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Functional recovery after civilian pelvic gunshot injuries: Insights from a 14-year retrospective study

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Abstract

This study aimed to evaluate long-term functional outcomes, fracture-related infection rates, and non-operative orthopaedic fracture management in civilian pelvic gunshot injuries caused by low-velocity firearms. A total of 47 patients with radiologically confirmed pelvic fractures treated between 2010 and 2024 at two tertiary referral hospitals were retrospectively analyzed. Only patients who met the eligibility criteria and had a minimum follow-up of 24 months were included. Demographic data, dominant primary fracture location, associated injuries, orthopaedic and non-orthopaedic treatment strategies, and complications were recorded. Functional outcomes were assessed using the Harris Hip Score (HHS). Exploratory univariable analyses were performed to evaluate factors associated with poor functional outcome. The majority of patients were male (89%) with a mean age of 32.4 years. The most common primary fracture locations were posterior pelvic ring injury (30%), anterior acetabular involvement (21%), anterior pelvic ring injury (21%), iliac wing injury (19%), and posterior acetabular involvement (9%). Gastrointestinal injury occurred in 47% of patients, and 64% underwent exploratory laparotomy. Orthopaedic fixation was performed in only 4% of cases. No fracture-related infections, osteomyelitis, or septic arthritis were observed. At a mean follow-up of 6.3 years, 68.1% of patients achieved good or excellent functional outcomes (HHS $\geq$ 80). In exploratory analyses, diabetes mellitus, smoking, and peripheral nerve injury were associated with poor functional outcome. Non-operative orthopaedic fracture management without routine fracture-site debridement or fixation was associated with favorable long-term functional outcomes in selected patients with low-velocity civilian pelvic gunshot injuries who met the eligibility criteria and had adequate follow-up. These findings should be interpreted cautiously because of the retrospective design, substantial exclusions, and potential attrition bias.

Keywords: Pelvic fracture, gunshot injury, low-velocity firearm trauma, Harris Hip score, fracture-related infection, non-operative fracture management

Introduction

Firearm-related trauma remains a critical global public health concern, with rising incidence in both civilian and conflict-affected regions. While epidemiological data are frequently drawn from countries like the United States, gun violence is a growing challenge in many parts of the world, including middle-income countries [1]. Civilian gunshot injuries are commonly caused by low-velocity firearms, with projectiles traveling at speeds below 610 m/s. These injuries frequently involve musculoskeletal tissues and may require orthopaedic evaluation and treatment [2,3].

Among gunshot-related skeletal injuries, ballistic fractures involving the pelvis constitute a complex and relatively understudied subset, accounting for approximately 10% to 16% of all gunshot fractures [4]. Despite their clinical significance, there is a paucity of high-quality evidence to guide the management of these injuries [5]. Much of the available literature consists of small, single-center case series, and there is ongoing

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debate regarding the indications for surgical fixation, appropriate antibiotic regimens, and the necessity of formal debridement procedures [6,7]. Moreover, the long term outcomes of these injuries, such as infection, osteomyelitis, implant failure, and functional impairment, remain inadequately characterized [8].

Ballistic pelvic fractures are often accompanied by visceral organ injuries or intra-abdominal trauma, further complicating management and emphasizing the need for a multidisciplinary approach. In particular, cases involving intestinal injury pose unique challenges due to the heightened risk of contamination and delayed infection [9].

This multicenter retrospective study was conducted at two tertiary referral hospitals in Istanbul with a considerable caseload of firearm-related injuries. The aim was to investigate the clinical characteristics, surgical management, and long-term outcomes of patients with pelvic gunshot injuries. Special attention was given to fracture localization, associated complications such as osteomyelitis or hardware failure, and functional recovery during extended follow-up.

Material and Methods

Ethical approval for this multicenter retrospective study was obtained from the Metin Sabancı Baltalimanı Bone Diseases Training and Research Hospital Scientific Research Ethics Committee (approval date: April 30, 2026; decision no.: 2/16). The study was conducted in accordance with the principles of the Declaration of Helsinki. Written informed consent was not required because of the retrospective design of the study and the exclusive use of anonymized patient data.

Medical records from Prof. Dr. Cemil Taşcıoğlu City Hospital and Istanbul Baltalimanı Metin Sabancı Bone Diseases Training and Research Hospital were reviewed to identify patients who sustained pelvic gunshot injuries (Figure 1) between January 2010 and April 2024. Adult patients (≥ 18 years old) with confirmed pelvic fractures or bone involvement caused by low-velocity firearm trauma were eligible for inclusion. Exclusion criteria comprised isolated pelvic soft-tissue injuries without osseous involvement, upper extremity or spinal gunshot wounds without pelvic osseous injury, combined blunt and penetrating trauma mechanisms, high-velocity or blast-pattern injuries, insufficient radiographic documentation, duplicate or incomplete medical records, and follow-up duration shorter than 24 months. Insufficient radiographic documentation was defined as the absence of a pelvic computed tomography (CT) scan or at least three orthogonal radiographic views of the pelvis. Out of 1,182 firearm-related trauma admissions during the study period, 180 patients were initially identified as having pelvic gunshot injuries. After eligibility assessment, 133 patients were excluded because of follow-up duration shorter than 24 months (n = 105), insufficient radiographic documentation (n = 10), isolated pelvic soft-tissue injury without osseous involvement (n = 7), combined blunt and penetrating trauma mechanism (n = 5), high-velocity or blast-pattern injury (n = 5), or duplicate/incomplete medical records (n = 1). Consequently, 47 patients were included in the final analysis. The patient selection process is illustrated in Figure 2.

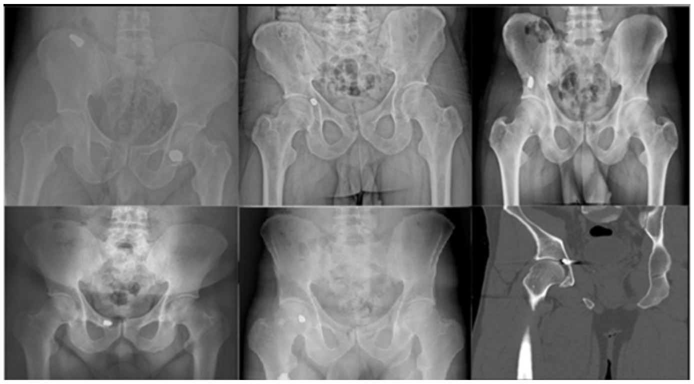

Figure 1. Representative radiographic and computed tomography images of patients with pelvic gunshot injuries included in the study; The images demonstrate retained bullet fragments involving different regions of the pelvic ring and acetabulum on anteroposterior pelvic radiographs; The far-right image shows a coronal computed tomography reconstruction demonstrating intra-articular bullet migration with adjacent soft-tissue air; These images illustrate the spectrum of osseous and ballistic injury patterns observed in civilian low-velocity pelvic firearm trauma

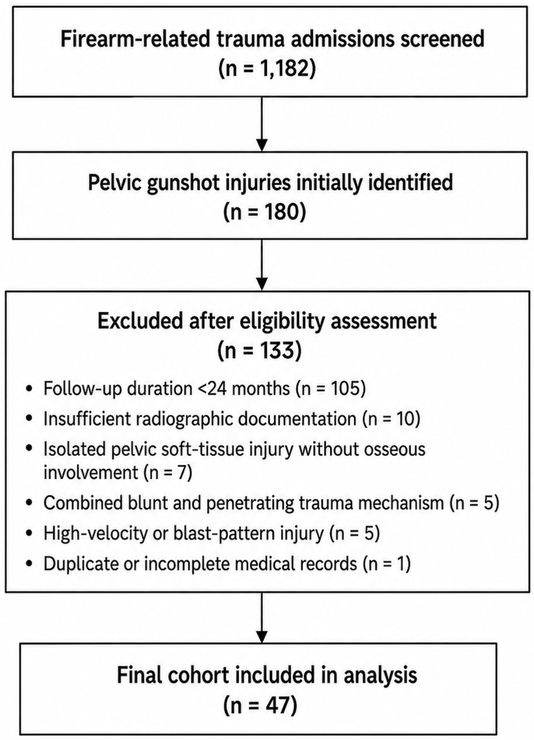

Figure 2. Flow diagram of patient selection; Of 1,182 firearm-related trauma admissions screened during the study period, 180 patients with pelvic gunshot injuries were initially identified; After eligibility assessment, 133 patients were excluded because of follow-up duration shorter than 24 months (n = 105), insufficient radiographic documentation (n = 10), isolated pelvic soft-tissue injury without osseous involvement (n = 7), combined blunt and penetrating trauma mechanism (n = 5), high-velocity or blast-pattern injury (n = 5), or duplicate/incomplete medical records (n = 1); The final cohort included 47 patients

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Initial management strategies were guided by the stability of the pelvic fracture, the presence or absence of visceral contamination, and overall injury burden. Patients without signs of bowel or urogenital tract injury were managed with local wound irrigation using a combination of povidone-iodine and saline, a single prophylactic dose of intravenous cefazolin, and confirmation of updated tetanus immunization. In contrast, patients with suspected visceral involvement received broader-spectrum antibiotics, including a seven-day course of ceftriaxone and metronidazole, along with surgical exploration when indicated by intra-abdominal findings. Orthopaedic operative interventions included the removal of retained intra-articular bullet fragments, open reduction and internal fixation of unstable acetabular fractures or pelvic ring injuries (Figure 3), and delayed reconstruction in cases complicated by infection or significant bone loss. All surgical procedures were performed by fellowship-trained orthopaedic trauma surgeons. Indications for orthopaedic fixation included documented instability on imaging, intra-articular fracture extension with joint incongruity, and failure of non-operative orthopaedic fracture management during follow-up. Fractures classified as stable by radiographic assessment, even in the presence of retained fragments or minor displacement, were managed non-operatively [7,10-12].

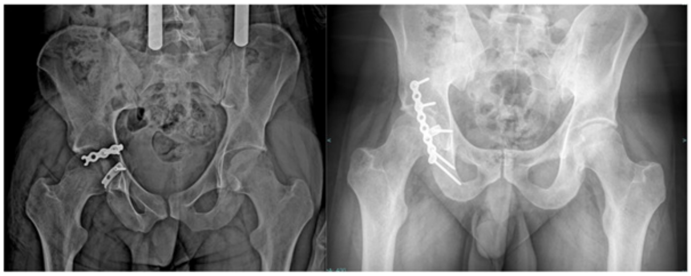

Figure 3. Representative postoperative anteroposterior pelvic radiographs of two patients who underwent internal fixation for unstable acetabular fractures following low-velocity ballistic trauma; The left image demonstrates anterior column plating after debridement of a displaced anterior column fracture with intra-articular bullet retention; The right image demonstrates anterior column stabilization using a reconstruction plate and screws following surgical treatment of a comminuted acetabular fracture

Low-velocity injuries were classified based on clinical context and radiologic injury patterns. Because weapon type documentation and forensic or ballistic reports were not available in the hospital records, no case could be classified using documented weapon type or ballistic confirmation. Accordingly, low-velocity status was based on documented weapon type in 0 patients, forensic or ballistic reports in 0 patients, and clinical-radiologic inference in 47 patients. Clinical-radiologic inference was based on civilian injury context and the absence of imaging findings suggestive of high-energy transfer, such as blast-related fragmentation, extensive cavitation, massive soft-tissue destruction, or comminution beyond the immediate bullet tract. Therefore, these cases should be interpreted as presumed low-velocity civilian firearm injuries rather than ballistically confirmed low-velocity injuries.

Demographic and clinical data including comorbidities such as diabetes mellitus and smoking history, number and anatomical location of gunshot wounds, associated injuries, surgical procedures, and antimicrobial regimens were extracted from the patients' charts. Radiographs and computed tomography scans were systematically reviewed to characterize fracture patterns. Acetabular fractures were classified according to the Judet-Letournel system. Each patient was assigned to one dominant primary fracture location to avoid overlapping anatomical categories. Fracture locations were grouped as anterior acetabular involvement, posterior acetabular involvement, iliac wing injury, anterior pelvic ring injury, and posterior pelvic ring injury. Pubic ramus injuries were included within anterior pelvic ring injuries, and sacral fractures were included within posterior pelvic ring injuries. The presence of visceral organ injury, performance of laparotomy, development of osteomyelitis, and concurrent injuries to other extremities were recorded. All diagnoses of osteomyelitis were confirmed by radiographic and microbiological criteria [5].

Functional outcomes were assessed using the Harris Hip Score during the final clinical follow-up visit. Additional outcomes included infection rates, implant survival, the requirement for revision surgery, and length of hospital stay. The minimum follow-up duration was 24 months, with a mean of 6.3 years (range, 2–11 years). Statistical analysis was performed using STATA version 17.0 (StataCorp, College Station, TX). The distribution of continuous variables was assessed using visual inspection of histograms and the Shapiro–Wilk test. Normally distributed continuous variables were compared using Student's t-test or analysis of variance (ANOVA), whereas non-normally distributed variables were compared using the Mann–Whitney U test or Kruskal–Wallis test, as appropriate. Categorical variables were analyzed using the chi-squared test or Fisher's exact test, as appropriate. Because only five patients had poor functional outcomes, multivariable logistic regression was not performed. Instead, exploratory univariable logistic regression analyses were used to evaluate associations between clinical variables and poor functional outcome. These analyses were interpreted cautiously because of the small number of events. A two-tailed P-value of < 0.05 was considered statistically significant.

Results

A total of 47 patients who sustained ballistic pelvic fractures were included in the final analysis. The majority were male (n = 42, 89%), with a mean age of 32.4 years (standard deviation (SD): 10.2). Overweight/obesity (body mass index (BMI) > 25) was present in 38% of patients, while 6% had a diagnosis of diabetes mellitus. A history of smoking was reported by 36% of patients. The average length of hospital stay was 10.1 days (SD: 7.5). Demographic, clinical, injury-related, and functional characteristics of the study cohort are summarized in Table 1.

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Table 1. Demographic, clinical, ınjury-related, and functional characteristics of the study cohort

Variable	Value
Total patients	47 (100%)
Male sex	42 (89%)
Age, years, mean (SD)	32.4 (10.2)
BMI > 25 kg/m²	18 (38%)
Diabetes mellitus	3 (6%)
Smoking	17 (36%)
Hospital stay, days, mean (SD)	10.1 (7.5)
Primary fracture location	
Anterior acetabular involvement	10 (21%)
Posterior acetabular involvement	4 (9%)
Anterior pelvic ring injury	10 (21%)
Posterior pelvic ring injury	14 (30%)
Iliac wing injury	9 (19%)
Injury Severity Score, mean (SD)	20.5 (12.2)
ISS < 18	28 (60%)
Bladder injury	5 (11%)
Ureteral injury	1 (2%)
Gastrointestinal tract injury	22 (47%)
Nerve injury	7 (15%)
Retained foreign body in pelvis	19 (40%)
Exploratory laparotomy	30 (64%)
Vascular injury requiring embolization or repair	6 (13%)
Orthopaedic pelvic/acetabular fixation	2 (4%)
Harris Hip Score, mean	83.4
Harris Hip Score category	
Excellent (90–100)	15 (31.9%)
Good (80–89)	17 (36.2%)
Fair (70–79)	10 (21.3%)
Poor (< 70)	5 (10.6%)

BMI: body mass index, ISS: Injury Severity Score, SD: standard deviation

Each patient was assigned to one dominant primary fracture location. The most common primary fracture locations were posterior pelvic ring injury (14/47, 30%), anterior acetabular involvement (10/47, 21%), anterior pelvic ring injury (10/47, 21%), iliac wing injury (9/47, 19%), and posterior acetabular involvement (4/47, 9%). The mean Injury Severity Score (ISS) was 20.5 (SD: 12.2), with 60% of patients presenting with an ISS less than 18.

Associated intra-abdominal or visceral injuries were frequent. Gastrointestinal tract injuries occurred in 47% of patients, and 64% underwent exploratory laparotomy. Retained pelvic foreign bodies were identified in 40%, while 13% required vascular intervention (embolization or repair). Urogenital injuries were less common, with bladder injury present in 11% and ureteral injury in 2% of cases. Nerve injuries were documented in 15% of patients. Orthopaedic fixation of pelvic or acetabular fractures was performed in only 4% of the cohort. No cases of fracture-related infection, osteomyelitis, or septic arthritis were observed during follow-up.

Functional outcomes were assessed using the Harris Hip Score (HHS) at the final follow-up. The mean HHS was 83.4. According to the Harris Hip Score categories, 15 patients (31.9%) had excellent outcomes (90–100), 17 patients (36.2%) had good outcomes (80–89), 10 patients (21.3%) had fair outcomes (70–79), and 5 patients (10.6%) had poor outcomes (< 70).

Exploratory univariable analyses showed that diabetes mellitus, smoking, and nerve injury were associated with poor functional outcome (HHS < 70). These exploratory univariable associations are summarized in Table 2. Because only five patients had poor outcomes, these findings were interpreted as exploratory associations rather than independent predictors.

Table 2. Exploratory univariable associations with poor functional outcome defined as Harris Hip Score < 70

Variable	OR	95% CI	P-value
Diabetes mellitus	4.25	1.08–16.72	**0.038***
Smoking	3.87	1.11–13.46	**0.032***
Hospital stay, days	1.12	0.92–1.34	0.276
Injury Severity Score	1.03	0.97–1.10	0.480
ISS < 18	0.84	0.24–2.93	0.790
Bladder injury	1.38	0.34–5.62	0.650
Ureteral injury	0.92	0.07–11.75	0.950
Gastrointestinal tract injury	0.96	0.32–2.87	0.940
Nerve injury	6.11	1.63–22.89	**0.007***

OR: odds ratio, CI: confidence interval, ISS: Injury Severity Score; *Nominally significant at P < 0.05 in exploratory univariable analyses; P-values were not adjusted for multiple comparisons

Discussion

The optimal management of low-velocity ballistic pelvic fractures continues to be debated, particularly in urban civilian contexts where gun violence is increasingly prevalent. Although prior literature has emphasized distinctions between military and civilian ballistic trauma, treatment protocols for pelvic fractures remain inconsistently applied. Our 14-year experience contributes to this evolving field by analyzing injury patterns, surgical strategies, associated complications, and long-term outcomes in a civilian setting.

One particular subset of ballistic pelvic injuries that warrants distinct attention is transabdominal gunshot wounds (GSWs), which are defined by a trajectory that crosses the gastrointestinal (GI) tract before reaching the pelvis. These injuries carry a high risk of contamination due to bowel flora, especially when the projectile involves the hip joint. According to Miller et al. intra-articular involvement necessitates urgent irrigation and debridement due to the significant risk of septic arthritis and long-term joint damage, while extra-articular injuries may be managed non-operatively with empiric antibiotic therapy depending on fracture stability and contamination severity [9]. In cases without hip joint violation, the need for debridement remains controversial. While retrospective studies have shown low infection rates even without surgical cleaning, Watters et al. emphasize that injury severity, the presence of comminution, and signs of devitalized tissue or periosteal stripping should guide the decision for surgical intervention [13]. Additionally, retained bullets within the hip joint should be removed to prevent lead toxicity and cartilage damage, whereas bullets lodged in extra-articular soft tissues can be monitored conservatively.

A distinctive feature of our cohort was that routine formal irrigation and debridement (I&D) of fracture sites was not performed, even in the presence of suspected bowel injury. Instead, debridement was reserved for selected cases with specific operative indications, such as intra-articular bullet retention or unstable fractures requiring surgical fixation. Despite retained bullet fragments and potential contamination, no cases of osteomyelitis or septic arthritis were observed. These findings are consistent with previous reviews [14,15], which suggest that routine debridement is not universally necessary for civilian pelvic gunshot injuries and support a selective, anatomy-guided approach.

Ballistic properties of the projectile significantly influence injury severity and treatment strategy. According to Bartlett, most civilian gunshot injuries involve low-velocity handguns that produce localized tissue disruption due to limited energy transfer [10]. In contrast to military-grade ammunition, which often causes cavitation and fragmentation, civilian projectiles create a narrow permanent tract and minimal temporary cavity formation—particularly in dense, inelastic anatomical regions like the pelvis. This ballistic profile may support selective non-operative orthopaedic fracture management for stable transpelvic injuries. Furthermore, Bartlett notes that retained bullets are typically inert unless lodged intra-articularly or near neurovascular structures, which aligns with our decision to avoid routine bullet extraction [10]. However, unpredictable trajectories due to bone deflection or secondary missile formation underscore the importance of advanced imaging in early evaluation. These ballistic insights help contextualize the low infection and complication rates observed in our series and reinforce the need for mechanism-specific treatment protocols.

Similarly, Portney et al. caution that overly aggressive debridement in stable, low-velocity injuries may increase morbidity without clinical benefit [2]. Dougherty also notes that retained bullets are generally inert and may be left in situ unless they involve a joint, traverse the bowel, or cause systemic toxicity [4]. In a systematic review, Erdman et al. found no high-quality evidence supporting routine debridement of pelvic fractures caused by gunshot wounds, especially in hemodynamically stable patients [6].

Only 4% of our patients required orthopaedic fixation, all for unstable acetabular or iliac wing fractures. This low rate supports Antoni and Maqungo's conclusion that most transpelvic ballistic fractures are stable and do not necessitate operative stabilization [14]. Portney et al. further note that surgical fixation should be reserved for biomechanically unstable injuries, neurovascular compromise, or intra-articular involvement [2]. Dougherty echoes this principle in his foundational work on extremity trauma, while Bartkiw et al. similarly found that the majority of civilian hip and pelvic gunshot injuries can be safely managed non-operatively [4,5]. Erdman et al. highlight that there is substantial heterogeneity in surgical indications worldwide, and they call for consensus on classification systems and treatment thresholds to guide future practice [6].

Our infection data reinforce a consistent theme across the literature: deep infections are primarily linked to bowel injury and abdominal contamination, not orthopaedic procedures. No fracture-related infection, osteomyelitis, or septic arthritis was observed in the present cohort. Antoni and Maqungo emphasize that fracture-related infections are rare when early appropriate antibiotic therapy is administered [14]. Our antibiotic protocol—cefazolin for low-risk patients and ceftriaxone plus metronidazole for high-risk patients—reflected institutional trauma practice during the study period. Dougherty and Erdman et al. both affirm that contamination severity and soft tissue injury are more critical infection predictors than the presence of a projectile or bone disruption alone [4,6]. This view is further supported by Coleman et al. who reported a fracture-related infection rate of 4.5% in a series of 242 patients with low-velocity pelvic gunshot fractures [16]. All infections occurred in patients with concomitant bowel injury, whereas retained bullet fragments were not associated with fracture-related infection.

Recent updates to surgical site infection (SSI) prevention guidelines by the Centers for Disease Control and Prevention (CDC) further support a cautious and evidence-based approach to infection control in surgical trauma cases. Borchardt and Tzizik emphasize that about 55% of SSIs are preventable and highlight the importance of targeted prophylaxis, glycemic control, and normothermia in reducing infection risk [17]. Importantly, they recommend administering preoperative parenteral antibiotics timed to reach effective tissue concentrations by incision, with no need for continued antibiotics postoperatively—even when drains are used—for clean or clean-contaminated procedures. These practices align with our cohort's infection-control strategy and likely contributed to the absence of fracture-related infections in our series. Additionally, the CDC advocates for intraoperative alcohol-based antiseptic preparation and strict glycemic and oxygenation targets, measures that should be standardized across institutions managing high-risk ballistic trauma patients.

Both Portney et al. and Antoni and Maqungo stress the necessity of multidisciplinary coordination, particularly due to the high rate of associated gastrointestinal and urogenital injuries [2,14]. In our cohort, nearly two-thirds of patients underwent exploratory laparotomy, necessitating coordination between orthopaedic, general, and trauma surgical teams. Bartkiw et al. also recommend early CT imaging, cystography, and rectal evaluation in all transpelvic cases with suspected visceral injury [5]. Erdman et al. advocate for institutional protocols integrating early imaging, triage criteria, and antibiotic regimens tailored to injury mechanism and anatomical trajectory [6].

Functionally, our patients fared well overall, with over two-thirds achieving good or excellent Harris Hip Scores. In exploratory univariable analyses, diabetes mellitus, smoking, and peripheral nerve injury were associated with worse outcomes; however, these findings should not be interpreted as independent predictors because of the small number of poor outcomes. Portney et al. underline the impact of comorbidities on healing and rehabilitation, while Dougherty emphasizes that nerve injuries are among the strongest predictors of poor functional recovery [2,4]. Bartkiw et al. report similar associations, particularly in acetabular fractures with neurologic deficits [5]. Erdman et al. in their synthesis, note that while anatomical fracture location and severity are often documented, functional recovery is inconsistently reported—highlighting a gap our study begins to address [6]. While our study focused on physical and functional outcomes, we acknowledge the substantial psychosocial burden associated with ballistic trauma. Future prospective studies should include patient-reported outcomes, pain, walking capacity, return to work, and quality-of-life measures to better characterize long-term recovery. These dimensions are critical to fully understanding long-term recovery, as highlighted by Portney et al. and Dougherty et al. [2,4].

This study has several limitations. Its retrospective design introduces potential selection and documentation biases. The exclusion of 133 of 180 initially identified patients represents a major source of potential selection and attrition bias. The largest exclusion subgroup consisted of patients with follow-up duration shorter than 24 months (n = 105), which may have led to an underestimation of late complications or delayed functional decline. Therefore, the favorable functional outcomes observed in this study should be interpreted as outcomes among patients who met all eligibility criteria and had adequate follow-up rather than as outcomes of all patients initially presenting with pelvic gunshot injuries. In addition, because this study covered a long period from 2010 to 2024, changes in trauma care, imaging availability, antibiotic protocols, and multidisciplinary treatment pathways may have influenced management and outcomes over time. Weapon type documentation and forensic or ballistic reports were not available in the hospital records; therefore, low-velocity classification relied on clinical-radiologic inference in all 47 patients. This may have introduced projectile-velocity misclassification and should be considered when interpreting the findings. The retrospective design also limited the availability of detailed data on pain, walking capacity, activities of daily living, return to work, psychological outcomes, and quality of life. Finally, because only five patients had poor functional outcomes, the exploratory association analyses should be interpreted cautiously.

Conclusion

In this retrospective series of selected patients with low-velocity civilian pelvic gunshot injuries and adequate long-term follow-up, most fractures were managed non-operatively from an orthopaedic standpoint within a multidisciplinary trauma care protocol. Fracture-related infection, osteomyelitis, and septic arthritis were not observed, and functional outcomes were generally favorable among the included patients. However, the high rate of follow-up loss, the retrospective design, and the small number of poor functional outcomes require cautious interpretation of these findings. Larger prospective studies are needed to define optimal treatment algorithms and reliable predictors of long-term recovery.

Ethical Approval

Ethical approval was obtained from the Metin Sabancı Baltalimanı Bone Diseases Training and Research Hospital Scientific Research Ethics Committee (Approval date: 30.04.2026; Decision No: 2/16). The study was conducted in accordance with the principles of the Declaration of Helsinki.

Patient Consent

Patient informed consent was waived by the ethics committee due to the retrospective design of the study and the use of anonymized patient data. No identifiable patient information is presented in the manuscript.

Conflict of Interest

The authors confirm the absence of any conflicts associated with this work.

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