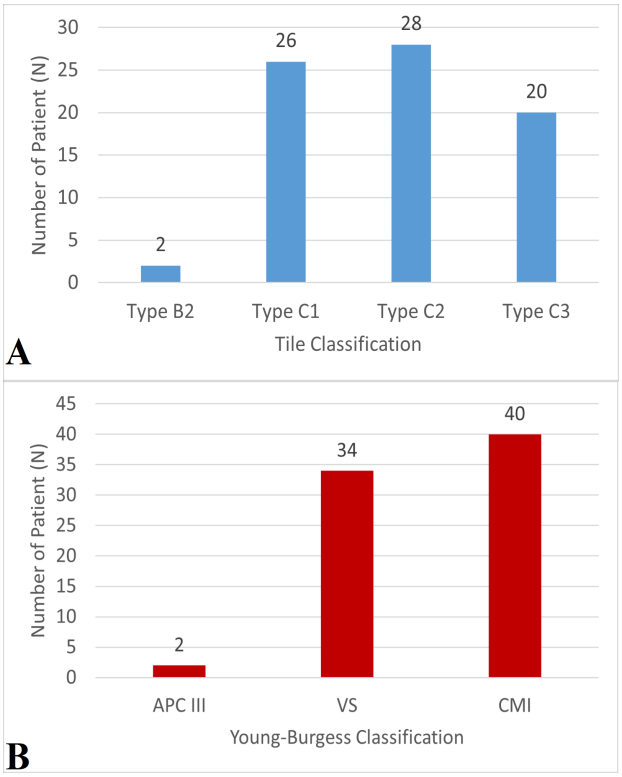

Figure 2. *Distribution of unstable pelvic fracture patterns in the study cohort (N=76). (A) Tile Classification showing the frequency of stability patterns, with bilateral unstable (Type C2) and unilateral unstable (Type C1) fractures being the most common. (B) Young-Burgess Classification illustrating the mechanism of injury, with Combined Mechanical Injury (CMI) and Vertical Shear (VS) patterns accounting for the majority of cases.*

from heights (n=20, 26.3%). Upon arrival at the hospital, 18 patients (23.7%) experienced hypovolemic shock that required immediate stabilization.

3.2. Fracture Types

All fractures were classified as unstable and fell into the Tile Type B or C categories (Figure 2). The most common pattern was Type C2 (bilateral unstable), which occurred in 28 patients (36.8%), followed by Type C1 (unilateral unstable), which occurred in 26 patients (34.2%). According to the Young-Burgess classification, the most prevalent injury type was Combined Mechanical Injury (52.6%), followed by Vertical Shear injuries (44.7%), which underscores the extreme forces involved in trauma.

3.3. Surgical Procedures and Reduction Quality

Surgery was performed after a mean delay of eight days. Anterior fixation alone was performed in 32 (42.1%) patients, whereas isolated posterior fixation was performed in 10 (13.2%) patients. A combined anterior and posterior approach was required in 34 patients (44.7%) (Table 1) (Figure 3).

Table 1. Distribution of Surgical Approaches and Fixation Techniques (N=76).

Surgical Approach	Specific Technique	N	%
Anterior Fixation Only		**32**	**42.1%**
	Modified Stoppa Approach	23	30.3%
	Suprapubic (Pfannenstiel) Approach	9	11.8%
Posterior Fixation Only		**10**	**13.2%**
	Closed Reduction (Percutaneous Screws)	7	9.2%
	Open Reduction (Plating/Sacroiliac)	3	4.0%
Combined Fixation		**34**	**44.7%**
	Anterior & Posterior Combined	34	44.7%
Total		**76**	**100%**

The quality of the surgical reduction was assessed radiologically. Excellent reduction, defined as less than 4 mm of residual displacement, was achieved in 53 patients (69.7%) at the final follow-up. Good reduction (4–10 mm displacement) was achieved in 18 patients (23.7%). Only five patients (6.6%) showed a fair reduction (10–20 mm displacement). None of the patients showed poor reduction (Table 2).

3.4. Complications

A total of 23 patients (30.3%) experienced at least one complication (Table 3). The most common early complication was wound infection, which occurred in seven patients (9.2%), with two patients having deep infections. Intraoperative vascular injury affecting major vessels, such as the corona mortis or pelvic veins, was reported in five patients (6.6%). Urological injuries (bladder or urethra) were sustained in three patients (4.0%) and were repaired during the initial surgery. Neurological deficits related to surgery or injury were noted in four patients (5.3%). Two patients (2.6%) developed thromboembolic events (DVT and PE).

Late complications included posttraumatic arthritis of the hip in two patients, hardware-related issues in three patients (maldirected screws or broken plates), and a single case of pelvic pseudoarthrosis and heterotopic ossification.

3.5. Functional Outcome

Functional outcomes were evaluated at the final four-year follow-up using the Majeed scoring system. The results indicated favorable outcomes for the majority of

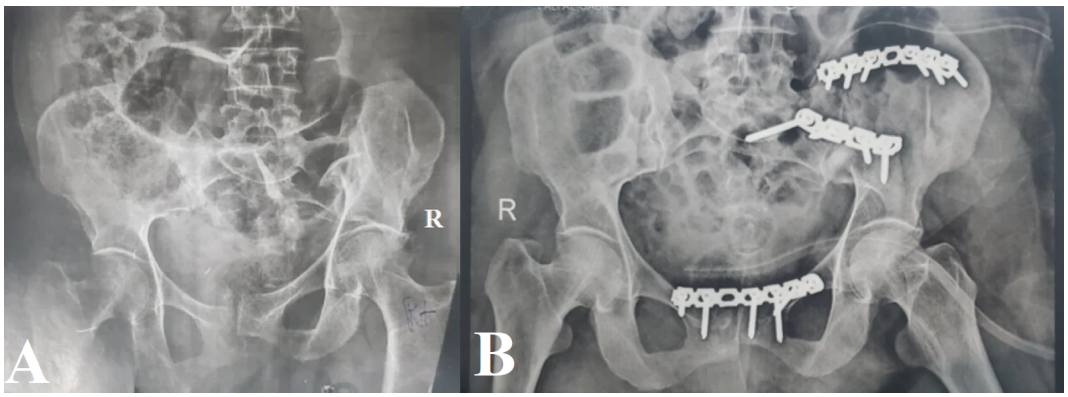

Figure 3. *Radiographs of a representative complex case (Tile Type C injury) in a 50-year-old female. (A) Preoperative antero-posterior (AP) radiograph showing significant displacement of the pelvic ring with bilateral pubic ramus fractures and sacroiliac disruption. (B) Postoperative inlet view radiograph demonstrating anatomical reduction and stable fixation achieved using anterior plating and posterior iliosacral screw fixation.*

Table 2. Postoperative Radiological Reduction Assessment (Matta and Tornetta Criteria) (N=76)

Reduction Grade	Maximal Displacement	N	%
Excellent	$\leq$ 4 mm	53	69.7%
Good	4-10 mm	18	23.7%
Fair	10-20 mm	5	6.6%
Poor	$>$ 20 mm	0	0.0%

Table 3. Early and Late Postoperative Complications (N=76)

Complication Category	N	%
Total Patients with $\geq$ 1 Complication	**23**	**30.3%**
Early Complications (Acute Phase)		
Wound Infection (Total)	7	9.2%
Vascular Injury (Intraoperative)	5	6.6%
Neurological Injury (New/Worsened)	4	5.3%
Urological Injury (Bladder/Urethra)	3	4.0%
Thromboembolism (DVT/PE)	2	2.6%
Late Complications		
Post-Traumatic Arthritis (Hip)	2	2.6%
Hardware Pitfall (Mal direction/Breakage)	3	4.0%
Pelvic Pseudoarthrosis/Nonunion	1	1.3%
Heterotopic Ossification (Myositis)	1	1.3%

patients: 48 (63.2%) achieved an excellent score, and 20 (26.3%) achieved a good score. This means that nearly 90% of the patients had good or excellent functional results. Six patients (7.9%) were graded as fair, and two patients (2.6%) had poor functional outcomes, which were attributed to the severity of their initial vertical shear injuries (Figure 4). Inferential statistical analysis revealed a significant association between the surgical reduction quality and functional outcomes. Patients who achieved "Excellent" or "Good" radiological reduction were significantly more likely to achieve "Excellent" or "Good" Majeed functional scores compared to those with "Fair" reduction ($p < 0.05$).

3.6. Relationship between Reduction and Outcome

We analyzed the relationship between radiological reduction quality and final functional outcomes. Postoperative radiographic assessment identified five patients with "Fair" reduction (10–20 mm displacement). Notably, clinical follow-up revealed that these patients still achieved "Good" functional scores according to the Majeed system. This indicates that while anatomical reduction remains the surgical goal, satisfactory functional recovery is achievable even with mild residual displacement, provided that pelvic stability is restored. Consequently, in this specific cohort, perfect anatomical reduction was not the sole prerequisite for favorable functional outcome.

4. DISCUSSION

This prospective cohort study represents one of the first comprehensive evaluations of surgical outcomes for unstable pelvic fractures in conflict-affected resource-limited settings. Our findings demonstrate that, despite significant operational challenges, acceptable functional and radiological outcomes can be achieved by adhering to established surgical principles and meticulous patient

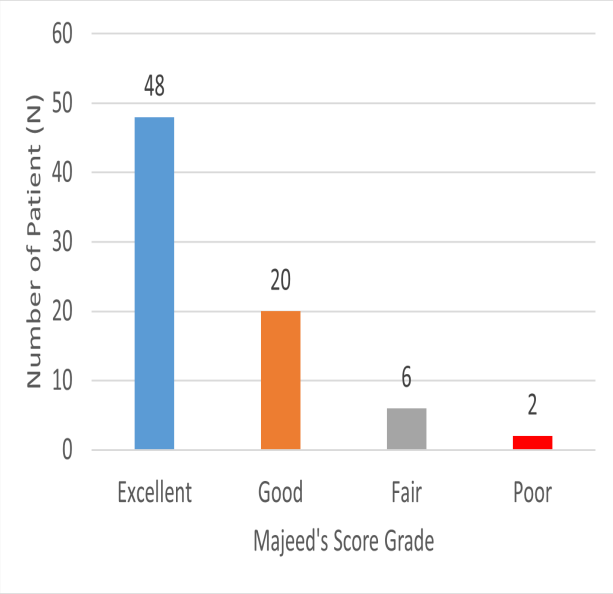

Figure 4. Distribution of functional outcomes at final follow-up using the Majeed Scoring System (N=76). The majority of patients achieved an Excellent (n=48, 63.2%) or Good (n=20, 26.3%) outcome, indicating successful functional recovery in 89.5% of the cohort.

management.

The functional outcomes observed in our cohort compared favorably with those of international studies from well-resourced centers. Our rate of excellent and good Majeed scores (89.5%) is consistent with recent multicenter studies from developed countries, which reported similar rates ranging from 85% to 92% [15, 16]. Furthermore, our findings resonate with recent reports from other conflict-affected and low-resource regions [17], suggesting that despite logistical constraints and delayed presentation, adherence to established AO surgical principles can yield satisfactory outcomes. While our overall complication rate (30.3%) mirrors the trends seen in other austere environments where high-energy mechanisms are prevalent [11], our analysis of prognostic factors revealed an interesting clinical trend regarding reduction quality. Although anatomical reduction is generally cited as a predictor of superior outcomes [18], our series included patients with ' fair ' radiological reduction who nonetheless achieved 'Good' Majeed functional scores. This aligns with the findings of other studies, suggesting that restoration of the posterior tension band and pelvic stability may be more critical for functional recovery than perfect anatomical alignment of the anterior ring.

Our radiological outcomes, with 93.4% of patients achieving excellent or good reduction according to the Matta and Tornetta criteria, align closely with the reported rates of 90-95% in contemporary series from trauma centers in high-income countries [18]. This suggests that despite the limitations of advanced imaging and surgical instrumentation, experienced surgeons can achieve satisfactory anatomical restoration using fundamental surgical principles.

The overall complication rate of 30.3% in our series was higher than the 15-25% typically reported in recent international literature [19]. This difference can be attributed to several factors specific to our setting: delayed presentation (mean, 8 days after injury), higher rates of polytrauma (63.2% had associated injuries), and limited access to specialized postoperative care. The wound infection rate of 9.2%, which is higher than the developed world standards of 3-6%, reflects the challenges of maintaining sterile conditions and optimal wound care in a resource-constrained environment.

Importantly, our neurological complication rate of 5.3% remained within the acceptable range reported internationally (3-8%), suggesting that despite resource limitations, careful surgical techniques can minimize iatrogenic nerve injuries [20].

Our analysis of the prognostic factors revealed an interesting clinical trend regarding the quality of the reduction. Although anatomical reduction is generally cited as a predictor of superior outcomes [18], our series included patients with 'Fair' radiological reduction who nonetheless achieved 'Good' Majeed functional scores. This aligns with findings from other studies, suggesting that restoration of the posterior tension band and pelvic stability may be more critical for functional recovery than perfect anatomical alignment of the anterior ring.

Several factors unique to the Yemeni context influenced the results and approach. This prolonged conflict has resulted in a damaged healthcare infrastructure, limited availability of implants, and challenges in patient transportation and follow-up. Despite these constraints, our team adapted by utilizing locally available resources, modifying surgical approaches when necessary, and implementing robust infection prevention protocols.

The high proportion of combined mechanical injury patterns (52.6%) and vertical shear injuries (44.7%) reflects the severe nature of trauma in conflict zones where explosive mechanisms and high-energy impacts are common. This pattern necessitates more complex surgical approaches and contributes to slightly elevated complication rates.

Our results demonstrate that modern pelvic trauma surgery can be successfully implemented in conflict-affected regions with appropriate planning and resource allocation. The key factors for success include surgeon training and experience, availability of basic surgical instrumentation, access to CT imaging for preoperative planning, and established perioperative care protocols.

The finding that 89.5% of the patients achieved good or excellent functional outcomes supports the cost-effectiveness of investing in pelvic trauma capabilities, even in resource-limited settings. Given the young age of our patient population (mean age, 34 years), successful treatment represents decades of restored productivity

and improved quality of life.

This study had several limitations that must be acknowledged. First, it was conducted at two specialized centers, which may not reflect the capabilities of the broader Yemeni health care system. Second, our follow-up, although comprehensive, was limited by patient mobility during the conflict, potentially introducing a selection bias toward those with better outcomes. Third, the lack of a control group limits our ability to definitively attribute outcomes to surgical intervention versus natural history of the disease.

In addition, our functional outcome assessment relied solely on the Majeed score, and the incorporation of patient-reported outcome measures and return-to-work data would strengthen future studies' findings. Finally, long-term complications beyond four years could not be assessed, and extended follow-up may reveal additional late sequelae.

This study lays the foundation for further research on conflict zone trauma care. Future investigations should focus on cost-effectiveness analyses, comparisons of different surgical approaches in resource-limited settings, and the development of simplified treatment algorithms adapted to local capabilities. Telemedicine consultations and training programs can help disseminate expertise in conflict-affected regions.

5. CONCLUSION

This study demonstrates that the surgical management of unstable pelvic fractures in conflict-affected Yemen can achieve functional outcomes comparable to international standards, despite significant resource constraints and operational challenges. The key finding that 89.5% of the patients achieved good or excellent Majeed scores supports the feasibility and effectiveness of implementing modern orthopedic trauma care in low-resource settings. While complication rates remain elevated compared with developed world standards, the overall outcomes justify investment in pelvic trauma capabilities. Success depends on experienced surgical teams, appropriate case selection, adherence to established surgical principles, and robust perioperative care protocols adapted to local conditions.

This study provides crucial evidence for healthcare policymakers and international organizations working to strengthen trauma care in conflict zones. This underscores that with proper resource allocation and training, high-quality orthopedic trauma care can be delivered even in the most challenging circumstances, ultimately improving outcomes for some of the world's most vulnerable trauma patients.

Future efforts should focus on developing sustainable training programs, ensuring consistent supply chains for essential implants and equipment, and establishing regional networks for knowledge sharing among trauma centers in conflict-affected regions. Only through such comprehensive approaches can the benefits demonstrated in this study be scaled to include a broader population of patients with trauma in similar settings, worldwide.

Author Contributions

Khalid Al-Shrif: Conceptualization, methodology, data collection, surgical procedures, data analysis, writing—original draft, writing—review and editing, and project administration. Haitham Mohammed Jowah: Methodology, data collection, surgical procedures, data analysis, writing review and editing, and validation.

All authors have read and approved the final manuscript.

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Conflicts of Interest

The authors declare no conflicts of interest. No commercial or financial relationships that could be construed as potential conflicts of interest were present during this study.

Ethics Statement

This study was conducted in accordance with the Declaration of Helsinki and approved by the Ethics Committee of the Faculty of Medicine and Health Sciences, Sana'a University, Sana'a, Yemen. Written informed consent was obtained from all patients or their legal guardians prior to their enrollment. Patient confidentiality was maintained throughout the study period.

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