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Interimplant femoral fractures: a heterogeneous fragility injury Fracture patterns, management, and outcomes of a consecutive series

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Abstract

Purpose

Interimplant femoral fractures occur between two preexisting femoral implants and, beyond interprosthetic fractures, remain poorly defined. We analyzed their characteristics, management, and outcomes, and propose a classification encompassing all implant combinations.

Methods

This retrospective single-center study included interimplant fractures treated from July 2013 to August 2025, with one-year follow-up. Fractures were classified by proximal and distal implant position as intramedullary (I) or extramedullary (E): II, IE, EI, and EE. Primary outcomes were one-year mortality and local complications.

Results

Forty-six fractures in 45 patients were included (median age 87.0 years; 89.1% female). Interprosthetic fractures represented 45.7% and IE fractures 73.9%. A compromised proximal implant was present in 28 of 40 fractures (70.0%) with an intramedullary proximal implant and in none of the 6 with an extramedullary one ($p < 0.01$), whereas a distal intramedullary implant was associated with a shorter implant gap (78.0 vs 209.2 mm, $p < 0.01$). Fixation alone was performed in 76.1%, revision-based procedures in 17.4%, and nonoperative management in 6.5%, regardless of fracture subtype ($p = 0.77$) or implant compromise ($p = 0.40$). Revision procedures required longer surgical time (195.0 vs 127.0 minutes, $p < 0.01$) and had more local complications (50.0% vs 11.4%, $p = 0.03$), mainly mechanical, even after stratification by subtype ($p = 0.04$). One-year mortality was 19.6%, and 15.2% returned home.

Conclusion

Interimplant femoral fractures are heterogeneous fragility injuries with high mortality and functional decline. The proposed classification identifies distinct biomechanical patterns, and fixation alone appears preferable whenever implant stability allows it.

INTRODUCTION

Due to increasing life expectancy and higher functional demands in the aging population, the number of individuals living with arthroplasties and other orthopaedic implants has grown dramatically. Consequently, the incidence of periprosthetic fractures (PPF) and other implant-related fractures continues to rise [1–3]. Despite the growing body of literature on implant-related fractures, interimplant fractures (IIF) remain relatively underrepresented. This entity includes not only interprosthetic fractures

(IPFs) but also those occurring between any combination of proximal and distal orthopaedic implants [4, 5].

Although less extensively studied, the risk factors for IIFs largely overlap with those described for PPFs, including patient-, implant-, and surgery-related variables [5]. Several factors have been specifically evaluated in IIFs. Increased risk has been associated with uncemented arthroplasties, a larger canal diameter distal to the proximal implant, and reduced cortical thickness. In contrast, the presence of more than two femoral implants may be protective, likely reflecting the stress-sharing effect of a third implant, while osteoporosis therapy has also been suggested to confer a protective effect [6, 7].

Considerable heterogeneity exists in the literature regarding both the classification and management of these injuries. Although several classification systems and treatment strategies have been proposed, no clear consensus has been reached. As a result, some fracture patterns remain inadequately or incorrectly classified, and their optimal management is still poorly defined [8–11]. Management of IIFs is inherently challenging, given the variability in implant configuration, spacing, fixation stability, and bone quality. Depending on the fracture pattern and implant configuration, treatment may involve fixation alone with overlapping plate constructs or reconstruction based on revision arthroplasty; however, evidence to guide treatment selection remains limited [4, 5, 12]. Moreover, these injuries occur in frail elderly patients and have been associated with high mortality and complication rates [13–15].

The aim of this study was to characterize the demographic profile, fracture patterns, management strategies, and clinical outcomes of interimplant femoral fractures. In addition, we sought to propose a pragmatic framework based on implant combination that addresses the limitations of existing classification systems and has broad clinical applicability.

METHODS

Approval from our Institutional Review Board was obtained prior to study initiation (code PR(AT)296/2022). This retrospective case series (level of evidence IV) included patients treated at a single level III public university hospital between July 2013 and August 2025. The study is reported in accordance with the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement. All skeletally mature patients with femoral fractures occurring between two preexisting orthopaedic implants (interimplant fractures) were included, regardless of implant type, indication, or treatment modality. Pathological fractures of oncological origin and intraoperative fractures were excluded. Procedures were performed by a team of orthopaedic surgeons with extensive experience in the management of implant-related fractures.

Patient data were retrospectively collected from medical records during the first year after fracture. The dataset included baseline patient characteristics, details of the preexisting implants, fracture characteristics, treatment modalities, and outcomes. A compromised implant was defined as a preexisting implant presenting with pain, mechanical failure, nonunion, dislocation, or infection prior to the fracture. Implant gap was defined as the distance, in millimetres, between the proximal and distal

implants. Fractures were classified using a novel system based on implant location, categorizing the proximal and distal implants as intramedullary (I) or extramedullary (E). This approach defines four possible combinations (II, IE, EI, and EE), providing a simplified, treatment-oriented framework that reflects distinct biomechanical environments (Fig. 1).

Primary outcomes were one-year mortality and local complications within the first year after fracture, classified as infectious or mechanical. Fracture-related infection (FRI) was diagnosed based on clinical, radiological and laboratory criteria, and only infections managed surgically were included in the analysis [16]. Mechanical complications were defined as prosthetic hip dislocation, regardless of its treatment, or any nonunion, aseptic loosening, new fracture, malalignment, or implant-related complication requiring unplanned revision surgery. Other complications managed nonoperatively and those occurring after the first year were not considered. Local complication rate was defined as the proportion of fractures presenting at least one local complication. Secondary outcomes comprised surgical time, length of hospital stay, red blood cell transfusion, emergency department visits after discharge, discharge destination, and changes in ambulatory status. Walking ability was assessed before the fracture and at final follow-up and classified as independent ambulation or need for walking aids. All baseline characteristics, treatment variables and outcomes were compared among fracture subtypes according to the proposed classification. In addition, fractures were grouped according to the position of the proximal and distal implants (intramedullary or extramedullary) to assess the influence of each component separately. Factors associated with mortality were analyzed in the whole cohort. Outcomes were compared between fixation and revision-based procedures (with or without additional fixation); nonoperatively treated fractures were excluded from this comparison.

Statistical analyses were conducted using Stata/IC 14.2 (StataCorp LLC, College Station, TX, USA). All analyses were performed on a per fracture basis. One patient sustained a second IIF after surgical treatment of the index fracture, which was analyzed as a separate case and also recorded as a complication of the index procedure. Normality was assessed with the Shapiro–Wilk test. As no continuous variable followed a normal distribution, continuous variables were summarized as medians and interquartile ranges (IQR), while categorical variables were presented as frequencies and percentages. Descriptive statistics and comparisons were calculated from the available data for each variable. Continuous variables were compared using the Mann–Whitney U test for two groups and the Kruskal–Wallis test for fracture subtypes. Categorical variables were compared using Fisher's exact test, with the Freeman–Halton extension for tables larger than 2×2, estimated by Monte Carlo simulation. To assess whether differences in local complications between treatment strategies were explained by fracture subtype, a stratified analysis by subtype was performed, reporting the Mantel–Haenszel pooled odds ratio and an exact stratified permutation test. All statistical tests were two-sided, and statistical significance was set at $p < 0.05$.

RESULTS

A total of 46 fractures in 45 patients were included. The cohort consisted predominantly of elderly women (median age 87.0 years, IQR 82.0–91.8, 89.1% female), with a substantial comorbidity burden (median age-adjusted Charlson Comorbidity Index 5.0, IQR 4.2–6.0). Only three patients (6.5%) ambulated independently without walking aids before the fracture, although most (76.1%) were living at home prior to injury. Baseline characteristics are summarized in Table 1.

Table 1

Patient characteristics, treatment modalities and outcomes, overall and according to fracture subtype

Variable	Overall (n = 46)	Fracture subtype[1]				*p*
		II (n = 6)	IE (n = 34)	EI (n = 3)[2]	EE (n = 3)	
Patient baseline characteristics						
Age (years)	87.0 (82.0–91.8)	80.0 (72.0–83.5)	89.5 (84.2–91.0)	93.0 (82.5–93.0)	80.0 (67.0–86.5)	0.25
Female sex	41 (89.1%)	4 (66.7%)	31 (91.2%)	3 (100.0%)	3 (100.0%)	0.24
Age-adjusted CCI[3]	5.0 (4.2–6.0)	4.0 (3.2–4.8)	5.0 (5.0–6.0)	7.0 (5.5–7.0)	5.0 (3.5–5.5)	0.048
Independent ambulation before fracture	3 (6.5%)	0 (0.0%)	1 (2.9%)	2 (66.7%)	0 (0.0%)	0.02
Previous compromised implant	33 (71.7%)	4 (66.7%)	28 (82.4%)	1 (33.3%)	0 (0.0%)	< 0.01
Proximal	28 (60.9%)	4 (66.7%)	24 (70.6%)	0 (0.0%)	0 (0.0%)	< 0.01
Distal	17 (37.0%)	3 (50.0%)	13 (38.2%)	1 (33.3%)	0 (0.0%)	0.61
Implant gap (mm)[4]	194.4 (165.1–223.1)	78.6 (55.0–100.1)	212.4 (185.4–230.6)	78.0 (48.4–168.5)	73.6 (60.6–145.9)	< 0.01
Time to fracture (years)[5]	2.4 (1.2–9.1)	3.0 (1.3–9.0)	2.4 (1.3–10.7)	0.0 (0.0–2.8)	8.2 (8.2–8.2)	0.31
Treatment modality						0.77

Data are presented as median (interquartile range) or n (%). Rows with statistically significant differences are shaded in grey.

[1] II, intramedullary proximal and distal implant; IE, intramedullary proximal and extramedullary distal implant; EI, extramedullary proximal and intramedullary distal implant; EE, extramedullary proximal and distal implant. [2] Two of the three EI fractures occurred in the same patient. [3] Age-adjusted Charlson Comorbidity Index. [4] Distance between the proximal and distal implants (n = 44). [5] Time from the most recent implantation to fracture (n = 40; II, n = 6; IE, n = 30; EI, n = 3; EE, n = 1). [6] Surgically treated fractures (n = 43; II, n = 6; IE, n = 31; EI, n = 3; EE, n = 3). [7] Surgically treated fractures (n = 42). [8] Red blood cell units; surgically treated fractures (n = 43). [9] Interimplant fracture.

Variable	Overall (n = 46)	Fracture subtype[1]				*p*
		II (n = 6)	IE (n = 34)	EI (n = 3)[2]	EE (n = 3)	
Patient baseline characteristics						
Fixation alone	35 (76.1%)	4 (66.7%)	26 (76.5%)	2 (66.7%)	3 (100.0%)	
Revision ± fixation	8 (17.4%)	2 (33.3%)	5 (14.7%)	1 (33.3%)	0 (0.0%)	
Nonoperative management	3 (6.5%)	0 (0.0%)	3 (8.8%)	0 (0.0%)	0 (0.0%)	
Removal of previous implants[6]	26 (60.5%)	3 (50.0%)	18 (58.1%)	2 (66.7%)	3 (100.0%)	0.62
Outcomes						
Surgical time (minutes)[7]	131.0 (104.8–156.5)	130.0 (110.0–162.0)	132.0 (100.5–160.5)	154.0 (147.5–154.5)	127.0 (115.0–128.5)	0.65
RBC transfusions (units)[8]	2.0 (1.0–2.5)	2.0 (2.0–4.2)	2.0 (1.0–2.5)	1.0 (0.5–2.0)	2.0 (1.5–2.0)	0.65
Length of stay (days)	16.5 (13.0–21.8)	16.0 (13.5–21.5)	15.5 (11.2–21.0)	70.0 (44.0–70.0)	15.0 (14.0–19.0)	0.13
Local complications	8 (17.4%)	1 (16.7%)	6 (17.6%)	1 (33.3%)	0 (0.0%)	1.00
Infection	3 (6.5%)	0 (0.0%)	3 (8.8%)	0 (0.0%)	0 (0.0%)	1.00
Mechanical complications	6 (13.0%)	1 (16.7%)	4 (11.8%)	1 (33.3%)	0 (0.0%)	0.82
Dislocation	3 (6.5%)	0 (0.0%)	3 (8.8%)	0 (0.0%)	0 (0.0%)	1.00
Aseptic loosening	2 (4.3%)	1 (16.7%)	1 (2.9%)	0 (0.0%)	0 (0.0%)	0.46

Data are presented as median (interquartile range) or n (%). Rows with statistically significant differences are shaded in grey.

[1] II, intramedullary proximal and distal implant; IE, intramedullary proximal and extramedullary distal implant; EI, extramedullary proximal and intramedullary distal implant; EE, extramedullary proximal and distal implant. [2] Two of the three EI fractures occurred in the same patient. [3] Age-adjusted Charlson Comorbidity Index. [4] Distance between the proximal and distal implants (n = 44). [5] Time from the most recent implantation to fracture (n = 40; II, n = 6; IE, n = 30; EI, n = 3; EE, n = 1). [6] Surgically treated fractures (n = 43; II, n = 6; IE, n = 31; EI, n = 3; EE, n = 3). [7] Surgically treated fractures (n = 42). [8] Red blood cell units; surgically treated fractures (n = 43). [9] Interimplant fracture.

Variable	Overall (n = 46)	Fracture subtype[1]				*p*
		II (n = 6)	IE (n = 34)	EI (n = 3)[2]	EE (n = 3)	
Patient baseline characteristics						
Secondary IIF[9]	1 (2.2%)	0 (0.0%)	0 (0.0%)	1 (33.3%)	0 (0.0%)	0.13
Emergency visits after discharge	3.5 (1.0–6.0)	8.0 (5.5–18.8)	2.0 (0.2–5.0)	9.0 (5.0–9.0)	4.0 (3.0–4.0)	0.14
Return home after discharge	7 (15.2%)	2 (33.3%)	4 (11.8%)	1 (33.3%)	0 (0.0%)	0.24
One-year mortality	9 (19.6%)	0 (0.0%)	8 (23.5%)	0 (0.0%)	1 (33.3%)	0.39

Data are presented as median (interquartile range) or n (%). Rows with statistically significant differences are shaded in grey.

[1] II, intramedullary proximal and distal implant; IE, intramedullary proximal and extramedullary distal implant; EI, extramedullary proximal and intramedullary distal implant; EE, extramedullary proximal and distal implant. [2] Two of the three EI fractures occurred in the same patient. [3] Age-adjusted Charlson Comorbidity Index. [4] Distance between the proximal and distal implants (n = 44). [5] Time from the most recent implantation to fracture (n = 40; II, n = 6; IE, n = 30; EI, n = 3; EE, n = 1). [6] Surgically treated fractures (n = 43; II, n = 6; IE, n = 31; EI, n = 3; EE, n = 3). [7] Surgically treated fractures (n = 42). [8] Red blood cell units; surgically treated fractures (n = 43). [9] Interimplant fracture.

IPFs (between two arthroplasties) represented 45.7% of cases (21 fractures), while the remaining 54.3% (25 fractures) involved other implant combinations. According to the proposed classification, IE was the predominant pattern (73.9%), followed by II (13.0%), EI (6.5%), and EE (6.5%). Hip arthroplasty/knee arthroplasty (45.7%) and cephalomedullary nail/knee arthroplasty (37.0%) were the most common IIF constructs (Fig. 1). Overall, 71.7% of fractures occurred in the presence of at least one previously compromised implant. Median time from the most recent implantation to fracture was 2.4 years (IQR 1.2–9.1), and median implant gap was 194.4 mm (IQR 165.1–223.1).

Comparisons among fracture subtypes are shown in Table 1. Previous implant compromise differed among subtypes ($p < 0.01$), being most frequent in IE (82.4%) and II (66.7%) fractures, less frequent in EI fractures (33.3%), and absent in EE fractures. Implant gap also differed significantly ($p < 0.01$), being longest in IE fractures (median 212.4 mm) and considerably shorter in II (78.6 mm), EI (78.0 mm), and EE (73.6 mm) fractures. When implant components were analyzed separately, a previously compromised proximal implant was found in 70.0% of fractures with an intramedullary proximal implant and in none of those with an extramedullary proximal implant ($p < 0.01$), and it was more frequent around hip arthroplasties than around cephalomedullary nails (82.6% vs 52.9%; $p = 0.08$). The presence of a distal intramedullary implant was associated with a shorter implant gap (median 78.0 vs 209.2 mm; $p < 0.01$). EI fractures showed a higher comorbidity burden (median Charlson 7.0 vs 4.0 to 5.0 in the other

subtypes; p = 0.048) and more frequent independent ambulation before fracture (66.7%; p = 0.02), although this subgroup included only three fractures, two of them in the same patient. No significant differences were found among subtypes regarding age, sex, treatment modality, surgical time, length of stay, transfusion requirements, emergency visits, local complications (p = 1.00), discharge destination, or one-year mortality (p = 0.39).

Regarding treatment, 35 fractures (76.1%) were treated by fixation alone, 8 (17.4%) by procedures involving arthroplasty revision, and 3 (6.5%) received nonoperative management. Among surgically treated fractures (n = 43), lateral plating was by far the most used construct, accounting for 67.4% of cases. Intramedullary nailing alone was used in 11.6% (9.3% antegrade long nails and 2.3% retrograde nails), and one case (2.3%) was treated by lateral plating combined with retrograde nailing. Procedures based on revision arthroplasty were performed in 18.6%, either isolated or combined with plate and/or nail fixation. In 26 cases (60.5%), total or partial removal of the previous implants was necessary. Treatment strategies and their outcomes are summarized in Table 2.

Table 2
Patient characteristics, surgical construct and outcomes according to treatment

Variable	Fixation (n = 35)	Revision ± fixation (n = 8)	*p*
Patient baseline characteristics			
Age (years)	90.0 (84.0–92.0)	82.5 (77.0–85.5)	0.07
Female sex	32 (91.4%)	6 (75.0%)	0.23
Age-adjusted CCI[1]	5.0 (5.0–6.0)	4.5 (3.8–5.2)	0.17
Independent ambulation before fracture	2 (5.7%)	1 (12.5%)	0.47
Previous compromised implant	23 (65.7%)	7 (87.5%)	0.40
Implant gap (mm)[2]	191.6 (161.4–221.2)	197.3 (169.5–234.9)	0.69
Time to fracture (years)[3]	2.0 (1.0–9.7)	2.5 (2.2–10.7)	0.41
Surgical construct			
Lateral plate	29 (82.9%)	–	
Intramedullary nail	5 (14.3%)	–	
Antegrade	4 (11.4%)	–	
Retrograde	1 (2.9%)	–	
Lateral plate + retrograde nail	1 (2.9%)	–	
Revision arthroplasty ± fixation	–	8 (100.0%)	
Hip revision	–	5 (62.5%)	
Knee revision	–	3 (37.5%)	
Removal of previous implants	20 (57.1%)	6 (75.0%)	0.45
Outcomes			
Surgical time (minutes)[4]	127.0 (100.5–152.0)	195.0 (158.0–244.0)	< 0.01

Data are presented as median (interquartile range) or n (%). Nonoperatively treated fractures (n = 3) were excluded. Rows with statistically significant differences are shaded in grey.

[1] Age-adjusted Charlson Comorbidity Index. [2] Distance between the proximal and distal implants (revision, n = 7). [3] Time from the most recent implantation to fracture (fixation, n = 31; revision, n = 7). [4] Revision, n = 7. [5] Red blood cell units. [6] Interimplant fracture.

Variable	Fixation (n = 35)	Revision ± fixation (n = 8)	*p*
Patient baseline characteristics			
RBC transfusions (units)[5]	2.0 (1.0–2.0)	2.5 (1.0–4.2)	0.17
Length of stay (days)	16.0 (12.5–21.0)	22.5 (13.8–35.2)	0.07
Local complications	4 (11.4%)	4 (50.0%)	0.03
Infection	2 (5.7%)	1 (12.5%)	0.47
Mechanical complications	2 (5.7%)	4 (50.0%)	< 0.01
Dislocation	1 (2.9%)	2 (25.0%)	0.08
Aseptic loosening	1 (2.9%)	1 (12.5%)	0.34
Secondary IIF[6]	0 (0.0%)	1 (12.5%)	0.19
Emergency visits after discharge	3.0 (1.0–5.5)	6.5 (2.5–16.2)	0.15
Return home after discharge	4 (11.4%)	3 (37.5%)	0.11
One-year mortality	8 (22.9%)	0 (0.0%)	0.32

Data are presented as median (interquartile range) or n (%). Nonoperatively treated fractures (n = 3) were excluded. Rows with statistically significant differences are shaded in grey.

[1] Age-adjusted Charlson Comorbidity Index. [2] Distance between the proximal and distal implants (revision, n = 7). [3] Time from the most recent implantation to fracture (fixation, n = 31; revision, n = 7). [4] Revision, n = 7. [5] Red blood cell units. [6] Interimplant fracture.

Patients treated with fixation were older (median 90.0 vs 82.5 years; p = 0.07) and had higher Charlson scores (5.0 vs 4.5; p = 0.17) than those undergoing revision procedures, although these differences were not significant. A previously compromised implant was more frequent in the revision group (87.5% vs 65.7%; p = 0.40). Median surgical time was 131.0 minutes (IQR 104.8–156.5) and was significantly longer in revision procedures than in fixation alone (195.0 vs 127.0 minutes; p < 0.01). Local complications were also significantly more frequent after revision procedures (50.0% vs 11.4%; p = 0.03), mainly because of mechanical complications (50.0% vs 5.7%; p < 0.01). Revision procedures showed longer hospital stay (22.5 vs 16.0 days; p = 0.07), more emergency visits after discharge (6.5 vs 3.0; p = 0.15), and higher transfusion requirements (2.5 vs 2.0 units; p = 0.17), although these differences did not reach statistical significance.

One-year mortality was 19.6% (9 fractures). Deceased patients were older than survivors (median 91.0 vs 86.0 years; p = 0.09), with similar Charlson scores (5.0 vs 5.0; p = 0.38). Mortality was numerically higher after fixation than after revision procedures (22.9% vs 0%; p = 0.32), and one of the three nonoperatively treated patients died during admission. Eight of the nine deaths occurred in IE fractures, whose patients

were older than those with other subtypes (median 89.5 vs 81.0 years; p = 0.16). Mortality did not differ between fractures with and without local complications (0% vs 23.7%; p = 0.32).

Nine local complications were recorded in eight fractures (17.4%), including three infections and six mechanical complications (three prosthetic hip dislocations, two cases of aseptic loosening, and one secondary IIF). One patient in the revision group developed both a dislocation and an infection, which were managed during a single surgical procedure. Local complications occurred in 50.0% of fractures treated with revision procedures and in 11.4% of those treated with fixation alone (p = 0.03); two of the four complicated revision cases corresponded to dislocations. Within each subtype, complications were more frequent after revision than after fixation (II, 1/2 vs 0/4; IE, 2/5 vs 4/26; EI, 1/1 vs 0/2; no revision procedures in EE), although no individual comparison was significant. After stratification by fracture subtype, the association between revision procedures and local complications persisted (Mantel–Haenszel OR 7.1; exact stratified p = 0.04). By subtype, local complications occurred in 16.7% of II, 17.6% of IE, 33.3% of EI, and 0% of EE fractures (p = 1.00). Implant gap did not differ between fractures with and without local complications (198.8 vs 194.4 mm; p = 0.71), nor between fractures with and without mechanical complications (216.0 vs 190.3 mm; p = 0.41).

Functional outcomes were poor: all three previously independent walkers required walking aids at final follow-up, and although 76.1% of patients lived at home before injury, only 15.2% returned directly home after discharge. No deaths occurred among patients discharged home (0% vs 23.1%; p = 0.32).

DISCUSSION

This study highlights three relevant aspects of IIFs. First, these injuries occurred predominantly in very elderly, frail women with substantial comorbidity, confirming that they represent a severe fragility fracture pattern [13, 14]. Second, marked heterogeneity was observed in implant combinations, fracture morphology, and treatment strategies, as each fracture presents a unique biomechanical environment that must be addressed individually [4]. Third, despite individualized management, outcomes remained poor, with high one-year mortality and major functional decline.

A key finding is that the concept of IIF extends beyond the traditional definition of IPF. Although IPFs represented nearly half of cases, more than half of our series corresponded to other combinations of proximal and distal implants. Previous literature has frequently grouped these injuries with periprosthetic fractures or failed to distinguish them from IPFs, which likely explains the inconsistency of published data [6, 17–19]. Current classification systems such as Vancouver, Su, or Rorabeck were not designed for these scenarios, while more specific systems such as Platzer or Pires have had limited adoption [5, 10, 14, 20]. Our proposed classification attempts to provide a simple framework encompassing the whole spectrum of IIFs. Nevertheless, treatment modality and outcomes did not differ among subtypes, suggesting that implant stability, rather than implant position alone, drives treatment decisions. Future studies should assess whether adding an implant stability modifier, analogous to the distinction between Vancouver B1 and B2 fractures, improves the therapeutic and prognostic value of the classification.

Type IE fractures were by far the most frequent pattern, likely reflecting the common coexistence of hip arthroplasty or proximal femoral nails with knee arthroplasty in elderly patients. However, implant prevalence alone may not explain this distribution, and specific biomechanical interactions between implant combinations probably contribute. One study observed more fractures around hip stems than around proximal femoral nails, which is consistent with our findings [6]. The interimplant gap has also been proposed as a risk factor: some authors reported that a gap shorter than 110 mm doubles the risk of fracture, whereas others found no association [6, 21]. In our series, IE fractures showed the largest gaps and were the most common, whereas II, EI, and EE fractures had considerably shorter gaps. Stem loosening, which may increase local stress, has also been proposed as a predisposing factor [22, 23]. Our findings suggest that two different mechanisms may be involved. Fractures with an intramedullary proximal implant, particularly around hip arthroplasties, frequently occurred in the presence of a compromised proximal implant despite long interimplant distances, suggesting a mechanism driven by implant failure. Conversely, when a distal intramedullary implant was present, the interimplant gap was markedly shorter, supporting a stress riser mechanism in which loads concentrate on a short femoral segment between two rigid implants. These hypotheses deserve confirmation in larger series.

Previously compromised implants were present in almost three quarters of fractures, particularly in type IE, and were more frequent in fractures treated with implant revision (87.5% vs 65.7%), although not significantly. This suggests that implant status may influence both fracture occurrence and treatment selection. To our knowledge, this association has not been specifically addressed before and deserves further research.

Treatment of these fractures remains challenging, as each case combines patient frailty, fracture complexity, implant stability, bone quality, and limited fixation options [4, 6, 13, 15]. Accordingly, management was highly individualized and often required implant removal, revision arthroplasty, or complex fixation constructs. Lateral locked plating was the most frequent strategy, supporting previous reports that bridge plating remains a versatile option [20, 22–25]. Although double plating or combined nail-and-plate fixation have been associated with lower nonunion rates, the optimal fixation strategy remains unclear [14, 20, 24]. Revision procedures required significantly longer surgical time and were associated with significantly more local complications, mainly prosthetic dislocations, reflecting their greater technical complexity and the instability inherent to revision hip arthroplasty. This is consistent with findings in Vancouver B2 periprosthetic fractures, in which revision arthroplasty has been associated with more hip-related complications, particularly dislocation, than internal fixation [26–28]. Since treatment modality did not differ among fracture subtypes and the association between revision procedures and local complications persisted after stratification, fixation alone may be the preferable option in any interimplant configuration when the preexisting implants are stable. Although revision procedures tended to be performed in fractures with compromised implants, this association was not significant (65.7% vs 87.5%; $p = 0.40$), suggesting that implant compromise alone did not determine the need for revision. These findings support the use of fixation alone whenever implant stability allows it, although the small number of revision procedures precludes firm conclusions.

Clinical outcomes were poor. One-year mortality reached 19.6%, comparable to other fragility fractures and within the range of previous interimplant series (0 to 66%) [13–15, 20, 29], although our population appears more complex and frail than patients with proximal femur or periprosthetic fractures [30, 31]. Local complications occurred in 17.4% of cases, within previously reported incidences of 12.6% to 30% [13, 14, 29], and similar to those of standard periprosthetic fractures [25]. No deaths occurred after revision procedures, whereas mortality after fixation reached 22.9%, in line with previous literature [14]. This most likely reflects patient selection rather than a protective effect, as patients treated with fixation were older and more comorbid. Similarly, the concentration of deaths in IE fractures appears to reflect the older age of these patients rather than an effect of the fracture pattern itself. Apart from previous implant compromise, implant gap, comorbidity, and independent ambulation, no relevant differences in treatment or outcomes were observed among subtypes, although the small EI and EE subgroups limit these comparisons.

Functional recovery was limited: only 15.2% of patients returned directly home, and all previously independent walkers required walking aids at the end of follow-up. Functional outcomes are reported in less than half of published cases, and the need for walking aids is frequently omitted [13–15, 29]. Worse functional results have been observed in older patients [13]. These findings suggest that IIFs should be viewed not only as a reconstructive problem but also as a geriatric fracture entity requiring multidisciplinary perioperative care and rehabilitation pathways.

This study has several limitations. Its retrospective, single-center design, small sample size, and potential selection bias may have prevented the detection of significant differences, particularly between treatment groups and among the less frequent subtypes. One patient contributed two fractures, which may have introduced some dependence between observations. Finally, the heterogeneity of these fractures and individualized treatment by different surgeons may have increased variability. Larger multicenter studies are needed to clarify the biomechanics of these fractures and to develop effective treatment and preventive strategies.

CONCLUSIONS

IIFs are heterogeneous fragility injuries that require individualized treatment, as every case presents a unique biomechanical environment. Affected patients are extremely frail and show high one-year mortality, a relevant rate of local complications, and major functional decline, with none walking without aids at the end of follow-up. Revision procedures required longer surgical time and had more local complications than fixation alone, whereas mortality did not differ significantly between treatments. When the preexisting implants are stable, fixation alone appears to be associated with fewer local complications regardless of fracture subtype. The proposed classification may facilitate the understanding and categorization of these fractures, although further validation in larger cohorts is required.

Declarations

- **Ethical Approval:** This study was approved by the Clinical Research Ethics Committee (Comité de Ética de la Investigación Clínica, CEIC) of Hospital Universitari Vall d'Hebron, Barcelona, Spain (approval reference number PR(AT)296/2022).
- **Consent to Participate and Publish:** This is a retrospective study. Its realization did not imply any risk for the participants and all the collected data were de-identified. Therefore, IRB approved a full waiver of informed consent.
- **Authors Contributions:** All authors contributed to the study's conception and design. JNS and JVAP performed material preparation, data collection, and analysis. The first draft of the manuscript was written by JNS and JVAP. All authors reviewed and commented on previous versions of the manuscript, and all read and approved the final version.
- **Funding:** No funding was received for conducting this study.
- **Competing Interests:** The authors have financial conflicts of interest to declare with Smith & Nephew, Zimmer-Biomet, Stryker, Link Orthopaedics, Acumed, Exactech and MBA Surgical Empowerment.
- **Availability of data and materials:** The data that support the findings of this study are available from the corresponding author, JVAP, upon reasonable request.

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Figures

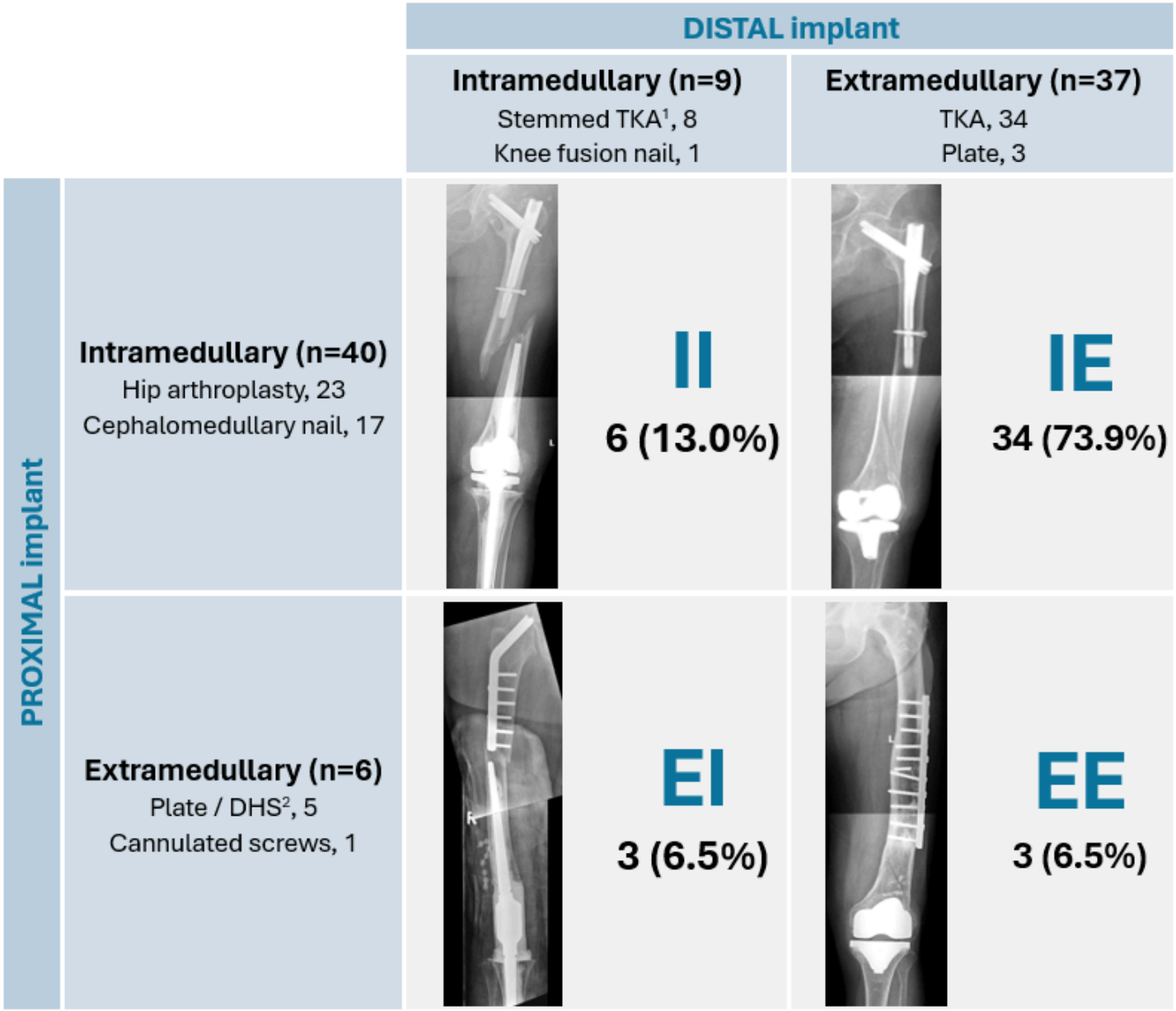


Figure 1

Classification of interimplant femoral fractures according to the position of the proximal and distal implants Fractures were classified according to whether the proximal (first letter) and distal (second letter) implants were intramedullary (I) or extramedullary (E), yielding four subtypes: II, IE, EI, and EE. Row headings show the proximal implants and column headings the distal implants in the whole series. Each cell shows a representative preoperative radiograph and the number (percentage) of fractures of each subtype.

[1] TKA, total knee arthroplasty; [2] DHS, dynamic hip screw.