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Clinical and Functional Outcomes of Interlocking and Küntscher Nailing in the Management of Femoral Shaft Fractures: A Prospective Study

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Abstract: Background: Femoral shaft fractures in adults are major long-bone injuries that commonly follow high-energy trauma and are associated with substantial morbidity, prolonged hospitalization, and clinically important complications. **Objective:** To determine the frequency, patterns, and predictors of complications among adults with femoral shaft fractures managed at Al-Kadhimiya Teaching Hospital and Imam Ali Hospital, Baghdad, Iraq. **Methods:** A hospital-based retrospective observational study was conducted from February 1, 2021 to June 30, 2025. Adults (≥18 years) with radiologically confirmed femoral shaft fractures and complete records were included, pathological and periprosthetic fractures and incomplete files were excluded. Data were extracted from admission logs, operative records, and radiology databases. Variables included demographics, injury mechanism, fracture characteristics (including AO/OTA classification), open/closed status, associated injuries, comorbidities (including smoking and diabetes), treatment modality, time to surgery, hospital course, and early/late complications. Standard radiographs were used to assess alignment and union. **Results:** A total of 312 patients were analyzed (mean age 36.8±12.4 years), most were males (236, 75.64%) and urban residents (204, 65.38%). Road traffic accidents were the leading mechanism (182, 58.33%), followed by falls from height (71, 22.76%). Most fractures were closed (247, 79.17%), with a substantial proportion of open fractures (65, 20.83%). AO/OTA 32-B patterns predominated (131, 41.99%). Intramedullary nailing was the main treatment (208, 66.67%), and the mean time to surgery was 3.4±1.9 days. Major complications included delayed union (36, 11.54%), surgical site infection (29, 9.29%), nonunion (21, 6.73%), malunion (18, 5.77%), and implant failure (15, 4.81%). Significant predictors of major complications were smoking ($p=0.002$), diabetes ($p=0.004$), open fractures ($p<0.001$), surgical delay >5 days ($p<0.001$), and associated injuries ($p=0.011$). **Conclusion:** Adult femoral shaft fractures in Baghdad predominantly affect young men and are primarily caused by road traffic trauma. Complications remain frequent and are strongly associated with modifiable patient factors (smoking, diabetes) and injury/management factors (open fractures, polytrauma, delayed surgery). Targeted prevention and optimized perioperative pathways focusing on early stabilization and risk-factor control may improve outcomes.

Keywords: Femoral Shaft Fracture, Intramedullary nailing, Open Fracture, Nonunion, Polytrauma

INTRODUCTION

Femoral shaft fractures in adults are among the most serious long-bone injuries encountered in trauma practice, typically resulting from high-energy mechanisms such as road traffic collisions and falls from height. They impose a substantial clinical and socioeconomic burden because they frequently affect young, economically active individuals and are commonly associated with polytrauma, prolonged hospitalization, and delayed return to function [1,2]. In many regions, the

continuing rise in motorization and road-traffic injury rates has maintained femoral shaft fractures as a major contributor to trauma-related morbidity [3]. From a pathophysiological perspective, femoral shaft fractures are not only a mechanical disruption of bone continuity, they are also accompanied by substantial soft-tissue injury and blood loss. This local tissue trauma can initiate a systemic inflammatory response, and in multiply injured patients the femoral fracture may amplify the overall "first-hit" inflammatory burden [4,5]. Furthermore, surgical fixation itself—particularly definitive intramedullary nailing—may contribute to a "second-hit" phenomenon in physiologically vulnerable patients, potentially increasing the risk of pulmonary complications such as acute respiratory distress syndrome (ARDS) and multiple organ dysfunction [4-6]. These considerations have shaped modern trauma strategies and explain why timing and method of stabilization remain central determinants of outcome. Non-operative treatment of adult femoral shaft fractures is now uncommon because surgical stabilization improves mobilization, reduces complications associated with prolonged recumbency, and enhances functional recovery [7,8]. Intramedullary nailing (IMN) is widely regarded as the standard of care due to its favorable biomechanics and high union rates [7-9]. Nevertheless, clinically important complications persist, including surgical site infection, deep venous thrombosis, fat embolism syndrome, malalignment, delayed union, nonunion, implant failure, and long-term functional deficits [10-13]. The occurrence of complications is multifactorial and reflects the interaction between injury severity, host factors, and treatment-related variables. Open fractures and extensive soft-tissue injury increase contamination risk and impair local biology, predisposing to infection and nonunion [10,11]. Patient-related risk factors such as smoking and diabetes mellitus are consistently associated with impaired fracture healing and increased postoperative complications, likely through microvascular compromise and altered inflammatory and immune responses [14-16]. In addition, delayed definitive stabilization, prolonged operative time, and the presence of chest or head trauma may influence outcomes by exacerbating systemic inflammation and pulmonary vulnerability [5,6,17]. Accordingly, damage control orthopedics (temporary external fixation followed by delayed definitive fixation) is often considered for physiologically unstable or "borderline" patients, although identifying the subgroup that benefits most remains challenging [16-18]. Despite extensive literature, there is ongoing need for institution-specific evaluation because risk profiles, trauma patterns, resource constraints, and perioperative pathways vary across settings. Understanding local determinants of complications can guide targeted prevention strategies, optimize timing and selection of fixation methods, and improve outcomes. This study aimed to identify the major risk factors and describe the frequency and patterns of complications among adults with femoral shaft fractures.

MATERIALS AND METHODS

Patients and Methods

This study was designed as a hospital-based retrospective observational study conducted at Al- Kadhimiya Teaching Hospital and Imam Ali Hospital, Baghdad, Iraq. The study aimed to evaluate the risk factors and complications associated with femoral shaft fractures in adult patients. Data were collected over a four-year and five-month period, from February 1, 2021, to June 30, 2025. The study included adult patients aged 18 years and above who were diagnosed with femoral shaft fractures and admitted to the Orthopedic Department of Al-Kindy Teaching Hospital during the study period. Patients were identified through hospital medical records, admission registers, operative logs, and radiological databases.

Inclusion Criteria

Patients were eligible for inclusion if they met the following criteria:

- Age ≥ 18 years at the time of injury
- Radiologically confirmed femoral shaft fracture
- Admission for definitive management at Al-Kindy Teaching Hospital
- Availability of complete medical records, including clinical, radiological, and treatment data

Exclusion Criteria

Patients were excluded if they had:

- Pathological fractures due to malignancy or metabolic bone disease
- Periprosthetic femoral fractures
- Pediatric fractures (age < 18 years)
- Incomplete or missing medical records
- Patients referred to other centers before definitive treatment

Data Collection

Data were retrospectively extracted using a standardized data collection form. Information was obtained from patients' files, electronic hospital records, operative reports, and radiographic archives.
The following variables were collected:

Demographic Characteristics

- Age
- Sex
- Residence (urban/rural)
- Occupation (when available)

Injury-Related Variables

- Mechanism of injury (road traffic accidents, falls from height, falls at ground level, assaults, occupational injuries)
- Side of fracture (right/left/bilateral)
- Fracture pattern (simple, comminuted, segmental)
- Fracture classification according to the AO/OTA system

- Open or closed fracture (Gustilo-Anderson classification for open fractures)
- Associated injuries (head, chest, abdominal, pelvic, or limb injuries)

Clinical and Medical Factors

- Presence of comorbidities (diabetes mellitus, hypertension, cardiovascular disease, osteoporosis, smoking status)
- Body mass index (BMI), when available
- Pre-injury functional status
- Time interval between injury and hospital admission

Management-Related Variables

- Mode of treatment (intramedullary nailing, plating, external fixation, conservative management)
- Timing of surgical intervention
- Type of anesthesia
- Duration of hospital stay
- Need for intensive care unit (ICU) admission
- Blood transfusion requirement

Outcome and Complication Variables

Early and late complications were recorded and categorized as follows:

Early Complications

- Surgical site infection
- Deep vein thrombosis (DVT)
- Fat embolism syndrome
- Hemorrhage
- Wound dehiscence
- Neurovascular injury

Late Complications

- Delayed union
- Nonunion
- Malunion
- Implant failure
- Chronic osteomyelitis
- Limb length discrepancy
- Persistent pain and functional limitation

Functional outcomes were assessed, when available, using documented clinical evaluations and follow-up records.

Radiological Assessment

All patients underwent standard anteroposterior and lateral radiographs of the femur at admission and during follow-up. Fracture classification, alignment, and evidence of union were evaluated by two independent orthopedic specialists. Fracture union was defined as the presence of radiological bridging callus in at least three cortices combined with clinical evidence of painless weight-bearing.

Follow-Up

Patients were followed up according to hospital protocols at regular intervals (2 weeks, 6 weeks, 3 months, 6 months, and annually when available). Follow-up duration ranged from 3 months to 36 months, depending on patient compliance and availability of records.

Complications and outcomes were recorded throughout the follow-up period.

Statistical Analysis

Data were entered and analyzed using the Statistical Package for the Social Sciences (SPSS), version 26.0 (IBM Corp., Armonk, NY, USA).

- Continuous variables were expressed as mean±standard deviation (SD) or median (interquartile range) as appropriate.
- Categorical variables were presented as frequencies and percentages.
- The Chi-square test or Fisher's exact test was used to analyze associations between categorical variables.
- Student's t-test or Mann–Whitney U test was applied for comparison of continuous variables.
- Multivariate logistic regression analysis was performed to identify independent risk factors associated with major complications.
- A p-value of <0.05 was considered statistically significant.

Ethical Considerations

Ethical approval for the study was obtained from the Scientific and Ethical Committee of Al-Kindy Teaching Hospital and the Iraqi Ministry of Health. As this was a retrospective study based on anonymized medical records, informed consent was waived.

Patient confidentiality was strictly maintained throughout the study. All collected data were coded and used exclusively for research purposes in accordance with the Declaration of Helsinki.

RESULTS

Table 1 shows that femoral shaft fractures predominantly affected young to middle-aged adults, with the largest proportion in the 31–45-year group (124, 39.74%) and a mean age of 36.8±12.4 years. There was a marked male predominance (236, 75.64%), reflecting greater exposure to high-energy trauma. Most patients were from urban areas (204, 65.38%), suggesting that traffic density and urban activity patterns may contribute to injury occurrence in this setting.

Table 2 indicates that road traffic accidents were the leading cause of femoral shaft fractures (182, 58.33%), confirming the high-energy nature of most injuries in this cohort. Falls from height represented the second most common mechanism (71, 22.76%), while low-energy mechanisms such as ground-level falls were less frequent (34, 10.90%). Occupational injuries and assaults were uncommon, together accounting for less than 10%, emphasizing that prevention strategies should prioritize road safety and high-risk fall prevention.

Table 1: Demographic Characteristics of the Study Population (n = 312)

Variable	n (%) / Mean±SD
Age (years)	36.8±12.4
18–30	98 (31.41)
31–45	124 (39.74)
>45	90 (28.85)
Male	236 (75.64)
Female	76 (24.36)
Urban	204 (65.38)
Rural	108 (34.62)

Table 2: Mechanism of Injury

Mechanism	n (%)
Road traffic accident	182 (58.33)
Fall from height	71 (22.76)
Fall at ground level	34 (10.90)
Occupational injury	17 (5.45)
Assault	8 (2.56)
Total	312 (100)

Table 3: Fracture Characteristics

Variable	n (%)
Right side	162 (51.92%)
Left side	142 (45.51%)
Bilateral	8 (2.56%)
Simple	124 (39.74%)
Comminuted	138 (44.23%)
Segmental	50 (16.03%)
Closed	247 (79.17%)
Open	65 (20.83%)

Table 4: AO/OTA Classification

Type	n (%)
32-A	118 (37.82)
32-B	131 (41.99)
32-C	63 (20.19)
Total	312 (100)

Table 5: Associated Injuries

Injury Type	n (%)
Head injury	56 (17.95)
Chest injury	43 (13.78)
Abdominal injury	29 (9.29)
Pelvic fracture	22 (7.05)
Upper limb injury	47 (15.06)
None	115 (36.86)

Table 3 demonstrates a slight predominance of right-sided fractures (162, 51.92%) compared with left-sided injuries (142, 45.51%), while bilateral fractures were rare (8, 2.56%). Regarding morphology, comminuted fractures were most frequent (138, 44.23%), followed by simple fractures (124, 39.74%), indicating that many injuries resulted from high-energy trauma. Most fractures were closed (247, 79.17%), although a clinically relevant proportion were open fractures (65, 20.83%), which carry higher risks of infection and delayed healing.

Table 4 shows that AO/OTA 32-B fractures were the most common (131, 41.99%), followed by 32-A (118, 37.82%) and 32-C injuries (63, 20.19%). The predominance of wedge (32-B) and complex (32-C) patterns supports the conclusion that a substantial portion of cases were due to high-energy mechanisms, which typically demand stable fixation and careful follow-up to minimize malalignment and nonunion.

Table 5 highlights that femoral shaft fractures frequently occurred in the context of additional trauma. Head injury was the most common associated injury (56, 17.95%), followed by upper limb injuries (47, 15.06%) and chest trauma (43, 13.78%). Importantly, more than one-third of patients had isolated femoral fractures with no associated injuries (115, 36.86%). This distribution underscores the need for systematic trauma assessment to detect concurrent injuries, particularly head and chest trauma that may influence timing of surgery and postoperative outcomes.

Table 6 demonstrates that intramedullary nailing was the predominant treatment approach (208, 66.67%), reflecting its role as the preferred fixation method for adult femoral shaft fractures. Plating (54, 17.31%) and external fixation (32, 10.26%) were used less frequently, likely reserved for selected indications such as specific fracture patterns, soft-tissue compromise, or damage-control settings. Conservative management was uncommon (18, 5.77%), consistent with current practice favoring operative stabilization for improved mobilization and functional recovery.

Table 6: Treatment Modalities

Treatment	n (%)
Intramedullary nailing	208 (66.67)
Plating	54 (17.31)
External fixation	32 (10.26)
Conservative	18 (5.77)
Total	312 (100)

Table 7: Hospital Course

Variable	Mean±SD / n (%)
Time to surgery (days)	3.4±1.9
Hospital stay (days)	9.6±4.3
ICU admission	41 (13.14)
Blood transfusion	74 (23.72)

Table 8: Early and Late Complications

Complication	n (%)
Surgical site infection	29 (9.29)
DVT	14 (4.49)
Fat embolism	9 (2.88)
Wound dehiscence	11 (3.53)
Delayed union	36 (11.54)
Nonunion	21 (6.73)
Malunion	18 (5.77)
Implant failure	15 (4.81)

Table 9: Risk Factors Associated with Major Complications

Risk Factor	Complications n (%)	No Complications n (%)	p-value
Smoking	42 (61.76)	26 (38.24)	0.002*
Diabetes	31 (58.49)	22 (41.51)	0.004*
Open fracture	38 (58.46)	27 (41.54)	<0.001*
Surgery delay >5 days	44 (62.86)	26 (37.14)	<0.001*
Associated injuries	47 (55.29)	38 (44.71)	0.011*

*Statistically significant

Table 7 shows that patients underwent surgery after a mean delay of 3.4±1.9 days, which may reflect the need for preoperative optimization, resource availability, or stabilization of associated injuries. The mean hospital stay was 9.6±4.3 days, indicating a moderate inpatient burden. A notable proportion required ICU admission (41, 13.14%), emphasizing that a significant subset represented physiologically complex or polytrauma patients. Nearly one-quarter required blood transfusion (74, 23.72%), consistent with the recognized blood loss and systemic impact of femoral shaft fractures.

Table 8 demonstrates that complications occurred across both early and late postoperative phases. Delayed union was the most common late complication (36, 11.54%), followed by surgical site infection (29, 9.29%) and nonunion (21, 6.73%). Rates of malunion (18, 5.77%) and implant failure (15, 4.81%) were clinically meaningful, reflecting the challenges of maintaining stability and alignment, particularly in comminuted and complex fractures. Early systemic events such as DVT (14, 4.49%) and fat embolism (9, 2.88%) were less frequent but remain important given their potential severity.

Table 9 identifies several statistically significant predictors of major complications. Smoking ($p = 0.002$) and diabetes mellitus ($p = 0.004$) were strongly associated with complications, supporting the influence of impaired microcirculation and altered inflammatory responses on healing and infection risk. Injury-related factors also played a major role: open fractures showed a highly significant association ($p < 0.001$), consistent with contamination and soft-tissue damage. Importantly, surgical delay >5 days was one of the strongest predictors ($p < 0.001$), suggesting that prolonged time to fixation may worsen outcomes. Finally, the presence of associated injuries ($p = 0.011$) increased complication risk, reflecting the physiologic burden and complexity of polytrauma management

DISCUSSION

The present study evaluated the demographic characteristics, injury mechanisms, fracture patterns, management strategies, and complication profiles of adult patients with femoral shaft fractures. The findings highlight that these injuries predominantly affect young, economically active males and are largely caused by high-energy trauma, particularly road traffic accidents. Moreover, complications were strongly influenced by patient comorbidities, fracture severity, associated injuries, and timing of surgical intervention. In this cohort, the mean age was 36.8 years, with the highest incidence observed in the 31–45-year age group. This distribution is consistent with epidemiological analyses indicating that femoral shaft fractures mainly affect young and middle-aged adults engaged in occupational and transportation-related activities. Walter et al. reported a similar demographic trend, although their study emphasized higher mortality in elderly patients [17-20]. Khan et al. also demonstrated that younger populations are more frequently affected in urban trauma centers [12].

The marked male predominance observed in this study is in agreement with previous reports, which

attribute this pattern to increased exposure to high-risk activities and traffic-related injuries [21-26]. Douglas et al. further demonstrated that advanced age is associated with increased postoperative complications, highlighting the vulnerability of elderly patients [27]. Road traffic accidents were the leading cause of injury, accounting for more than half of all cases. This finding aligns with studies from developing regions, including Nigeria and Cameroon, which identified motor vehicle crashes as the principal mechanism of femoral shaft fractures [20,27]. Similar patterns were observed in multicenter trauma analyses involving large patient populations [28-30]. Falls from height constituted the second most common mechanism, particularly among construction workers and elderly individuals. This observation supports the findings of Clement and Beresford, who emphasized the role of occupational hazards in young adults [11]. These data underscore the importance of strengthening road safety regulations and occupational protection measures. The predominance of comminuted and segmental fractures reflects the high-energy nature of trauma in the present cohort. Vasilopoulou et al. reported similar fracture complexity in segmental femoral fractures, highlighting their association with prolonged healing and increased complication rates [10]. Metsemakers et al. also identified fracture comminution as a major predictor of nonunion after intramedullary nailing [2]. The proportion of open fractures (20.83%) observed in this study is clinically significant. Kruppa et al. and Saleeb et al. demonstrated that open fractures are strongly associated with deep infection, delayed union, and poor functional outcomes [5,24]. These findings emphasize the need for early debridement and meticulous soft-tissue management. According to AO/OTA classification, wedge and complex fractures predominated. Similar distributions were reported by Clement et al. and Paiva et al., who showed that fracture complexity independently predicts mechanical failure and malalignment [11,26]. More than 60% of patients in this study sustained associated injuries, most commonly involving the head and chest. Anandasivam et al., in their analysis of over 26,000 patients, demonstrated that associated internal organ injuries significantly increase mortality and complication rates [14]. Byun et al. further highlighted the frequent coexistence of knee injuries with femoral shaft fractures, emphasizing the need for comprehensive evaluation [3]. Polytrauma complicates management by delaying definitive fixation and increasing physiological stress. Yoon et al. showed that severely injured patients experience higher nonunion rates and longer recovery periods [17]. These findings support the need for multidisciplinary trauma care. Intramedullary nailing was the most frequently used treatment in this study, consistent with current recommendations. Memarzadeh et al. confirmed that IM nailing remains the standard of care due to high union rates and favorable biomechanics [28]. Salman et al. and Metsemakers et al. also reported satisfactory outcomes with locked IM nailing in adult populations [20,8]. External fixation was mainly used in damage-control settings, reflecting modern trauma principles. Cantu et al. demonstrated that early fixation within 24–48 hours reduces in-hospital mortality [28]. Similarly, Huang et al. showed that reamed nailing is associated with improved union compared with unreamed techniques [3]. Surgical delay beyond five days was significantly associated with complications in the present study. This finding is supported by Cantu et al. and Eliezer et al., who reported increased reoperation and mortality rates with delayed fixation [7,28]. Delayed union and nonunion were the most common late complications. Metsemakers et al. and Wu et al. identified smoking, diabetes, fracture comminution, and poor reduction as major contributors to nonunion [2,6]. Vasilopoulou et al. also reported high nonunion rates in segmental fractures [10]. Infection remains a major concern, particularly in open fractures. Saleeb et al. reported significantly higher deep infection rates in Gustilo grade III injuries [24]. Paiva et al. similarly demonstrated increased infection risk in high-energy distal femoral fractures [26]. Malunion and implant failure were observed in a clinically relevant proportion of patients. Boscher et al. highlighted the importance of intraoperative alignment to prevent rotational malalignment and functional impairment [25]. Zeckey et al. also emphasized the long-term impact of malrotation [27]. Systemic complications, including DVT and fat embolism, were relatively infrequent but clinically important. Yang et al. and Ren et al. reported similar DVT incidences and stressed the importance of early prophylaxis [22]. Rare complications such as avascular necrosis of the femoral head were uncommon in this cohort. Kim et al. confirmed that AVN after IM nailing is rare, although isolated cases continue to be reported [23]. Smoking and diabetes mellitus were strong predictors of complications. Wu et al. and Metsemakers et al. demonstrated that metabolic disorders and smoking impair fracture healing through microvascular dysfunction and altered inflammatory responses [2,6]. Weinlein et al. further reported that morbid obesity increases systemic complications [9]. Open fractures showed the strongest association with adverse outcomes, consistent with findings by Kruppa et al. and Saleeb et al. [5,26]. Surgical delay was another critical determinant, reinforcing evidence from Eliezer et al. and Cantu et al. [7,28]. Associated injuries also significantly increased complication risk. Anandasivam et al. and Yoon et al. demonstrated that polytrauma patients experience higher mortality and poorer functional recovery [14,17]. This study benefits from a relatively large sample size and comprehensive analysis of multiple risk factors over an extended period. However, its retrospective design may introduce selection bias and incomplete documentation. Functional outcome measures were not uniformly available, and the single-center nature may limit generalizability. The present findings emphasize that femoral shaft fractures remain a major public health problem in Iraq, predominantly affecting young males involved in road traffic accidents. Prevention strategies should focus on traffic regulation, workplace safety, and fall prevention. Early fixation, optimization of

comorbidities, and strict adherence to trauma protocols are essential to minimize complications. Future prospective multicenter studies incorporating functional and quality-of-life outcomes are recommended.

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