

Assessment of Incidence and Associated Risk Factors of Fracture-Related Infection in Patients Undergoing Internal Fixation of Long Bone Fractures

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ABSTRACT

Background: Fracture-related infection (FRI) is a major complication following internal fixation of long bone fractures and is associated with delayed fracture healing, repeated surgical interventions, prolonged hospitalization, and increased healthcare expenditure. Identification of associated risk factors is essential for developing effective preventive strategies.

Objectives: To assess the incidence of fracture-related infection and evaluate the associated patient-related, injury-related, and operative risk factors among patients undergoing internal fixation of long bone fractures. **Materials and Methods:** A prospective observational study was designed involving 120 adult patients undergoing internal fixation of long bone fractures. Demographic characteristics, comorbidities, fracture characteristics, surgical duration, timing of fixation, and postoperative outcomes were evaluated. Fracture-related infection was defined according to internationally accepted consensus criteria. Associations between potential risk factors and infection were assessed using appropriate statistical methods. **Results:** The provisional dataset included 14 patients (11.7%) with FRI. Infection occurred in 31.3% of open fractures compared with 4.5% of closed fractures. Diabetes mellitus (crude OR 5.24), current smoking (OR 5.27), obesity (OR 3.97), open fractures (OR 9.55), prolonged operative duration (OR 5.29), and delayed definitive fixation (OR 3.98) demonstrated higher crude odds of infection. *Staphylococcus aureus* was the most frequently recorded microorganism. Repeat surgical intervention was recorded in 85.7% of patients with FRI. **Conclusion:** Fracture-related infection following internal fixation of long bone fractures is associated with multiple patient-related, injury-related, and operative factors. Recognition of high-risk patients, appropriate soft tissue management, optimization of modifiable risk factors, and structured postoperative surveillance are important for reducing infection-related morbidity.

Keywords: Fracture-related infection; Long bone fractures; Internal fixation; Open fractures; Risk factors; Surgical infection; Orthopaedic trauma.

INTRODUCTION

Long bone fractures represent a significant proportion of orthopaedic trauma cases and contribute substantially to morbidity, functional disability, and socioeconomic burden worldwide. These fractures commonly involve the femur, tibia, humerus, radius, and ulna and frequently require operative stabilization to restore anatomical alignment, maintain mechanical stability, and

facilitate early mobilization. Internal fixation using intramedullary nails, plates, and screws has become an established treatment modality for displaced and unstable fractures. Despite advances in implant technology, surgical techniques, perioperative antimicrobial prophylaxis, and postoperative care, infection following fracture fixation remains a challenging complication that may compromise

treatment outcomes and prolong recovery.[1,2]Fracture-related infection (FRI) refers to infection involving the fracture environment, which may include bone, surrounding soft tissues, and fixation implants. Historically, terms such as postoperative osteomyelitis, implant-associated infection, and surgical site infection were used inconsistently, resulting in considerable variation in reported infection rates and diagnostic approaches. To address this limitation, Metsemakers et al. observed an internationally accepted consensus definition of FRI, incorporating confirmatory and suggestive diagnostic criteria. Confirmatory criteria include the presence of a sinus tract communicating with bone or an implant, purulent drainage, microbiological confirmation from appropriately collected deep tissue specimens, and characteristic histopathological findings.[1,3]

The incidence of FRI varies according to the anatomical location of the fracture, severity of soft tissue injury, fracture type, patient comorbidities, surgical management, and duration of postoperative surveillance. Closed fractures generally have lower infection rates than open fractures, particularly those associated with severe contamination and extensive tissue damage. Open fractures are especially vulnerable because disruption of the skin and soft tissue envelope permits bacterial contamination of the fracture site. Severe open fractures may require repeated debridement, staged fixation, and complex soft tissue reconstruction, thereby increasing the risk of postoperative infection.[2,4]

Several patient-related factors have been associated with infection following fracture fixation. Diabetes mellitus, smoking, obesity, malnutrition, immunosuppression, and peripheral vascular disease may impair tissue perfusion, immune responses, and wound healing. Hyperglycaemia can interfere with leukocyte function and collagen synthesis, while smoking contributes to tissue hypoxia, impaired angiogenesis, and reduced microvascular circulation. Obesity may increase surgical complexity and predispose patients to wound-related complications. Identification and optimization of these modifiable risk factors are important components of preoperative assessment and perioperative care.[2,5]

Injury-related characteristics also influence the development of FRI. High-energy trauma, open fractures, severe soft tissue disruption, contamination, fracture comminution, and vascular injury are recognized factors associated with postoperative infection. The Gustilo–Anderson classification is widely used to assess open fracture severity and guide management decisions. Higher-grade open fractures are generally associated with extensive tissue damage, greater contamination, and an increased requirement for complex reconstructive procedures. Tibial fractures are particularly susceptible to infection because of their

relatively limited soft tissue coverage and frequent association with high-energy trauma.[2,6]

Operative factors, including prolonged surgical duration, extensive tissue dissection, repeated surgical procedures, inadequate debridement, and delayed soft tissue coverage, may further contribute to infection. Appropriate antimicrobial prophylaxis, meticulous surgical technique, preservation of tissue vascularity, and stable fixation are essential for reducing postoperative complications. Once infection develops, microorganisms may form biofilms on implant surfaces, making eradication difficult and often requiring a combination of surgical debridement and prolonged antimicrobial treatment.[5,7]

The consequences of FRI extend beyond the immediate postoperative period. Patients may experience persistent pain, delayed union, nonunion, chronic osteomyelitis, implant failure, repeated hospitalization, and prolonged functional disability. Management frequently requires multiple surgical procedures, prolonged antibiotic therapy, and extended rehabilitation, placing a considerable financial burden on patients and healthcare systems. Early diagnosis and appropriate treatment are therefore essential for preventing long-term complications.[5,7]

Although previous studies have investigated infectious complications following fracture fixation, considerable variation exists in reported incidence and associated risk factors. Differences in study populations, fracture characteristics, surgical practices, diagnostic criteria, and follow-up duration may explain these inconsistencies. Evaluation of infection rates and associated risk factors within a defined clinical population may help identify high-risk patients and support targeted preventive interventions.

Therefore, the present study was designed to assess the incidence of fracture-related infection and identify associated demographic, clinical, injury-related, and operative risk factors among 120 patients undergoing internal fixation of long bone fractures.

MATERIALS AND METHODS

Study design and setting

The study was designed as a hospital-based prospective observational study involving patients undergoing internal fixation of long bone fractures in the Department of Orthopaedics at a tertiary care teaching hospital. A total of 120 patients were included in the observed study population.

Study population

Adult patients aged 18 years and above who underwent internal fixation of fractures involving the femur, tibia, humerus, radius, or ulna were eligible for inclusion.

Inclusion criteria

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

Exclusion criteria

1. Patients with pre-existing osteomyelitis or established infection at the fracture site.
2. Patients with pathological fractures secondary to malignancy.
3. Patients undergoing revision surgery for previously infected implants.
4. Patients with incomplete clinical records or unavailable follow-up data.

Data collection

Patient-related variables included age, sex, body mass index, diabetes mellitus, smoking status, hypertension, and other relevant comorbidities. Injury-related variables included mode of injury, anatomical site, open or closed fracture status, and Gustilo–Anderson grade for open fractures.

Operative variables included method of internal fixation, duration of surgery, and time interval between injury and definitive fixation.

Surgical management

Fracture fixation was planned according to fracture location, configuration, soft tissue condition, and the patient's clinical status. Internal fixation methods included intramedullary nailing and plate-and-screw fixation. Open fractures required appropriate wound

assessment, irrigation, debridement, antimicrobial prophylaxis, and soft tissue management according to institutional protocols.

Assessment of fracture-related infection

FRI was assessed using internationally accepted consensus criteria.[1,4] Patients with suspected infection underwent clinical evaluation for wound discharge, sinus formation, wound breakdown, persistent pain, swelling, redness, and fever. Additional investigations, including inflammatory markers, radiological imaging, and deep tissue microbiological sampling, were considered when clinically indicated.

Confirmatory diagnostic findings were distinguished from suggestive clinical findings to reduce misclassification.

Follow-up

Postoperative assessments were planned at approximately 2 weeks, 6 weeks, 3 months, 6 months, and 12 months. Patients were evaluated for wound healing, clinical signs of infection, fracture union, and the requirement for additional surgical interventions.

Statistical analysis

Data were to be analyzed using SPSS 27 statistical software. Categorical variables were expressed as frequencies and percentages, while continuous variables were summarized as mean $\pm$ standard deviation or median with interquartile range, as SPSS 27. Associations between categorical risk factors and FRI were assessed using the Chi-square test or Fisher's exact test. Crude odds ratios were calculated for selected risk factors. A p-value below 0.05 was considered statistically significant where valid inferential testing was performed.

RESULTS

The study dataset comprised 120 patients undergoing internal fixation of long bone fractures. Fourteen patients were classified as having fracture-related infection, while 106 were classified as having no FRI.

Table 1. Distribution of Demographic and Baseline Clinical Characteristics of Study Participants (N = 120)

Parameter	Frequency (n)	Percentage (%)
Age group (years)		
18–30	28	23.3
31–45	38	31.7
46–60	34	28.3
>60	20	16.7
Age (years), mean $\pm$ SD	43.8 $\pm$ 14.6	—
Sex		
Male	82	68.3
Female	38	31.7
BMI (kg/m ²)		
48 hours	42	35.0
Duration of surgery		

≤120 minutes	76	63.3
>120 minutes	44	36.7

Table 3. Incidence, Clinical Presentation, and Microbiological Characteristics of Fracture-Related Infection (N = 120)

Parameter	Frequency (n)	Percentage (%)
Fracture-related infection		
Present	14	11.7
Absent	106	88.3
Time to FRI diagnosis (n = 14)		
≤30 days	6	42.9
31–90 days	5	35.7
>90 days	3	21.4
Clinical findings among FRI cases (n = 14)		
Purulent wound discharge	10	71.4
Wound breakdown communicating with bone/implant	6	42.9
Local pain and swelling	12	85.7
Fever	5	35.7
Microbiological findings (n = 14)		
Staphylococcus aureus	6	42.9
Coagulase-negative staphylococci	2	14.3
Escherichia coli	2	14.3
Pseudomonas aeruginosa	1	7.1
Culture negative	3	21.4

Clinical findings were not mutually exclusive.

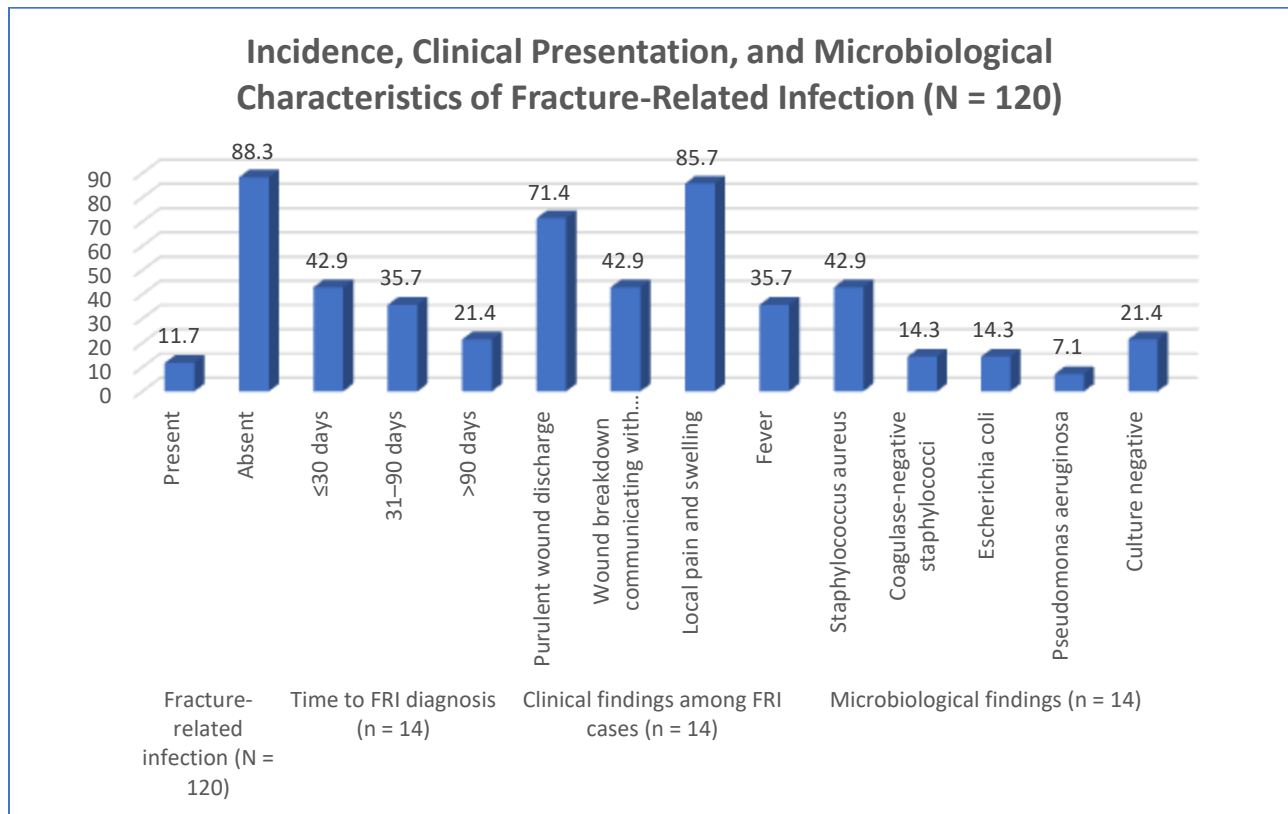


Figure 1 Incidence, Clinical Presentation, and Microbiological Characteristics of Fracture-Related Infection (N = 120)

Table 4. Association of Patient-Related Risk Factors with Fracture-Related Infection (N = 120)

Parameter	FRI (n = 14)	No FRI (n = 106)	Crude OR
Age group			
≤45 years	5 (35.7)	61 (57.5)	Reference
>45 years	9 (64.3)	45 (42.5)	2.44
Sex			
Female	3 (21.4)	35 (33.0)	Reference
Male	11 (78.6)	71 (67.0)	1.81
Diabetes mellitus			
Absent	7 (50.0)	89 (84.0)	Reference
Present	7 (50.0)	17 (16.0)	5.24
Current smoking			
No	5 (35.7)	79 (74.5)	Reference
Yes	9 (64.3)	27 (25.5)	5.27
Obesity (BMI ≥30 kg/m ²)			
No	9 (64.3)	93 (87.7)	Reference
Yes	5 (35.7)	13 (12.3)	3.97
Hypertension			
Absent	9 (64.3)	83 (78.3)	Reference
Present	5 (35.7)	23 (21.7)	2.00

Values are n (%) within each infection-status group. Odds ratios are unadjusted.

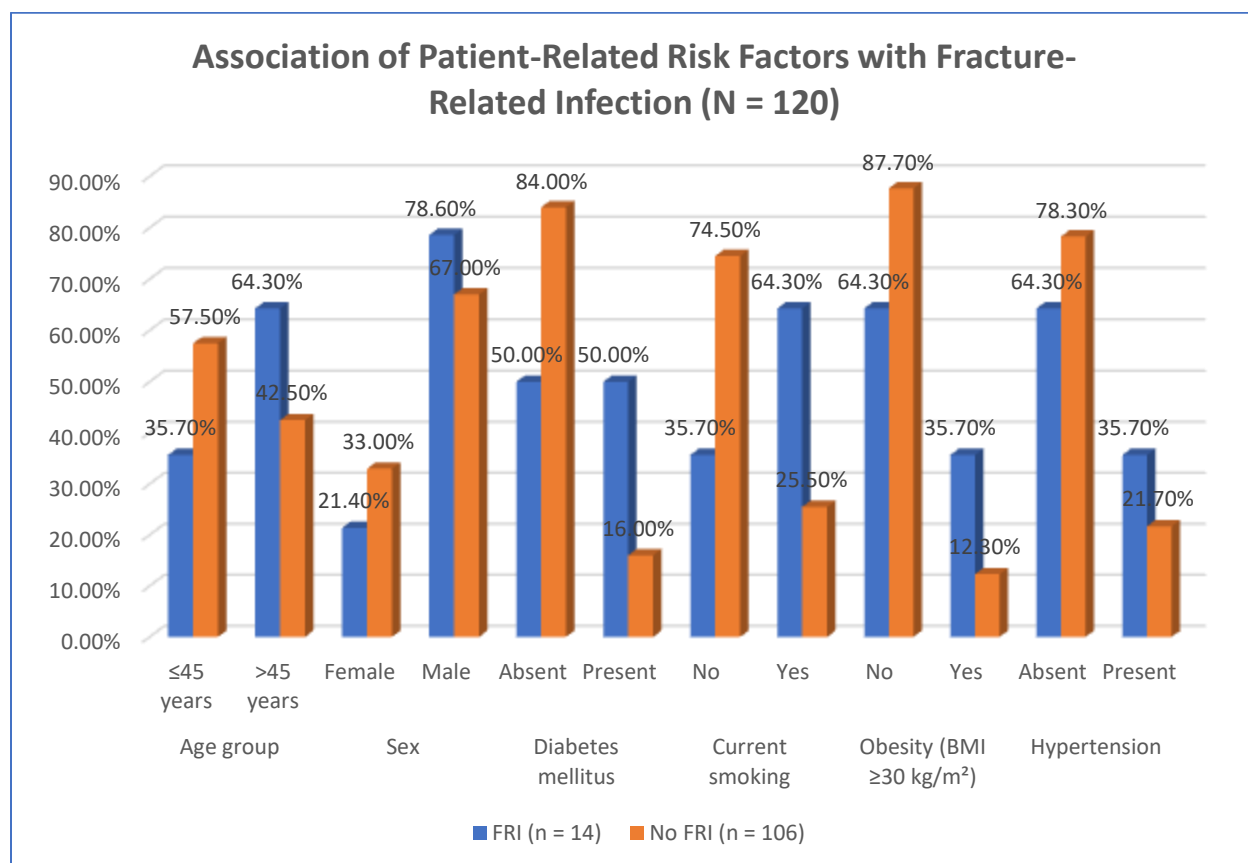


Figure 2 Association of Patient-Related Risk Factors with Fracture-Related Infection (N = 120)

Table 5. Association of Injury-Related and Operative Factors with Fracture-Related Infection (N = 120)

Parameter	FRI (n = 14)	No FRI (n = 106)	Crude OR
Fracture type			
Closed	4 (28.6)	84 (79.2)	Reference
Open	10 (71.4)	22 (20.8)	9.55
Fractured bone			
Tibia	8 (57.1)	36 (34.0)	2.59
Femur	4 (28.6)	32 (30.2)	—
Humerus	1 (7.1)	21 (19.8)	—
Radius/ulna	1 (7.1)	17 (16.0)	—
Time to definitive fixation			
≤48 hours	5 (35.7)	73 (68.9)	Reference
>48 hours	9 (64.3)	33 (31.1)	3.98
Operative duration			
≤120 minutes	4 (28.6)	72 (67.9)	Reference
>120 minutes	10 (71.4)	34 (32.1)	5.29
Fixation method			
Intramedullary nailing	7 (50.0)	61 (57.5)	Reference
Plate and screw fixation	7 (50.0)	45 (42.5)	1.36

The OR for tibial fracture compares tibial with all non-tibial fractures.

Table 6. Severity of Open Fractures and Postoperative Outcomes Among Patients with Fracture-Related Infection

Parameter	Frequency (n)	Percentage (%)
FRI according to open fracture grade		
Grade I (n = 10)	1	10.0
Grade II (n = 10)	2	20.0
Grade III (n = 12)	7	58.3
Principal management among FRI cases (n = 14)		
Surgical debridement with implant retention	8	57.1
Implant removal/revision fixation	4	28.6
Antibiotic treatment without additional surgery	2	14.3
Fracture healing at 12 months (n = 14)		
United	9	64.3
Delayed union	3	21.4
Nonunion	2	14.3
Repeat surgical intervention (n = 14)		
Required	12	85.7
Not required	2	14.3

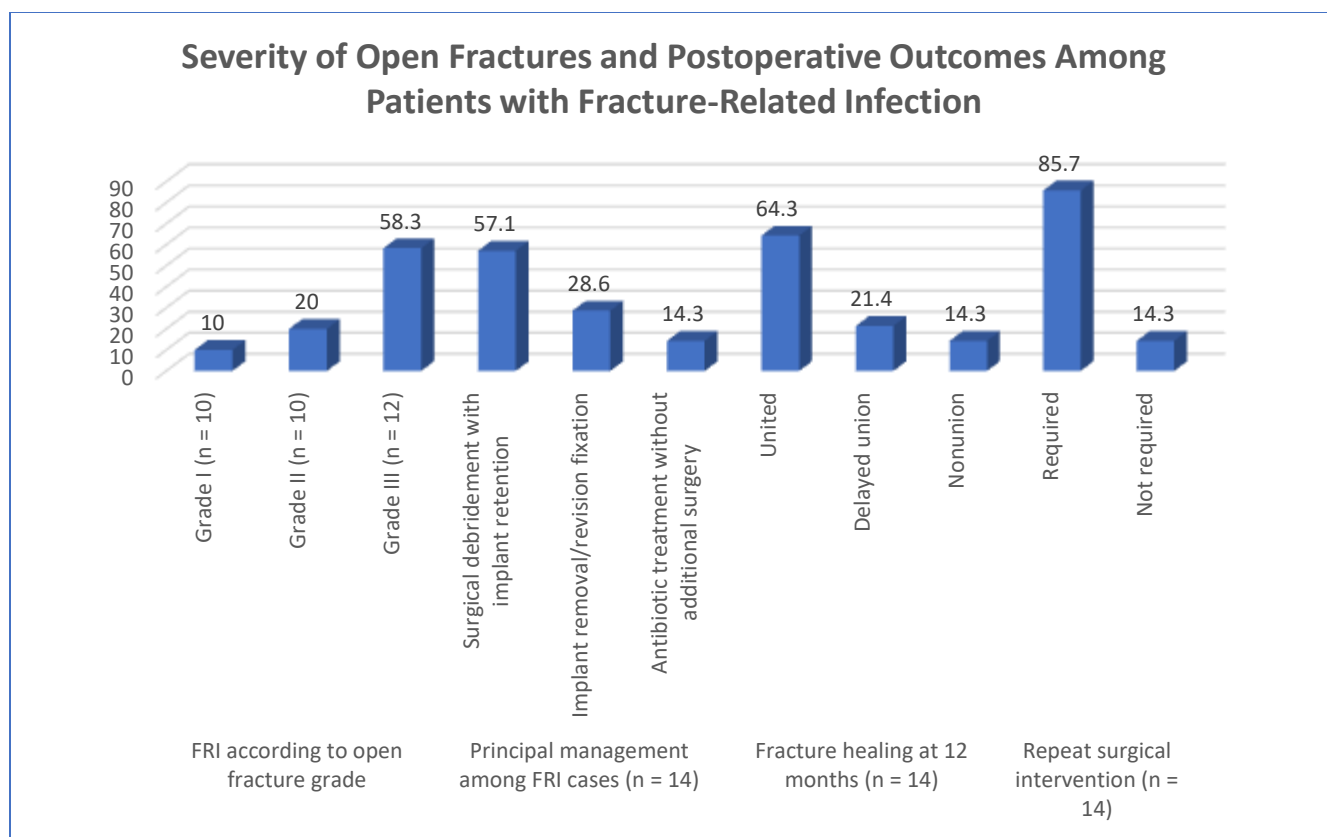


Figure 3 Severity of Open Fractures and Postoperative Outcomes Among Patients with Fracture-Related Infection

DISCUSSION

Fracture-related infection remains an important complication following internal fixation of long bone fractures, affecting fracture healing, functional recovery, and healthcare utilization. The present study dataset comprised 120 patients, of whom 14 (11.7%) were classified as having FRI. Open fractures, diabetes mellitus, smoking, obesity, prolonged operative duration, and delayed definitive fixation demonstrated higher crude odds of infection. These findings emphasize the need to evaluate patient characteristics, injury severity, and operative factors together when assessing infection risk. The overall FRI incidence in the present dataset was 11.7%. Infection rates reported in the literature vary considerably because of differences in fracture type, anatomical site, injury severity, fixation methods, and diagnostic criteria.

Metsemakers et al. (2018) [1] highlighted the importance of standardized diagnostic criteria for FRI to improve consistency in clinical research. Kortram et al. (2017) [2], in a systematic review and meta-analysis of open fractures, demonstrated that infection risk was influenced by several patient-related and injury-related factors. The relatively high proportion of open fractures in the present dataset may have contributed to the recorded overall infection frequency.

Diabetes mellitus was associated with higher crude odds of FRI (OR 5.24). Hyperglycaemia may impair

neutrophil function, reduce tissue perfusion, and interfere with collagen synthesis and wound healing. Patients with diabetes may therefore be more susceptible to postoperative wound complications.

Kortram et al. (2017) [2] reported diabetes mellitus as a significant risk factor for infectious complications following open fractures. Their findings support the clinical importance of preoperative metabolic assessment and perioperative glycaemic optimization.

Current smoking demonstrated a crude OR of 5.27. Smoking is associated with tissue hypoxia, impaired angiogenesis, and reduced microvascular circulation, which may adversely affect wound healing and fracture union. Kortram et al. (2017) [2] also identified smoking as a risk factor for infection following open fractures.

Obesity demonstrated a crude OR of 3.97. Increased adipose tissue, reduced wound perfusion, and greater technical complexity may contribute to postoperative wound complications. However, the association between obesity and infection should be interpreted cautiously because obesity may coexist with diabetes and other comorbidities.

Open fractures demonstrated a markedly higher infection frequency than closed fractures. Infection occurred in 31.3% of open fractures compared with 4.5% of closed fractures, corresponding to a crude OR of 9.55.

Kortram et al. (2017) [2] identified severe open fractures and wound contamination as important risk factors for

infectious complications. The present dataset showed an increase in infection frequency with Gustilo–Anderson grade, reaching 58.3% among grade III injuries.

Tibial fractures accounted for the largest proportion of FRI cases. The relatively limited soft tissue coverage of the tibia, combined with its frequent involvement in high-energy trauma, may contribute to infection susceptibility. Nevertheless, fracture location should be evaluated alongside soft tissue damage, contamination, and injury severity.

Operative duration exceeding 120 minutes demonstrated higher crude odds of FRI (OR 5.29). Longer procedures may involve greater tissue manipulation, prolonged wound exposure, and increased technical complexity. However, operative duration may also serve as a marker of severe or complex fractures rather than being an independent causal factor.

Metsemakers et al. (2020) [5] emphasized the importance of appropriate surgical debridement, stable fixation, and soft tissue management in the treatment of FRI. Their recommendations also underline the need to preserve viable tissue and achieve adequate infection control.

Time to definitive fixation exceeding 48 hours was associated with higher crude odds of infection. This finding requires careful interpretation because delayed fixation may be clinically necessary in patients with severe soft tissue injuries, physiological instability, or a requirement for staged surgical management. The timing of definitive fixation should therefore be individualized rather than assessed solely according to a fixed time threshold.

Local pain and swelling were the most frequently recorded clinical findings among patients with FRI, followed by purulent wound discharge. *Staphylococcus aureus* was the most frequently recorded microorganism. Govaert et al. (2020) [4] emphasized that clinical signs such as pain, swelling, and redness are suggestive rather than confirmatory criteria for FRI. Definitive diagnosis requires appropriate clinical, microbiological, and histopathological evidence.

Metsemakers et al. (2018) [1] similarly recommended standardized confirmatory criteria to improve diagnostic accuracy. Deep tissue sampling and appropriate microbiological assessment are particularly important because superficial wound swabs may not reliably identify the organisms responsible for implant-associated infection.

FRI was associated with considerable treatment burden in the dataset. Repeat surgical intervention was recorded in 85.7% of infected patients. Delayed union and nonunion were also recorded among patients with FRI.

Metsemakers et al. (2020) [5] described the importance of combining appropriate surgical management with

antimicrobial treatment to achieve infection control and promote fracture healing. Depypere et al. (2020) [6] provided consensus recommendations for systemic antimicrobial therapy in FRI, emphasizing individualized treatment according to the causative microorganism, surgical strategy, and clinical circumstances.

The occurrence of delayed union and nonunion highlights the potential adverse effects of infection on fracture healing. Persistent infection can compromise bone biology, impair implant stability, and increase the requirement for revision surgery.

Strengths of the Study

- The study evaluated fracture-related infection in 120 patients undergoing internal fixation of long bone fractures.
- Patient-related, injury-related, and operative risk factors were assessed, including diabetes mellitus, smoking, obesity, fracture type, and duration of surgery.
- The study documented clinical presentation, microbiological findings, fracture healing, and the need for repeat surgical intervention among patients with infection.
- Follow-up for up to 12 months was planned to assess infection occurrence and postoperative outcomes.

Future Scope

Further multicentre studies involving larger patient populations are recommended to validate the observed incidence and risk factors for fracture-related infection. Future research should use adjusted statistical analyses to identify independent predictors of infection and evaluate the influence of fracture severity, comorbidities, surgical techniques, and antimicrobial protocols. Longer follow-up may help assess late-onset infection, fracture union, implant-related complications, and long-term functional outcomes.

Limitations

The sample size of 120 patients and the relatively small number of infection events limit the precision of risk estimates and the feasibility of reliable multivariable analysis. Differences in fracture severity, anatomical location, and operative management may introduce confounding. The observed 12-month follow-up may not capture all late-onset infections. Larger multicenter studies with longer follow-up and adjusted analyses are required to establish independent predictors of FRI.

CONCLUSION

Fracture-related infection remains an important complication following internal fixation of long bone fractures. The dataset recorded an infection frequency of 11.7%, with higher crude odds among patients with open fractures, diabetes mellitus, smoking, obesity, prolonged operative duration, and delayed definitive fixation. Severe open fractures showed particularly high infection frequencies. Identification of high-risk patients, optimization of modifiable factors, appropriate surgical management, and structured postoperative surveillance are essential considerations for reducing infection-related morbidity.

DECLARATIONS

Ethical Approval: Ethical approval was obtained from the Institutional Ethics Committee.

Informed Consent: Written informed consent was obtained from all participants.

Conflict of Interest: The authors declare no conflict of interest.

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Author Contributions: All authors contributed to the study and approved the final manuscript.

Data Availability: Data are available from the corresponding author upon reasonable request.

Use of Artificial Intelligence: No artificial intelligence tools were used in the preparation of this manuscript.

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