

Research Article

Incidence and Risk Factors of Fracture-Related Infection Following Internal Fixation of Long Bone Fractures

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ABSTRACT

Background: Fracture-related infection (FRI) is a significant complication following internal fixation of long bone fractures, contributing to delayed healing and implant failure. This study aimed to determine the incidence and associated risk factors of FRI.

Materials and Methods: This prospective observational study included 150 patients undergoing internal fixation of long bone fractures. Patients were categorized into FRI and Non-FRI groups. Demographic, clinical, fracture-related, and operative factors were evaluated. Statistical significance was considered at $p < 0.05$.

Results: FRI developed in 18 patients (12.0%), while 132 (88.0%) remained infection-free. Infection was significantly higher in open fractures than closed fractures (28.9% versus 6.3%; $p < 0.001$), diabetic than nondiabetic patients (30.0% versus 7.5%; $p = 0.002$), and smokers than nonsmokers (20.8% versus 7.8%; $p = 0.022$). Mean operative duration was significantly longer in the FRI group (132.4 ± 28.6 versus 108.7 ± 25.3 minutes; $p = 0.003$). Staphylococcus aureus was the predominant organism (44.4%). Delayed union occurred in 33.3%, nonunion in 16.7%, and additional surgical intervention was required in 38.9% of infected patients.

Conclusion: Open fractures, diabetes mellitus, smoking, and prolonged operative duration were associated with increased FRI occurrence. Early risk identification and appropriate perioperative management may reduce postoperative complications.

Keywords: Fracture-Related Infection, Long Bone Fractures, Internal Fixation, Risk Factors, Surgical Site Infection.

INTRODUCTION

Long bone fractures are among the most common musculoskeletal injuries encountered in orthopaedic practice and represent a significant cause of morbidity, functional disability, and socioeconomic burden[1]. Internal fixation using plates, screws, and intramedullary nails is widely employed for managing displaced and unstable fractures, providing mechanical stability, facilitating fracture healing, and allowing early mobilization[2]. Despite advances in surgical techniques, implant technology, perioperative antibiotic prophylaxis, and infection prevention measures, fracture-related infection (FRI) remains a serious complication following

internal fixation [1,2]. The incidence of infection following fracture fixation varies considerably depending on fracture characteristics, anatomical location, injury severity, and patient-related factors. Previous studies have reported postoperative infection rates ranging from approximately 0.4% to 16.1%, with substantially higher rates observed following open fractures than closed fractures [3,4]. FRI may result in delayed union, nonunion, chronic osteomyelitis, implant failure, and permanent functional impairment. Management frequently requires repeated surgical debridement, prolonged antimicrobial therapy, implant revision or removal, and extended hospitalization. Severe infections may

necessitate limb amputation, imposing considerable physical, psychological, and financial burdens on patients and healthcare systems [5,6]. The development of FRI is multifactorial and involves interactions between patient characteristics, fracture-related factors, microbial contamination, and surgical management. Patient-related factors such as diabetes mellitus, smoking, obesity, malnutrition, and associated systemic illnesses may impair wound healing and increase susceptibility to infection. Injury-related factors, including open fractures, high-energy trauma, extensive soft tissue damage, and wound contamination, further contribute to infection risk [7,8]. Surgical factors such as prolonged operative duration, extensive tissue dissection, delayed definitive fixation, and inadequate management of contaminated wounds may also influence postoperative infection rates. Previous studies have identified several of these variables as important predictors of infection, emphasizing the need for comprehensive perioperative risk assessment and targeted preventive measures [9,10]. The diagnosis of FRI remains challenging because clinical manifestations may range from obvious wound discharge, sinus formation, and implant exposure to nonspecific symptoms such as persistent pain, swelling, and delayed fracture healing. Traditional definitions of surgical site infection (SSI) and prosthetic joint infection (PJI) do not fully address the distinct characteristics of infection associated with fracture fixation. Consequently, an international expert group established consensus diagnostic criteria for FRI incorporating confirmatory and suggestive clinical, microbiological, and histopathological findings [11,12]. Standardized diagnostic criteria are essential for accurate estimation of infection incidence and comparison of findings across studies. Although several investigations have evaluated postoperative infections following orthopaedic procedures, many have focused on specific fracture sites, selected patient populations, or individual fixation techniques. Variations in diagnostic definitions, fracture patterns, surgical practices, and follow-up duration have contributed to inconsistencies in reported infection rates and associated risk factors [10]. Further evaluation across different long bone fractures is therefore necessary to identify potentially modifiable determinants and improve infection prevention strategies. Therefore, the present study was undertaken to determine the incidence of

fracture-related infection following internal fixation of long bone fractures and to identify the associated patient-related, injury-related, and treatment-related risk factors.

MATERIALS AND METHODS

The present study was designed as a hospital-based prospective observational study to determine the incidence of fracture-related infection (FRI) following internal fixation of long bone fractures and identify associated risk factors. The study was conducted in the Department of Orthopaedics at a tertiary care teaching hospital over a defined study period. Eligible patients were enrolled and followed postoperatively to assess the development of FRI. A total of 150 adult patients undergoing internal fixation of long bone fractures involving the humerus, radius, ulna, femur, or tibia were included. Patients were recruited using consecutive sampling according to predefined eligibility criteria.

Inclusion Criteria

1. Patients aged 18 years and above.
2. Patients with open or closed long bone fractures.
3. Patients undergoing internal fixation using plates, screws, or intramedullary nails.
4. Patients providing written informed consent and willing to undergo postoperative follow-up.

Exclusion Criteria

1. Patients with pathological fractures due to malignancy or metabolic bone disorders.
2. Patients with pre-existing osteomyelitis or infection at the fracture site.
3. Patients undergoing revision surgery for previously infected fractures.
4. Patients managed exclusively with external fixation or conservative treatment.
5. Patients with incomplete records or inadequate postoperative follow-up.

Group Classification

Based on the occurrence of FRI during postoperative follow-up, patients were categorized into two groups:

- Group A (FRI Group): Patients who developed confirmed fracture-related infection following internal fixation.
- Group B (Non-FRI Group): Patients who did not develop fracture-related infection during follow-up.

Data Collection and Preoperative Assessment

Demographic characteristics, including age, sex, body mass index (BMI), smoking status,

diabetes mellitus, and associated comorbidities, were recorded using a structured case record form. Clinical examination and radiographic evaluation were performed to assess fracture location, configuration, soft tissue condition, and neurovascular status. Fractures were classified as open or closed, with open fractures graded according to the Gustilo–Anderson classification. Routine preoperative investigations were performed as clinically indicated.

Surgical Management

All patients underwent internal fixation under appropriate anaesthesia and standard aseptic precautions. Fixation techniques included plate osteosynthesis or intramedullary nailing, depending on fracture characteristics and surgeon preference. Perioperative antibiotics were administered according to institutional protocols. Open fractures underwent appropriate irrigation, debridement, and soft tissue management. The type of fixation, interval between injury and surgery, operative duration, and intraoperative complications were documented.

Postoperative Care and Follow-up

Patients received routine postoperative care, including wound assessment, analgesia, antibiotics as indicated, and rehabilitation. During hospitalization and scheduled follow-up visits, surgical wounds were examined for redness, swelling, tenderness, discharge, and wound dehiscence. Clinical and radiographic assessments were performed to evaluate fracture healing, implant stability, and infection-related complications.

Diagnosis of Fracture-Related Infection

FRI was diagnosed according to international consensus criteria. Confirmatory findings included a sinus or wound breakdown communicating with the fracture or implant, purulent drainage, isolation of phenotypically indistinguishable microorganisms from at least two separate deep tissue or implant specimens, or microorganisms identified in deep tissue by histopathological examination. Suggestive findings included persistent pain, swelling, redness, fever, wound drainage, elevated inflammatory markers, and radiological abnormalities. Suspected cases underwent further evaluation, and infection was confirmed when at least one confirmatory criterion was fulfilled.

Assessment of Risk Factors

Potential risk factors were evaluated under three categories: patient-related factors (age, sex, BMI, diabetes, smoking, and comorbidities), injury-related factors (fracture location, mechanism of injury, open or closed fracture, and soft tissue injury), and treatment-related factors (fixation method, injury-to-surgery interval, operative duration, and perioperative management). These variables were compared between the FRI and Non-FRI groups.

Outcome Measures

The primary outcome was the incidence of confirmed FRI following internal fixation of long bone fractures. Secondary outcomes included identification of associated risk factors, time to infection diagnosis, microbiological findings, and infection-related complications, including delayed union, nonunion, implant failure, and additional surgical interventions.

Statistical Analysis

Data were entered into Microsoft Excel and analysed using IBM SPSS Statistics software. Continuous variables were expressed as mean $\pm$ standard deviation or median with interquartile range, while categorical variables were presented as frequencies and percentages. The incidence of FRI was calculated as the proportion of patients developing infection among the total 150 patients. Categorical variables were compared using the Chi-square test or Fisher's exact test, while continuous variables were analysed using the independent-samples t-test or Mann–Whitney U test, as appropriate. Univariable analysis was performed to assess potential risk factors, and multivariable logistic regression was considered when sufficient infection events were available. A p-value of less than 0.05 was considered statistically significant.

RESULTS

A total of 150 patients who underwent internal fixation for long bone fractures were included in the study. Of these, 18 patients (12.0%) developed fracture-related infection (FRI), whereas 132 patients (88.0%) did not develop infection. The overall incidence of FRI was 12.0% (Table 1). The mean age of patients with FRI was higher than that of patients without FRI (44.7 ± 12.8 vs. 39.1 ± 13.5 years), although the difference was not statistically significant ($p=0.097$). The incidence of FRI was higher among males than females (13.9% vs. 7.1%); however, the association was not statistically

significant ($p=0.254$). An increasing trend in FRI incidence was observed with advancing age, ranging from 6.8% in patients aged 18–30 years to 18.2% in those aged above 50 years, although this association was not statistically significant ($p=0.447$) (Table 2). The highest incidence of FRI was observed in tibial fractures (18.5%), followed by femoral fractures (9.5%), humeral and ulnar fractures (8.3% each), and radial fractures (5.6%). However, the association between fracture site and FRI was not statistically significant ($p=0.465$). Open fractures demonstrated a significantly higher incidence of FRI compared with closed fractures (28.9% vs. 6.3%; $p<0.001$) (Table 3, Figure 1). Diabetes mellitus was significantly associated with FRI, with an infection incidence of 30.0% among diabetic patients compared with 7.5% among nondiabetic patients ($p=0.002$). Similarly, smokers had a significantly higher incidence of FRI than nonsmokers (20.8% vs. 7.8%; $p=0.022$) (Table 4, Figure 2). The incidence of FRI was slightly higher among patients undergoing plate and screw fixation compared with those undergoing intramedullary nailing (13.3% vs. 10.0%); however, this difference was not statistically significant ($p=0.538$). The mean operative

duration was significantly longer in patients who developed FRI compared with those without infection (132.4 ± 28.6 vs. 108.7 ± 25.3 minutes; $p=0.003$) (Table 5). Among the 18 patients who developed FRI, 11 (61.1%) were diagnosed within 30 days, while 7 (38.9%) were diagnosed after 30 days. *Staphylococcus aureus* was the most commonly isolated microorganism (44.4%), followed by *Pseudomonas aeruginosa* (22.2%) and *Escherichia coli* (16.7%). Other microorganisms accounted for 5.6% of cases, while 11.1% were culture-negative. Delayed union was observed in 33.3% of patients, nonunion in 16.7%, and implant failure in 11.1%, whereas 38.9% required additional surgical intervention (Table 6). Univariable logistic regression analysis demonstrated that open fractures were significantly associated with increased odds of FRI (OR=6.11; 95% CI: 2.16–17.27; $p<0.001$). Diabetes mellitus was also significantly associated with FRI (OR=5.29; 95% CI: 1.90–14.76; $p=0.001$), followed by smoking (OR=3.09; 95% CI: 1.14–8.38; $p=0.027$). However, plate fixation did not demonstrate a statistically significant association with FRI (OR=1.38; 95% CI: 0.49–3.86; $p=0.540$) (Table 7, Figure 3).

Table 1. Incidence of Fracture-Related Infection Following Internal Fixation of Long Bone Fractures

Infection status	Number	Percentage (%)
FRI	18	12.0
Non-FRI	132	88.0
Total	150	100.0

Table 2. Association of Demographic Characteristics with Fracture-Related Infection

Parameters	FRI (n=18)	Non-FRI (n=132)	p-value	Statistical test
Mean age (years)	44.7 $\pm$ 12.8	39.1 $\pm$ 13.5	0.097	Welch's t-test
Sex			0.254	Pearson Chi-square test
Male	15 (13.9%)	93 (86.1%)		
Female	3 (7.1%)	39 (92.9%)		
Age group (years)			0.447	Pearson Chi-square test
18–30	3 (6.8%)	41 (93.2%)		
31–40	4 (10.3%)	35 (89.7%)		
41–50	5 (14.7%)	29 (85.3%)		
>50	6 (18.2%)	27 (81.8%)		

Table 3. Association of Fracture Characteristics with Fracture-Related Infection

Parameters	FRI (n=18)	Non-FRI (n=132)	p-value	Statistical test
Fracture site			0.465	Pearson Chi-square test
Humerus	2 (8.3%)	22 (91.7%)		
Radius	1 (5.6%)	17 (94.4%)		
Ulna	1 (8.3%)	11 (91.7%)		
Femur	4 (9.5%)	38 (90.5%)		
Tibia	10 (18.5%)	44 (81.5%)		
Fracture type			<0.001	Fisher's exact test

Open fracture	11 (28.9%)	27 (71.1%)		
Closed fracture	7 (6.3%)	105 (93.8%)		

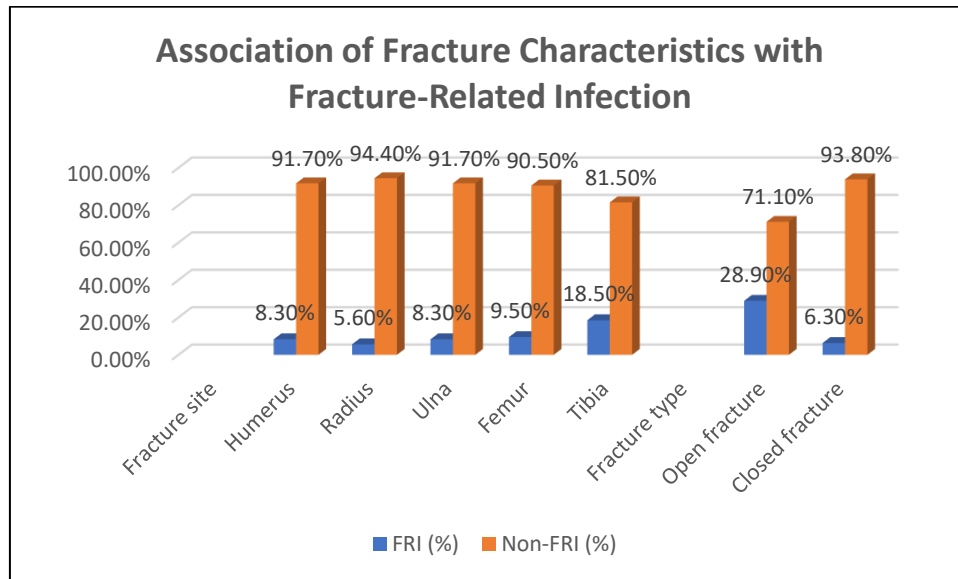


Figure 1. Association of Fracture Characteristics with Fracture-Related Infection

Table 4. Association of Patient-Related Risk Factors with Fracture-Related Infection

Risk factors	FRI (n=18)	Non-FRI (n=132)	p-value	Statistical test
Diabetes mellitus			0.002	Fisher's exact test
Present	9 (30.0%)	21 (70.0%)		
Absent	9 (7.5%)	111 (92.5%)		
Smoking status			0.022	Pearson Chi-square test
Smoker	10 (20.8%)	38 (79.2%)		
Nonsmoker	8 (7.8%)	94 (92.2%)		

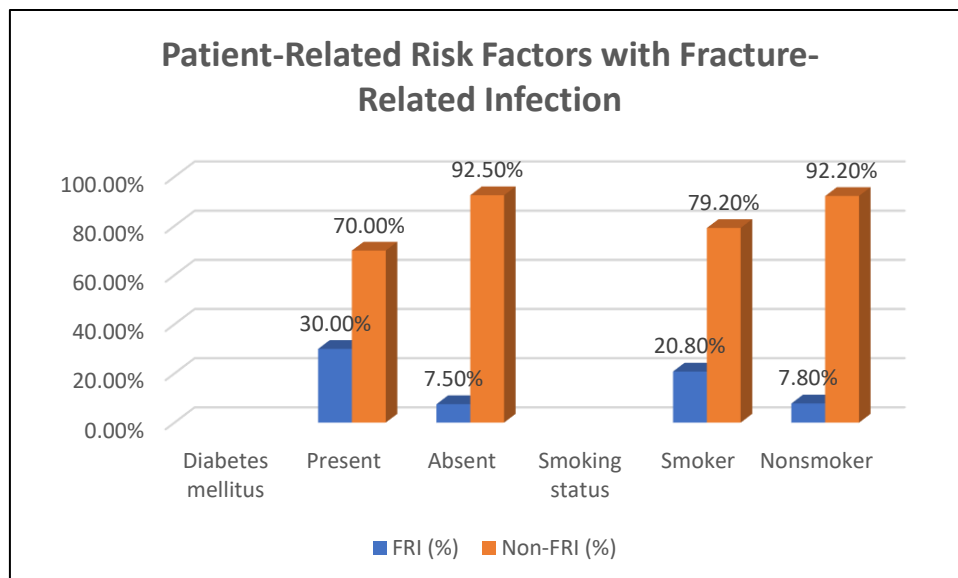


Figure 2. Association of Patient-Related Risk Factors with Fracture-Related Infection

Table 5. Association of Operative Characteristics with Fracture-Related Infection

Parameters	FRI (n=18)	Non-FRI (n=132)	p-value	Statistical test
Type of fixation			0.538	Pearson Chi-square test
Plate and screw fixation	12 (13.3%)	78 (86.7%)		

Intramedullary nailing	6 (10.0%)	54 (90.0%)		
Operative duration (minutes)				
Mean $\pm$ SD	132.4 $\pm$ 28.6	108.7 $\pm$ 25.3	0.003	Welch's t-test

Table 6. Clinical Characteristics, Microbiological Profile, and Complications Among Patients with FRI (n=18)

Parameters	Number	Percentage (%)
Time to infection diagnosis		
Within 30 days	11	61.1
After 30 days	7	38.9
Microorganisms isolated		
Staphylococcus aureus	8	44.4
Pseudomonas aeruginosa	4	22.2
Escherichia coli	3	16.7
Other microorganisms	1	5.6
Culture-negative	2	11.1
Infection-related complications		
Delayed union	6	33.3
Nonunion	3	16.7
Implant failure	2	11.1
Additional surgical intervention	7	38.9

Table 7. Univariable Association of Potential Risk Factors with Fracture-Related Infection

Risk factors	Odds ratio (OR)	95% confidence interval	p-value	Statistical test
Open fracture	6.11	2.16–17.27	<0.001	Univariable logistic regression
Diabetes mellitus	5.29	1.90–14.76	0.001	
Smoking	3.09	1.14–8.38	0.027	
Plate fixation	1.38	0.49–3.86	0.540	

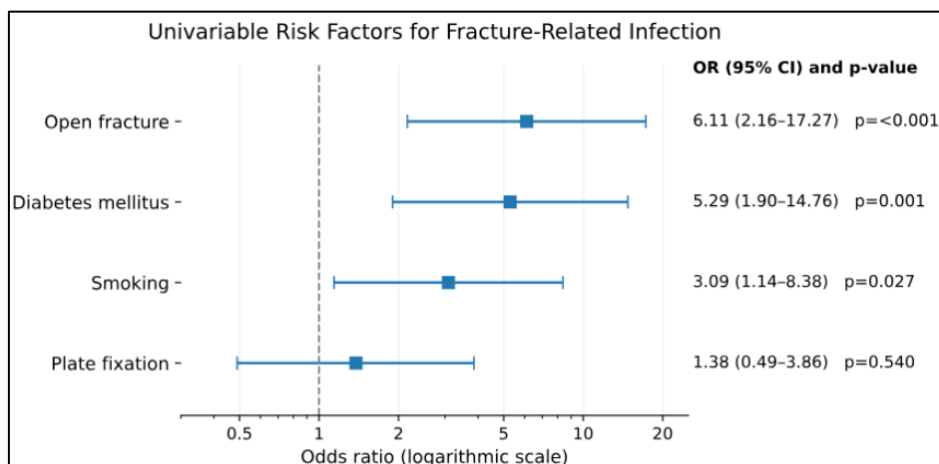


Figure 3. Univariable Association of Potential Risk Factors with Fracture-Related Infection

DISCUSSION

The present study evaluated the incidence and risk factors of fracture-related infection (FRI) following internal fixation of long bone fractures in 150 patients. The overall infection proportion was 12.0%, with higher infection rates among patients with open fractures, diabetes mellitus,

smoking history, and prolonged operative duration. These findings highlight the importance of identifying high-risk patients and implementing appropriate perioperative infection-prevention measures. In the present study, FRI developed in 18 patients (12.0%), whereas 132 patients (88.0%) remained

infection-free. Rosenberger et al. [13] emphasized standardized perioperative infection-prevention practices under the Surgical Care Improvement Project, which targeted a 25% reduction in surgical site infections. Their review highlighted appropriate antibiotic prophylaxis, glycaemic control, and perioperative care. Although the authors did not report a directly comparable FRI incidence, their recommendations support the importance of preventive measures in fracture fixation surgery. The mean age was higher among patients with FRI (44.7 ± 12.8 years) than among those without infection (39.1 ± 13.5 years), although the difference was not statistically significant ($p=0.097$). Infection occurred in 13.9% of males and 7.1% of females. Oguz et al. [14], in a study involving 80 orthopaedic patients, reported a mean age of 43 ± 15 years, with 55% males and 45% females. Their demographic findings were broadly comparable to the present study, although their investigation primarily evaluated operating-room bacterial contamination rather than postoperative FRI. In the present study, FRI occurred in 30.0% of diabetic patients compared with 7.5% of nondiabetic patients ($p=0.002$). Similarly, infection was observed in 20.8% of smokers compared with 7.8% of nonsmokers ($p=0.022$). Rosenberger et al. [13] emphasized perioperative glycaemic control as an important component of surgical infection prevention. These findings support the importance of identifying and optimizing modifiable patient-related risk factors before surgery. Tibial fractures were the most common injuries (36.0%) and demonstrated the highest infection proportion (18.5%). FRI occurred in 28.9% of patients with open fractures compared with 6.3% of those with closed fractures ($p<0.001$). Open fractures demonstrated approximately 6.11-fold higher unadjusted odds of infection. These findings suggest that soft tissue injury and contamination may contribute substantially to postoperative infection. Rosenberger et al. [13] similarly emphasized the importance of appropriate antimicrobial prophylaxis and standardized surgical infection-prevention practices, although their review did not specifically compare open and closed fractures. The mean operative duration was significantly longer in patients with FRI (132.4 ± 28.6 minutes) than in those without infection (108.7 ± 25.3 minutes; $p=0.003$). Oguz et al. [14], in a randomized pilot study of 80 patients, reported that prolonged surgical duration and

the absence of unidirectional laminar airflow significantly increased airborne bacterial contamination. Their findings support the possible relationship between prolonged surgery and increased infection risk observed in the present study. FRI occurred in 13.3% of patients undergoing plate fixation and 10.0% undergoing intramedullary nailing, without a significant difference ($p=0.538$). Bendich et al. [15], in a study involving 15,972 total knee arthroplasty patients, reported lower infection-related revision rates with antibiotic-laden cement compared with plain cement (1.9% versus 2.6%; $p=0.005$). Although their study involved arthroplasty rather than fracture fixation, it highlights the potential importance of implant-related infection-prevention strategies. *Staphylococcus aureus* was the predominant microorganism isolated in the present study (44.4%), followed by *Pseudomonas aeruginosa* (22.2%) and *Escherichia coli* (16.7%). Proctor [16] highlighted the clinical importance of *S. aureus* infections and discussed challenges in developing effective vaccines against this organism, including unsuccessful clinical vaccine trials. Although the review did not report FRI-specific isolation rates, it reinforces the importance of preventing and appropriately managing staphylococcal infections.

Among patients with FRI, 61.1% developed infection within 30 days, while 38.9% were diagnosed after 30 days. Toon et al. [17], in a Cochrane review involving 280 patients, compared early dressing removal within 48 hours ($n=140$) with delayed removal ($n=140$). They found no significant difference in superficial surgical site infection (RR 0.64; 95% CI 0.32–1.28). These findings suggest that dressing-removal timing alone may not substantially influence superficial infection rates, although the evidence was of very low certainty. The present findings emphasize the importance of continued postoperative wound surveillance. Among patients with FRI, delayed union occurred in 33.3%, nonunion in 16.7%, and implant failure in 11.1%, while 38.9% required additional surgical intervention. Bendich et al. [15] reported lower all-cause revision rates with antibiotic-laden cement than with plain cement (5.3% versus 6.7%; $p=0.0009$). Although the surgical procedures differed, both studies highlight the clinical burden of infection-related orthopaedic complications and subsequent surgical interventions.

CONCLUSION

The present study demonstrated a fracture-related infection (FRI) proportion of 12.0% following internal fixation of long bone fractures. Open fractures, diabetes mellitus, smoking, and prolonged operative duration were significantly associated with increased infection occurrence. Early identification of risk factors, appropriate perioperative management, and regular postoperative surveillance may help reduce infection-related complications and improve fracture healing outcomes.

LIMITATIONS

The study was limited by its relatively small sample size, limited number of infection events, and observational design, which restricted the assessment of independent risk factors. The findings may also have been influenced by differences in fracture severity, surgical techniques, and postoperative management.

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