

Factors Associated with Infection Following Open Fracture Management

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ABSTRACT

Background: Open fractures are associated with substantial infection risk because of soft-tissue damage, contamination and exposure of the fracture site to the external environment. Identifying modifiable risk factors is important for preventing infectious complications and improving outcomes. **Methods & Materials:** This prospective observational study included 230 patients with open fractures managed in the Department of Orthopaedic Surgery, 250-Bedded General Hospital, Naogaon, from November 2024 to October 2025. Patients were enrolled using consecutive sampling. Demographic, injury-related and management-related variables were recorded and infection following fracture management was assessed. Data were analyzed using IBM SPSS Statistics version 25.0. Associations were evaluated using the chi-square or Fisher's exact test, with $p < 0.05$ considered statistically significant. **Results:** Most patients were aged 18–29 years (62, 27.0%), male (181, 78.7%) and from rural areas (142, 61.7%). Road traffic accidents were the leading mechanism (119, 51.7%) and tibia/fibula was the most common fracture site (94, 40.9%). Grade II fractures predominated (88, 38.3%). Infection was significantly associated with age ≥ 40 years (29, 25.4% vs. 19, 16.4%; $p = 0.041$), Grade III fractures (30, 38.0% vs. 18, 11.9%; $p < 0.001$), severe wound contamination (21, 51.2% vs. 27, 14.3%; $p < 0.001$), delayed presentation ($p = 0.001$), delayed antibiotic administration ($p < 0.001$), delayed debridement ($p < 0.001$) and diabetes mellitus (10, 47.6% vs. 38, 18.2%; $p = 0.004$). **Conclusion:** Infection was significantly associated with injury severity, wound contamination, treatment delays, older age and diabetes mellitus. Early antibiotics and timely debridement may help reduce infectious complications.

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Keywords: Open fracture; infection; risk factors; wound contamination; debridement; antibiotics; diabetes mellitus.

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INTRODUCTION

Open fractures are among the most challenging injuries encountered in orthopaedic practice because they combine skeletal disruption with varying degrees of soft-tissue damage and contamination [1]. Unlike closed fractures, the communication between the fracture site and the external environment creates a substantial risk of bacterial contamination, wound complications, delayed healing and deep infection [2]. The severity of these complications depends on the extent of tissue injury, degree of contamination, vascular compromise and the overall condition of the patient. Appropriate early management is therefore essential to minimize morbidity and improve functional recovery [3].

Infection remains one of the most important complications following open fracture management. It may range from superficial wound infection to deep surgical-site infection and osteomyelitis, potentially resulting in prolonged hospital stay, repeated surgical procedures, delayed fracture union, nonunion, implant failure and permanent functional impairment [4]. Infection can also impose a considerable financial and social burden on patients and healthcare systems, particularly where access to timely specialist care, advanced wound management, microbiological

investigations and reconstructive procedures may be limited [5].

Several factors may influence the development of infection after an open fracture. Injury-related factors include the mechanism of trauma, fracture location, extent of soft-tissue damage, wound contamination and the severity of the fracture according to the Gustilo-Anderson classification [6]. Patient-related factors such as increasing age, diabetes mellitus, smoking, nutritional status and other comorbidities may further impair immune response and tissue healing [7,8]. Treatment-related factors, including delay in hospital presentation, delayed administration of antibiotics, inadequate or delayed surgical debridement, inappropriate wound closure and the method of fracture stabilization, may also affect infection risk [9].

Early administration of appropriate antibiotics, thorough surgical debridement, adequate irrigation, assessment of soft-tissue viability, appropriate fracture stabilization and timely wound coverage are fundamental principles in the management of open fractures [10]. However, the risk of infection may persist despite appropriate treatment, particularly in patients with severe injuries or unfavorable clinical characteristics [11]. Identifying factors associated with

infection can therefore help clinicians recognize high-risk patients and optimize treatment strategies [12].

The present study was undertaken to evaluate the clinical and injury-related characteristics of patients with open fractures and to identify factors associated with infection following open fracture management. The findings may assist orthopaedic surgeons in improving early risk assessment, treatment planning, infection prevention and follow-up of patients with open fractures.

METHODS & MATERIALS

This prospective observational study was conducted in the Department of Orthopaedic Surgery, 250-Bedded General Hospital, Naogaon, from November 2024 to October 2025. A total of 230 patients with open fractures who received treatment at the study hospital during the study period were enrolled using a consecutive sampling technique. Patients aged 18 years or above with clinically and radiologically confirmed open fractures who underwent initial wound management and definitive fracture treatment at the study hospital were included. Patients with pathological fractures, established infection at the time of admission, previous surgery for the same fracture, chronic osteomyelitis, isolated soft-tissue injuries without fracture

and those who were lost to follow-up were excluded. After obtaining informed written consent, demographic and clinical information was collected using a structured questionnaire and from hospital records. Data included age, sex, residence, occupation, comorbidities, mechanism of injury, fracture site, Gustilo-Anderson grade, degree of wound contamination, associated soft-tissue injury, time from injury to hospital presentation, time to antibiotic administration, time to surgical debridement, method of fracture fixation, wound closure technique and duration of hospital stay. Patients were followed during hospitalization and subsequent follow-up visits for evidence of infection, including wound discharge, erythema, swelling, wound breakdown, fever,

positive wound culture, or clinical/radiological evidence of deep infection or osteomyelitis. Infection following open fracture management was considered the primary outcome. Data were entered, cleaned and analyzed using IBM SPSS Statistics version 25.0. Categorical variables were expressed as frequency and percentage, while continuous variables were summarized using mean $\pm$ standard deviation or median with interquartile range as appropriate. Associations between potential risk factors and infection were assessed using the chi-square test or Fisher's exact test, as appropriate. A p-value of <0.05 was considered statistically significant.

RESULTS

Table I presents the sociodemographic and clinical characteristics of the study participants. The majority were aged 18–29 years (62, 27.0%), followed by 30–39 years (54, 23.5%). Most participants were male (181, 78.7%) and from rural areas (142, 61.7%). Farmers constituted the largest occupational group (58, 25.2%), followed by day laborers (47, 20.4%). Most patients had no comorbidity (184, 80.0%), while diabetes mellitus was present in 21 (9.1%) and hypertension in 16 (7.0%) participants.

Table I
Sociodemographic and Clinical Characteristics of Study Participants (n=230).

Variable	Category	n	%
Age (years)	18–29	62	27.0
	30–39	54	23.5
	40–49	47	20.4
	50–59	39	17.0
	≥ 60	28	12.2
Sex	Male	181	78.7
	Female	49	21.3
Residence	Rural	142	61.7
	Urban	88	38.3
Occupation	Farmer	58	25.2
	Day laborer	47	20.4
	Business/service	41	17.8
	Student	29	12.6
	Homemaker	31	13.5
	Others	24	10.4
Comorbidity	None	184	80.0
	Diabetes mellitus	21	9.1
	Hypertension	16	7.0
	Other comorbidities	9	3.9

Table II presents the injury-related characteristics of the patients. Road traffic accidents were the most common mechanism of injury (119, 51.7%), while tibia/fibula fractures were the most

frequent fracture site (94, 40.9%). Regarding Gustilo-Anderson classification, Grade II was predominant (88, 38.3%), followed by Grade I (63, 27.4%). Moderate wound contamination was observed in 98

(42.6%) patients, while associated soft-tissue injury was present in 107 (46.5%) patients.

Table IIInjury-Related Characteristics of the Patients ($n=230$).

Variable	Category	n	%
Mechanism of injury	Road traffic accident	119	51.7
	Fall from height	38	16.5
	Agricultural injury	31	13.5
	Workplace injury	27	11.7
	Other causes	15	6.5
Site of fracture	Tibia/fibula	94	40.9
	Femur	42	18.3
	Forearm	36	15.7
	Humerus	22	9.6
	Ankle/foot	21	9.1
Gustilo-Anderson classification	Other sites	15	6.5
	Grade I	63	27.4
	Grade II	88	38.3
	Grade IIIA	43	18.7
	Grade IIIB	27	11.7
Wound contamination	Grade IIIC	9	3.9
	Mild	91	39.6
	Moderate	98	42.6
Associated soft-tissue injury	Severe	41	17.8
	Present	107	46.5
	Absent	123	53.5

Table III presents the management characteristics of open fractures. Most patients presented to the hospital within 6 hours of injury (71, 30.9%), while 42 (18.3%) presented after more than 24 hours. Antibiotics were administered

within 1 hour in 97 (42.2%) patients, whereas 49 (21.3%) received them after more than 3 hours. Surgical debridement was performed within 7–12 hours in 91 (39.6%) patients. Delayed primary closure was the most common wound management

method (94, 40.9%), while external fixation was the most frequently used fixation method (87, 37.8%). Most patients had a hospital stay of 8–14 days (92, 40.0%).

Table IIIManagement Characteristics of Open Fractures ($n=230$).

Variable	Category	n	%
Time from injury to hospital presentation	≤6 hours	71	30.9
	7–12 hours	63	27.4
	13–24 hours	54	23.5
	>24 hours	42	18.3
Time to first antibiotic	≤1 hour	97	42.2
	1–3 hours	84	36.5
	>3 hours	49	21.3
Time to surgical debridement	≤6 hours	82	35.7
	7–12 hours	91	39.6
	>12 hours	57	24.8
Initial wound management	Primary closure	76	33.0
	Delayed primary closure	94	40.9
	Secondary healing	39	17.0
	Skin graft/flap	21	9.1
Fracture fixation	External fixation	87	37.8
	Internal fixation	78	33.9
	Intramedullary fixation	42	18.3
	Conservative/other	23	10.0
Hospital stay	≤7 days	83	36.1
	8–14 days	92	40.0
	>14 days	55	23.9

Table IV presents the factors associated with infection following open fracture management. Infection was more frequent among patients aged ≥40 years (29, 25.4%) than those aged <40 years (19, 16.4%) ($p=0.041$). Patients with Grade III fractures had a higher infection rate (30, 38.0%) compared with Grade I–II fractures (18,

11.9%) ($p<0.001$). Severe wound contamination was also strongly associated with infection (21, 51.2% vs. 27, 14.3%; $p<0.001$). Infection was more common among patients presenting after >12 hours (30, 31.3%), receiving antibiotics after >3 hours (26, 53.1%) and undergoing debridement after >12 hours (24, 42.1%),

with all associations being statistically significant ($p=0.001$, $p<0.001$ and $p<0.001$, respectively). Diabetes mellitus was also significantly associated with infection (10, 47.6% vs. 38, 18.2%; $p=0.004$), whereas sex was not significantly associated with infection ($p=0.286$).

Table IV
Factors Associated with Infection Following Open Fracture Management (n=230).

Variable	Category	Infection n (%)	No infection n (%)	p-value
Age	<40 years	19 (16.4)	97 (83.6)	0.041
	≥40 years	29 (25.4)	85 (74.6)	
Sex	Male	40 (22.1)	141 (77.9)	0.286
	Female	8 (16.3)	41 (83.7)	
Mechanism	Road traffic accident	32 (26.9)	87 (73.1)	0.018
	Other causes	16 (14.4)	95 (85.6)	
Gustilo grade	Grade I–II	18 (11.9)	133 (88.1)	<0.001
	Grade III	30 (38.0)	49 (62.0)	
Wound contamination	Mild/moderate	27 (14.3)	161 (85.7)	<0.001
	Severe	21 (51.2)	20 (48.8)	
Time to hospital	≤12 hours	18 (13.4)	116 (86.6)	0.001
	>12 hours	30 (31.3)	66 (68.7)	
Time to antibiotic	≤3 hours	22 (12.1)	159 (87.9)	<0.001
	>3 hours	26 (53.1)	23 (46.9)	
Time to debridement	≤12 hours	24 (13.9)	149 (86.1)	<0.001
	>12 hours	24 (42.1)	33 (57.9)	
Diabetes mellitus	Present	10 (47.6)	11 (52.4)	0.004
	Absent	38 (18.2)	171 (81.8)	

DISCUSSION

Open fractures remain a major orthopaedic challenge because the combination of bone injury, soft-tissue disruption and contamination increases the risk of infection and subsequent impairment of fracture healing. In the present study, most patients were young adults, with 62 (27.0%) aged 18–29 years and 54 (23.5%) aged 30–39 years and males predominated (181, 78.7%). This demographic pattern is consistent with the findings of Noorlander-Borgdorff et al., who reported that open tibial fractures commonly affect younger, predominantly male populations and are frequently related to high-energy trauma [13]. The predominance of males in our study may reflect greater exposure to road traffic and occupational injuries.

Road traffic accidents were the leading mechanism of injury in our study, accounting for 119 (51.7%) cases, while tibia/fibula fractures were the most frequent fracture site (94, 40.9%). These findings are clinically important because high-energy trauma can produce extensive soft-tissue destruction and environmental contamination. Noorlander-Borgdorff et al., similarly highlighted the substantial burden of open tibial fractures and their relationship with injury severity [13]. In our cohort, Grade II fractures were most common (88, 38.3%), while Grade III injuries collectively represented a considerable proportion of cases, reflecting the severity of injuries encountered in routine orthopaedic practice.

The overall infection rate in our study was 48/230 (20.9%). The strongest association was observed with fracture severity. Patients with Grade III fractures had an infection rate of 30 (38.0%), compared with 18 (11.9%) among those with Grade I–II injuries ($p<0.001$). This finding is consistent with the broader evidence that

greater tissue injury, contamination and compromised soft-tissue coverage increase surgical-site infection risk. Bucataru et al. emphasized that tissue damage, contamination, patient factors and perioperative variables collectively contribute to surgical-site infection [14]. Similarly, Gálvez-Sirvent et al. demonstrated that complications following fracture surgery are influenced by injury severity and local soft-tissue conditions [15].

Wound contamination was another prominent determinant of infection in our study. Severe contamination was associated with infection in 21 (51.2%) patients compared with 27 (14.3%) among those with mild/moderate contamination ($p<0.001$). This substantial difference supports the biological importance of contamination as a source of bacterial inoculation in open injuries. The findings are also compatible with the systematic review by Bucataru et al., which identified contamination and perioperative factors among important contributors to surgical-site infection [14].

Timeliness of treatment was significantly associated with infection. Patients presenting after >12 hours had a higher infection rate than those presenting within ≤12 hours (30, 31.3% vs. 18, 13.4%; $p=0.001$). Likewise, infection occurred in 26 (53.1%) patients when antibiotics were administered after >3 hours compared with 22 (12.1%) when antibiotics were given within ≤3 hours ($p<0.001$). Delayed debridement was similarly associated with infection, with rates of 24 (42.1%) after >12 hours compared with 24 (13.9%) when performed within ≤12 hours ($p<0.001$). These findings emphasize the importance of early antimicrobial therapy and effective surgical debridement in limiting bacterial proliferation and progression of tissue infection. Yamamoto et al. also identified

perioperative and injury-related factors as important determinants of surgical-site infection following spinal fractures [16].

Diabetes mellitus was significantly associated with infection in our study, occurring in 10 (47.6%) diabetic patients compared with 38 (18.2%) patients without diabetes ($p=0.004$). This finding is biologically plausible because impaired immune function, microvascular dysfunction and delayed tissue healing can increase susceptibility to infection. Rodriguez-Merchan and Delgado-Martinez similarly identified diabetes among important patient-related risk factors for postoperative orthopaedic infection [17]. In contrast, sex was not significantly associated with infection in our study ($p=0.286$), suggesting that injury severity, contamination, treatment delays and comorbidity may be more influential determinants than sex alone.

LIMITATIONS

This study was conducted at a single centre with a relatively limited sample size, which may restrict the generalizability of the findings to other healthcare settings. The observational design also limits the ability to establish causal relationships between identified risk factors and infection.

CONCLUSION

Infection following open fracture management was significantly associated with older age, higher Gustilo-Anderson grade, severe wound contamination, delayed hospital presentation, delayed antibiotic administration, delayed surgical debridement and diabetes mellitus. Early antibiotic therapy, timely debridement, appropriate fracture management and careful monitoring of high-risk patients may help reduce infectious complications and improve outcomes.

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CONFLICTS OF INTEREST

There are no conflicts of interest.

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