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Comparing Preventive Antibiotic Regimens and Prevalence of Fracture-Related Infections Following Open Long Bone Fractures: A Two-Center Retrospective Study in Northwest Cameroon

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Abstract

Background: Fracture-related infection (FRI) is one of the most serious complications following open long bone fractures, resulting in prolonged hospitalization, repeated surgical procedures, increased healthcare costs, disability, and poor functional outcomes. Appropriate antibiotic prophylaxis remains a cornerstone of infection prevention, particularly in low-resource settings where standardized treatment protocols are often lacking. **Objective:** To compare preventive antibiotic regimens and determine the prevalence of fracture-related infection among patients with open long bone fractures managed at two tertiary hospitals in the North West Region of Cameroon. **Methods:** A retrospective cross-sectional study was conducted using medical records of patients with open long bone fractures treated at Nkwen Baptist Hospital and The People's Clinic between January 2023 and January 2024. Data on patient characteristics, fracture classification, antibiotic prophylaxis, surgical management, and infection outcomes were extracted using a structured data collection tool and analyzed with SPSS version 23. Associations between study variables and fracture-related infection were evaluated at a significance level of $p < 0.05$. **Results:** Among 450 patients with long-bone fractures managed during the study period, 120 had open long-bone fractures and were screened for eligibility; 94 met the eligibility criteria and were included in the final analysis. Nineteen patients (20.2%) developed postoperative wound infections. Of these, 8 met consensus-confirmatory criteria for fracture-related infection (FRI), giving a confirmed FRI prevalence of 8.5%, while 11 were superficial wound infections and were analysed separately. Confirmed FRI occurred in 2.9% of Grade I, 5.0% of Grade II, and 25.0% of Grade III fractures, with infection increasing with fracture severity. Confirmed FRI occurred in 9.1% of patients receiving cloxacillin and 8.0% of those receiving ceftriaxone, gentamicin, and metronidazole, with no statistically significant difference between the hospital/regimen groups. Delayed surgical debridement (>6 hours) was associated with a higher occurrence of confirmed FRI. **Conclusion:** Postoperative wound infection remained an important complication following open long-bone fractures, although fewer than half of the postoperative infections met consensus-confirmatory criteria for FRI. Confirmed FRI was more frequent among patients with severe open fractures and those undergoing delayed surgical debridement. Confirmed FRI proportions were similar between the two hospital-specific antibiotic strategies; however, because the antibiotic regimen was completely linked to the treatment hospital, the findings cannot establish comparative regimen effectiveness. Differences in case mix and clinical management between hospitals may have confounded the observed association.

Keywords

Fracture-Related Infection, Open Fracture, Antibiotic Prophylaxis, Long Bone Fracture, Gustilo-Anderson Classification, Orthopedic Trauma, Cameroon

1. Introduction

Open fractures are among the most serious musculoskeletal injuries encountered in orthopedic practice because they create direct communication between the fracture site and the external environment, exposing bone and surrounding soft tissues to microbial contamination. Consequently, patients are at increased risk of fracture-related infection, delayed union, non-union, chronic osteomyelitis, repeated surgical procedures, prolonged disability, and limb amputation [1] [2]. Despite advances in trauma care, fracture-related infection remains a major cause of morbidity, particularly in low- and middle-income countries, where delays in treatment, limited healthcare resources, and inadequate infection prevention measures are common [3]. Road traffic crashes are a major cause of serious musculoskeletal trauma worldwide and disproportionately affect young adults [4].

The risk of fracture-related infection is influenced by injury severity, contamination, vascular compromise, host factors, timing of antibiotic administration, and adequacy of surgical management [5]. The Gustilo-Anderson classification remains the most widely used system for grading open fractures, and infection risk rises with increasing injury severity [2] [5] [6]. In 2018, an international expert group established standardized diagnostic criteria for fracture-related infection, distinguishing confirmatory from suggestive criteria [7]. Early systemic antibiotic prophylaxis is a cornerstone of open-fracture care; major guidance documents recommend administration as soon as possible after injury, together with timely surgical management [8]-[10]. AAOS guidance recommends cefazolin or clindamycin for most major extremity trauma, with additional Gram-negative coverage preferred for Type III (and possibly Type II) open fractures [8].

The management of fracture-related infection is particularly challenging in low-resource settings because of limitations in specialist services, microbiology capacity, implants, and access to timely surgery [3]. A recent Cameroonian study of surgically treated open tibial fractures reported FRI in 31.4% of patients, illustrating the substantial local burden [11]. In the conflict-affected North West Region, disruption of healthcare delivery may further complicate trauma management. During the study period, Nkwen Baptist Hospital primarily used cloxacillin monotherapy, whereas The People's Clinic routinely administered a combination of ceftriaxone, gentamicin, and metronidazole. However, evidence directly comparing these hospital-specific regimens is limited. Therefore, this study compared the preventive antibiotic regimens used at the two hospitals and determined the prevalence of fracture-related infections among patients with open long-bone fractures managed between January 2023 and January 2024. The study also evaluated the association between Gustilo-Anderson fracture severity and fracture-related infection to inform context-appropriate prophylaxis protocols.

2. Methods

2.1. Study Design

A hospital-based retrospective cross-sectional study was conducted to compare preventive antibiotic regimens and to determine the prevalence of fracture-related infection (FRI) among patients with open long-bone fractures managed at two referral hospitals in the North West Region of Cameroon. The study involved a review of medical records of eligible patients treated between 1 January 2023 and 31 January 2024.

2.2. Study Setting

The study was conducted at Nkwen Baptist Hospital (NBH) and The People's Clinic (TPC), both located in Bamenda, North West Region of Cameroon. These institutions are among the major referral centers that provide emergency orthopedic and trauma care to patients from the North West Region and neighboring areas.

Nkwen Baptist Hospital is a well-established faith-based tertiary healthcare institution with a specialized orthopedic unit managing both emergency and elective trauma cases. The People's Clinic is a private referral hospital that also provides comprehensive orthopedic services, including emergency fracture management, surgical stabilization, and postoperative follow-up.

During the study period, the two hospitals adopted different empirical antibiotic prophylaxis protocols for open fractures. Nkwen Baptist Hospital routinely administered cloxacillin monotherapy, whereas The People's Clinic predominantly used a combination regimen of ceftriaxone, gentamicin, and metronidazole.

2.3. Study Population

The study population comprised all patients diagnosed with open long bone fractures who received definitive management at either study hospital during the study period.

1) Inclusion Criteria

Patients were eligible for inclusion if they had a confirmed diagnosis of an open long bone fracture, were managed primarily at Nkwen Baptist Hospital or The People's Clinic, had complete medical records documenting fracture characteristics, antibiotic regimen, surgical management, and treatment outcomes, and completed adequate follow-up to determine the presence or absence of fracture-related infection.

2) Exclusion Criteria

Patients were excluded if they had incomplete or missing medical records, received definitive treatment at another health facility before referral, had pathological fractures, had pre-existing chronic osteomyelitis before sustaining the fracture, or were lost to follow-up before their fracture-related infection status could be determined.

3) Follow-Up and Ascertainment of Infection Status

Patients were required to have a minimum documented follow-up period of 12 weeks (3 months) after definitive fracture management to permit assessment of fracture-related infection. The median follow-up duration was 6 months (IQR: 4 - 9 months). Infection status was determined through review of inpatient records, operative notes, wound assessment findings, microbiological results where available, records of additional antibiotic treatment or surgical debridement, and outpatient follow-up documentation. Patients were classified as having an infection when documented clinical and/or confirmatory evidence of infection was identified during follow-up. Patients without documented infection were classified as infection-free only if they had completed at least 12 weeks of follow-up without clinical or confirmatory evidence of infection. Patients lost to follow-up before 12 weeks and for whom infection status could not be reliably established were excluded from the analysis.

2.4. Sample Size and Sampling Technique

A census sampling approach was adopted. All eligible patient records meeting the inclusion criteria during the study period were reviewed. Among 450 long bone fractures managed during the study period, 94 open fractures fulfilled the eligibility criteria and were included in the final analysis.

2.5. Study Variables

1) Dependent Variable

The primary outcome variable was the occurrence of fracture-related infection (FRI) following management of an open long bone fracture.

2) Independent Variables

The independent variables included patient demographic characteristics (age and sex), hospital of treatment, mechanism of injury, bone involved, Gustilo-Anderson fracture grade, time from injury to hospital presentation, time to initiation of antibiotic therapy, time to surgical debridement, antibiotic prophylaxis regimen, duration of antibiotic therapy, method of fracture stabilization, presence of associated injuries, and documented comorbidities.

3) Operational Definitions

Fracture-related infection (FRI) was classified in accordance with the international consensus definition proposed by Metsemakers *et al.* [7]. Confirmatory criteria included the presence of a fistula, sinus, or wound breakdown communicating with the fracture or implant; purulent drainage or intraoperative pus; microbiological confirmation from appropriately collected deep tissue or implant specimens; or histopathological evidence consistent with infection. Clinical, radiological, or laboratory findings that were suggestive but not confirmatory were considered supportive evidence requiring further investigation. Superficial wound infections limited to the skin and subcutaneous tissues, without evidence of communication with or involvement of the fracture, were classified separately and were not considered confirmed FRI.

2.6. Data Collection Procedure

Data were extracted retrospectively from patients' medical records using a structured data extraction form informed by established guidance for open-fracture management and FRI diagnosis [7]-[10]. Information collected included demographic characteristics, date and mechanism of injury, anatomical location of the fracture, Gustilo-Anderson fracture grade, initial wound management, timing of antibiotic administration, prescribed antibiotic regimen, timing of surgical debridement, method of fracture stabilization, duration of hospitalization, clinical evidence of fracture-related infection, and patient outcomes at follow-up.

Data collection was conducted by trained investigators to ensure consistency and reliability. All extracted information was cross-checked against operative notes, inpatient records, and outpatient follow-up files to verify accuracy, resolve discrepancies, and maximize dataset completeness.

2.7. Outcome Measures

The primary outcome was the prevalence of fracture-related infection (FRI) among patients with open long bone fractures. Secondary outcomes included a comparison of infection prevalence between the two antibiotic prophylaxis regimens, an assessment of the association between Gustilo-Anderson fracture grade and the occurrence of FRI, and a description of the distribution of open fractures by patient demographic characteristics and anatomical location.

2.8. Statistical Analysis

Data were entered into Microsoft Excel, cleaned, coded, and exported to IBM Statistical Package for the Social Sciences (SPSS) version 23.0 for statistical analysis. Continuous variables were summarized using means and standard deviations or medians with interquartile ranges, depending on data distribution. Categorical variables were summarized using frequencies and percentages. Associations between categorical variables were assessed using the Chi-square test or Fisher's exact test where appropriate. Odds ratios (ORs) with 95% confidence intervals (95% CI) were calculated to estimate the strength of associations. Variables with a p-value < 0.05 were considered statistically significant. Candidate variables for multivariable logistic regression were selected based on clinical relevance and/or evidence of association in bivariable analysis. Because only 19 infection events occurred, the number of predictors that could be reliably evaluated was limited. Accordingly, the multivariable analysis was considered exploratory, and adjusted odds ratios were interpreted cautiously because of the possibility of model overfitting and imprecise estimates.

2.9. Ethical Considerations

Ethical approval for this retrospective study was obtained from the appropriate Institutional Review Board/Ethics Committee prior to data collection. Permission to access patients' medical records was also obtained from the administrative authorities of the participating hospitals. As the study involved a retrospective review of existing medical records with no direct patient contact or intervention, the requirement for individual informed consent was waived by the ethics committee in accordance with applicable national and institutional regulations.

Data were extracted exclusively from hospital records using a standardized data extraction form by trained investigators. To ensure data quality, extracted information was cross-checked against operative notes, inpatient records, and outpatient follow-up files. All patient identifiers were removed during data extraction, and each participant was assigned a unique study identification code to maintain anonymity. The collected data were stored securely and accessed only by authorized members of the research team.

3. Results

A total of 450 patients with long-bone fractures were managed at Nkwen Baptist Hospital (NBH) and The People's Clinic (TPC) between January 2023 and January 2024. Of these, 120 patients had open long-bone fractures, and their medical records were screened for eligibility. Twenty-six records were excluded: 10 because of incomplete or missing medical records, 5 because definitive treatment had been initiated at another health facility before referral, 3 because they involved pathological fractures, 2 because of pre-existing chronic osteomyelitis, and 6 because of inadequate follow-up or loss to follow-up before infection status could be reliably determined. The final analysis, therefore, included 94 eligible patients, comprising

44 patients from Nkwen Baptist Hospital and 50 patients from The People's Clinic.

3.1. Socio-Demographic Characteristics

Table 1 shows the socio-demographic characteristics of patients. Young adult males constituted the majority of patients presenting with open long bone fractures. The mean age of the patients was 34.8 years ± 13.7 years (range: 18 - 79 years). Most patients were between 21 and 40 years (58.5%). Males accounted for 69 (73.4%) of the cases, giving a male-to-female ratio of 2.8:1.

Table 1. Socio-demographic characteristics of patients (N = 94).

Variable	Frequency	Percentage (%)
Age Group (years)		
<20	9	9.6
21 - 30	31	33.0
31 - 40	24	25.5
41 - 50	15	16.0
>50	15	16.0
Sex		
Male	69	73.4
Female	25	26.6

3.2. Mechanism of Injury

Table 2 shows that road traffic crashes were the leading mechanism of injury, accounting for nearly two-thirds of open long bone fractures (64.9%). Falls were the second most common cause (18.1%), while assault (8.5%), occupational injuries (6.4%), and sports injuries (2.1%) contributed relatively few cases.

Table 2. Mechanism of injury.

Mechanism	Frequency	Percentage (%)
Road traffic crash	61	64.9
Fall	17	18.1
Assault	8	8.5
Occupational injury	6	6.4
Sports injury	2	2.1

3.3. Anatomical Distribution of Fractures

Table 3 shows the anatomical distribution of open fractures. The tibia/fibula was the most frequently affected anatomical site, accounting for half of all open fractures (50.0%). The femur (20.2%) and radius/ulna (16.0%) were the next most commonly involved bones, whereas fractures of the humerus (9.6%) and other bones (4.2%) were relatively uncommon.

Table 3. Anatomical distribution of open fractures.

Bone Involved	Frequency	Percentage (%)
Tibia/Fibula	47	50.0
Femur	19	20.2
Radius/Ulna	15	16.0
Humerus	9	9.6
Others	4	4.2

3.4. Gustilo-Anderson Classification

Table 4 shows the distribution of fractures according to Gustilo-Anderson classification. Grade II fractures were the most common, representing 42.6% of all open fractures, followed by Grade I fractures (36.2%). Grade III fractures accounted for 21.3% of cases, indicating that approximately one-fifth of patients presented with severe open injuries.

Table 4. Distribution of fractures according to Gustilo-Anderson classification.

Grade	Frequency	Percentage (%)
Grade I	34	36.2
Grade II	40	42.6
Grade III	20	21.3

3.5. Antibiotic Prophylaxis

Preventive antibiotic regimens in the two health facilities are shown in **Table 5**. Forty-four patients were managed at Nkwen Baptist Hospital using cloxacillin monotherapy, whereas fifty patients received a combination of ceftriaxone, gentamicin, and metronidazole at The People's Clinic.

Table 5. Preventive antibiotic regimens.

Hospital	Antibiotic Regimen	Patients
NBH	Cloxacillin	44
TPC	Ceftriaxone + Gentamicin + Metronidazole	50

NBH: Nkwen Baptist Hospital; TPC: The People's Clinic.

3.6. Prevalence of Fracture-Related Infection

Overall, 19 of the 94 patients developed a postoperative infection, corresponding to an overall postoperative infection prevalence of 20.2% (95% CI: 12.8% - 29.6%). Of these 19 postoperative infections, 8 (42.1%) met the consensus criteria for confirmed fracture-related infection (FRI), corresponding to a prevalence of confirmed

FRI of 8.5% (8/94). The remaining 11 infections (57.9%) were superficial wound infections confined to the skin and subcutaneous tissues, without evidence of communication with or involvement of the fracture, and were therefore analysed separately and were not classified as confirmed FRI. Among the 8 confirmed FRI cases, 6 represented deep fracture-related infections, and 2 had progressed to chronic osteomyelitis.

3.7. Comparison of Antibiotic Regimens

Table 6 shows the distribution of consensus-confirmed fracture-related infection according to the antibiotic regimen received. Confirmed FRI occurred in 4 of 44 patients (9.1%) receiving cloxacillin and 4 of 50 patients (8.0%) receiving ceftriaxone, gentamicin, and metronidazole. There was no statistically significant association between antibiotic regimen and confirmed FRI (Fisher's exact test p = 1.000; crude OR = 1.15, 95% CI: approximately 0.27 - 4.85). Because the antibiotic regimen was completely linked to the treatment hospital, this comparison cannot be regarded as evidence of therapeutic equivalence between the two antibiotic regimens.

Table 6. Comparison of fracture-related infection according to antibiotic regimen.

Regimen	Confirmed FRI	No Confirmed FRI	Total	FRI Prevalence
Cloxacillin	4	40	44	9.1%
Ceftriaxone + Gentamicin + Metronidazole	4	46	50	8.0%
Total	8	86	94	8.5%

Fisher's exact p = 1.000; crude OR = 1.15, 95% CI: 0.27 - 4.85.

3.8. Fracture Grade and Infection

Table 7 shows the occurrence of consensus-confirmed fracture-related infection according to Gustilo-Anderson fracture grade. The prevalence of confirmed FRI increased progressively with fracture severity, from 2.9% (1/34) among Grade I fractures, 5.0% (2/40) among Grade II fractures, to 25.0% (5/20) among Grade III fractures. This pattern indicates a strong association between increasing fracture severity and the occurrence of confirmed FRI (Pearson $\chi^2 = 8.97$, df = 2, p = 0.011).

Table 7. Fracture-related infection according to Gustilo-Anderson grade.

Gustilo-Anderson Grade	Total	Confirmed FRI	No Confirmed FRI	FRI Prevalence
Grade I	34	1	33	2.9%
Grade II	40	2	38	5.0%
Grade III	20	5	15	25.0%
Total	94	8	86	8.5%

Pearson $\chi^2 = 8.97$, df = 2, p = 0.011.

3.9. Time to Surgical Debridement

Table 8 shows the association between time to surgical debridement and consensus-confirmed fracture-related infection. Confirmed FRI occurred in 1 of 48 patients (2.1%) who underwent debridement within 6 hours compared with 7 of 46 patients (15.2%) who underwent debridement more than 6 hours after injury. Delayed debridement was associated with a higher occurrence of confirmed FRI (Fisher's exact p = 0.029).

Table 8. Time to debridement and fracture-related infection.

Time to Debridement	Confirmed FRI	No Confirmed FRI	Total	FRI Prevalence
≤6 hours	1	47	48	2.1%
>6 hours	7	39	46	15.2%
Total	8	86	94	8.5%

3.10. Multivariable Logistic Regression

Because only eight patients met the consensus-confirmatory criteria for fracture-related infection, the number of outcome events was considered insufficient to support a reliable conventional multivariable logistic regression model containing the prespecified clinical predictors. Consequently, adjusted estimates were not reported because of the substantial risk of model overfitting and unstable effect estimates. Associations between potential risk factors and confirmed FRI were therefore primarily evaluated using bivariable analyses, with Fisher's exact test applied where expected cell frequencies were small. Larger prospective studies are required to determine whether fracture severity, delayed debridement, and other clinical factors are independently associated with confirmed FRI.

4. Discussion

Fracture-related infection (FRI) remains one of the most serious complications of open long bone fractures and can lead to repeated surgery, impaired healing, chronic infection, disability, and substantial healthcare burden [1] [12]. Preventing infection following open fractures is therefore a major priority in orthopedic trauma care. This two-center retrospective study compared two hospital-specific empirical prophylactic antibiotic strategies and evaluated factors associated with FRI among patients managed in the North West Region of Cameroon. The principal findings demonstrated an overall postoperative wound-infection prevalence of 20.2%, while the prevalence of consensus-confirmed FRI was 8.5%. Of the 19 postoperative infections identified, 8 met consensus-confirmatory criteria for FRI, whereas 11 were superficial wound infections and were analysed separately [13]. No statistically significant difference in confirmed FRI was observed between the two hospital/regimen groups. Higher Gustilo-Anderson fracture grade and delayed surgical debridement were associated with confirmed FRI in bivariable analyses.

Importantly, the antibiotic regimen was completely linked to the treatment hospital in this study. Consequently, the observed similarity in infection prevalence cannot be attributed solely to the antibiotic regimens. Differences between the hospitals in injury severity, delays in presentation, timing and quality of debridement, fracture fixation, soft-tissue management, postoperative care, and other unmeasured clinical factors may have confounded the comparison. The findings should therefore be interpreted as a comparison of two hospital-specific management strategies rather than evidence of therapeutic equivalence between cloxacillin and triple-antibiotic prophylaxis.

4.1. Prevalence of Postoperative Wound Infection and Confirmed Fracture-Related Infection

The overall prevalence of postoperative wound infection in this study was 20.2% (19/94). However, after distinguishing superficial wound infections from infections meeting consensus-confirmatory criteria for fracture-related infection, 8 patients had confirmed FRI, corresponding to a prevalence of 8.5%. The remaining 11 cases were superficial wound infections confined to the skin and subcutaneous tissues without evidence of communication with or involvement of the fracture and were therefore not classified as confirmed FRI. This distinction is important because studies using broader definitions of postoperative infection may report higher infection rates than studies applying contemporary consensus criteria for FRI. Consequently, comparisons between the present findings and previously published infection rates should take differences in case definitions and diagnostic criteria into consideration.

Studies from resource-limited settings nevertheless demonstrate a substantial infection burden. In a Nigerian prospective series of open fractures, 42.5% of wounds became infected [14]. In Cameroon, a study of open tibial fractures reported FRI in 31.4% of patients using the international FRI consensus definition [11]. This should, however, be softened because the cited studies may not have applied exactly the same consensus-confirmatory definition. Nevertheless, these findings support the interpretation that infection after open fracture remains an important problem in sub-Saharan African trauma care.

Several factors may explain these disparities. First, healthcare systems in many LMICs continue to face shortages of orthopedic surgeons, operating theatre capacity, advanced imaging facilities, microbiology laboratories, and essential surgical implants. Second, financial barriers frequently delay patient presentation, diagnosis, and definitive treatment. Third, many patients initially seek care from traditional bone setters before presenting to the hospital, resulting in increased wound contamination and delayed initiation of evidence-based management. Finally, the sociopolitical instability affecting the North West Region of Cameroon during the study period may have further compromised timely access to emergency trauma services. Collectively, these factors likely contributed to the relatively high prevalence of FRI observed in this study.

4.2. Demographic Characteristics and Mechanism of Injury

The predominance of young adult males observed in this study is consistent with trauma patterns reported in African open-fracture series. Approximately three-quarters of the patients were male, and nearly 60% were aged between 21 and 40 years. In the Nigerian series cited above, most patients were aged 20 - 49 years [14], while the Cameroonian open-tibial-fracture study reported a mean age of 37.9 years and a male majority [11]. This pattern is plausibly related to greater exposure to road traffic and occupational hazards among economically active adults.

Road traffic crashes accounted for approximately 65% of all injuries in the present study, making them the leading cause of open fractures. This is consistent with the World Health Organization's Global Status Report on Road Safety, which identifies road traffic injury as a major cause of death and disability, particularly among younger populations [4].

The tibia and fibula were the most commonly affected bones, accounting for half of all open fractures. This pattern is also reported in open-fracture series from resource-limited settings; in the Nigerian prospective study, the tibia/fibula was the most frequently affected site [14]. The limited soft-tissue envelope over much of the tibia makes it particularly vulnerable to open injury and subsequent contamination.

4.3. Influence of Fracture Severity on Infection

One of the important findings of this study was the progressive increase in consensus-confirmed FRI with increasing Gustilo-Anderson fracture grade. Confirmed FRI occurred in 2.9% of Grade I fractures, 5.0% of Grade II fractures, and 25.0% of Grade III fractures. The association between fracture severity and confirmed FRI was statistically significant in bivariable analysis. However, because only eight confirmed FRI events occurred, a conventional multivariable logistic regression model was considered insufficiently reliable to establish fracture grade as an independent predictor. The observed association should therefore be interpreted cautiously.

These findings are consistent with previous investigations. Gustilo and Anderson demonstrated the relationship between severe soft-tissue injury and infection risk in open fractures [2], and the later Type III subclassification further characterized severe injuries according to soft-tissue damage, contamination, and vascular injury [6]. Contemporary reviews likewise identify increasing Gustilo-Anderson grade as an important infection risk factor [5].

The biological explanation for this relationship is well established. Severe soft tissue injury compromises local blood supply, reduces oxygen delivery, impairs immune cell migration, and creates an environment conducive to bacterial colonization and biofilm formation. Extensive contamination and larger wound surfaces further increase the inoculum of pathogenic microorganisms. These factors collectively impair fracture healing while simultaneously increasing susceptibility to persistent infection. Consequently, patients with Grade III injuries require particularly aggressive multidisciplinary management, including urgent debridement, broad-spectrum empirical antibiotics when indicated, early soft tissue coverage, and close postoperative surveillance.

Our findings therefore reinforce the continued clinical value of the Gustilo-Anderson classification not only as a descriptive grading system but also as an important prognostic tool for identifying patients at greatest risk of fracture-related infection. Early recognition of severe injuries should facilitate risk stratification, individualized treatment planning, and allocation of specialized reconstructive resources where available.

4.4. Comparison of Confirmed FRI between Hospital-Specific Antibiotic Strategies

The principal objective of this study was to compare two empirical antibiotic prophylaxis strategies used at the participating hospitals. Patients managed at Nkwen Baptist Hospital received cloxacillin monotherapy, whereas those treated at The People's Clinic received ceftriaxone, gentamicin, and metronidazole. Confirmed FRI occurred in 4 of 44 patients (9.1%) managed with cloxacillin and 4 of 50 patients (8.0%) managed with ceftriaxone, gentamicin, and metronidazole. No statistically significant association was observed between hospital/regimen group and confirmed FRI. However, because the antibiotic regimen was completely determined by the treatment hospital, these findings cannot establish equivalence or comparative effectiveness of the antibiotic regimens. Hospital-level differences in patient characteristics, fracture severity, timing of treatment, surgical management, and postoperative care may have confounded the observed comparison. Prevention of infection after open fracture depends on multiple components of care, including early antibiotics, adequate debridement, stabilization, and soft-tissue management [8]-[10] [15].

Classic studies established the importance of antibiotic prophylaxis in open fractures [16], and subsequent evidence-based guidance supports starting antibiotics as soon as possible after injury [9] [17]. The present study should therefore be interpreted as a comparison of hospital-specific strategies rather than as evidence that cloxacillin and triple therapy are therapeutically equivalent.

A Cochrane review found that antibiotic prophylaxis reduces early infection compared with no antibiotics or placebo, but it did not establish the superiority of one multidrug regimen over another [18]. Thus, the current data do not justify a conclusion that broader combination therapy is inherently more or less effective than a narrower regimen.

Current guidance is not completely uniform regarding spectrum. AAOS recommends systemic cefazolin or clindamycin for major extremity trauma, with additional Gram-negative coverage preferred for Type III (and possibly Type II) open fractures [8]. BOAST emphasizes immediate intravenous prophylactic antibiotics, ideally within one hour of injury, and timely orthoplastic management [10]. Antibiotic selection should therefore follow an explicit institutional protocol informed by current guidance and local microbiology rather than routine use of the broadest possible regimen.

The comparable outcomes observed in this study should not be interpreted as evidence that cloxacillin is equivalent to internationally recommended first-generation cephalosporins. Rather, these findings illustrate that within this dataset, broader empirical antimicrobial coverage did not compensate for other important determinants of infection. In real-world clinical practice, antibiotic selection should always follow established evidence-based guidelines while taking into account local antimicrobial resistance profiles and drug availability.

From an antimicrobial stewardship perspective, these observations have important implications for low-resource settings. Broad-spectrum antibiotic combinations are substantially more expensive than narrow-spectrum agents and may increase the risk of nephrotoxicity, gastrointestinal complications, *Clostridioides difficile* infection, and antimicrobial resistance. Hospitals should therefore develop local treatment protocols supported by institutional antibiograms to ensure rational antibiotic use while preserving antimicrobial effectiveness.

4.5. Effect of Timing of Surgical Debridement

Delayed surgical debridement was associated with a higher occurrence of consensus-confirmed fracture-related infection. Confirmed FRI occurred in 1 of 48 patients (2.1%) who underwent debridement within 6 hours compared with 7 of 46 patients (15.2%) who underwent debridement more than 6 hours after injury. Although this association was statistically significant in bivariable analysis, the small number of confirmed FRI events limits the precision of the estimate and precludes a robust assessment of delayed debridement as an independent predictor.

Historically, a "six-hour rule" was used for debridement. More recent evidence has questioned a rigid six-hour threshold, and contemporary guidance emphasizes timely debridement according to injury characteristics rather than an inflexible universal cutoff [10] [19]. The present study's association between debridement after six hours and infection should therefore be interpreted as an observational finding from this cohort, not proof of a universal causal threshold.

Published evidence on the exact timing threshold for debridement is mixed. Some studies have not found a significant increase in infection when surgery occurred after six hours, particularly when antibiotics were administered early [19]. Accordingly, the present finding of higher infection with debridement after six hours requires cautious interpretation and confirmation in larger prospective studies.

In many resource-limited healthcare systems, however, timely debridement remains challenging because of transportation barriers, shortages of orthopedic surgeons, limited operating theatre availability, financial constraints, and delayed referral from peripheral facilities. The sociopolitical instability affecting the North West Region of Cameroon during the study period may also have contributed to delays in presentation and definitive surgical management. These systemic barriers highlight the importance of strengthening trauma systems in addition to optimizing antimicrobial therapy.

4.6. Clinical Implications

The findings suggest that greater fracture severity and delayed surgical debridement are associated with an increased occurrence of consensus-confirmed FRI. These observations underscore the importance of rapid assessment, appropriate antibiotic prophylaxis, timely and adequate surgical debridement, fracture stabilization, and appropriate soft-tissue management in patients with severe open fractures. The absence of a statistically significant difference in confirmed FRI between the two hospital/regimen groups should not be interpreted as evidence that the antibiotic regimens are therapeutically equivalent, particularly because the antibiotic strategy was completely linked to the treatment hospital. The findings also support antimicrobial stewardship and the development of locally appropriate treatment protocols informed by microbiological surveillance and institutional antibiograms.

4.7. Limitations

Several limitations should be acknowledged. The retrospective study design is inherently susceptible to incomplete documentation, missing data, and information bias. Variables such as smoking status, diabetes mellitus, nutritional status, contamination severity, microbiological culture findings, antibiotic timing relative to injury, and patient adherence to postoperative care were not consistently documented and therefore could not be evaluated. In addition, treatment protocols may have varied among surgeons, potentially introducing practice-related heterogeneity. Furthermore, only eight patients met the consensus-confirmatory criteria for FRI. This small number of confirmed outcome events substantially limited statistical power and precluded reliable conventional multivariable logistic regression. Consequently, associations between fracture severity, delayed debridement, antibiotic strategy, and confirmed FRI should be interpreted as exploratory rather than causal or independently predictive. The distinction between superficial wound infection and confirmed FRI also depended on the completeness of retrospective clinical documentation, introducing the possibility of outcome misclassification. Larger prospective studies applying standardized consensus FRI criteria are required to confirm these findings.

5. Conclusion

Postoperative wound infection occurred in 20.2% of patients with open long-bone fractures; however, only 8.5% of the study population met consensus-confirmatory criteria for fracture-related infection, while superficial wound infections accounted for the remaining postoperative infections. Confirmed FRI occurred more frequently among patients with severe Gustilo-Anderson Grade III fractures and those undergoing delayed surgical debridement. No statistically significant difference in confirmed FRI was observed between the two hospital-specific antibiotic strategies. However, because the antibiotic regimen was completely linked to the treatment hospital, the findings cannot establish comparative effectiveness or therapeutic equivalence between the regimens. The small number of confirmed FRI events also limits statistical inference. Standardized FRI diagnostic criteria, timely surgical management, evidence-based antibiotic prophylaxis, and prospective multicentre studies are needed to improve infection prevention and generate more robust evidence for open-fracture management in resource-limited settings.

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Author Contributions

Tagakou MJ: Conceptualization, methodology development, and manuscript drafting. Mohnchimbare, CM: Critical revision of the manuscript and interpretation of findings. Mbabazi, A: Critical revision of the manuscript. Tekeoh GT: Data collection, data curation, and statistical analysis. Pisoh TC: Research supervision. Kamga FHL: Approval of the final manuscript. All authors read and approved the final version of the manuscript.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

References

[1] Metsemakers, W.J., Moriarty, T.F., Morgenstern, M., Marais, L., Onsea, J., O'Toole, R.V., *et al.* (2024) The Global Burden of Fracture-Related Infection: Can We Do Better? *The Lancet Infectious Diseases*, **24**, e386-e393. https://doi.org/10.1016/s1473-3099(23)00503-0

[2] Gustilo, R.B. and Anderson, J.T. (1976) Prevention of Infection in the Treatment of One Thousand and Twenty-Five Open Fractures of Long Bones: Retrospective and Prospective Analyses. *The Journal of Bone & Joint Surgery, American Volume*, **58**, 453-458. https://doi.org/10.2106/00004623-197658040-00004

[3] Tissingh, E.K., Marais, L., Loro, A., Bose, D., Paner, N.T., Ferguson, J., *et al.* (2022) Management of Fracture-Related Infection in Low Resource Settings: How Applicable Are the Current Consensus Guidelines? *EFORT Open Reviews*, **7**, 422-432. https://doi.org/10.1530/eor-22-0031

[4] World Health Organization (2018) Global Status Report on Road Safety 2018. World Health Organization.

[5] Coombs, J., Billow, D., Cereijo, C., Patterson, B. and Pinney, S. (2022) Current Concept Review: Risk Factors for Infection Following Open Fractures. *Orthopedic Research and Reviews*, **14**, 383-391. https://doi.org/10.2147/orr.s384845

[6] Gustilo, R.B., Mendoza, R.M. and Williams, D.N. (1984) Problems in the Management of Type III (Severe) Open Fractures: A New Classification of Type III Open Fractures.

The Journal of Trauma: *Injury*, *Infection*, *and Critical Care*, **24**, 742-746. https://doi.org/10.1097/00005373-198408000-00009

[7] Metsemakers, W., Morgenstern, M., McNally, M.A., Moriarty, T.F., McFadyen, I., Scarborough, M., *et al.* (2018) Fracture-Related Infection: A Consensus on Definition from an International Expert Group. *Injury*, **49**, 505-510. https://doi.org/10.1016/j.injury.2017.08.040

[8] American Academy of Orthopaedic Surgeons (2022) Prevention of Surgical Site Infections After Major Extremity Trauma: Evidence-Based Clinical Practice Guideline. AAOS.

[9] Hauser, C.J., Adams, C.A. and Eachempati, S.R. (2006) Prophylactic Antibiotic Use in Open Fractures: An Evidence-Based Guideline. *Surgical Infections*, **7**, 379-405. https://doi.org/10.1089/sur.2006.7.379

[10] British Orthopaedic Association (2017) BOAST: Open Fractures. British Orthopaedic Association.

[11] Fonkoué, L., Tissingh, E.K., Muluem, O.K., Kong, D., Ngongang, O., Tambekou, U., *et al.* (2023) Predictive Factors for Fracture-Related Infection in Open Tibial Fractures in a Sub-Saharan African Setting. *Injury*, **54**, Article ID: 110816.

[12] Depypere, M., Morgenstern, M., Kuehl, R., Senneville, E., Moriarty, T.F., Obremskey, W.T., *et al.* (2020) Pathogenesis and Management of Fracture-Related Infection. *Clinical Microbiology and Infection*, **26**, 572-578. https://doi.org/10.1016/j.cmi.2019.08.006

[13] Govaert, G.A.M., Kuehl, R., Atkins, B.L., Trampuz, A., Morgenstern, M., Obremskey, W.T., *et al.* (2020) Diagnosing Fracture-Related Infection: Current Concepts and Recommendations. *Journal of Orthopaedic Trauma*, **34**, 8-17. https://doi.org/10.1097/bot.0000000000001614

[14] Ikem, I.C., Oginni, L.M., Bamgboye, E.A., Ako-Nai, A.K. and Onipede, A.O. (2001) Open Fractures of the Lower Limb in Nigeria. *International Orthopaedics*, **25**, 386-388. https://doi.org/10.1007/s002640100277

[15] Metsemakers, W.J., Morgenstern, M., Senneville, E., Borens, O., Govaert, G.A.M., Onsea, J., *et al.* (2020) General Treatment Principles for Fracture-Related Infection: Recommendations from an International Expert Group. *Archives of Orthopaedic and Trauma Surgery*, **140**, 1013-1027. https://doi.org/10.1007/s00402-019-03287-4

[16] Patzakis, M.J., Harvey, J.P. and Ivler, D. (1974) The Role of Antibiotics in the Management of Open Fractures. *The Journal of Bone & Joint Surgery*, *American Volume*, **56**, 532-541. https://doi.org/10.2106/00004623-197456030-00010

[17] Lack, W.D., Karunakar, M.A., Angerame, M.R., Seymour, R.B., Sims, S., Kellam, J.F., *et al.* (2015) Type III Open Tibia Fractures: Immediate Antibiotic Prophylaxis Minimizes Infection. *Journal of Orthopaedic Trauma*, **29**, 1-6. https://doi.org/10.1097/bot.0000000000000262

[18] Gosselin, R.A., Roberts, I. and Gillespie, W.J. (2004) Antibiotics for Preventing Infection in Open Limb Fractures. *Cochrane Database of Systematic Reviews*, **2010**, CD003764. https://doi.org/10.1002/14651858.cd003764.pub2

[19] Schenker, M.L., Yannascoli, S., Baldwin, K.D., Ahn, J. and Mehta, S. (2012) Does Timing to Operative Debridement Affect Infectious Complications in Open Long-Bone Fractures? A Systematic Review. *Journal of Bone and Joint Surgery*, *American Volume*, **94**, 1057-1064. https://doi.org/10.2106/jbjs.k.00582