THE OCCURRENCE OF INFECTION IN OPEN LONG-BONE FRACTURES AMONG ADULT PATIENTS AT MOI TEACHING AND REFERRAL HOSPITAL, ELDORET, KENYA

BY

KESENTSENG KEMANG

RESEARCH DISSERTATION SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENT FOR THE AWARD OF DEGREE OF MASTERS OF MEDICINE IN ORTHOPAEDIC SURGERY, SCHOOL OF MEDICINE, MOI UNIVERSITY

DECLARATION

Declaration by Candidate

This proposal is my original and personal work and has not been presented to any other University for any reward.

KESENTSENG KEMANG

REG. NO: MS/ORT/4884/23

Signature:…… Date:……

Declaration by Supervisors

This proposal has been submitted to Moi University with our approval as university supervisors

DR. BARRY R. AYUMBA

Department of Orthopaedics and Rehabilitation

Consultant Orthopaedic Surgeon

Signature:…… Date:……

DR. SARATIEL. L. NYABERA

Department of Orthopaedics and Rehabilitation

Consultant Orthopaedic Surgeon

Signature:…… Date:……

DISCLOSURE

The candidate did not receive any grants or outside funding in support of this study. Neither he nor the anyone connected to him received payments or benefits or commitments or agreement to provide such benefits from a commercial entity.

Sign: ……. Date: …….

Dr Kesentseng Kemang

MS/ORT/4884/23

DEDICATION

This study is dedicated to my wife and children whose unwavering love, encouragement, and sacrifices have been my greatest source of strength.

To my supervisors and mentors, whose guidance and wisdom have shaped my academic and professional journey. Your dedication to knowledge and research has been an inspiration.

To my friends and colleagues, for their invaluable encouragement and motivation throughout this process.

Lastly, I dedicate this work to all patients who endure the challenges of open fractures and to the dedicated healthcare professionals striving to improve their care and outcomes. May this study contribute, even in a small way, to the advancement of medical knowledge and better patient care.

ACKNOWLEDGEMENT

I would like to express my sincere gratitude to all those who have contributed to the successful completion of this study.

First and foremost, I extend my deepest appreciation to my supervisors Dr. B. R. Ayumba and Dr. S.L Nyabera, for their invaluable guidance, patience, and insightful feedback throughout this research process. Their expertise and encouragement have been instrumental in shaping this study. I am also profoundly grateful to the orthopaedic consultants at MTRH, Department of Orthopaedics and Rehabilitation for their support, constructive criticism, and motivation, which have helped me refine my research. My sincere thanks go to the participants of this study for their willingness to share their experiences and data was invaluable in achieving the objectives of this research. I would also like to acknowledge my colleagues for their encouragement and thought-provoking discussions, which have kept me motivated throughout this journey.

Lastly, I am forever grateful to my family for their unwavering love, patience, and support. Their belief in me has been my greatest source of strength and determination.

To everyone who has played a role in this academic endeavor—thank you!

LIST OF ABBREVIATIONS

AO	(ArbeitsgemeinschaftfürOsteosynthesefragen (Association of Osteosynthesis)
ASEPSIS	Additional treatment, Serous discharge, Erythema, Purulent exudate, Separation of deep tissues, Isolation of bacteria and Stay
BOA	British Orthopaedic Association
CDC	Center for Disease Control and Prevention
CT	Computed Tomography
FDG-PET	Fluorodeoxyglucose Positron Emission Tomography
I&D	Irrigation and Debridment
IO	Injury to the skin (open)
IREC	Institutional Research and Ethics Committee
MRI	Magnetic Resonance Imaging
MT	Muscle and Tendon Injury
MTRH	Moi Teaching and Referral Hospital
NHSC	National Health Service Corps
NV	Nerve and Vessel Injury
RTA	Road Traffic Accident
SOP	Standard Operating Procedure
SPSS	Statistical Package for the Social Sciences Software

OPERATIONAL DEFINITIONS OF VARIABLES AND KEY CONCEPTS

Adult: An individual who is 18 years and above.

Co-morbidities: Pre-existing medical conditions the patients had.

Gustilo-Anderson classification: classification system for open fractures

Long bone: It is a type of bone that is longer than it is wide and has a cylindrical or tubular structure consisting of diaphysis, metaphysis and an epiphysis at both ends. Only the humerus, radius and ulna, femur and tibia and fibula will be considered for this study.

Mechanism of injury: The circumstances or events that led to the injury.

Open Fractures: Are injuries involving a broken bone that directly communicate with the external environment due to breach of the skin's protective barrier exposing the fractured bone to potential contamination from the external environment.

Timing of debridement: Time from injury to beginning of surgical debridement

ABSTRACT

Background: Open injuries of long bones are complex, with substantial implications for patients' well-being. These injuries pose a significant challenge in orthopaedic surgery, as they are highly susceptible to infections that can compromise patient outcomes and increase morbidity and mortality. Identifying factors that are associated with the occurrence of infection among adult patients with open fractures of long bones can provide clinicians with information critical in making informed decisions regarding fracture management protocols, antibiotic selection, and preventive measures to reduce infection and improve patient outcomes.

Objectives: To describe the characteristics, incidence, patterns of prophylaxis antibiotic use and to determine the factors associated with occurrence of infection in open long bones fractures among adult patients at Moi Teaching and Referral Hospital (MTRH), Eldoret, Kenya.

Methods: A prospective descriptive study which involved 247 adult patients with 258 open fractures of long bones admitted at MTRH Orthopaedics wards between January 2024 and September 2024. Data from the participants was collected using an interviewer-administered questionnaire. Data on socio-demographic and fracture characteristics, co-morbidities, Gustilo-Anderson classification, the time of injury, duration from injury to debridement, timing and duration of prophylactic antibiotics were recorded. Participants were followed up for 3 months to monitor for development of infection using the Center for Disease Control and Prevention (CDC) criteria based on clinical features and microbiological culture- sensitivity procedure. There were 230 participants with 241 fractures analyzed.

Results: The majority of patients were male (74.3%) with a mean age of 36.9 (SD: 14.9) years. Road traffic accidents were the leading cause of fractures (65.2%), and lower extremity fractures were the commonest (82.2%), primarily affecting the tibia and fibula (57.3%). Comminuted fractures were the most frequent pattern (58.5%). The overall infection rate was 38.2%, with *Staphylococcus aureus* being commonest isolated organism (20.6%), followed by *Escherichia coli* (10.8%) and *Proteus mirabilis* (8.7%). Infection rates were significantly higher with delayed surgical debridement, increasing from 0% within 6 hours to 72.4% when delayed beyond 48 hours ($p < 0.001$). Other factors that increased risk of infection included Gustilo-Anderson type III fractures, especially type IIIB, had the highest infection rates (91.2%), smoking ($p < 0.001$) and diabetes ($p = 0.038$). Early prophylactic antibiotic administration reduced infection rates. Cefazolin was the commonest used prophylactic antibiotic, with a mean duration of 13.6 (SD: 4.6) days.

Conclusion: Road traffic accidents were the primary cause of open long bone fractures, predominantly in young males. The infection rate was higher than documented elsewhere, risks being increased with delayed debridement and prophylactic antibiotics, type III fractures, smoking, and diabetes mellitus. Cefazolin was the commonest prophylactic antibiotic used beyond usual recommended 24 hours.

Recommendation: Infection prevention strategies must be enhanced. Early surgical debridement and antibiotic administration should be prioritized and prophylactic antibiotics should follow a standardized protocol to avoid resistance and unnecessary healthcare costs. Public health initiatives should improve road safety and educate high-risk groups.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER ONE: INTRODUCTION

1.1 Background

Open fractures are complex injuries with substantial implications for patients' well-being. These fractures pose a significant challenge in orthopaedic surgery, as they are highly susceptible to infections that can compromise patient outcomes and increase morbidity (Coombs et al., 2022). Health facilities can gain valuable insights into infection prevention strategies and improve patient care by examining factors that influence the occurrence of infection in open fractures among adult patients.

1.1.1 Open Fractures

According to Sop and Sop (2022), open fractures involve a broken bone that directly communicates with the external environment due to a breach of the skin's protective barrier exposing the fractured bone ends to potential contamination from the external environment. Most of these fractures occur in patients involved in high energy mechanisms events like road traffic accidents or gunshots, however, patients can still experience open fractures caused by relatively minor incidents, such as a fall, which involve simple low-energy mechanisms (Cross III & Swiontkowski, 2008). There are various classification methods of open fractures that have been proposed to aid in the communication, categorisation, and guide treatment of soft tissue injuries accompanying these fractures. The Gustilo and Anderson classification (figure 1) is the most frequently utilized and universally accepted method of classifying open fractures. This classification assesses the injury based on factors such as the mechanism of injury, wound size, extent to which soft tissues have been damaged, and wound contamination (Whittle, 2017).

- Type I: Involves a clean wound, usually caused by a low-energy injury. The wound size is less than one centimeter and nominal soft tissues have been injured.
- Type II: The size of the wound is more than one centimeter and accompanied by a modest injury to soft tissues. May be associated with a higher degree of contamination.
- Type III: These are the most severe and are divided into three categories:
    - Type IIIA: The extent of damage to soft tissues is extensive, however there is sufficient skin to cover the fractured bone.
    - Type IIIB: Major loss of soft tissues accompanied by stripping of the periosteum, exposing the fractured bone and a higher degree of contamination
    - Type IIIC: Arterial injury which requires vascular repair.

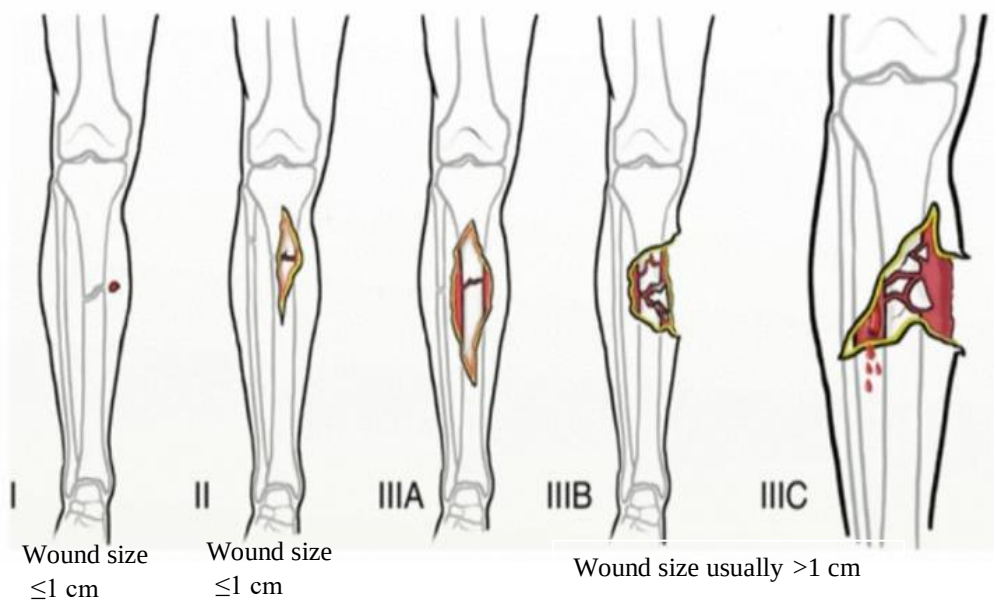


Figure 1: The Gustilo and Anderson Classification (Lasanianos et al., 2015.)

The AO classification system (Table 1) is another classification method used to evaluate damage to soft tissues in open fractures. In this system, the degree of soft tissue damage is classified based on the injury affecting three specific anatomical structures: the skin, the muscles and the tendons, and neurovascular tissue (Buckley et al., 2017).

The Tscherne classification of open fractures takes into account wound size, level of contamination, and fracture mechanism. It comprises four grades, ranging from Grade I to Grade IV (Ibrahim et al., 2017). In Grade I there is a small puncture wound without associated contusion, negligible bacterial contamination and it is a low-energy mechanism fracture. Grade II fractures have a small laceration, skin and soft tissue contusions, moderate bacterial contamination and they are of variable mechanisms of injury. Large laceration with heavy bacterial contamination, extensive soft tissue damage, with frequent associated arterial or neural injury are considered Grade III fracture while Grade IV fractures are associated with incomplete or complete amputation with variable prognosis based on location and nature of injury (e.g., cleanly amputated middle phalanx vs. crushed leg at the proximal femoral level).

Table 1: AO classification system of damage to soft tissues in open fractures (Buckely et al., 2017).

Type of Injury	Description
Skin Lesion (open fracture)	
IO 1	Skin rupture occurring internally and extending outwardly.
IO 2	Skin rupture less than five centimeters in size, originating externally and progressing inwardly, characterized by bruised edges.
IO 3	Skin rupture more than five centimeters in size, originating externally and progressing inwardly, with intensified bruising and edges showing tissue death.
IO 4	Severe contusion, abrasion, and significant loss of skin due to a deep and extensive injury, including an open degloving wound.
IO 5	Extensive loss of skin resembling degloving wound.
Muscle/tendon	
MT 1	Absence of muscle damage.
MT 2	Limited muscle damage confined to a single compartment
MT 3	Significant muscle damage affecting more than one compartment.
MT 4	Muscle tear, tendon cut, and extensive muscle bruising resulting in a defect.
MT 5	Development of compartment syndrome or crush syndrome, characterized by a broad area of injury.
Neurovascular	
NV 1	Absence of any nerve or vascular damage.
NV 2	Nerve injury occurring in isolation
NV 3	Localized injury to the blood vessels
NV 4	Extensive and segmented injury to blood vessels
NV 5	Simultaneous involvement of nerves and blood vessels, potentially leading to partial or complete amputation.

1.1.2 Long Bone

Bones can be classified into five main types: flat, irregular, long, sesamoid and short. Long bones are characterized by their cylindrical shape and are longer in length than wide. These include the humerus, radius and ulna, metacarpals, femur, tibia and fibula, metatarsals and phalanges. Embryonic development of long bones through endochondral ossification is a highly regulated and intricate process involving the differentiation of mesenchymal cells into chondrocytes, formation of

a cartilaginous template, invasion of blood vessels and osteoprogenitor cells, and subsequent replacement of cartilage with bone tissue (Setiawati & Rahardjo, 2019). This process establishes the foundation for skeletal growth and development, ultimately giving rise to the mature skeletal system capable of supporting the body's structure and facilitating movement.

Long bones have three distinct regions: the epiphysis, metaphysis and diaphysis (Betts et al., 2017). The epiphysis region of the bone comprises a type of bone called cancellous bone. This cancellous bone which is found in both ends of the long bone is spongy, has an articular surface covered by hyaline cartilage and contains bone marrow that synthesizes blood cells (Shier et al., 2016). The metaphysis of a long bone includes an area that consists of the epiphyseal plate. During human growth, the presence of the epiphyseal plate facilitates the bones to grow in length. In young adulthood, once the growth process stops, the cartilage in the epiphyseal plate undergoes ossification and becomes an epiphyseal line (Barrett et al., 2019). The diaphysis is the long, hollow shaft between the ends of the bone containing a medullary cavity filled with bone marrow. Its outer layer is dense and hard compact bone covered by a protective layer called periosteum (Betts et al., 2017).

Long bones are an important component of the human skeletal system, serving various essential functions in maintaining overall health and functionality. One of the primary functions of long bones is to provide mechanical support and structural integrity to the body. Long bones, with their cylindrical shape and dense cortical bone, bear the majority of the body's weight and assist in maintaining posture and also serve as levers for muscle action, enabling coordinated movement and locomotion (Su et al., 2019). Muscles attach to long bones via tendons, and when

muscles contract, they exert force on these bones, causing them to move around their joints. In addition to their role in support and movement, long bones harbor red bone marrow, a specialized tissue responsible for hematopoiesis – the formation of blood cells (Šromová et al., 2023). Hematopoietic stem cells located within the marrow give rise to erythrocytes, leukocytes, and thrombocytes. Thus, they play a role in the body's immune response, oxygen transport, and blood clotting mechanisms. Long bones serve as reservoirs for calcium and phosphorus, storing and releasing these minerals as needed to maintain extracellular ion concentrations within narrow physiological ranges therefore contributing to mineral homeostasis in the body (Shaker & Deftos, 2023). Long bones are susceptible to various injuries and infections which can significantly affect their function. Traumatic fractures or bacterial invasion from open fractures can disrupt the structural integrity, mechanical support, and physiological functions of long bones (Croes et al., 2019, Zheng et al., 2023).

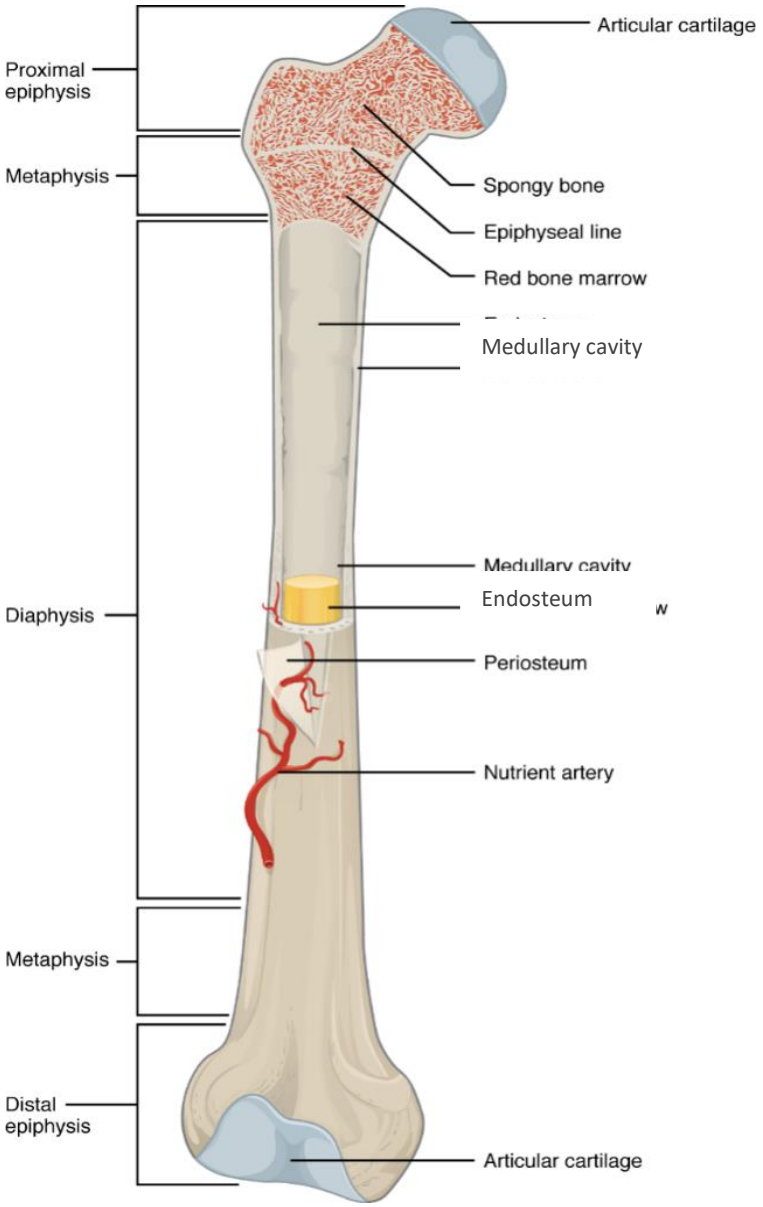


Figure 2: Anatomy of a long bone (Adopted from Betts et al., 2017)

1.1.3 Infection in Open Fractures

According to the revised guidelines of the Centre for Disease Control and Prevention (CDC), infection in open fractures is characterized by a combination of clinical symptoms including fever, redness/cellulitis, positive tissue cultures, and pus drainage within 90 days (3 months) following the initial procedure in which an implant was used and within 30 days if no implant was used (CDC, 2023). Centre for Disease Control categorises infections as superficial or deep incisional surgical infections. Infection on the outer surface of the tissue, above the fascia is referred

to as superficial and deep infections which occur beneath the fascia, involving deeper layers of tissue (CDC & NHSN, 2014).

Infection is a relatively frequent complication that can have severe implications for the patient's health and well-being, leading to increased morbidity and mortality rates. Infection from open fracture can result in prolonged hospital length of stay, non-union, limb amputation and even death. Therefore, one of the key goals of managing open fractures is to minimize infection risk. This can be achieved through early prophylactic systemic antibiotics, wound debridement and irrigation with normal saline (Coombs et al., 2022). Immediate and thorough wound debridement to remove contaminants and devitalized tissue minimizes bacterial load and promotes wound healing (Thomas et al., 2021). Early administration of broad-spectrum antibiotics tailored to the likely pathogens based on the mechanism of injury and degree of contamination helps prevent bacterial colonization and systemic spread (Coombs et al, 2022). Furthermore, advancements in wound care techniques, including negative pressure wound therapy and tissue engineering approaches, hold promise in optimizing wound healing and reducing infection rates.

Timely and accurate diagnosis of infection in open fractures is essential for effective management. Clinical evaluation, including assessment of wound appearance, signs of inflammation, and systemic symptoms, serves as the initial diagnostic step. However, given the limitations of clinical judgment alone, adjunctive investigations such as laboratory tests (e.g., white blood cell count, inflammatory markers), wound cultures and imaging studies (e.g., plain

radiographs, MRI, CT scans, nuclear imaging) can be used in confirming or ruling out infection (Govaert et al., 2018).

1.1.4 Risk Factors for Infection in Open Fracture

Several factors contribute to the development of infections in open long-bone fractures which significantly impact patient outcomes (Coombs et al., 2022). These factors include time to surgical debridement, fracture classification, the severity of soft tissue injury, patient-related factors such as overall health status, immune function, presence of comorbidities (e.g., diabetes), and tobacco use, administration of antibiotic prophylaxis, environmental and local factors and surgeon expertise (Kortram et al., 2017; Metsemakers et al., 2017; Zalavras, 2017).

The severity of the fractures, as assessed by the Gustilo-Anderson classification system is a common factor that influences the frequency of infection in adults with open fractures. As the classification level progresses the rates of infection also increase. A study by Zalavras, (2017), revealed that the incidence of infection was 2% for type I fractures, and it increased up to 10% and 50% for type II and type III respectively.

1.1.5 Management of Infection in Open fractures

The management of infection in open fractures represents a complex clinical scenario requiring a multidisciplinary approach and tailored interventions (Metsemakers et al., 2020). A comprehensive approach integrating surgical, antimicrobial, and adjunctive therapies tailored to the individual patient's presentation and the specific characteristics of the injury is essential for optimizing outcomes and reducing the burden of infection in open fractures (Depypere et al., 2020).

1.2 Problem Statement

Infection in open fractures of long bones poses significant challenges to healthcare systems worldwide, as it not only leads to substantial morbidity and mortality but also contributes to a considerable economic burden on patients' lives and their families (Schenker et al., 2012). Infection associated with open fractures can lead to prolonged hospital stays, multiple surgeries, increased healthcare costs, and potential long-term disability such as amputation (Olesen et al., 2017).

A study done at MTRH which assessed the demographic characteristics, symptomatology, treatment options and outcomes in patients who had exposed bones due to open fractures has shown that 32% of the patients presented with infection as the main complication, constituting 60% of all complications (Ayumba et al., 2015). This high number of infections observed in aforementioned study suggests underlying factors predisposing patients to infection which were not explored.

MTRH covers an area with a population of over 25 million. A high prevalence of fractures within the community contributes to the overall burden of open fractures and subsequent infections. Most of the cases of open fractures in Kenya and other East African countries are due to accidents involving motorcycle and motor vehicles, gun-shot wounds, falls and sports injuries (Buteera & Byimana, 2009; Ondari et al., 2016; Thuita et al., 2021). Due to the high demand for trauma care at MTRH, many patients with open fracture injuries wait 24 to 48 hours before initial surgical debridement (Nyamosi, 2019). Timely surgical intervention is recognised as critical in reducing infection risk, as delays may lead to prolonged exposure of the fracture site and compromised tissue viability (Coombs et al., 2022). Infections

in patients presents challenges such as high treatment costs, extended recovery period, increasing morbidity as well as psychosocial impact.

1.3 Justification

Infection in open fractures of long bones has significant clinical and public health implications. Establishing factors contributing to infection rates in these fractures is essential for improving patient outcomes, optimizing resource allocation, and implementing targeted preventive measures. Investigating the factors associated with infection rates will help identify modifiable variables that can be targeted to reduce the incidence of infections and improve patient outcomes. Identifying these factors will be essential in developing tailored preventive and cost-effective strategies to minimize the financial burden of these infections and optimise patient care. Understanding the specific characteristics of these fractures, including fracture types, patterns, and associated injuries, can provide valuable insights into the potential risk factors associated with infection.

Therefore, this research will be essential for developing evidence-based guidelines and interventions to effectively reduce infection risk. Furthermore, this research will contribute to developing standardized protocols and guidelines for the initial assessment, debridement, antibiotic prophylaxis, wound management, and subsequent follow-up care of patients with open fractures. Research on factors influencing infection rates in open fractures will also serve as a foundation for further studies at MTRH, including prospective clinical trials, comparative effectiveness research, or the development of novel interventions to combat infection. This research will also guide the development and implementation of preventive measures, such as educational programs for clinicians and patients and improved adherence to infection control protocols.

1.4 Research Question

What are the factors associated with the occurrence of infection in open long bone fractures among adult patients treated at MTRH?

1.5 Objectives

1.5.1 Broad Objective

The study aims to describe characteristics, incidence, patterns of prophylaxis antibiotic use and to determine factors associated with the occurrence of infection in open long bone fractures among adult patients treated at MTRH, Eldoret, Kenya.

1.5.2 Specific Objectives

1. To describe characteristics of adult patients with open long bone fractures treated at MTRH.
2. To describe the incidence of infection among adult patients with open long bone fractures at MTRH.
3. To determine factors associated with the occurrence of infection among adult patients with open long bone fracture at MTRH.
4. To describe the pattern of prophylactic antibiotic use among adult patients with open long bone fractures at MTRH.

CHAPTER TWO: LITERATURE REVIEW

2.1 Characteristics of patients with open long bone fractures

2.1.1 Epidemiology

The frequency and reasons for open fractures vary across regions and this differences are influenced by the socioeconomic and cultural profiles of the respective populations (Costa et al., 2022). An international study conducted in Europe over a period of fifteen years by Court-Brown et al., (2012), revealed the occurrence of open fractures among adult population at a rate of 30.7 per 100,000 individuals. In an earlier study by Court-Brown et al., (1998), the occurrence rate of open fracture of long bones was 11.5 per 100,000 persons per year. The overall incidence rate of these fractures in England was 6.94 per 100,000 person-years (Shah et al., 2022). In a Swedish study aiming to ascertain fracture rates in adults, the percentage of open fractures among all fractures was found to be 2.3% (Bergh et al., 2021).

In Africa, there need to be more published literature on the frequency of open fractures. The epidemiological aspect of this fractures in Africa remains poorly documented. Nevertheless, Kombate et al., (2017) suggest that these injuries are common in developing countries like Kenya and tend to be severe. The predominance of trauma resulting from road traffic accidents, industrial mishaps, and interpersonal violence exacerbates the likelihood of encountering open fractures, which are often more severe due to delayed or inadequate medical intervention. According to Nana et al., (2021), the burden of open fractures in low-middle income Sub-Saharan African communities is on the rise. Many patients in these areas tend to seek surgical treatment after experiencing a delay, resulting in severe injuries or complications that are challenging to manage with the available

diagnostic and therapeutic resources in local facilities. The scarcity of suitable hospital facilities or healthcare infrastructure challenges, cultural factors, a lack of healthcare personnel, and financial limitations further complicate the treatment of open fractures involving long bones in these communities (Nana et al., 2021).

As a developing nation with limited data concerning the prevalence of open fractures, Kenya follows the pattern observed in other low- and middle-income countries. Kenya faces a significant burden of injuries, with 88.4 deaths per 100,000 population attributed to this cause, and over 27% of these injury-related fatalities stem from road traffic accidents (Wesson et al., 2015). Various factors contribute to the elevated mortality rates associated with injuries in low- and middle-income countries, including rapid urbanization, inadequate road infrastructure, the widespread use of motorcycles for transportation, lax enforcement of road safety regulations, and deficiencies in trauma care systems (Botchey et al., 2017).

2.1.2 Socio-demographic characteristics

In Europe, a significant number of open fractures was observed in individuals with an average age of 45.5 years. Among the affected individuals, 69.1% were males and their average age was 40.8 years, while the average age in females was found to be 56.0 years of age. The highest incidence of open fractures among adult males was seen in ages 15 and 19, with a rate of 54.5 per 100,000 individuals annually. A consistent decline follows this incidence, as age increases. Females had an unimodal distribution rising from 9.2/100 000 individuals annually in the 15–19-year group to 14.6/100 000 individuals annually in the 50–59-year group and rapidly decreasing thereafter (Court-Brown et al., 2012). An investigation carried out in Ethiopia to evaluate the prevalence of delayed hospital presentation among

patients with open long bone fractures indicated that 85% of the patients were male, resulting in a male-to-female ratio of 5.4:1. The mean age of the patients was 32 ± 14.23 years, with over 75% falling within the age range of 18 to 45 years (Hailu & Mengesha, 2020). Similarly, in a study conducted in Togo, by Kombate et al., (2017), open fractures were observed to be common among individuals of ages between 16 and 29 years, having an average age of 38.1 years. In this age group, males had a higher incidence than females, with a sex ratio of 3:1. These findings are consistent with research conducted in the southwestern region of Cameroon, where open fractures were observed to be more prevalent in males than females and accounted for 75.4% of the cases. In comparison, females constituted 24.6%, resulting in a sex ratio of 3:1. The research participants had an average age of 34.1± 13.67 years, with the age group most susceptible to open fractures falling within the range of 20-40 years (Nana et al., 2021). Another study conducted in Rwanda, East Africa, also found a male predominance of 77% compared to females with an equal ratio of 3:1 and most participants were in the age bracket of 18 – 44 years (Twagirayezu & Bonane, 2008).

Limited published literature exists regarding the socio-demographic characteristics of open fractures involving long bones in Kenya and locally. The available body of research is scanty, providing only fragmentary insights into this facet of orthopedic trauma within the region. However, the data that is available has shown similar gender distribution and age demographics as in the other regions outside Kenya. A local study done at Moi Teaching and Referral Hospital involving patients with post-traumatic exposed bones with 97% of the cases having open fractures, has also shown a male majority with a higher sex ratio of 5.8:1 and an average age of 32.5years ± 13.3 (Ayumba et al., 2015). In a separate investigation conducted

locally by Ibrahim, (2019), which centered on open long-bone fractures managed with external fixators, it was discovered that males comprised 82.1% of the cases, with an average age of 37.3 ± 15.2 years.

Studies have shown that certain occupations may have a higher risk of traumatic injuries, including open fractures. According to Costa et al., (2022), epidemiological characterization of open fractures in Brazil revealed that the demographic group most frequently afflicted comprised farmers (23.38%), self-employed individuals (11.29%), masons (8.87%), and industrial workers (8.06%). Cumulatively, these 4 occupational categories accounted for over half of the total cases of open fractures (51.60%). Similar research conducted by Kombate et al., (2017) in a Low-Income Country in Africa found that a significant portion of individuals with open fractures belonged to liberal professions such as healthcare workers, educators, legal practitioners, and journalists. This demographic exhibited high levels of activity and mobility, often encountering road accidents, particularly when they commute between home and work. In Nigeria, traders were most affected by open fractures followed by students and artisans (Odatuwa-Omagbemi, 2019). In Cameron, the majority of the study cohort, constituting 71.3%, engaged in informal occupations, encompassing roles such as farming, business, motorcycle riders, construction work, carpentry, hairdressing, driving, domestic service, among others. Conversely, 14.9% of participants held formal occupations, including positions as civil servants, technicians, and engineers. The remaining individuals were identified as students, comprising 13.8% of the total sample (Nana et al., 2021). A study conducted in Kenya on patients with open fractures of long bones treated with external fixation has reported that the majority of patients with open

fractures of long bones were farmers with 28% followed by motorists and casual labourers with 18.9% and 14.7% respectively (Nyamosi, 2019).

In terms on education level, subjects examined in the Brazilian study indicated that over half of the patients (50.80%) had either completed all or some primary education, with a minimal proportion (0.8%) being classified as illiterate. Individuals with lower levels of education typically exhibit low professional qualification, engage in manual labor, and are more frequently involved in hazardous activities, thus increasing susceptibility to open fractures (Costa et al., 2022). In a study describing the pattens of open fractures of the long bones in the lower limb treated across three major hospitals in the southwestern region of Cameroon, as reported by Nana et al., (2021), it was revealed that a predominant proportion of participants, constituting 89.2%, possessed educational backgrounds encompassing both primary and secondary levels. Only 7.2% of the cohort had attained tertiary education, whereas 3.6% lacked formal educational attainment. Odatuwa-Omagbemi (2019), reported higher cases of open fractures in patients with secondary education (42.3%) compared to those with tertiary education (32.9%) and primary education (13.5%). This is in contrast to the educational attainment described by Nyamosi, (2019) who reported 49.5 % in primary education level followed by 36.8% and 9.5% in tertiary and secondary education level respectively.

2.1.3 Fracture Characteristics

Mechanism of injury

Open fractures can arise from both high energy and low energy injuries. In a European study analyzing the incidence and severity of open fractures over a 15-year period, the primary causes of these fractures typically included road traffic

accidents (RTA), crush injuries, falls, sporting accidents and assaults (Court-Brown et al., 2012). According to Costa et al., (2022), findings from a study conducted in Brazil indicate that the predominant trauma mechanisms related to open fractures resulted from occupational incidents associated with the operation of industrial and agricultural machinery, comprising 39.5%, followed by RTA and falls constituting 29.0% and 9.7% respectively. In a retrospective observational analysis spanning five years, conducted at a tertiary trauma care institute in Saudi Arabia, it was observed that RTA emerged as the primary etiology of open fractures, representing 28.47% of total incidents. Subsequent to this, falls from height, attributed to occupational hazards or intentional self-harm, constituted the second most prevalent cause at 18.96%, while assault accounted for 2.9% of the identified causes (Alhawas & Alghamdi, 2023).

In Africa, the most common aetiology of open fracture is also RTA involving motorbike-motorbike, automobile-automobile, automobile- Motorbike accident, automobile –pedestrian, motorbike-pedestrian and cyclist accidents. Other causes include occupational accidents, domestic accidents, assaults and sports injuries (Kombate et al., 2017). Studies done in Cameroon and Rwanda showed that RTA caused an average of 72% of open fractures, with other causes being falls, assaults, crush injuries and sports injuries(Nana et al., 2021; Twagirayezu & Bonane, 2008). According to a local study by Ayumba et al., (2015), involving patients with traumatic exposed bones, motor vehicle accidents accounted for 49.5% of the cases, followed by assaults 32.1% and occupational accidents 10.2%.

Fracture patterns

Court-Brown et al., (2012) observed a tendency for open fractures to manifest more frequently in the lower extremities compared to the upper extremities, as per their 15-year review findings. Among open long bone fractures excluding those of the hands and feet, 52.6% were located in the lower limbs, whereas 47.4% involved long bones of the upper limb. Within the lower limbs category, the majority comprised fractures of both the tibia and fibula (35.5%), followed by femur fractures (9.2%) and isolated tibia fractures (7.9%). In contrast, among the upper extremity fractures, the highest occurrence was noted in isolated radius fractures (25.1%), followed by ulna fractures (10.1%), humerus fractures (6.1%), and both radius and ulna fractures (6.1%). In the investigation conducted by Costa et al., (2020), it was found that upper limb fractures accounted for the majority of open fractures, comprising 64.51% of cases, with hand bone fractures representing 58.02% of all fractures. Among lower limb fractures, both the tibia and fibula were most frequently affected, constituting 13.54% of cases. Additionally, 55% of fractures occurred on the left side of the body. In a separate study by Alhawas and Alghamdi, (2023), it was observed that a significant proportion of open injuries occurred in the lower extremities (76.8%), with the tibia being the most commonly affected long bone (26.1%), followed by the femur (4.4%). Regarding upper extremity injuries, 23.2% of fractures occurred, with the radius and ulna being the most commonly injured bones (10.2%), followed by the humerus (5.1%) and radius (2.9%). Analysis of fracture laterality revealed that the majority of patients sustained injuries on the right side (50.7%), followed closely by the left side (49.3%).

A similar observation was documented by Kombate et al., (2017), who noted that lower extremities injuries are more common than upper extremities with a predominance of the tibia/fibula fractures. Nana et al., (2021) conducted research which found that concomitant open fractures involving the fibula and tibia were the most observed (39.0%). The tibia was the most affected isolated lower limb long bone at 38.5%, followed by the femur at 16.4%, with only 1.5% of cases affecting the fibula. Notably, these fractures affected the left side of the lower limb, accounting for 50.3% of cases compared to 49.2% on the right side. In Rwanda, open injuries of the tibia and fibula constituted 69.4% of the cases, while fractures of the femur comprised 17.6% of the total (Twagirayezu & Bonane, 2008). Previous studies done at MTRH also showed that tibia was the most affected bone (Ayumba et al., 2015). A study by Court-Brown et al., (2012) found that most (94.2%) cases involved a single bone open fracture, while 5.8% had multiple open injuries.

The patterns of fractures observed in open injuries can vary depending on multiple factors, including the mechanism of injury, energy imparted, and the anatomical site involved and they have significant implications for patient management and outcomes (Almigdad et al., 2022). Common fracture patterns encountered include transverse fractures, oblique fractures, spiral fractures, comminuted fractures and segmental fractures (Cohen et al., 2016). Nana et al., (2021) observed that among the fracture patterns in open fractures of lower limbs, comminuted fractures were the most prevalent at 64.6%, followed by transverse fractures at 14.4%, and oblique fractures at 13.3%. In a Nigerian context, Abang et al., (2018) conducted a review of open tibial shaft fractures, finding comminuted fractures to be predominant at 52.5%, followed by oblique fractures (25%), segmental fractures

(12.5%), and transverse fractures (5%). In contrast, Enweluzo et al., (2015) reported a different pattern, with oblique fractures being the most frequent (47.2%), followed by transverse fractures (32%), and comminuted, segmental, and spiral fractures at 11.2%, 5.6%, and 4.1% respectively. However, Kouassi et al., (2021) conducted a systematic review across multiple sub-Saharan countries, finding that comminuted fractures were the most common pattern (46.4%), followed by transverse (28.9%) and oblique fractures (25%).

Severity of Injury

Court-Brown et al., (2012), observed that 26.8% of all open fractures injuries were classified as Gustilo-Anderson Type III. Among upper limb fractures, 18.6% were categorized as Gustilo-Anderson Type III, whereas the proportion was higher at 42.6% in lower limb fractures. Several studies in developing countries have identified a similar pattern. In Togo, it was observed that Gustilo-Anderson Type III open fractures were the most prevalent, contributing 56.3% of the cases. Type II fractures accounted for 32.2%, while Type I fractures constituted only 11.5% of the total (Kombate et al., 2017). In Cameroon, most injuries were categorised as Gustilo-Anderson type II and III. Type IIIA fractures were the most common, accounting for 39.0% of the cases. Type IIIB fractures followed by 28.7%, and Type II fractures constituted 23.6%. Type IIIC fractures were less frequent, comprising only 8.7% of the total cases (Nana et al., 2021). In Rwanda, type III fractures were the most predominant, comprising 48.7% of the cases. Among type III fractures, 17.6% were classified as type IIIA, type IIIB accounted for 23.8% and type IIIC 7.3% (Twagirayezu and Bonane, 2008). There needs to be more data in the severity of open fractures among the population in Kenya. However, a study conducted in Uganda, which has a comparable population to Kenya has revealed

that most open fracture of long bone were type IIIB, accounting for 40.4%. The least common clarification was type IIIC, observed in only 3.4% of the cases (Kironde et al., 2019).

2.2 Incidence of infection in patients with open long bone fractures

2.2.1 Incidence of infection

Open fractures present an increased susceptibility to infection due to their frequent association with substantial bone injury, including periosteal stripping, extensive soft tissue damage, and significant contamination (Morgenstern et al., 2018). Moreover, in orthopedic trauma surgical interventions, apart from the inherent risk posed by normal skin flora, there exists an additional vulnerability to wound contamination originating from external sources and hospital-acquired infections (Graan & Balogh, 2022). Globally, infections following open fractures range as high as 50% among severe or grossly contaminated injuries (Bhandari, 2010; Coombs et al., 2022). A study reviewing more than one thousand patients on the management of open fractures was conducted through a Systematic Review and Meta-Analysis, revealing an aggregate infection rate of 14.3% (Nicolaides et al., 2021). Subsequent investigations done in different regions have shown variable results. A retrospective analysis in the United Kingdom, of three hundred and eighty-three cases of open fractures, reported a notably higher incidence of infection, with 27% of cases affected (Charalambous et al., 2005). Similarly, a prospective observational study conducted in Australia documented an overall infection rate of 17% (Enninghorst et al., 2011). A teaching hospital research in South East Asia revealed that infection rates post open fractures ranged from 34.6% to 45.1% (Islam et al., 2022). Research conducted in Brazil, have identified infection rates ranging between 13.24% and 18.8% among individuals with open

fractures occurring at various anatomical sites (Fernandes et al., 2015; Guerra et al., 2017). *Staphylococcus aureus* is the most prevalent pathogen in orthopedic infections (Islam et al., 2022; Latha et al. 2019). In studies done in India and Brazil gram-negative bacteria accounted for the majority of isolates (Guerra et al., 2017; Lingaraj et al., 2015). Other isolates included *Escherichia coli, Proteus mirabilis* and *Pseudomonas aeruginosa* (Islam et al., 2022; Guerra et al., 2017).

Infections associated with open fractures are more prevalent in developing countries compared to developed countries, primarily due to limited healthcare infrastructures (Zhang et al., 2022). According to a systemic review that assessed treatment of individuals with open tibia fractures in Sub-Saharan Africa, the infection rate following open fracture injuries was 30% (Kouassi et al., 2021). A study in Nigeria, showed a high proportion of wound infection of 42.5% in open fractures which were done initial debridement between one hour and seven days post-injury (Odatuwa-Omagbemi, 2019). There is scanty data regarding the incidence of infection post-open fractures in Kenya, however, a study done at the Nakuru County Hospital, Kenya, which evaluated outcomes of patients treated for open femur injuries, demonstrated an infection rate of 13.2% (Kalande, 2018). In a local investigation examining the outcomes of open long bone fractures managed with external fixation, findings revealed that 23% of the patients experienced infection as a complication (Nyamosi, 2019).

2.2.2 Diagnosis of infection

Research indicates that infections associated with fractures manifest across a spectrum of clinical presentations, posing challenges in distinguishing them from noninfectious causes. During the initial postoperative phase, traditional signs of infection, including pain, redness, warmth, or swelling, coincide with typical

features of normal fracture healing. Subsequently, more subtle clinical manifestations such as fracture nonunion or persistent pain may be indicative of both infective and noninfective conditions. The complexity and variety of infections in fractures presents a diagnostic challenge, impeding the formulation of standardized diagnostic criteria (Govaert et al., 2020). In the study conducted by (Govaert et al., 2018), which surveyed practitioners engaged in the management of patients afflicted with fracture-related infections, findings revealed a lack of consensus regarding the most effective diagnostic approach for identifying infection or a universally acknowledged definition of fracture-related infection.

According to Rupp et al., (2024), clinical assessment holds a significant role in diagnosing infections related to fractures. In systematic reviews of clinical indicators defining infections in fractures, specific criteria including the presence of a fistula, sinus, or wound breakdown, along with purulent drainage from the wound or the presence of pus during surgical intervention, are considered pathognomonic and confirmatory clinical signs for diagnosis (Bezstarosti et al., 2019; Metsemakers et al., 2018,. Clinical manifestations such as local erythema, edema, elevated local temperature, fever (≥38.3°C), or persistent, escalating, or new-onset wound discharge beyond the initial postoperative phase suggest the presence of infection (Govaert et al., 2020, Metsemakers et al., 2018).

Serum biomarkers associated with inflammation, such as leukocyte count, C-reactive protein (CRP), and erythrocyte sedimentation rate (ESR), have been extensively investigated for their diagnostic utility in assessing infection presence and severity. However, their diagnostic specificity is limited, given that elevations in these markers can occur not only during infection but also following trauma,

surgical procedures, malignancies, or various other inflammatory states (Rupp et al., 2024). Furthermore, these markers may remain within normal ranges even in cases of chronic or advanced-stage infections. Although CRP exhibits some promise as a diagnostic indicator, analysis of existing literature reveals only moderate reliability in terms of sensitivity and specificity (van den Kieboom et al., 2018). Consequently, these biomarkers should not be solely relied upon to definitively confirm or exclude the presence of an infection.

Imaging techniques are utilized for the comprehensive assessment of bone involvement, fracture healing progress, implant stability, and identification of anatomical anomalies suggestive of undetectable infections during physical examination, as well as for the detection of infection-related complications (Stevenson et al., 2022). Initial imaging typically involves conventional radiography, facilitating the evaluation of fracture alignment, hardware integrity, and periosteal reaction (Rupp et al., 2024). However, conventional radiography's ability to detect early infection signs is limited. Advanced imaging modalities such as computed tomography (CT), magnetic resonance imaging (MRI), and nuclear medicine techniques, including technetium-99m bone scintigraphy and fluorodeoxyglucose positron emission tomography (FDG-PET), exhibit enhanced sensitivity in identifying soft tissue inflammation, bone marrow edema, and sequestra formation indicative of infection associated with fractures (Glaudemans et al., 2019, Govaert et al., 2020, Rupp et al., 2024).

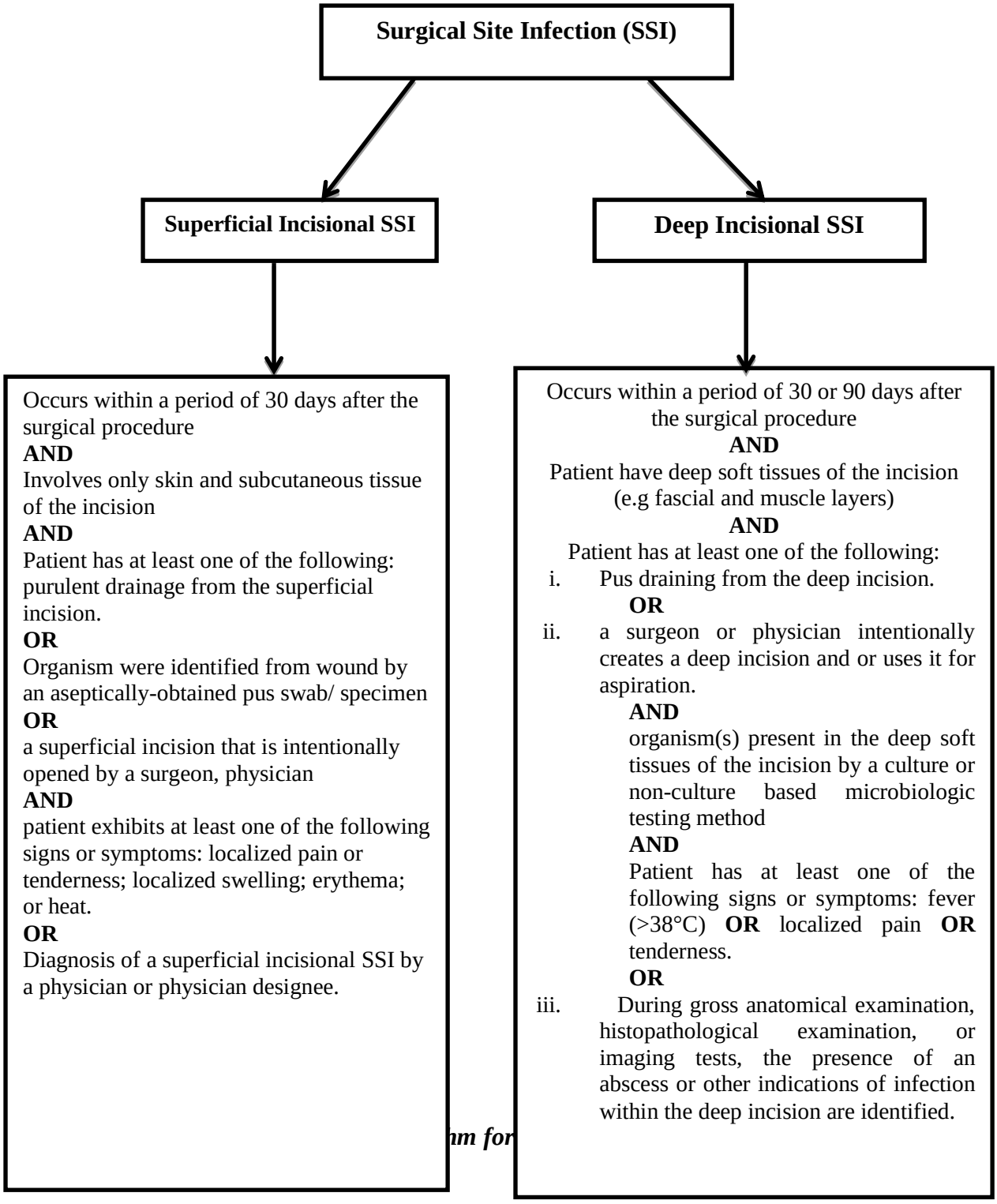
Microbiological analysis is the gold standard for the identification of pathogens and diagnosing infections linked to fractures. Employing microbiological diagnostics alongside tissue samples and sonication has improved the efficacy of pathogen detection (Rupp et al., 2024). The culture of distinct pathogens from at least 2 separate deep tissue/implant specimens is considered a confirmatory criterion of infection associated with fractures (Metsemakers et al., 2018). Furthermore, the antibiotic susceptibility of the identified pathogens will guide the choice of antimicrobial treatment (Govaert et al., 2020).

Diagnosing infections associated with fractures in resource-limited settings such as in low- and middle-income countries is a complex and multifaceted challenge, encompassing limitations in diagnostic tools, expertise, socioeconomic factors, geographical and cultural barriers (Geurts et al., 2017, Tissingh et al., 2022). In such cases several tools have been created to provide objective assessments, surveys, and diagnoses of infections. These tools are based on different combinations of infection indicators (Herman & Bordoni, 2022). The two most commonly used assessment systems are

i. Center for Disease Control and Prevention criteria
ii. ASEPSIS scoring system

In relevance to fractures, CDC classifies surgical site infections into superficial infections and deep infections. These infections are associated with a surgical procedure and manifest at or near the surgical incision or fracture site or in the deep tissues within 30 days of the procedure or within 90 days of the procedure in cases where prosthetic material is implanted during surgery (Borchardt & Tzizik, 2018). The ASEPSIS scoring system is a quantitative scoring system commonly

utilized for monitoring surgical wound infections. This scoring system assigns points based on various criteria and considers multiple parameters such as wound appearance, exudate, surrounding tissue and systemic signs. It provides a structured approach for evaluating and monitoring surgical wound infections (Copanitsanou et al., 2018). Studies comparing the two systems have established that although the ASEPSIS score is considered valid and reliable, it missed a significant number of patients whom CDC criteria diagnosed and were clinically relevant (Henriksen et al., 2010; Wilson et al., 1986). For this reason, it is concluded that CDC criteria is the best-established tool to monitor and identify wound infection following operative procedures (Henriksen et al., 2010). The CDC criteria used for surveying the development of infections in surgical wounds is summarized in the figure 3 (CDC, 2023).


Surgical Site Infection (SSI)
Superficial Incisional SSI
Deep Incisional SSI
Occurs within a period of 30 days after the surgical procedure
AND
Involves only skin and subcutaneous tissue of the incision
AND
Patient has at least one of the following: purulent drainage from the superficial incision.
OR
Organism were identified from wound by an aseptically-obtained pus swab/ specimen
OR
a superficial incision that is intentionally opened by a surgeon, physician
AND
patient exhibits at least one of the following signs or symptoms: localized pain or tenderness; localized swelling; erythema; or heat.
OR
Diagnosis of a superficial incisional SSI by a physician or physician designee.
Occurs within a period of 30 or 90 days after the surgical procedure
AND
Patient have deep soft tissues of the incision (e.g fascial and muscle layers)
AND
Patient has at least one of the following:
i. Pus draining from the deep incision.
OR
ii. a surgeon or physician intentionally creates a deep incision and or uses it for aspiration.
AND
organism(s) present in the deep soft tissues of the incision by a culture or non-culture based microbiologic testing method
AND
Patient has at least one of the following signs or symptoms: fever (>38°C) OR localized pain OR tenderness.
OR
iii. During gross anatomical examination, histopathological examination, or imaging tests, the presence of an abscess or other indications of infection within the deep incision are identified.

nm for

2.3 Factors associated with the occurrence of infection in open long bone fracture

The occurrence of infection related to open fractures is influenced by factors such as patient-related factors, fracture related factors and health care factors including the time duration of initiating prophylactic antibiotics following injury, the timing of debridement and irrigation procedures as well as the severity of the fracture and soft tissue injury. These factors collectively contribute to the overall risk level for infection development in open fractures (Coombs et al., 2022).

2.3.1 Patient-Specific Factors

Patients' ability to resist infection differs depending on their immune status. Some factors can impair the patients' immune response to pathogens, thereby increasing their risk of infection (Kortram et al., 2017). In a retrospective multicenter study analyzing infection rates following postoperative treatment of open fractures at three level I hospitals, researchers discovered that individuals over the age of 40 were more prone to developing infections, and this age group was identified as an independent risk factor for infection (Hu et al., 2020). Kang et al., (2023) conducted a comprehensive national cohort study in South Korea focusing on ankle fractures, wherein they observed a correlation between age and infection rates among the study population. The findings revealed a significant increase in infection incidence with advancing age. The infection group had a higher mean age of 49.7 years (± 19.99) compared to the non-infection cohort, which displayed a relatively lower mean age of 47.2 years (± 18.61). The retrospective study conducted by Matos et al., (2015), based on patient records of individuals with open fractures, did not identify a statistically significant association between age and the incidence of infection following such fractures. The mean age of patients

who developed infections was reported as 31.5 ±13.5 years, a figure comparable to the mean age of the non-infection group, which was 31.7 ±14.3 years.

In a study conducted by Kang et al. in 2023, it was observed that males exhibited a significantly higher odds ratio for developing infections following open ankle fractures when compared to females. Similarly, in a systematic review and meta-analysis encompassing data from 20,367 fractures, it was observed that male gender emerged as a statistically significant risk factor associated with the occurrence of infectious complications. Male patients displayed a higher susceptibility to infections, with a comparative risk of 16.1% compared to 11.6% in female with a relative risk (RR) of 1.42, supported by a statistically significant p-value of 0.004 (Kortram et al., 2017). The study conducted by Matos et al., (2015) did not reveal a statistically significant association between gender and the occurrence of infection following open fractures. However, there was a substantial prevalence of male patients, accounting for 83.6% of the total cases, compared to females.

Several studies have shown linkage between comorbidities and susceptibility to developing infection in fractures. Patients suffering from endocrinological and cardiovascular disorder, has shown high susceptibility to fracture-related infections. A German study has shown that persons with heart failure or arterial hypertension have an increased relative risk of suffering an infection following a fracture compared to the general population (Szymski et al., 2022). Diabetes mellitus exerts a negative influence on the process of wound healing, rendering individuals afflicted with this metabolic disorder particularly susceptible to complications following surgical procedures. Emerging evidence has shown that

diabetes mellitus significantly increases the risk of postoperative infections among surgical patient cohorts (Hu et al., 2020). Hu et al., (2020) identified a range of comorbidities associated with the occurrence of infections following operative interventions for open fractures in patients. These comorbid conditions encompassed a diverse spectrum of medical disorders, including diabetes mellitus, hypertension, cardiovascular or cerebrovascular diseases, rheumatoid diseases, liver and kidney diseases, chronic respiratory diseases, anemia, benign or malignant tumors, and immune system disorders.

According to Kang et al., (2023), as the number of comorbidities increased, the risk of infection also significantly increased. The influence of comorbidities on infection development following fractures was further described by Saiz et al., 2022. This study asserted that individuals with open tibial shaft fractures, with conditions such as congestive heart failure, bleeding disorders, or obesity, have a high risk of developing acute inpatient infections during their initial hospital stay, ranging from three to 4.5 times higher compared to patients without these comorbidities. Moreover, patients presenting with diabetes, psychiatric disorders, hypertension, or chronic obstructive pulmonary disease exhibit a 1.5 to 2-fold increased likelihood of developing subsequent infections in comparison to those without these underlying medical conditions.

The research conducted by Nåsell et al., (2011) has demonstrated that individuals who smoke tend to experience a higher prevalence of postoperative complications, including wound infections, following surgical intervention. A recent statistical analysis by Sun et al., (2024) also noted history of smoking as a modifiable risk factor which heightened risk for postoperative wound infections. Smoking showed

a statistically significant difference between the infected and uninfected groups among patients undergoing open reduction and internal fixation for tibial plateau fractures. Among individuals who developed postoperative wound infections, 72.73% had a history of smoking, whereas only 38.24% of those without infections reported a similar smoking history. This observed disparity yielded a statistically significant difference ($p = 0.014$). According to findings from meta-analyses, smoking emerges as a significant risk factor for the development of postoperative infections following elective orthopedic and trauma surgeries. In comparison to non-smokers, smokers exhibit a substantially elevated relative risk of 2.20 for developing such infections (Smolle et al., 2021). Moreover, in fracture surgery, smokers face a 2.1 times higher risk of postoperative infections compared to non-smokers (Smolle et al., 2021). Consistently, another meta-analysis aimed at identifying risk factors for infection post open fracture fixation confirmed that smokers are at a significantly heightened risk, with a postoperative infection rate of 17.7% among smokers compared to 13.8% among non-smokers, corresponding to a relative risk of 1.29 (Kortram et al., 2017). However, conflicting evidence exists regarding the association between smoking and postoperative infection risk. Some prior studies, such as those by Tornetta et al., (2020) and Olesen et al., (2017) failed to demonstrate a significant correlation between smoking status and the occurrence of postoperative infections.

2.3.2 Fracture Related Factors

Zalavras, (2017) reported that the severity and extent of contamination of the injury influences the incidence of infection following open fractures. Furthermore, the rates of infection varied depending on the Gustilo-Anderson type. The infection rates in type I fractures was from 0% to 2%. Type II fractures had a higher

infection rate, up to 10%. The most severe category, type III fractures, carried a significantly higher risk, with infection rates reaching as high as 50%.

Gustilo and Anderson, (1976) conducted a seminal study where they demonstrated that type III open fractures had a greater risk of infection than lower-grade fractures. Specifically, type IIIB fractures were associated with high infection rate of 52% and type IIIC fractures with 42%. In contrast, type IIIA fractures had a lower infection rate of 4%. Infection rates were observed to decrease further in type I fractures with 2% and type II fractures, which had a rate of 2.4%. These findings shows that the more severe the fracture, the higher the likelihood of infection. A large retrospective study that evaluated Gastilo Anderson classification as a predictor for infection had comparable results. The risk of infections in type IIIC, IIIB and IIIA were 62%, 30% and 14 % respectively. The risk also significantly decreased in type II and type I to 8% and 2% respectively (Thakore et al., 2017). In a multicenter retrospective analysis focusing on patients diagnosed with infection subsequent to operative management of open fractures, the incidence of infection also increased significantly with the severity of open fractures, with type III fractures having the highest incidence rate. Among the cohort studied, infection manifested in 45 cases (6.6%) out of 678 cases classified as type I open fractures, 164 cases (13.1%) out of 1254 classified as type II, and 292 cases (38.4%) out of 760 categorized as type III open fracture wounds (Hu et al., 2020).

The Tscherne classification is another system which assesses the extent of damage of soft tissues in open fractures based on the fracture pattern and energy. According to Matos et al., (2015) Tscherne type II and type III fractures are associated with a greater risk of developing infection, with infection rates of 25.8% and 48.4% respectively. Furthermore, studies have indicated that grossly contaminated

wounds can considerably raise the risk of developing wound infection (Coombs et al., 2022).

Performing early surgical debridement reduces the risk of wound infection by decreasing the bacterial load in the open wound (Coombs et al., 2022). Historically, it was recommended that surgical debridement be done within six hours following the injury to reduce the risk of infection significantly. Nonetheless, current studies have yielded conflicting findings, and the optimal timing for surgical debridement remains uncertain (Foote et al., 2021; Srour et al., 2015). In the investigation conducted by Matos et al., (2015), an association was observed between the occurrence of infection and the duration of exposure of the open fracture prior to surgical intervention. The findings revealed a significant correlation between infection incidence and exposure time, particularly within the first 24 hours post-trauma. The patients who developed infections had a mean exposure time of 30.3 ±19.5 hours, whereas those who remained infection-free had a shorter mean exposure time of 21.4 ±12.1 hours. In a retrospective cohort investigation, Malhotra and colleagues, (2014) conducted a multivariate analysis to assess the incidence of deep infections in open extremity fractures relative to the timing of the first incisional and debridement (I&D). This study involved the examination of 415 cases of open extremity fractures. The findings from this analysis revealed a significant association between the timing of the initial I&D procedure and infection rates, particularly in fractures involving the lower extremities. A delay exceeding 8 hours to the first I&D procedure for open fractures of the lower extremity was correlated with an increased risk of infection. However, no such association was observed for fractures of the upper extremity.

Khatod et al., (2003) found in their study that there was no statistically significant difference in the time elapsed from injury to the initial incision and debridement procedure between fractures that subsequently developed infected and those that did not, across various fracture types. Upon further analysis, they also determined that there was no difference in the overall infectious outcome when comparing cases where the initial irrigation and debridement were performed within 6 hours of the injury to those where it was conducted after 6 hours from the time of injury. A retrospective study conducted by Li et al., (2020) examined the correlation between the length of time from injury to the first debridement of open tibial fractures and perioperative infection rates. Their analysis led to the conclusion that the occurrence of perioperative infection in patients with open tibial fractures was not significantly associated with the timing of the initial debridement. The study reported infection rates among different groups based on the time interval between injury and the first debridement. The infection rates were 9.2% for individuals debrided in less than six hours, 9.5% for those debrided between six and 12 hours, 11.1% for the 12 to 24-hour group, and 10.5% for patients undergoing debridement after 24 hours from injury. While there was an observed trend of increasing infection rates with longer delays in initiating debridement, this trend was not statistically significant across the four groups. Tornetta et al., (2020) and Singh et al., (2012) conducted studies in which participants were categorized into four groups based on the timing of debridement following injury: less than 6 hours, 6-12 hours, 12-24 hours, and more than 24 hours. However, neither study found any significant association between the timing of debridement and the occurrence of infection.

In the study conducted by Matos et al., (2015), internal fixation was selected as the treatment modality for 20.5% of the fractures, while casting or external fixation was utilized in 79.5% of cases. Despite the variation in treatment approaches, the study found no significant association between infection occurrence and the chosen treatment method. Similarly, a systematic review and meta-analysis conducted by Kortram et al., (2017) evaluating the efficacy of internal fixation versus external fixation in the management of open fractures revealed that there was no significant difference in the incidence of infection between the two treatment modalities. The analysis reported infection rates of 20.7% for cases treated with internal fixation and 23.6% for those managed with external fixation. However, in the study by Khatod et al., (2003), which focused on assessing the infectious outcomes associated with open tibia fractures, various methods of bony stabilization were employed. Among the patients who ultimately developed infections, the distribution of treatment modalities was as follows: 4% underwent casting, 64% were managed with external fixation, 16% underwent open reduction with plate-and-screw fixation, and an additional 16% received intramedullary fixation. Saiz et al., (2022), also argues that patients with open long bone fractures, such as tibial shaft fractures that had infection were nearly three times more likely to have had external fixation.

2.3.3 Health Care Related Factor

Research has established a correlation between the antibiotic delay and a higher likelihood of infection. Prompt administration of systemic antibiotics in open injuries has been proven to significantly decrease the likelihood of infection (Atwan et al., 2020). If administered early, antibiotics will aid the immune system and inhibit excessive bacterial replication, which will lead to infection prevention

(Coombs et al., 2022). Historically, it was advised to initiate antibiotic prophylaxis promptly following the injury. There is currently no established or universally agreed-upon optimal timeframe for administration of antibiotics after an injury to reduce infection risk. However, a recent study by Suzuki et al., (2023), emphases that antibiotics should be administered within three hours after the injury. This time frame was considered crucial due to the potential impact of altered circulation and bacterial proliferation on the development of infections (Patzakis & Wilkins, 1989). According to Hoff et al., (2011), antibiotic administration should be done as "soon as possible" after the injury. While other studies continue to support the evidence of starting antibiotics as soon as possible, some studies urges that infection rates following open fracture injuries is not associated with timing of initial antibiotics administration (Mundi et al., 2015; Weber et al., 2014). A study validating the impact of timing in administering antibiotics to predict infection in open fractures illustrated that delaying antibiotic administration by more than two hours after the injury is linked to a higher risk of wound infection (Roddy et al., 2020). In addition, Lack et al., (2015) demonstrated that delayed administration of antibiotics was linked to a higher incidence of infection. Infection rate increased from 6.8% for those who received antibiotics within an hour to 27.9% in patients who were administered after more than ninety minutes (Lack et al., 2015). In a study by Penn-Barwell et al., (2012), delaying the administration of antibiotics to either six or 24 hours following injury had a significantly adverse impact on the infection rate, irrespective of the timing of subsequent surgery. Similarly, in a prospective cohort study involving 133 patients, Al-Arabi et al., (2007) classified participants into categories based on the timing of antibiotic administration: less than 2, 4, 6, 8, 12, and more than 12 hours from injury. Their findings revealed that

the timing of antibiotic administration within the first 24 hours had no significant effect on the rate of infection.

Several studies have investigated the impact of primary versus delayed wound closure on infection rates in open fractures bones (Hull et al., 2014; Rupp et al., 2024; Scharfenberger et al., 2017; Tornetta et al., 2020). In a systematic review and meta-analysis by Kortram et al., (2017), the comparison between immediate and delayed wound closure in the management of open fractures did not reveal any significant differences in the development of infectious complications. However, contrasting findings were reported in a study by Davis et al., (2015), where patients who underwent single-stage definitive fixation and wound coverage were compared to those who had definitive fixation and wound coverage at separate operations. In this study, a notable difference was observed in favor of the single-stage approach, with results indicating that 4.2% of patients in the single-stage group developed infectious complications, compared to 34.6% in the group undergoing separate operations for fixation and wound coverage. While findings vary, there is historical evidence to suggest that delayed closure may be associated with lower infection rates compared to primary closure (Russell et al., 1990). Delayed closure allows for more comprehensive debridement, which reduces the bacterial burden and creates an environment conducive to wound healing (Gustilo & Anderson, 1976). Conversely, immediate closure without adequate debridement may trap bacteria within the wound, increasing the likelihood of infection.

The duration of surgery and the experience level of the surgeon may influence the incidence of postoperative infections. Several studies have shown that longer surgical durations and inexperienced surgeons are associated with higher rates of

infections in various orthopedic procedures, including open reduction and internal fixation of long bone fractures. In a study conducted by Hu et al., (2020), it was revealed that surgical procedures lasting longer than 122 minutes were associated with a higher risk of infection following operative management of open fractures, with a corresponding increase of 2.52-fold in infection risk compared to procedures of shorter duration. Moreover, Colman et al., (2013) demonstrated that for each additional hour of surgical duration beyond a certain threshold, the risk of infection surged by approximately 78%. Hu et al., (2020) also assets that surgical expertise in conjunction with a synergistically cooperative surgical team has an influence in abbreviating operative durations and consequently mitigating the occurrence of infections. In a multivariable analysis conducted by Ovaska et al., (2013), it was determined that a surgical duration exceeding ninety minutes was independently associated with an increased risk of infection. Similarly, Sun et al., (2024) conducted a study where the duration of surgery exceeding 150 minutes emerged as a notable factor associated with infection risk. Within their study cohort, the incidence of infection was 54.6% in the infected group versus 17.7% in the uninfected group among patients undergoing surgeries lasting over 150 minutes compared to those with shorter operative durations.

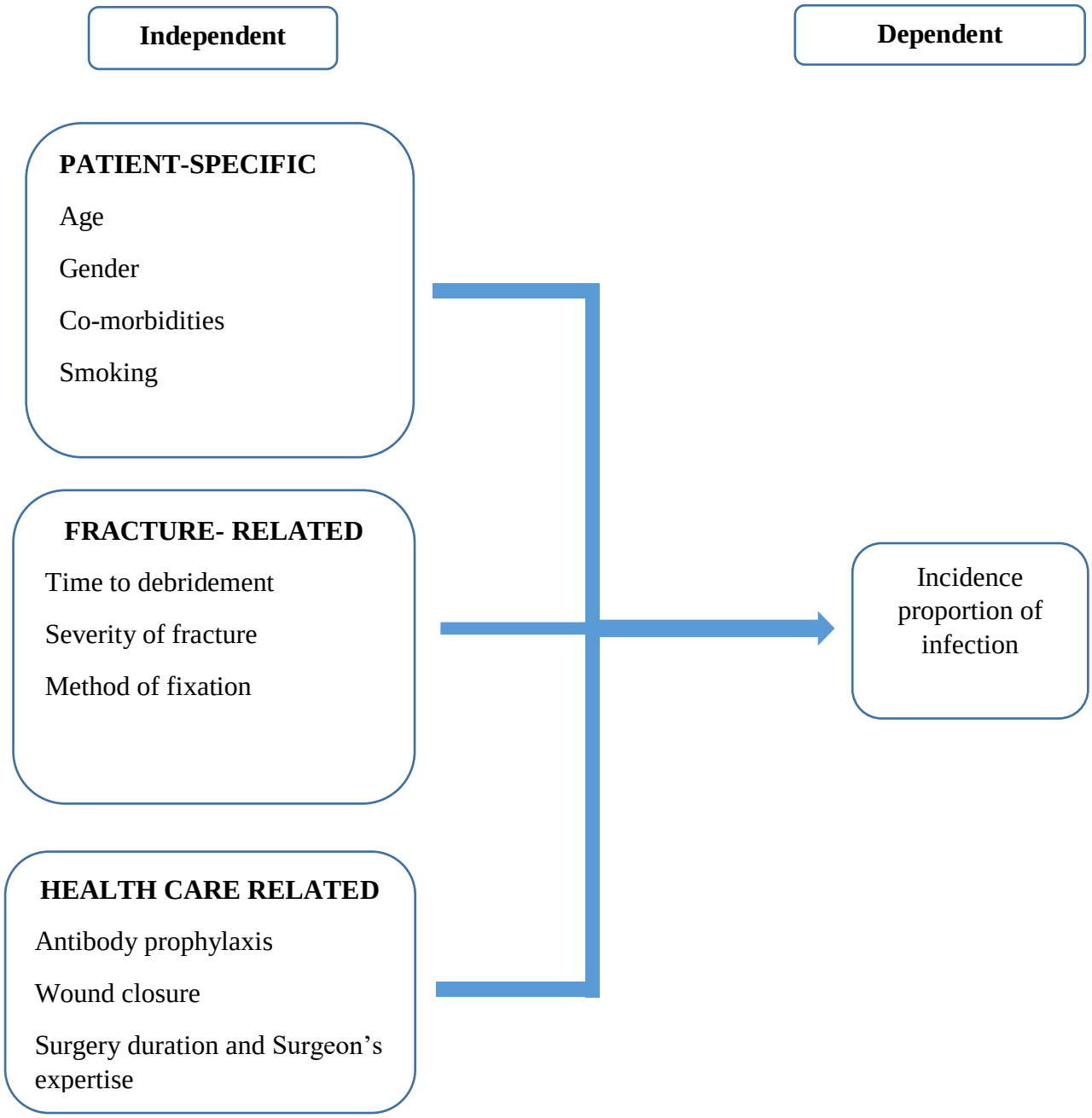


Figure 4: Conceptual framework – factors associated with incidence of infection

2.4 Patterns of prophylactic antibiotic use in patients with open long bone fractures

2.4.1 Prophylactic use of antibiotics

Prophylactic antibiotic therapy is considered a standard practice in management of open fractures, aimed at reducing the risk of fracture related infection. The significance of early initiation of antibiotic prophylaxis was highlighted in a study by Melvin et al., (2010). Evidence supports intravenous antibiotic therapy as the most significant predictor of developing infection among patients with open fractures (Anderson et al., 2011; Griffin et al., 2012). A systematic review study confirmed that antibiotics significantly decreases the occurrence of wound infections compared to no antibiotic treatment. Moreover, the choice of antibiotics is influenced by factors such as the Gustilo-Anderson classification of the fracture and the specific microorganisms known to colonize wound sites. These factors play a role in determining the most suitable class and duration of antibiotics for effective infection management (Chang et al., 2019). In research conducted in Uganda, East Africa, to investigate the utilization of antibiotics in open fractures, particularly in terms of timing and antibiotics selection, the findings showed that 6% of patients did not receive any antibiotics. Among the participants, 54% were initiated on antibiotics in the accident and emergency department, 24% in the operating room, and 16% during the postoperative phase (Kigera & Shamim, 2012).

2.4.2 Type and duration of antibiotic use

Earlier studies, such as the work by Wilkins and Patzakis, (1991), have advocated for the use of broad-spectrum prophylactic antibiotic therapy that is effective against both gram-positive and gram-negative organisms. Research studies have consistently recommended using intravenous antibiotics, specifically first- or second-generation cephalosporins like cefazolin, as the preferred choice for antimicrobial prophylaxis in open fractures. However, in cases where patients have a beta-lactam allergy, clindamycin is considered the most suitable alternative. In Gustilo-Anderson type III, studies recommend additional antibiotics against gram negative bacteria. This is often achieved by adding gentamicin to the antibiotic regimen (Carver et al., 2017). However, even after the initiation of antibiotics for open fractures, there remains debate regarding the optimal duration of treatment (Atwan et al., 2020; Isaac et al., 2016). Following the closure of Gustilo-Anderson type I and II injuries, it is recommended to continue antibiotic coverage targeting gram-positive bacteria for twenty-four hours. This is typically achieved by administering a first-generation cephalosporin. Antibiotic treatment can minimise the risk of infection from gram-positive bacteria during the crucial post-closure period (Mundi et al., 2015). In the case of Gustilo-Anderson type III injuries, in addition to providing gram-positive coverage, Mundi and colleagues (2015) advised to administer an aminoglycoside antibiotic for seventy-two hours following the injury. However, it is essential to discontinue the use of aminoglycosides beyond twenty-four hours after the closure of the wound. This approach ensures proper antibiotic management, considering the fracture's severity and aiming to prevent infection effectively. According to the current AO guidelines, for Gustilo-Anderson type I and type II, a first- or second-generation

cephalosporin should be administered for twenty-four hours. In the case of Gustilo-Anderson type III, the guidelines suggest administering a third-generation cephalosporin such as ceftazidime in combination with gentamicin for seventy-two hours or until closure of soft-tissue, whichever comes first (Buckley et al., 2017). Previous research and literature indicated that an appropriate duration for administering antibiotics in cases of open fractures ranged from three to five days. For Gastilo-Anderson type I and II open fracture wounds, it's recommended to administer antimicrobial therapy for three days, while for Gastilo-Anderson type III open fracture wounds, a treatment duration of five days is recommended (Wilkins & Patzakis, 1991). However, findings from a meta-analysis study by Messner et al., (2017), which pooled data from both comparative and observational studies focusing on the duration of antibiotic administration in open long bone fractures, did not support that prolonged antibiotic regimen lasting more than 72 hours offered any protective effect against septic complications of open fractures.

The analysis revealed that in Gustilo-Anderson type I and II open fractures, the infection rate did not significantly differ when antibiotic treatment exceeded 72 hours (6%) compared to shorter antibiotic duration (4%). Similarly, for Gustilo-Anderson type III open fractures, there was no significant difference in infection rates (21.3% for prolonged treatment versus 17.7% for shorter treatment). In a randomized, double-blind, prospective study by Dellinger et al., (1988), which assessed the duration of antibiotics in the setting of open long bone fractures, 264 cases were randomized to receive either 24 hours or five days of antibiotics post-operatively. The study concluded that a short course of antibiotics was as effective as a longer course in terms of the incidence of infection. Furthermore, Anderson et al., (2011) recommends specific antibiotic protocols for different grades of open

fractures. For grade I and II open fractures, they suggest administering a first-generation cephalosporin (such as cefazolin) within 3 hours of injury and continuing it for 24 hours. Grade III open fractures necessitate coverage with an aminoglycoside alongside a first-generation cephalosporin within 3 hours of injury. Antibiotics should be sustained for 48–72 but not beyond 24 hours after wound closure. Additionally, if a fracture carries a risk of contamination with Clostridium species, like in farm-related injuries, penicillin should be included in the antibiotic regimen. In a prospective investigation involving 227 patients with open fractures, Vasenius et al., (1998) conducted a comparative analysis between clindamycin and cloxacillin. The study revealed clindamycin's effectiveness in managing type I and type II fractures, with infection rates of 3.3% and 1.8%, respectively. However, concerning grade III fractures, both clindamycin (29.0%) and cloxacillin (51.8%) exhibited very high infection rates. This study highlights the effectiveness of gram-positive coverage for type I and II fractures while emphasizing the importance of additional gram-negative coverage in more severe Gustilo type fractures. The British Orthopaedic Association (BOA) also provides guidelines and recommendations for the appropriate use of antibiotics in open fracture management, aiming to prevent infection and optimize patient outcomes. The current guidelines outlined by Nanchahal et al., (2009) are as follows:

- Administration of Co-amoxiclav at a dose of 1.2 g every eight hours or a cephalosporin like cefuroxime at a dose of 1.5 g every eight hours intravenously as soon as possible after the injury. This antibiotic should be continued until the surgical debridement procedure.
- During debridement, Co-amoxiclav/cephalosporin in combination with gentamicin at a dose of 1.5 mg/kg. The Co-amoxiclav/cephalosporin should

be continued until definitive closure of the soft tissues or for a maximum duration of seventy-two hours, whichever comes first.

- During the operative procedure, gentamicin at a dose of 1.4 mg/kg and vancomycin at 1 g or teicoplanin at 800 mg is administered.

In East Africa, specifically Uganda, the most frequently administered initial antibiotic for open fracture injuries was ceftriaxone, followed by ampiclox, cloxacillin, and ciprofloxacin. The duration of antibiotic treatment varied between one day and thirteen days. In this study the average duration of the antibiotic course was 7.3 days (Kigera & Shamim, 2012). In a local study conducted at Kenyatta National Hospital, most cases received intravenous cefuroxime or ceftriaxone and, in some cases, combined with metronidazole as prophylactic antibiotics. The duration of prophylactic antibiotic treatment was four to five days in 54% of the cases and two to three days in 39% of the cases, as reported by Macharia, 2020.

Current Guideline at MTRH

A recent standard operating procedure (SOP) concerning adult antibiotic prophylaxis in open fractures at MTRH recommends the prompt administration of intravenous antibiotics within the first hour post-injury, accompanied by appropriate surgical debridement and fracture stabilization (Kisorio, 2023). In cases where the time of injury cannot be determined, antibiotics should be given within one hour of arrival to the emergency department. For Gustilo-Anderson type I and type II fractures, first generation cephalosporin (such as Cefazolin) should be administered for 24 hours and 24-48 hours respectively, following wound closure. In all type III Gustilo-Anderson open fractures, a first-generation cephalosporin for gram positive coverage and an aminoglycoside (such as gentamycin) for gram

negative coverage should be administered for 48-72 hours post-wound closure. Specific considerations include penicillin for farm injuries, flouroquinolones for fresh or salt water wounds and doxycycline or third or fourth-generations (e.g., Ceftazidine) for salt water wounds.

CHAPTER THREE: METHODOLOGY

3.1 Study Setting

The study was conducted in the Orthopaedic wards and Orthopaedic Clinics of Moi Teaching and Referral Hospital (MTRH). The hospital is located along Nandi Road in Eldoret, in Uasin Gishu County, found in Western Kenya's North Rift region. The hospital is a major referral centre with a wide catchment area, catering to over 25 million people. This setting provides an excellent opportunity to study open fractures of long bones among adult patients, considering the hospital's expertise, resources, and the diverse population it serves.

3.2 Study Design

The study was a prospective descriptive study. Participants were followed up at MTRH orthopaedic clinics at two weeks, six weeks and three months from the date of surgery for surveillance of development of infection.

3.3 Target Population

Patients with open fractures of long bone treated at MTRH were targeted for enrolment in the study. For this study, long bones included the humerus, radius and ulna, femur and tibia and fibula.

3.4 Study Population

The study enrolled all adult patients (18 years and above) with open fractures of long bones treated from 1 January 2024 until 30 September 2024 who were admitted in the orthopaedics wards of MTRH following debridement.

3.5 Eligibility Criteria

3.5.1 Inclusion Criteria

- All adult patients (18 years and above) with open fractures of long bones treated at MTRH.
- Patients with confirmed open fractures of long bones, diagnosed based on clinical and radiographic evaluation.
- At least three months of follow-up.

3.5.2 Exclusion Criteria

- Patients who had surgical debridement done in other institutions.
- Long bone fractures other than femur, tibia, fibula, humerus, radius, and ulna.
- Patients with pre-existing wound or infection on the affected limb.
- Patients whose limbs were amputed following open fracture of long bone.
- Patients who were transferred to another facility.

3.6 Sample Size Determination

The primary objective of this study was to identify factors associated with the incidence of infection among adult patients with open long bone fractures at MTRH. Assuming an incidence proportion of 50% and a minimum of 10 factors, the minimum representative sample size for the study was estimated using a formula by Peduzzi et al., (1996) as follows:

$$n = \frac{10K}{p}$$

Where

n = minimum sample size

K = 10 -number of factors under consideration

p = 50% - estimated proportion of interest

Substituting for the above values the minimum sample size required was 200 participants.

$$n = \frac{10 \times 10}{0.5} = 200$$

To account for potential loss to follow-up, the sample was adjusted using the standard formula (Hulley et al., 2013; Kirkwood & Sterne, 2003):

$$n_{adjusted} = \frac{n}{1 - L}$$

Assuming an anticipated loss to follow-up of 10% (L= 0.10):

$$n_{adjusted} = \frac{200}{1 - 0.10} = \frac{200}{0.90} = 223$$

Thus, the final sample size required for the study was 223 participants, ensuring sufficient statistical power despite potential dropouts.

3.7 Sampling Method

A consecutive sampling method was employed. All eligible individuals who provided informed consent during the sampling period (1st January 2024 – 30th September 2024) were enrolled in the study.

3.8 Study Procedure

The initial encounter with the prospective study participants was after patient stabilization and surgical debridement. Eligible patients were identified from the Orthopaedic department admission registers. After identification, the purpose and procedure, potential risks and benefits of the study were explained to the participants, and informed consent obtained.

Information on different variables were gathered from patients who had consented to be part of the study by interviewing them face-to-face using a questionnaire developed based on a comprehensive literature review and consultation with experts in the field. Additional information was also collected from the patient's medical records to assess the participants' conditions comprehensively. To monitor the development of surgical wound infection, participants were followed up at two weeks, six weeks and three months from the surgery date. The monitoring was done using the validated CDC criteria data collection tool adopted from *"WHO Protocol for Surgical Site Infection Surveillance with a Focus on Settings with Limited Resources"*(WHO, 2018).

3.9 Data Collection Method

The principal researcher was responsible for the data collection process. Data collection was commenced once informed consent had been obtained from the participants. To ensure the security and confidentiality of the collected data, all data collection tools, including questionnaires, were stored in lockable filing cabinets accessible solely to the principal researcher. This prevented unauthorized access to the data and maintain its integrity. After data collection, the questionnaire information was transferred to an electronic database. To further safeguard the confidentiality of the data, the database was encrypted with a password known only to the principal researcher. This encryption protected against unauthorized access and ensure the confidentiality of the participants' information.

3.10 Study Variables

Information on independent variables and dependent variables was collected.

3.10.1 Independent variables

- Socio-demographic characteristics: Patients' demographic profiles, including age, gender, education level (none, primary, secondary and tertiary), occupation, and smoking status were collected.
- Co-morbidities: Pre-existing medical conditions the patients had, such as diabetes mellitus, hypertension, cardiovascular or cerebrovascular disease, rheumatoid disease, kidney and liver disease, chronic respiratory diseases, anaemia or cancers were recorded.
- Mechanism of injury: The circumstances or events that led to the injury included road traffic accident, gunshot, assault, fall, work-related injury, sports.
- Nature of injury: Bones involved were classified as humeral, radio/ulnar, femoral, or tibia/fibular, in location. Upper extremity fractures (humeral and radio/ulnar) were collapsed into a single category for analysis. Similarly lower extremity fractures were also grouped. Additional information about the fracture such as laterality to indicate the side of the body affected, i.e. whether the left side or right side.
- Pattern of fracture: The specific classification or pattern of the fracture, such as spiral, oblique, transverse, comminuted, etc were recorded.
- Gustilo-Anderson classification: To categorize and measure the injury's severity, the open fractures were graded by the operating surgeon according to the Gustilo-Anderson classification, which was determined at the time of

the initial debridement in the operating room. The fractures were categorized as Gustilo-Anderson type I, II, IIIA, IIIB, and IIIC for analysis.

- Timing of debridement: Time from injury to surgical debridement was determined by historical data. It was defined as the time between the injury and the commencement of surgical debridement. For analysis purpose patients were divided into five categories based on time from injury to surgical debridement: less than six hours, between six hours and twelve hours, between twelve hours and twenty-four hours, between twenty-four and forty-eight hours and more than forty-eight hours.
- Time from injury to initiation of antibiotics: The timing of prophylactic antibiotic administration following injury was recorded. Patients were divided into five categories based on time from injury to initiation of prophylactic antibiotics: less than three hours, between three hours and six hours, between six hours and twelve hours, between twelve hours and twenty-four and more than twenty-four hours.
- Duration of prophylactic antibiotics: The duration of prophylactic antibiotics in open fractures was defined as a period for which antibiotics are administered after the injury to reduce the risk of infection. It was calculated from the time the first dose of antibiotics is administered after the injury to the time of stopping antibiotics without patient having developed signs or symptoms of infection or if the patient develops an infection during antibiotic course, the duration ends when the infection is diagnosed and specific therapeutic antibiotics are initiated to treat the infection.

- Type of antibiotics used: The choice of prophylactic antibiotic regimen used were recorded.
- Method of fracture stabilisation: The technique or approach for fracture immobilization were considered as follows: back-slab or cast, external fixation, or internal fixation with Intermedullary (IM) nailing, Plate and screws, etc.
- Surgeons' expertise: Surgeons' experience was categorised as either consultant or resident (operating without supervision of a consultant)
- Duration of surgery: Duration of initial surgical debridement procedure.
- Wound closure after debridement: Primary closure at the time of debridement or wound left open.

3.10.2 Dependent variable

- Infection: The criteria to define infection in patients followed the rules of the Center for Diseases Control and Prevention which requires either clinical signs (purulent drainage from the incision, local pain, tenderness, swelling, erythema or heat) along with surgeon’s confirmation of the diagnosis or identification of microorganisms in aseptically collected specimens for the purpose of diagnosis or treatment. Pin site infections in patients who had undergone external fixation were excluded as these are a recognized complication of external fixator devices.

3.11 Data Analysis

The data was inputted into Microsoft Excel, where it was revised, cleaned, coded, and subsequently analyzed utilizing IBM SPSS Statistics 26 (Statistical Package for the Social Sciences Software, Chicago, Illinois, USA). Analysis of data summarised the study participants’ sociodemographic and clinical characteristics.

Categorical variables such as gender, co-morbidities, smoking fracture severity, time to debridement, time to antibiotics initiation, wound closure and fracture immobilization methods were presented as frequencies and their respective percentages while variables that are numerical like age and duration of surgery were summarized using either means and their corresponding standard deviation or ranges.

Further analysis was done per each objective as summarized in the table below.

Table 2: Summary if data analysis procedure

Objective	**Outcome**	**Independent**	**Statistical Test**
One: To describe characteristics of adult patients with open long bone fractures treated at MTRH	Categorical variables e.g. gender, co-morbidity Numerical variables e.g. age, time	-	Frequency & proportion Mean & Standard Deviation/ Range
Two: To describe the incidence of infection among adult patients with open long bone fractures at MTRH	Infection: (Yes/No) – binary categorical variable	-	Frequency & proportion
Three: To identify factors associated with the occurrence of infection among adult patients with open long bone fractures at MTRH	Infection: (Yes/No) – binary categorical variable	Categorical variables e.g. gender, co-morbidity Numerical variables e.g. age, time	Chi Square/ Fisher's exact tests *t*-test/ Mann Whiney U test Binary logistic regression
Four: To describe the pattern of prophylactic antibiotic use among adult patients with open long bone fractures at MTRH	Antibiotic used Categorical variables		Frequency & proportion

The study findings were presented using figures, tables, and graphs. All the test results were deemed statistically significant if p- value was less than 0.05.

3.12 Ethical Consideration

IREC approval and approval from MTRH management as well a research license issued by the National Commission for Science, Technology and Innovation (NACOSTI) were sought before the commencement of data collection. All eligible patients were asked to provide informed consent before participating in the study. This was done after explaining the nature of the study including its purpose, potential risks and benefits in a language they fully understand. The participating patients also receive information about their right to withdraw or drop out from the research at any time they wanted to do so without any consequences.

Patient privacy and confidentiality was maintained throughout the study and when depositing the completed thesis in an institutional repository or publishing the report in a peer-reviewed academic journal, as per ethical guidelines,

3.13 Study limitations

The prospective nature of this study presented certain limitations such as loss to follow-up. To mitigate this issue, patient's contact information was recorded and participants were telephonically reminded of their scheduled follow-up visits. Home visits were also done for those patients who could not attend clinic follow-up, solely for completion of data.

CHAPTER FOUR: RESULTS

4.0 Introduction

This chapter presents the key findings derived from the research investigation, aiming to provide a comprehensive overview of the data analysis and outcomes addressing the study's objectives.

A total of 247 participants with 258 open long bone fractures satisfied the inclusion criteria and were recruited into the study. The participants were admitted to the MTRH Orthopaedics wards from 1st January 2024 to 30 September 2024. Sixteen (16) participants were lost to follow up and one participant died during the study period; Therefore, 230 participants with 241 open fractures completed the study and had their data analysed.

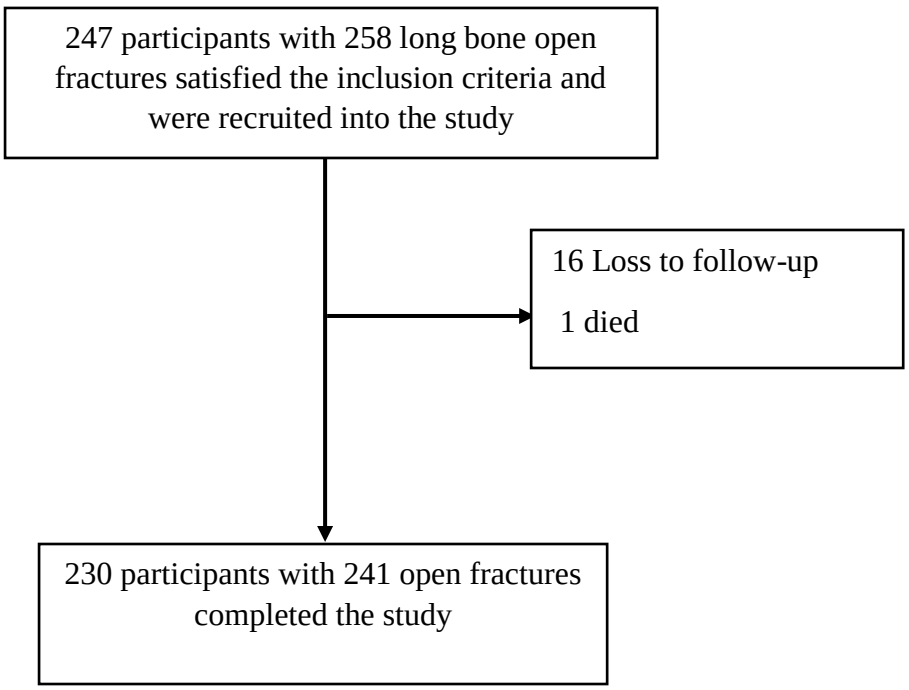


Figure 5: Recruitment algorithm

4.1 Characteristics of patients with open long bone fractures

4.1.1 Socio-demographic characteristics

The sociodemographic characteristics of the 230 participants are summarized in Table 3. The ages of the participants ranged from 18 to 91 years with a mean age of 36.9 ± 14.9 years. Analysis showed that 74.3% of open long bone fractures occurred in males with mean age of 35.5 ± 13.2 years and 25.7% occurred in females with a mean age of 41.1 ± 18.7 years. The male to female ratio of the participants was 3: 1. The majority of the participants 105 (45.6%) had informal occupation (motorist, farmers, traders, construction workers, casual labourers, domestic workers), 37 (16.1%) had a formal occupation (health carer workers, teachers, technicians, administration officers, security officers and engineers), 52 (22.6%) were unemployed, 16 (7.0%) were students and 20 (8.7%) were pensioners. Forty-two (18.3%) of the participants had primary, 97 (42.2%) had secondary education while 57 (24.8%) had completed tertiary education. Only 34 (14.7%) had no formal education.

Table 3: Socio-demographic characteristics

Variable	n =230 Frequency	Percentage (%)
Age (years)	36.9 (14.9) years	
Range	18 – 91 years	
Gender		
Male	171	74.3
Female	59	25.7
Occupation		
Formal	37	16.1
Informal	105	45.6
Unemployed	52	22.6
Students	16	7.0
Pensioner	20	8.7
Education		
none	34	14.7
Primary	42	18.3
Secondary	97	42.2
Tertiary	57	24.8

The overall age distribution of these open fractures is shown in figure 6 which shows that in all patients the highest incidence of open long bone fractures was in the 20-25 age group, followed by the 26-30 age group with the least incidence in the 61-65 age group. Figure 7 shows that in males the highest incidence of open fractures occurred between 26– 30 years and in females the highest incidence was in the 20–25-year group. The least incidence of open fracture in males occurred in the 61-65 years group and in females the least incidence was in the less than 20 years and the 51-55 age group.

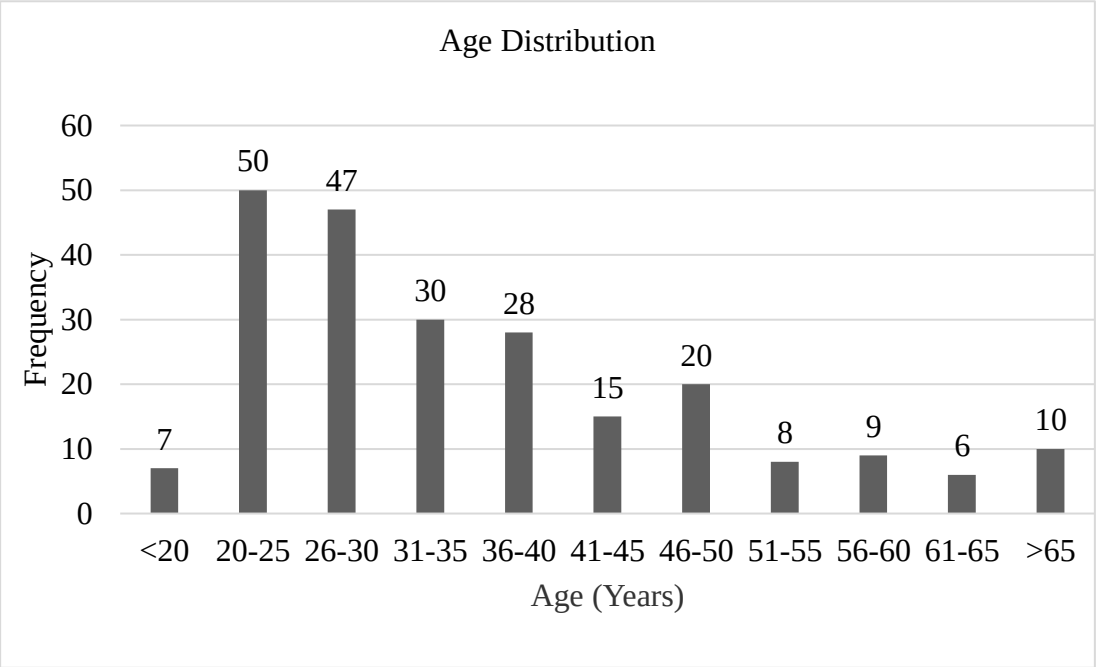


Figure 6: Age distribution

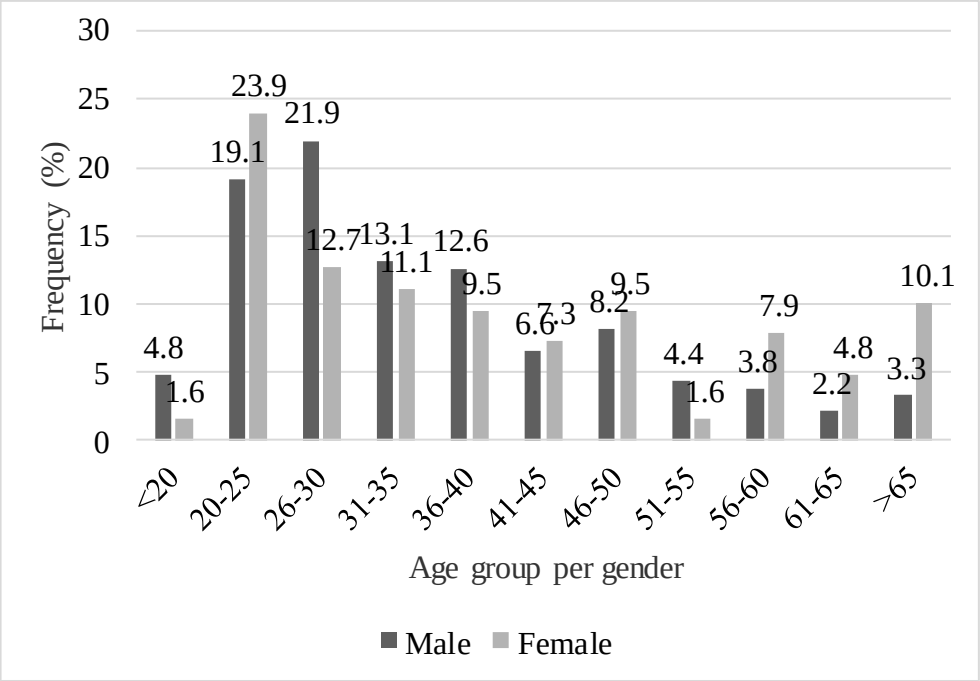


Figure 7: Age distribution by Gender

Table 4: Aetiology of injury

	n =230	
Mechanism of Injury (Aetiology)	Frequency	Percentage (%)
Road traffic accident	150	65.2
Assault	32	13.9
Falls	16	7.0
Work-Related Injury	11	4.8
Sports	6	2.6
Gunshot	14	6.1
Others	1	0.4

As shown in table 4 the majority of cases were due to road traffic injuries 150 (65.2%) followed by assaults 32 (13.9%). Other cases on injury included falls (7%), work-related injury (4.8%), sports (2.6%) and gunshot injuries (6.1%).

4.1.2 Fracture Characteristics

Table 5 shows that most of the injuries were observed on the lower extremity 198 (82.2%) compared to the upper extremity 43 (17.8%). In the lower extremity, fracture of both tibia and fibula was observed in 138 (57.3%) cases. The femur with 41 (17.0%) case was the most isolated lower limb long bone affected, followed by the tibia 17 (6.6%) and only 3 (1.2%) cases of the fibula were recorded. In the upper extremity fracture of the radius and ulna was seen in 13 (5.4%) patients and humerus was isolated upper extremity fracture 15 (6.2%). Figure 8 illustrates the distribution of fractures across the affected long bones. The most common fracture patterns observed were comminuted fracture pattern 141 (58.5 %), followed by transverse fracture pattern 34 (14.1%) and oblique fracture 34 (14.1%). These fractures were observed to show a slight predilection for the right side 123 (51.0%) compared to the left, 118 (49.0%).

Table 5: Fracture characteristics

Variable	N= 241 Frequency (n)	Percentage (%)
Bones Involved		
Upper Extremity		
Humerus	15	6.2
Radius/Ulna	13	5.4
Radius	3	1.2
Ulna	12	5.0
Lower Extremity		
Femur	41	17.0
Tibia/Fibula	138	57.3
Tibia	16	6.6
Fibula	3	1.2
Fracture Pattern		
Comminuted	141	58.5
Spiral	19	7.9
Oblique	34	14.1
Transverse	34	14.1
Segmental	13	5.4
Laterality (side)		
Right	123	51.0
Left	118	49.0

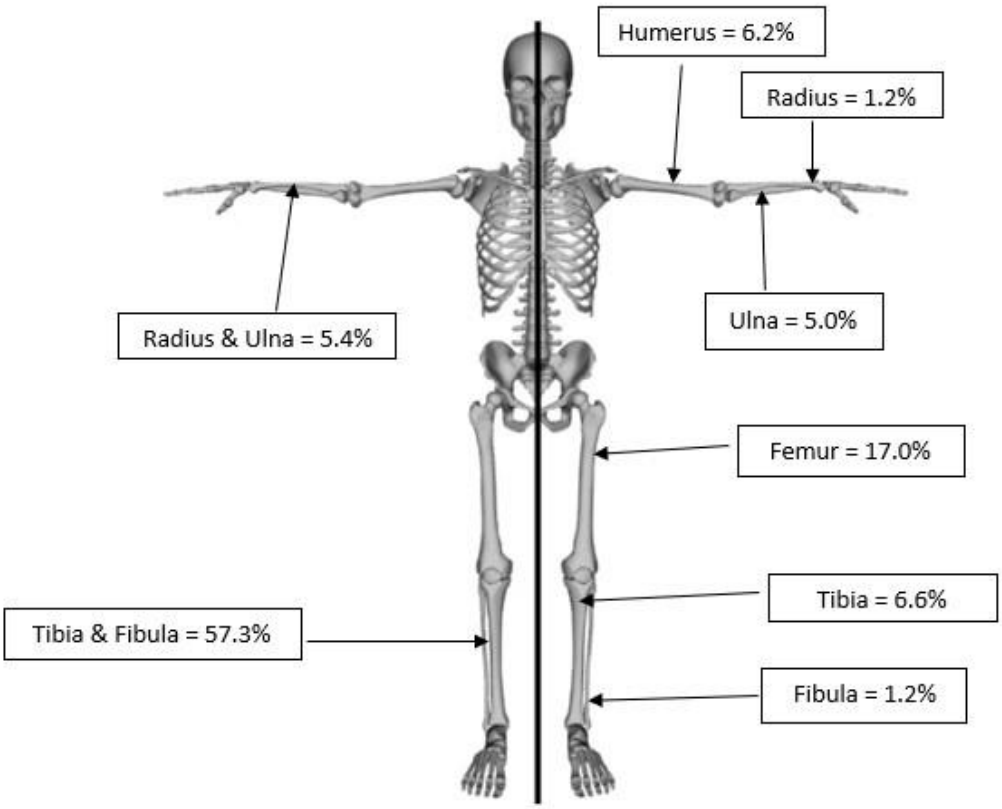


Figure 8: Bones involved

Table 6: Fracture severity

Gustilo Anderson Classification	N=241 Frequency	Percentage (%)
I	48	19.9
II	92	38.2
III		
A	61	25.3
B	34	14.1
C	6	2.5

As shown in table 6, among the cases of open fractures, 48 (19.9%) were of type I: 92 (38.2%) were of type II and a total of 101 (41.9%) were type III according to the Gustilo-Anderson classification system of open fracture. Among the type III open fractures 61 (25.3%) were of type IIIA, 34 (14.1%) were of type IIIB, and 6 (2.5%) were of type IIIC.

4.2 Incidence of infection in patients with open long bone fractures

Figure 9: Occurrence of infection

Figure 9 illustrates that 92 participants (38.2%) developed infections during the three-month follow-up period. Microbial analysis revealed that 93% of these infections were monomicrobial in nature, with 35.9% involving Gram-positive bacteria and 57.5% involving Gram-negative bacteria. Among the remaining cases, 3.3% were polymicrobial infections, and 3.3% showed no microbial growth. *Staphylococcus aureus* was the most frequently isolated organism, accounting for 20.6% of cases. This was followed by *Escherichia coli* (10.8%), *Proteus mirabilis* (8.7%), *Pseudomonas aeruginosa* (7.6%), *Morganella morganii* (7.6%), *Enterobacter cloacae* (6.5%), Coagulase-negative *Staphylococci* (6.5%), and *Klebsiella pneumoniae* (5.4%). Figure 10 presents the frequency of microorganisms isolated from microbial cultures.

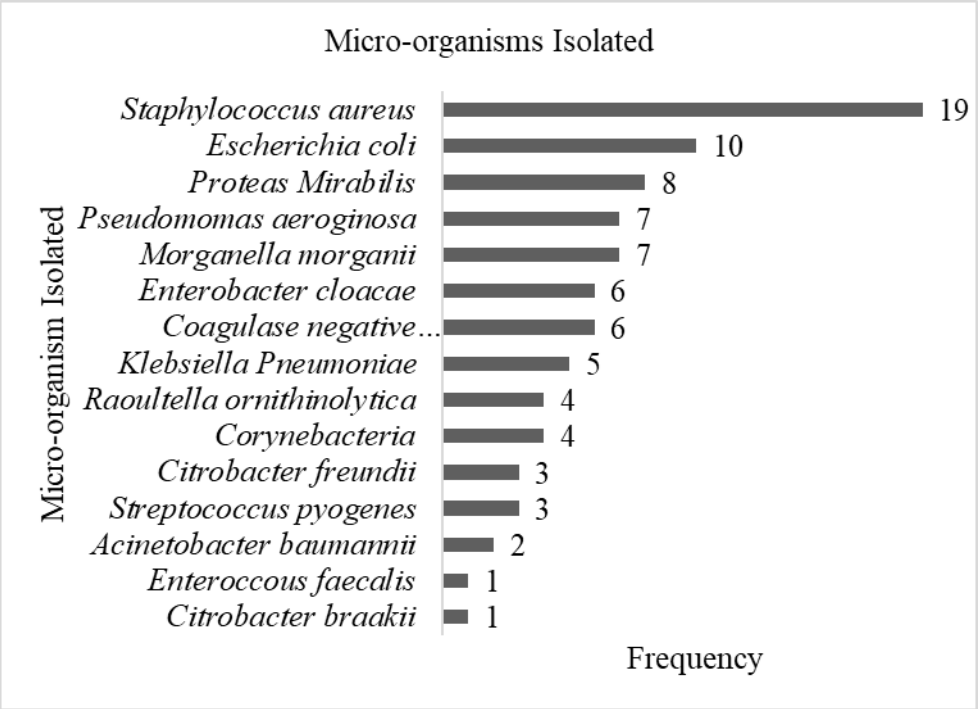


Figure 10: Micro-organisms isolated

4.3 Factors associated with the occurrence of infection in open long bone fracture

Table 7: Patient related fractures

Variable	Category	Frequency of Infection		p-value
		No Infection n=142	Infection n= 88	
Age		36.0 (14.5)	39.2 (16.3)	0.12
Age group	<40	94 (64.4%)	52 (35.6%)	0.35
	40 - 60	38 (58.5%)	27 (41.5%)	
	>60	10 (52.6%)	9 (47.4%)	
Gender	Male	110 (64.0%)	62 (36.0%)	0.24
	Female	32 (55.2%)	26 (44.8%)	
Smoking	No	122 (68.9%)	55 (31.1%)	<0.001
	Yes	20 (37.7%)	33 (62.3%)	
Comorbidities	No	105 (64.4%)	58 (35.6%)	0.21
	Yes	37 (55.2%)	30 (44.7%)	

Table 7 summarizes the analysis of patient related factors. The incidence of infection based on the age group demonstrated the of age > 40 years was associated with fewer incidences of infection. Trend analysis showed that there was no significant association between the occurrence of infection and increase in the age group ($p > 0.05$). The results of the multiple logistic regression analysis showed

higher infection rate was observed in males compared with females however the results were not statistically significant with p>0.24. Smokers had a significantly increased risk of infections compared to non-smokers (p< 0.001). Overall, the presence of comorbidities was not significantly associated with an increased risk of infection in open long bone fractures. However, table 8 shows that patients with diabetes mellitus developed more post-operative infections.

Table 8: Comorbidities

Variable	**Category**	**Frequency of Infection (%)**		**p-value**
		No Infection (%)	**Infection (%)30**	
Comorbidities				
	Diabetes	1 (11.1%)	8 (88.9%)	0.038
	Hypertension	11 (63.2%)	7 (36.8%)	
	Psychosis	4 (66.7%)	2 (33.3%)	
	Asthma	3 (100.0%)	0 (0.0%)	
	Alcohol Abuse	3 (60.0%)	2 (40.0%)	
	Renal Failure	4 (80.0%)	1 (20.0%)	
	Hepatitis	3 (60.0%)	2 (40.0%)	
	COPD	2 (50.0%)	2 (50.0%)	
	Epilepsy	1 (100.0%)	0 (0.0%)	
	HIV	5 (45.5%)	6 (54.5%)	

Table 9: Fracture related factors

Variable	Category	Frequency of Infection (%)		p-value
		No Infection (%)	Infection (%)	
Time to debridement	< 6 hours	3 (100.0%)	0 (0.0%)	< 0.001
	6- 12 hours	27 (84.4%)	5 (15.6%)	
	12-24 hours	86 (74.8%)	29 (25.2%)	
	24-48 hours	25 (40.3%)	37 (59.7%)	
	>48 hours	8 (27.6%)	21 (72.4%)	
Severity of injury	I	37 (77.1%)	11 (22.9%)	< 0.001
	II	70 (76.1%)	22 (23.9%)	
	IIIA	37 (60.7%)	24 (39.3%)	
	IIIB	3 (8.8%)	31 (91.2%)	
	IIIC	4 (66.6%)	2 (33.3%)	
Method of Fixation	Cast	15 (71.4%)	6 (28.6%)	0.016
	External	56 (51.9%)	52 (48.1%)	
	Internal	78 (69.6%)	34 (30.4%)	

Table 9 summarizes the analysis of fracture related factors. There was no infection among the patients who had surgical debridement less than 6 hours from injury. The infection rate of patients done between 6 hours and 12 hour was 15.6%, with 5 of 32 patients being infected. In group of 12 hours to 24 hours, the infection rate was 25.2% (29 of 115 total cases), the category of 24 hours to 48 hours, the infection rate was 59.7% (37 of 62 total cases), and in cases where surgical debridement was done after more than 48 hours the infection rate was 72.4% (21 of 29 total cases)- Figure 11. The infection rate showed increasing trend with delay of surgical debridement which was statistical significance between the groups. Among the patients who had Gustilo- Anderson type I wound, 11 (22.9%) developed infection, 22 (23.9%) among type II, and 57 (56.4%) among type III open fracture wounds.

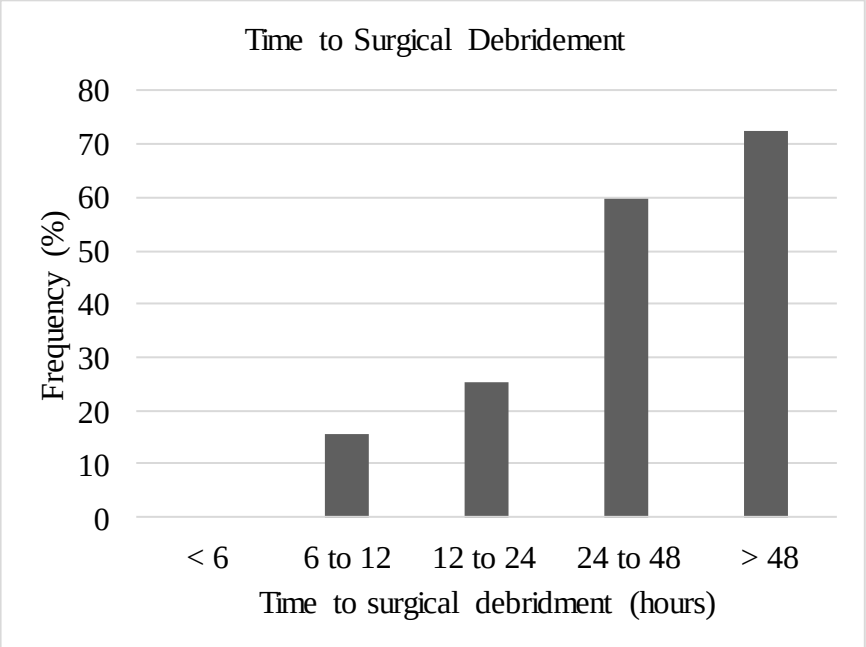


Figure 11: Time to surgical debridement (hours)

Among the sub-groups the Gustilo-Anderson type III the incidences of infection were 39.3%, 91.2% and 33.3% for type A, B and C respectively. Infection rates in type III fractures was significantly higher than in type I and II fractures ($p < 0.001$) with a significant number of infection among the type IIIB. Among patients with eventual infection, 6 (28.6%) were casted, 52 (48.1%) were treated with external fixation and 34 (30.4%) underwent internal fixation with either plate-and-screw fixation or intramedullary fixation or K wire pinning). There was a statistically significant association between the method of immobilization and the occurrence of infection, $p = 0.016$.

Table 10: Health care related factors

Variable	Category	Frequency of Infection		p-value
		No Infection (%)	Infection (%)	
Timing of antibiotic	< 3 hours	28 (80.0%)	7 (20.0%)	<0.001
	3- 6 hours	32 (71.1%)	13 (28.9%)	
	6-12 hours	58 (66.7%)	29 (33.3%)	
	12-24 hours	23 (48.9%)	24 (51.1%)	
	> 24 hours	8 (29.6%)	19 (70.4%)	
Wound closure	No	9 (19.1%)	38 (80.9%)	<0.001
	Yes	140 (72.2%)	54 (27.8%)	
Surgeon expertise	Resident	140 (61.7%)	87 (38.3%)	0.98
	Consultant	9 (64.3%)	5 (35.7%)	
Duration of Surgery		103.5 (38.5)	105 (30.1)	0.68

Table 10 summarises the analysis of health care related factors. The patients were placed into five groups of antibiotic administration timing; <3 hours, 3-6 hours, 6-12 hours, 12-24 hours and >24 hours . The incidence of infection among the patients who were administered prophylactic antibiotics less than 3 hours from injury was 20.0%, with 7 of 35 patients being infected. The infection rate of patients administered between 3 hours and 6 hours was 28.9%, with 13 of 45 patients being infected. In group of 6 hours to 12 hours, the infection rate was 33.3% (29 of 87 total cases), in the category of 12 hours to 24 hours, the infection rate was 51.1% (24 of 47 total cases) and in cases where prophylactic antibiotic was administered after more than 24 hours the infection rate was 70.4% (19 of 27 total cases). The study showed significant relationship between infection rates and the timing of antibiotic prophylaxis in open long bone fracture (Figure 12).

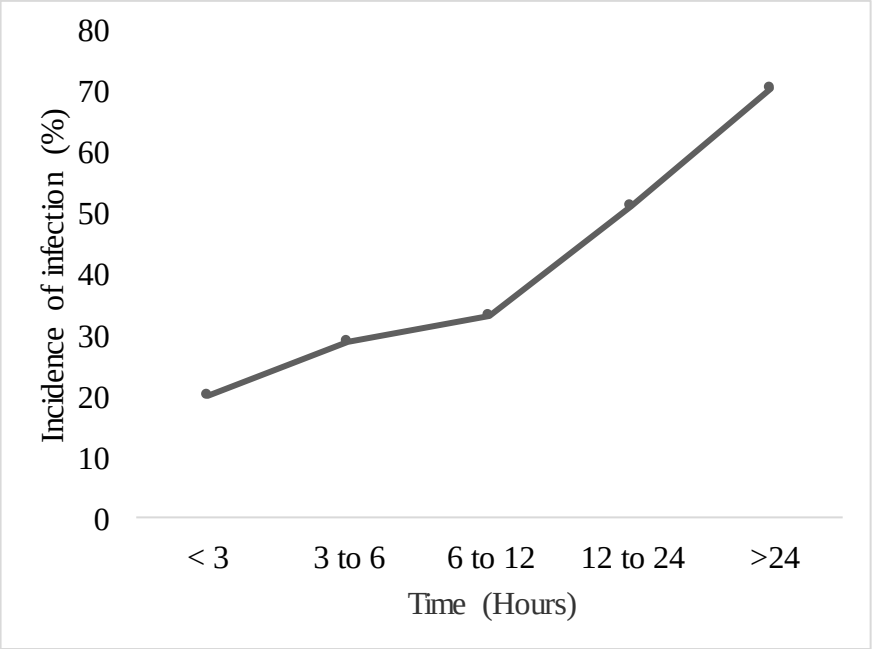


Figure 12: Relationship between timing of antibiotics and occurrence of infection

A significant difference was observed in favour of closure of wound at the time of debridement with 27.8% of patients developing infection compared to 80.9% who underwent wound closure at a later stage developing infection ($p < 0.001$). In 14 cases where a consultant orthopaedic surgeon was involved in the initial procedure 5 cases (35.7%) were complicated by infection compared with 87 cases (38.3%) where a resident was involved in the initial surgical debridement procedure. The experience of surgeon showed no significant difference in the development of infection. The average surgical duration of the debridement was not shown to be an independent indicator for development of infection.

4.4 Patterns of prophylactic antibiotic use in patients with open long bone fractures

Cefazolin monotherapy was the most common parenteral regimen administered, followed by cefuroxime and ceftriaxone. The most common double regimen was cefazolin and gentamicin followed by cefazolin and metronidazole. Cefazolin, gentamycin and metronidazole was the mostly used triple therapy regimen. In the

majority of cases, a sequential antibiotic regimen was employed, transitioning from parenteral to oral administration, with clindamycin and cefuroxime being the most frequently utilized oral antibiotics. The average duration of prophylactic antibiotics prophylaxis was 13.6 ± 4.6 days.

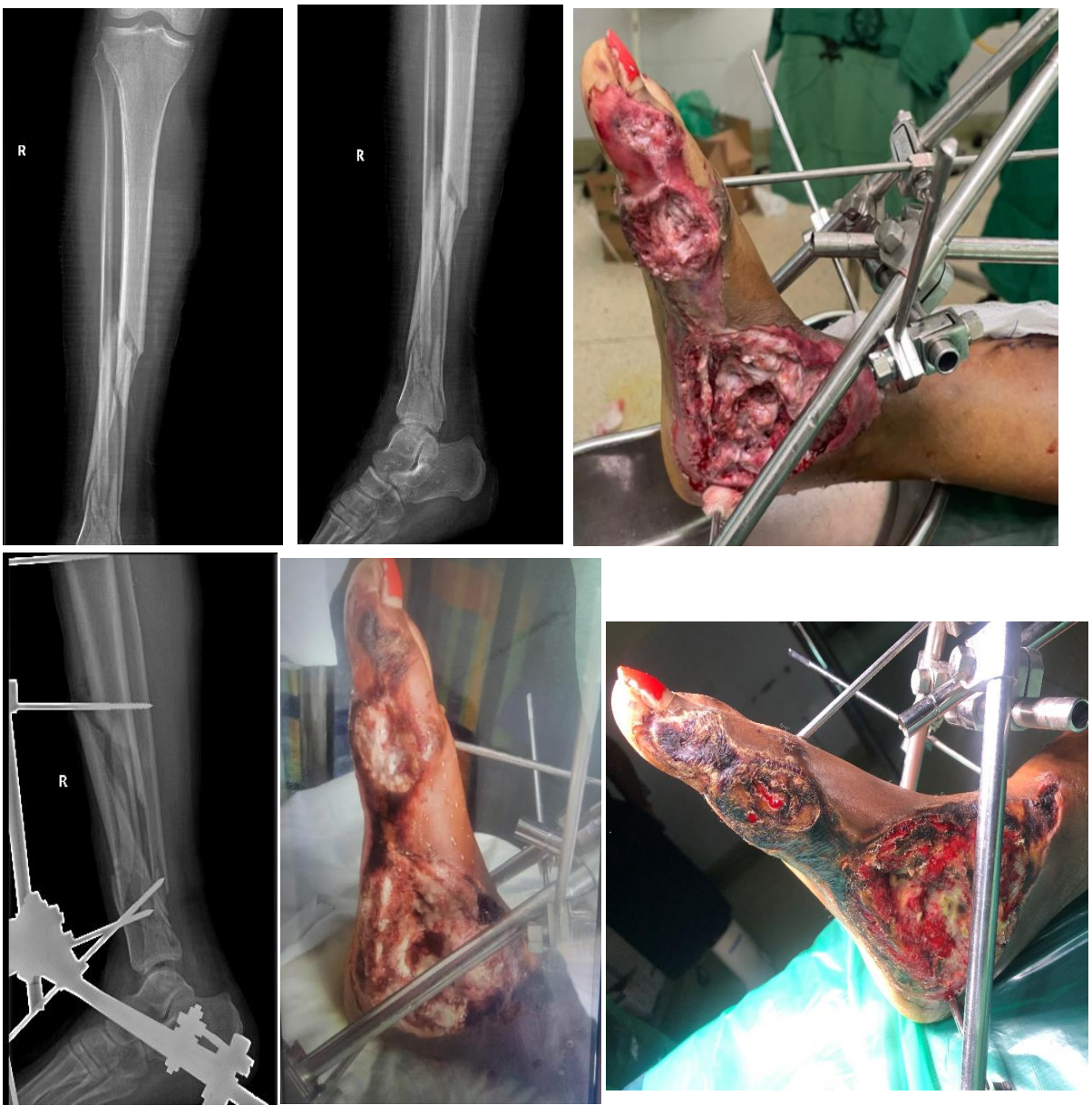


Figure 13: 28 year old female with GA IIIB open fracture of right distal tibia and fibula treated with external fixation after debridement and delayed wound closure

CHAPTER FIVE: DISCUSSION

5.0 Introduction

This chapter discuss the results findings as per objective.

5.1 Characteristics of patients with open long bone fractures

5.1.1 Socio-demographic characteristics

The study revealed that the majority of individuals with open long bone fractures were males, with a male-to-female ratio of 3:1. The mean age of affected individuals was 36.9 ± 14.9 years, with males having a mean of 35.5 ± 13.2 years and females 41.1 ± 18.7 years. The highest incidence was observed in the 20–25 age group, followed by the 26–30 age group, while the lowest incidence was noted in the 61–65 age group.

Gender Distribution

This study's male-to-female ratio of 3:1 concurs with reports from studies conducted in Togo (Kombate et al., 2017) and Cameroon (Nana et al., 2021), both of which documented the same sex ratio. Similar trends were observed in Ethiopia, where Hailu and Mengesha, (2020) reported a higher male-to-female ratio of 5:1. In a study conducted by Ayumba et al., (2015), which evaluated the characteristics of 196 patients with post-traumatic exposed bones who underwent surgical interventions, a significantly higher male-to-female ratio of 6:1 was observed. The predominance of males was similarly noted in Europe, with 69.1% of cases being male (Court-Brown et al., 2012). The predominance of males can be attributed to increased exposure to risk factors such as occupational hazards, higher involvement in physically demanding activities, and a higher likelihood of engaging in high-energy trauma mechanisms such as road traffic accidents and sports injuries.

Age Distribution

The mean age of 36.9 years observed in this study is consistent with findings of Kombate et al. (2017) in Togo who reported an average age of 38.1 years, and Nana et al. (2021) in Cameroon who observed a mean age of 34.1 ± 13.67 years. Hailu and Mengesha, (2020) in Ethiopia documented a slightly lower mean age of 32 ± 14.23 years. These findings show that open fractures predominantly affect individuals in their most economically productive years, typically between the ages of 20 and 40 years.

The highest incidence was observed in the 20–30 age group for both genders, with males peaking in the 26–30 age group and females in the 20–25 age group. This age distribution concurred with findings in Rwanda, where Twagirayezu & Bonane, (2008) reported most cases within the 18–44 age bracket, and in Ethiopia, where over 75% of cases fell within the 18–45 age range (Hailu & Mengesha, 2020). The ages groups of highest incidences in this study were higher than the observations in Europe, where Court-Brown et al., (2012) documented the highest incidence among adult males aged 15–19 years.

Males consistently exhibited higher incidences of open fractures across nearly all age groups, with the highest incidence observed between the ages of 26–30 years. Conversely, females showed a peak in the 20–25 age group. This suggests that individuals in the younger adult age bracket may have greater exposure to high-energy mechanisms of injury, such as motor vehicle collisions and occupational accidents. The least incidence of open fractures in males occurred in the 61–65 age group, reflecting reduced exposure to high-energy trauma mechanisms as individuals age. Similarly, females showed the least incidence in the less-than-20

and 51–55 age groups. Thisconcurs with findings from Kombate et al. (2017), who also reported a decline in open fractures among older populations in Togo. In Europe, Court-Brown et al., (2012) observed a higher mean age of 45.5 years for open fracture patients, with males averaging 40.8 years and females 56.0 years. These figures are slightly higher than those in this study and other African studies, potentially reflecting differences in demographics and lifestyle in different regions.

Occupation

There was a significant occupational trend among individuals affected by open long bone fractures. The majority of participants engaged in informal occupations, such as motorists, farmers, traders, construction workers, casual labourers, and domestic workers. Costa et al., (2022) in Brazil reported that farmers (23.38%), self-employed individuals (11.29%), masons (8.87%), and industrial workers (8.06%) were the most frequently afflicted. Similarly, Nyamosi (2019) in Kenya found that farmers (28%), motorists (18.9%), and casual labourers (14.7%) were predominantly affected, reflecting similar trends in occupational exposure to injury risks. In Cameroon, Nana et al. (2021), also corroborated the findings of this study observing that 71.3% of individuals with open fractures were engaged in informal occupations, while 14.9% held formal jobs, and 13.8% were students. These proportions closely mirror the findings of this study, emphasizing the increased vulnerability of those in informal and physically demanding roles. Additionally, Odatuwa-Omagbemi, (2019) in Nigeria reported that traders, students, and artisans as the most affected groups, further supporting the significant representation of informal and economically active individuals in open fracture cases. The lower representation of formal workers in these findings suggests that the nature of

injuries in the population may be more closely tied to physically intensive or high-risk informal activities.

Education

The majority of the participants (42.2%) had completed secondary education, with only 14.7% of participants having no formal education. Costa et al., (2022) reported that over half (50.80%) of individuals with open fractures in Brazil had completed some or all primary education, with a minimal proportion (0.8%) being classified as illiterate. The study showed that individuals with lower levels of education often engage in manual labour and hazardous activities, increasing their risk of sustaining open fractures. Similarly, Nana et al., (2021) in Cameroon found that 89.2% of participants had primary and secondary education, whereas only 7.2% had tertiary education, and 3.6% had no formal education. This pattern underscores the role of education in influencing occupational choices and exposure to high-risk environments.

In Nigeria, Odatuwa-Omagbemi, (2019) observed a higher prevalence of open fractures among individuals with secondary education (42.3%) compared to those with tertiary education (32.9%) and primary education (13.5%). Contrastingly, Nyamosi, (2019) in Kenya reported that the majority of individuals with open fractures (49.5%) had followed by 36.8% with tertiary education and 9.5% with secondary education. While the proportions differ slightly, the predominance of individuals with primary and secondary education levels across studies shows a similar risk profile.

5.1.2 Mechanism of injury

RTA were the leading cause of open long bone fractures, accounting for 150 cases (65.2%). This was followed by assaults (13.9%), gunshot injuries (6.1%), falls (7%), work-related injuries (4.8%), and sports injuries (2.6%). Court-Brown et al., (2012) in Europe identified RTA, alongside crush injuries, falls, sporting accidents, and assaults, as the primary aetiologies. In this study, assaults were the second most common cause, aligning with findings locally, where Ayumba et al., (2015) reported assaults accounting for 32.1% of cases following RTA at 49.5%. Similarly, Kombate et al. (2017) in Togo found that RTA involving motorbikes, automobiles, and pedestrians were the leading cause of open fractures, with other causes including occupational and domestic accidents, assaults, and sports injuries. In Cameroon and Rwanda, RTA accounted for an average of 72% of open fractures, with falls, assaults, crush injuries, and sports injuries contributing to the remaining cases (Nana et al., 2021; Twagirayezu & Bonane, 2008). The findings concurs with the 65.2% of RTA-related cases observed in this study, emphasising the prominent role of motor vehicle and motorbike incidents as a primary aetiology of open long bone fractures, attributable to their high-energy mechanisms.

In Saudi Arabia, Alhawas and Alghamdi, (2023) reported that RTA represented 28.47% of open fracture causes, followed by falls at 18.96% and assaults at 2.9%. Although the proportion of RTA cases in Saudi Arabia is lower compared to this study, the pattern still shows RTA as the leading cause. Falls, which constituted 7% of cases in this study, were also a significant cause in Saudi Arabia, often attributed to occupational hazards or self-harm. Contrastingly, Costa et al., (2022) in Brazil observed that occupational incidents involving industrial and agricultural machinery were the primary trauma mechanisms (39.5%), followed by RTA

(29.0%) and falls (9.7%). While occupational injuries were less frequent in this study (4.8%), they remain a notable contributor to the burden of open fractures.

5.1.3 Fracture Characteristics

Bone Involved

Fractures involving both the tibia and fibula were the most frequently observed, occurring in 138 cases (57.3%). These findings concur with those reported by Kombate et al., (2017) and Nana et al., (2021), who also observed a predominance of concomitant tibia and fibula fractures among lower extremity injuries. Similarly, Twagirayezu and Bonane, (2008) in Rwanda reported that open injuries of the tibia and fibula constituted 69.4% of cases, while femur fractures accounted for 17.6%. Court-Brown et al., (2021) observed a similar trend in their analysis, noting that 52.6% of open fractures occurred in the lower limbs. Among these, fractures of the tibia and fibula were most common (35.5%), followed by femur fractures (9.2%) and isolated tibia fractures (7.9%). The tibia has a relatively thin layer of soft tissue and skin covering it, especially along its anterior and medial aspects. This makes it particularly vulnerable to direct trauma, leading to high incidence open fractures involving the tibia bone.

Upper extremity fractures were less frequent, with 15 cases (6.2%) involving the humerus and 13 cases (5.4%) involving both the radius and ulna. These findings are different to those reported by Court-Brown et al., (2021), who found that isolated radius fractures were the most common upper extremity injury (25.1%), followed by ulna fractures (10.1%), humerus fractures (6.1%), and radius and ulna fractures (6.1%). Alhawas and Alghamdi, (2023) also observed a different trend where upper extremity injuries constituted 23.2% of fractures, with the radius and ulna being the most commonly affected bones (10.2%). In contrast to these

findings, Costa et al., (2020) reported a higher prevalence of upper limb fractures, which accounted for 64.51% of open fractures in their study, with hand bone fractures being predominant. This difference may be attributed to factors such as inclusion of hand fractures in their study.

Laterality

A slight predilection for right-sided injuries was observed in this study, with 123 cases (51.0%) compared to 118 cases (49.0%) on the left side; however, the difference was not statistically different. This distribution concurs with findings by Alhawas and Alghamdi, (2023), who reported right-sided injuries in 50.7% of cases and left-sided injuries in 49.3%. Nana et al., (2021) also noted a near-equal distribution however with the left side being slightly more affected (50.3%) than the right (49.2%).

Fracture Pattern

This study identified comminuted fractures as the most common fracture pattern, observed in 141 cases (58.5%). Transverse and oblique fractures were equally prevalent, each accounting for 34 cases (14.1%). Comminuted fractures are frequently linked to high-energy trauma, such as road traffic accidents, which were the leading cause of injuries in this study. The predominance of comminuted fractures is consistent with findings by Nana et al., (2021), who reported a prevalence of 64.6% for this fracture pattern in open lower limb fractures. Similarly, Kouassi et al., (2021) conducted a systematic review across multiple sub-Saharan countries and found comminuted fractures to be the most common pattern, accounting for 46.4% of cases. These results reinforce the association between comminuted fractures and high-energy mechanisms of injury. Transverse fractures were the second most common pattern, aligning with the findings of

Kouassi et al., (2021), who reported a prevalence of 28.9%. Nana et al., (2021) also observed transverse fractures in 14.4% of cases, closely mirroring the results of this study. Oblique fractures accounted for 14.1% of cases in this study, a figure comparable to the 13.3% reported by Nana et al., (2021) while Kouassi et al., (2021) noted a slightly higher incidence of 25%. Abang et al,. (2015) in Nigeria found comminuted fractures to be the most common (52.5%), followed by oblique fractures (25%) and segmental fractures (12.5%). Enweluzo et al., (2015) presented data from 197 patients on the patterns, aetiology, and treatment outcomes of open tibia fractures at a teaching hospital in Lagos, Nigeria. Their findings revealed a different pattern, with oblique fractures being the most common (47.2%), followed by transverse fractures (32%), and comminuted fractures accounting for only 11.2% of cases.

Fracture Severity

Using the Gustilo-Anderson classification, Type I fractures accounted for 19.9% of cases, Type II fractures for 38.2%, and Type III fractures for 41.9%. Among the Type III fractures, Type IIIA was the most common, representing 25.3% of all cases, followed by Type IIIB at 14.1% and Type IIIC at 2.5%. In Togo, Kombate et al., (2017) reported that Type III fractures were the most prevalent, comprising 56.3% of cases. Type II fractures accounted for 32.2%, while Type I fractures were the least common at 11.5%. Nana et al., (2021) in Cameroon observed that Type IIIA fractures were the most common, accounting for 39.0% of cases, followed by Type IIIB at 28.7% and Type II at 23.6%. Type IIIC fractures were less frequent, comprising 8.7% of cases. In Rwanda, Twagirayezu and Bonane, (2008) reported a similar dominance of Type III fractures, which constituted 48.7% of cases. Among these, Type IIIA accounted for 17.6%, Type IIIB for 23.8%, and Type IIIC for

7.3%. A study in Uganda reported a different trend in Type III open fractures with a high prevalence of Type IIIB fractures, which accounted for 40.4% of cases (Kironde et al., 2019). In the same study, Type IIIC fractures were the least common, at 3.4%. This aligns with the current study, where Type IIIB fractures were more frequent than Type IIIC fractures. A European study by Court-Brown et al., (2012), also reported similar trend, with a high prevalence of Gustilo-Anderson Type III fractures. The study's findings of a higher proportion of Type III fractures emphasize the severity and complexity of injuries and demonstrate the burden of high-energy trauma, often resulting from road traffic accidents.

5.2 Incidence of infection in patients with open long bone fractures

The incidence of infection in long bone open fractures among adult patients in this study was 38.2% during the three-month follow-up period. Infections following open fractures have been reported to reach as high as 50% in cases of severe or grossly contaminated injuries (Bhandari, 2010; Coombs et al., 2022). In South East Asia, infection rates post-open fractures ranged from 34.6% to 45.1%, reflecting a similar burden of infections (Islam et al., 2022). These parallels show the global challenge of preventing infections in open fracture cases, especially in high-energy trauma scenarios. However, the infection rate observed in this study is higher than reported in some high-income settings, such as the United Kingdom (27%) and Australia (17%) (Charalambous et al., 2005; Enninghorst et al., 2011). In South America, infection rates for open fractures were also reported to be generally lower, ranging between 13.24% and 18.8% (Guerra et al., 2017; Fernandes et al., 2015). These differences may be attributed to variations in healthcare infrastructure and adherence to infection prevention protocols.

In sub-Saharan Africa, infection rates are generally higher. Kouassi et al. (2021) found an average infection rate of 30% in open tibia fractures in the region, while Odatuwa-Omagbemi, (2019) documented an infection rate of 42.5% in Nigeria. This aligns closely with the 38.2% infection rate observed in this study. In Kenya, studies have reported varying infection rates depending on the anatomical site and treatment methods. Kalande, (2018) documented a lower infection rate of 13.2% in open femur injuries treated at Nakuru County Hospital, while Nyamosi, (2019) observed a 23% infection rate among adult patients treated with external fixation for long bone open fractures at MTRH, Eldoret.

Staphylococcus aureus was identified as the most prevalent pathogen, representing 20.6% of all isolates, a finding consistent with a study by Islam et al., (2022), which identified *Staphylococcus aureus*, *Pseudomonas spp*., *Escherichia coli*, *Klebsiella spp.*, and *Proteus spp.* as common causative agents in open fracture infections. Similarly, Latha et al., (2019) reported *Staphylococcus aureus* as the leading pathogen in orthopaedic infections, comprising 48.4% of cases in India, emphasizing its significance as a global primary infective organism.

The predominance of Gram-negative bacteria in this study, accounting for 57.5% of isolates, corroborates findings from studies conducted in India and Brazil. Lingaraj et al., (2015) reported a 76% prevalence of Gram-negative bacteria among bacterial isolates, while Guerra et al., (2017) documented a similar trend, with Gram-negative organisms comprising 66.7% of infections in a Brazilian cohort. The frequent isolation of *Escherichia coli* (10.8%), *Proteus mirabilis* (8.7%), *Pseudomonas aeruginosa* (7.6%), and *Klebsiella pneumoniae* (5.4%) in this study mirrors these findings. *Morganella morganii* and *Enterobacter cloacae* were also

isolated in significant proportions (7.6% and 6.5%, respectively). These organisms are less frequently reported in similar studies but have been documented as opportunistic pathogens in traumatic wounds and hospital-acquired infections. Guerra et al. (2017) identified *Enterobacter aerogenes* as a prevalent Gram-negative pathogen in their study.

Polymicrobial infections were less common in this study, occurring in only 3.3% of cases, consistent with some open fracture studies, which emphasize the monomicrobial nature of most infections (Guerra et al., 2017; Islam et al., 2022). The absence of microbial growth in 3.3% of cases could be attributed to prior antibiotic use before sample collection or suboptimal sample collection techniques. This phenomenon has been observed in a study by Islam et al (2022) and emphasise the importance of adhering to standardized protocols for obtaining and processing microbiological specimens to avoid false-negative results. The high prevalence of Gram-negative bacteria suggests the need for empirical antibiotic regimens with broad-spectrum activity against these organisms while awaiting culture results. The frequent isolation of *Staphylococcus aureus* also demonstrates the necessity of coverage for Gram-positive pathogens in initial antibiotic protocols.

5.3 Factors associated with the occurrence of infection in open long bone fractures

5.3.1 Patient Related Factors

The incidence of infection in this study did not demonstrate a significant association with age, as determined by the Cochran–Armitage test for trend analysis ($p > 0.05$). Although infections were less common among individuals over 40 years old, this trend was not statistically significant. This finding diverges from

some prior research that suggests age as a contributing factor to infection risk. Hu et al., (2020) reported that individuals over the age of 40 were more prone to developing infections in a retrospective multicenter study. Similarly, Kang et al., (2023) found that in the context of ankle fractures, the incidence of infection increased with advancing age. In their cohort, the mean age of the infection group was higher (49.7 years ± 19.99) compared to the non-infection group (47.2 years ± 18.61). These findings suggest that advancing age may predispose patients to infections due to factors such as comorbidities, declining immune function, or delayed wound healing. Matos et al., (2015) reported no statistically significant association between age and infection incidence following open fractures. The mean age of patients who developed infections (31.5 ± 13.5 years) was comparable to that of the non-infection group (31.7 ± 14.3 years). This aligns with the findings of this study, where age did not emerge as a significant predictor of infection. The discrepancies across studies could be attributed to differences in study populations, fracture severity, comorbid conditions, or healthcare settings.

Males exhibited a higher infection rate compared to females, but the difference was not statistically significant ($p > 0.24$). This concurs with the findings of Matos et al., (2015), who also reported no significant association between gender and infection rates. However, their study highlighted a substantial male predominance, with males constituting 83.6% of the total cases. This overrepresentation of males, a common finding in trauma-related studies, may reflect their higher exposure to high-energy trauma mechanisms such as road traffic accidents and occupational injuries. In contrast, other studies have identified male gender as a significant risk factor for infection. Kang et al., (2023) observed a significantly higher odds ratio for infection among males in their South Korean cohort. Similarly, a systematic

review and meta-analysis by Kortram et al., (2017) concluded that male gender was a statistically significant risk factor for infectious complications. Male patients in their analysis exhibited a higher infection risk of 16.1%, compared to 11.6% among females, with a relative risk (RR) of 1.42 and a p-value of 0.004. The proposed explanations for this disparity include behavioural factors such as delayed healthcare-seeking, and increased exposure to high-risk environments among males.

This study identified smoking as a significant risk factor for infections following open long bone fractures ($p < 0.001$). Smokers demonstrated a markedly increased incidence of infection compared to non-smokers, demonstrating the detrimental impact of smoking on wound healing and postoperative outcomes. Nasell et al., (2011) reported that smokers tend to experience a higher prevalence of wound infections and other complications following surgery. Similarly, Sun et al., (2023) observed a statistically significant association between smoking and postoperative wound infections, with 72.73% of infected patients having a history of smoking, compared to 38.24% among those without infections ($p = 0.014$). Meta-analyses have further substantiated the link between smoking and postoperative infections. Smolle et al., (2021) confirmed smoking as a significant risk factor for postoperative infections in orthopaedic and trauma surgeries. Kortram et al., (2017) reported a postoperative infection rate of 17.7% among smokers compared to 13.8% among non-smokers, corresponding to a relative risk of 1.29. The physiological mechanisms underlying this relationship include impaired oxygenation of tissues, reduced immune function, and delayed collagen synthesis, all of which contribute to suboptimal wound healing in smokers. However, not all studies have demonstrated a significant correlation between smoking and infection

risk. Tornetta et al., (2020) and Olsen et al., (2017) failed to establish a significant association, suggesting that other factors, such as surgical technique, antibiotic prophylaxis, and the severity of injury, may mediate the relationship between smoking and infections.

The presence of comorbidities overall was not significantly associated with an increased risk of infection following open long bone fractures. However, diabetes mellitus emerged as an exception, with patients with diabetes experiencing a significantly higher rate of postoperative infections ($p = 0.038$). Hu et al., (2020) identified diabetes mellitus as a major risk factor for infections in surgical patients, attributing this association to hyperglycemia-induced impairments in immune response and wound healing. Szymski et al., (2022) demonstrated that patients with conditions such as heart failure or arterial hypertension have an increased relative risk of infection following fractures. Kang et al., (2023) noted a significant increase in infection risk with a rising number of comorbidities, underscoring the cumulative effect of multiple health conditions on postoperative outcomes. Similarly, Saiz et al., (2022) found that individuals with congestive heart failure, bleeding disorders, or obesity faced a three- to 4.5-fold higher risk of acute infections during their initial hospital stay compared to those without these conditions. Hu et al., (2020) provided a comprehensive overview of comorbidities associated with infection risk in open fractures, including hypertension, cardiovascular and cerebrovascular diseases, chronic respiratory diseases, liver and kidney diseases, and immune system disorders. The diverse range of conditions demonstrate the broad spectrum of factors that can compromise the body’s ability to combat infection.

5.3.2 Fracture Related Factors

A statistically significant association between the timing of initial surgical debridement and the incidence of infection in patients with open long bone fractures was observed. The infection rate increased progressively with delays in debridement: no infections occurred in patients treated within 6 hours, whereas rates rose to 15.6% for debridement performed between 6 and 12 hours, 25.2% for debridement between 12 and 24 hours, 59.7% for debridement between 24 and 48 hours, and 72.4% for debridement beyond 48 hours. These findings strongly support the principle of early debridement in the management of open fractures to mitigate infection risks. The observed trends concur with the findings of Matos et al. (2015), who reported a significant correlation between infection rates and the duration of exposure of the open fracture prior to surgical intervention. In their study, patients who developed infections had a mean exposure time of 30.3 hours (±19.5), while those without infections had a significantly shorter exposure time of 21.4 hours (±12.1). Similarly, Malhotra et al., (2014) emphasized the significance of timely surgical intervention, particularly in lower extremity fractures. Delays exceeding 8 hours to the first surgical debridement procedure were associated with increased infection rates.

In contrast, other studies have not consistently demonstrated a significant relationship between timing and infection rates. Khatod et al., (2003) did not find a statistically significant difference in the elapsed time to initial debridement between infected and non-infected cases across various fracture types. Similarly, Li et al., (2020), Tornetta et al., (2020), and Singh et al., (2023) observed no significant association between the timing of initial surgical debridement and the occurrence of infections. These findings challenge the notion of a universally

critical window for debridement and suggest that other factors, such as fracture severity, contamination level, and perioperative care protocols, may play significant roles in determining infection outcomes. The discrepancies between studies could be attributed to variations in study design, patient populations, and healthcare system capabilities. For instance, resource-limited settings may face logistical challenges that extend the time to surgical intervention, making it difficult to isolate the impact of timing from other confounding factors, such as delayed antibiotic administration or inadequate follow-up care. Furthermore, differences in injury mechanisms, contamination levels, and antibiotic Early debridement likely reduces the bacterial load at the injury site, prevents biofilm formation, and optimizes the local wound environment for healing.

The study demonstrated a significant correlation between the severity of open fractures, as classified by the Gustilo-Anderson system, and the incidence of infections. The findings concur with a study conducted by Zalavras, (2017) who reported infection rates of up to 2% in type I fractures and 10% in type II fractures, with type III fractures exhibiting rates as high as 50%. This consistency shows the role of fracture severity in determining the likelihood of infection. Gustilo and Anderson, (1976), in their foundational classification, noted similar trends, with type III fractures having substantially higher infection rates compared to types I and II. Their study found infection rates of 52% for type IIIB fractures and 42% for type IIIC fractures, while type IIIA fractures had a significantly lower rate of 4%. The high infection rates observed in type III fractures are consistent with findings by Thakore et al., (2017), who reported a 62% infection rate for type IIIC fractures, 30% for type IIIB, and 14% for type IIIA. The high infection rates in these cases likely stem from extensive soft tissue damage, significant contamination, and the

complexity of surgical intervention required, including repeated surgical debridement and potential use of reconstructive techniques.

The overall trend of increasing infection rates with fracture severity was also observed in a multicenter analysis by Hu et al., (2020), which reported infection rates of 6.6% for type I fractures, 13.1% for type II, and 38.4% for type III. These findings closely align with the results of this study, further demonstrating the role of fracture severity as a determinant of infection risk. The observed infection rates for type I and type II fractures in this study (22.9% and 23.9%, respectively) are higher than those reported in many other studies. For example, Gustilo and Anderson, (1976) reported infection rates of 2% for type I and 2.4% for type II fractures, while Zalavras, (2017) reported rates of up to 2% and 10%, respectively. This disparity could be attributed to differences in patient populations, healthcare infrastructure, and adherence to infection control protocols. In resource-constrained settings, delays in accessing care may contribute to higher infection rates. The findings of this study show the need for early and aggressive management of open fractures, particularly those classified as type III.

There was also a statistically significant association between the method of immobilization and the incidence of infection in open long bone fractures ($p = 0.016$). The results showed that external fixation was the most commonly associated method of immobilization in patients who developed infections. The high rate of infections among patients treated with external fixation concur with the findings of Khatod et al., (2003), who reported that 64% of infected cases had undergone external fixation, compared to lower rates in those managed with casting (4%), plate-and-screw fixation (16%), or intramedullary fixation (16%).

Similarly, Saiz et al., (2022) noted that patients with infections were nearly three times more likely to have been treated with external fixation, emphasizing the potential vulnerability associated with this method. External fixation, while often the preferred choice for severe open fractures due to its ability to stabilize fractures while accommodating wound management, may increase infection risk due to the presence of pins traversing the skin and soft tissues, creating potential entry points for pathogens.

Contrasting these findings, Matos et al., (2015) reported no significant association between the method of immobilization and the risk of infection, while Kortram et al., (2017) found comparable infection rates between internal fixation (20.7%) and external fixation (23.6%). These discrepancies may reflect differences in fracture severity. More severe fractures requiring external fixation are inherently at greater risk for infection due to extensive soft tissue damage and contamination, rather than the fixation method itself being the primary determinant of infection risk. In this study, casting was associated with the lowest proportion of infections (28.6%). While casting is typically reserved for less severe fractures, its limited use in complex cases may explain the relatively lower infection rates.

5.3.3 Health Care Related Factors

The timing of antibiotic prophylaxis plays an important role in mitigating the risk of infection following open long bone fractures, as demonstrated by the findings of this study. Patients were categorized into five groups based on the timing of antibiotic administration after injury: less than 3 hours, 3–6 hours, 6–12 hours, 12–24 hours, and more than 24 hours. A clear trend emerged, with infection rates increasing significantly as the delay in antibiotic administration extended beyond 3 hours. The lowest infection rate was observed among patients who received

antibiotics within 3 hours (20.0%), and the rate escalated to 70.4% among those who received antibiotics more than 24 hours post-injury. These findings align with earlier studies, such as Suzuki et al., (2023), which emphasize that antibiotics should be administered as early as possible, ideally within 3 hours of injury, to minimize infection risks. Similarly, the classic study by Patzakis and Wilkins, (1989) demonstrated a significantly lower infection rate (4.7%) when antibiotics were administered within 3 hours of injury, compared to a rate of 7.4% when antibiotics were delayed beyond 3 hours. The adverse impact of delayed antibiotic administration observed in this study are also consistent with findings by Penn-Barwell et al., (2012), who noted a significant increase in infection rates when antibiotics were delayed to either 6- to 24-hours post-injury. These studies collectively demonstrate the protective effect of early antibiotic administration in preventing perioperative infections in open fractures. Conversely, some studies, such as Al-Arabi et al., (2007), did not find a statistically significant association between the timing of antibiotic administration and infection rates.

The progressive increase in infection rates observed in this study as the delay in antibiotic administration extended beyond 6 hours shows the cumulative risk of bacterial colonization and subsequent infection. The findings suggest that while early antibiotic prophylaxis is important, every hour of delay significantly exacerbates the risk of infection. These results therefore, emphasize the need for streamlined protocols in the management of open fractures, emphasizing rapid initiation of antibiotic prophylaxis.

The timing of wound closure following surgical debridement has long been debated in the management of open fractures. This study showed a significant

association between early wound closure and reduced infection rates. Patients whose wounds were closed at the time of debridement had an infection rate of 27.8%, whereas those who underwent delayed wound closure experienced a significantly higher infection rate of 80.9% ($p < 0.001$). These results strongly support the benefits of immediate wound closure in minimizing the risk of infection in open long bone fractures. The results are consistent with Davis et al., (2015), who reported a significant reduction in infectious complications with a single-stage approach to fixation and wound closure. Their study found that only 4.2% of patients in the single-stage group developed infections, compared to 34.6% in the group that underwent separate procedures for fixation and wound closure. In contrast, historical evidence, such as the work of Russel et al., (1990), suggested that delayed wound closure might result in lower infection rates. A systematic review by Kortram et al., (2017) found no significant difference between immediate and delayed wound closure in terms of infection rates. Such conflicting results may be due to the influence of patient-specific factors, fracture characteristics, and surgeon expertise on outcomes.

In this study, neither the surgeon's experience nor the duration of surgical debridement was significant predictors of infection. Cases managed by consultant orthopaedic surgeons demonstrated an infection rate of 35.7%, compared to 38.3% for those managed by residents, with no statistically significant difference ($p = 0.98$). Similarly, the mean duration of surgical debridement, which was 103 ± 38.5 minutes for the non-infection group and 105 ± 30.1 minutes for the infection group, did not emerge as a significant predictor of infection ($p = 0.68$). This concurs with previous observations by Hu et al., (2020), who emphasized that a synergistic,

well-coordinated surgical team can offset the potential impact of prolonged operative times and variable experience levels.

However, the results differ from several studies that demonstrated the impact of prolonged surgical duration on infection risk. Hu et al., (2020) found that procedures lasting longer than 122 minutes increased the risk of infection by 2.52 times compared to shorter procedures. Similarly, Colman et al., (2013) observed that every additional hour of operative time beyond a certain threshold increased the infection risk by 78%. Ovaska et al., (2013) further noted that surgeries exceeding 90 minutes were independently associated with a heightened risk of infection. Sun et al., (2023) demonstrated that operations lasting over 150 minutes were linked to significantly higher infection rates, with 54.55% of infected cases undergoing longer procedures compared to 17.65% in the uninfected cohort. The lack of significant differences in our study might reflect the implementation of standardized protocols that ensure consistent quality of care, regardless of the surgeon's experience level.

5.4 Patterns of prophylactic antibiotic use in patients with open long bone fracture

In this study, cefazolin monotherapy emerged as the most common parenteral regimen. These findings are consistent with the recommendations by Anderson et al., (2011), who suggest using a first-generation cephalosporin (e.g., cefazolin) for Type I and II open fractures and adding an aminoglycoside for Type III fractures. However, these guidelines recommend limiting antibiotic use to 24 hours after wound closure for Type I and II fractures and 48–72 hours for Type III fractures, significantly shorter than the mean prophylaxis duration in this study, which was 13.6 ± 4.6 days. The duration of antibiotics is longer than that reported by Declercq

et al., (2021), who reported a median antibiotic prophylaxis duration of 4.3 days, with a significant proportion of cases extending beyond 72 hours. The international consensus guidelines, as referenced by Messner et al., (2017), strongly discourage extending prophylaxis beyond 72 hours due to the lack of evidence for added protection against infections and the risk of adverse effects such as antimicrobial resistance. Obremskey et al., (2020) also reported that prolonged antibiotic regimens beyond 72 hours offered no additional benefit in reducing septic complications.

Studies from East Africa also report longer durations of antibiotic prophylaxis, likely influenced by differences in healthcare infrastructure, local bacterial resistance patterns, and the prevalence of severe fractures. Kigera and Shamim, (2012) reported an average antibiotic duration of 7.3 days in Uganda, while Macharia, (2020) noted durations of four to five days in 54% of cases at Kenyatta National Hospital. These durations remain shorter than those observed in this study but reflect regional variability in practices. The prolonged duration of antibiotic prophylaxis in this study may be attributed to concerns about high infection risks, the severity of injuries, and delays in wound closure. However, extending prophylaxis beyond internationally recommended durations raises concerns about potential antimicrobial resistance and adverse effects.

CHAPTER SIX: CONCLUSION AND RECOMMENDATIONS

6.0 Introduction

This chapter cover the conclusions and recommendation of the study.

6.1 Conclusion

1. The majority of patients were male with a mean age of 36.9 years. The leading cause of injury was road traffic accidents. Most fractures affected the lower extremities, particularly the tibia and fibula, with comminuted fractures being the most common.
2. The overall infection rate was 38.2%, with *Staphylococcus aureus* as the predominant pathogen.
3. Infection rates were higher in severe fractures and cases with delayed intervention. Independent predictors of infection included delayed surgical debridement, delayed antibiotic administration, severity of the fractures, smoking, diabetes, external fixation, and delayed wound closure.
4. Cefazolin was the most commonly used prophylactic antibiotic, often combined with gentamicin or metronidazole, with an average duration of 13.6 days.

6.2 Recommendations

1. Infection prevention strategies (preoperative measures: early administration of broad-spectrum antibiotics and adequate initial wound care; intraoperative measures: prompt and thorough surgical debridement, copious irrigation, strict aseptic technique, and appropriate fracture stabilization; postoperative measures: continued appropriate antibiotic therapy, regular wound inspection and dressing changes, early soft-tissue coverage, and close monitoring for signs of infection) should be strengthened to address the high infection rate (38.2%) among patients with open fractures.
2. Early surgical debridement within 24 hours of injury should be emphasized, as delays beyond 48 hours are associated with significantly higher infection rates. Wound closure should be performed at the earliest appropriate stage to minimize infection risk.
3. Prophylactic antibiotic administration should adhere to standardized protocol, with Grade I and II fractures receiving prophylactic antibiotics for no more than 24 hours and Grade III for 48–72 hours, but not beyond 24 hours after wound closure to prevent antibiotic resistance and unnecessary healthcare costs.
4. Given that road traffic accidents were the leading cause of open long-bone fractures, public health initiatives should strengthen road safety measures and focus education on high-risk groups such as motorcyclists and pedestrians to reduce the incidence of these injuries.

REFERENCES

Abang, I. E., Asuquo, J. E., Anisi, C. O., Mpama, E. A., Onuba, O. O., Udosen, A. M., Ngim, N. E., & Ikpeme, I. A. (2018). Early Outcome of Treatment of Open Tibial Shaft Fractures Using External Fixators in Resource-Poor Setting. *Recent Advances in Biology and Medicine*, *04*(January), 1.

Al-Arabi, Y. B., Nader, M., Hamidian-Jahromi, A. R., & Woods, D. A. (2007). The effect of the timing of antibiotics and surgical treatment on infection rates in open long-bone fractures: A 9-year prospective study from a district general hospital. *Injury*, *38*(8), 900–905.

Alhawas, A., & Alghamdi, M. (2023). Epidemiology, Etiology, Timing and Severity of Open Fracture-a Five Years Review From a Tertiary Trauma Center, Eastern Province, Saudi Arabia. *Medical Archives*, *77*(5), 391–395.

Almigdad, A., Mustafa, A., Alazaydeh, S., Alshawish, M., Bani Mustafa, M., & Alfukaha, H. (2022). Bone Fracture Patterns and Distributions according to Trauma Energy. *Advances in Orthopedics*, *2022*.

Anderson, A., Miller, A. D., & Brandon Bookstaver, P. (2011). Antimicrobial prophylaxis in open lower extremity fractures. *Open Access Emergency Medicine*, *3*, 7–11.

Atwan, Y., Miclau, T., Schemitsch, E. H., & Teague, D. (2020). Antibiotic utilization in open fractures. *OTA International: The Open Access Journal of Orthopaedic Trauma*, *3*(1), e071.

Ayumba, B. R., Lelei, L. K., Emarah, A. M., & Lagat, D. J. (2015). Management of Patients with Post- Traumatic Exposed Bones at Moi Teaching and Referral Hospital, Eldoret, Kenya. *East African Orthopaedic Journal*, *9*(1), 21–26.

Barrett, K. E., Barman, S. M., Brooks, H. L., & Yuan, J. (2019). *Chapter 27: Hormonal Control of Calcium & Phosphate Metabolism & the Physiology of Bone. Ganong's Review of Medical Physiology* (26th ed.). McGraw-Hill Education.

Bergh, C., Wennergren, D., Möller, M., & Brisby, H. (2021). Fracture incidence in adults in relation to age and gender: A study of 27,169 fractures in the Swedish Fracture Register in a well-defined catchment area. *PLoS ONE*, *15*(12 December), 1–18.

Betts, J. G. C., Desaix, P., Johnson, E., Johnson, J. E., Korol, O., Kruse, D., Poe, B., Wise, J. A., Womble, M., & Young, K. A. (2017). *Chapter 6: Bone Tissue and the Skeletal System. Anatomy and physiology*. OpenStax, Rice University.

Bezstarosti, H., Van Lieshout, E. M. M., Voskamp, L. W., Kortram, K., Obremskey, W., McNally, M. A., Metsemakers, W. J., & Verhofstad, M. H. J. (2019). Insights into treatment and outcome of fracture-related infection: a systematic literature review. *Archives of Orthopaedic and Trauma Surgery*, *139*(1), 61–72.

Bhandari, M. (2010). Fluid lavage of open wounds (FLOW): Design and rationale for a large, multicenter collaborative 2 × 3 factorial trial of irrigating pressures and solutions in patients with open fractures. *BMC Musculoskeletal Disorders*, *11*, 1–14.

Borchardt, R. A., & Tzizik, D. (2018). Update on surgical site infections: The new CDC guidelines. *Journal of the American Academy of Physician Assistants*, *31*(4), 52–54.

Botchey, I. M., Hung, Y. W., Bachani, A. M., Saidi, H., Paruk, F., & Hyder, A. A. (2017). Understanding patterns of injury in Kenya: Analysis of a trauma registry data from a National Referral Hospital. *Surgery (United States)*, *162*(6), S54–S62.

Buckley, R. E., Moran, C. G., & Apivatthakakul, T. (2017). AO Principles of Fracture Management. 3rd edition. In *Thieme*.

Buteera, A. M., & Byimana, J. (2009). Principles of management of open fractures. *East and Central African Journal of Surgery*, *14*(2), 2–8.

Carver, D. C., Kuehn, S. B., & Weinlein, J. C. (2017). Role of Systemic and Local Antibiotics in the Treatment of Open Fractures. *Orthopedic Clinics of North America*, *48*(2), 137–153.

CDC. (2023). Surgical Site Infection Event (SSI) Introduction. *National Healthcare Safety Network*, *January*, 1–39.

CDC, & NHSN. (2014). CDC / NHSN Surveillance Definitions for Specific Types of Infections. *Surveillance Definitions*, *2015*(January), 1–24.

Chang, Y., Bhandari, M., Zhu, K. L., Mirza, R. D., Ren, M., Kennedy, S. A., Negm, A., Bhatnagar, N., Naji, F. N., Milovanovic, L., Fei, Y., Agarwal, A., Kamran, R., Cho, S. M., Schandelmaier, S., Wang, L., Jin, L., Hu, S., Zhao, Y., … Guyatt, G. H. (2019). Antibiotic Prophylaxis in the Management of Open Fractures. *JBJS Reviews*, *7*(2).

Charalambous, C. P., Siddique, I., Zenios, M., Roberts, S., Samarji, R., Paul, A., & Hirst, P. (2005). Early versus delayed surgical treatment of open tibial fractures: Effect on the rates of infection and need of secondary surgical procedures to promote bone union. *Injury*, *36*(5), 656–661.

Cohen, H., Kugel, C., May, H., Medlej, B., Stein, D., Slon, V., Hershkovitz, I., & Brosh, T. (2016). The impact velocity and bone fracture pattern: Forensic perspective. *Forensic Science International*, *266*, 54–62.

Colman, M., Wright, A., Gruen, G., Siska, P., Pape, H. C., & Tarkin, I. (2013). Prolonged operative time increases infection rate in tibial plateau fractures. *Injury*, *44*(2), 249–252.

Coombs, J., Billow, D., Cereijo, C., Patterson, B., & Pinney, S. (2022). Current Concept Review: Risk Factors for Infection Following Open Fractures. *Orthopedic Research and Reviews*, *14*(November), 383–391.

Copanitsanou, P., Kechagias, V. A., Grivas, T. B., & Wilson, P. (2018). Use of ASEPSIS scoring method for the assessment of surgical wound infections in a Greek orthopaedic department. *International Journal of Orthopaedic and Trauma Nursing*, *30*, 3–7.

Costa, F. C. D., Reis, J. M. D., Reis, S. P. D., Bartelega, L. A., Melo, N. F. D., & Araújo, C. D. M. (2022). Epidemiology of Open Fractures and Degree of Satisfaction of Initial Care. *Acta Ortopedica Brasileira*, *30*(4), 1–5.

Court-Brown, C. ., Rimmer, S., Prakash, U., & McQueen, M. M. (1998). Sensitivity patterns of bacteria isolated from patients at Sidamo Regional Hospital. *Injury*, *27*(7), 529–534.

Court-Brown, C. M., Bugler, K. E., Clement, N. D., Duckworth, A. D., & McQueen, M. M. (2012). The epidemiology of open fractures in adults. A 15-year review. *Injury*, *43*(6), 891–897.

Croes, M., van der Wal, B. C. H., & Vogely, H. C. (2019). Impact of Bacterial Infections on Osteogenesis: Evidence From In Vivo Studies. *Journal of Orthopaedic Research*, *37*(10), 2067–2076.

Cross III, W. W., & Swiontkowski, M. F. (2008). Treatment principles in the management of open fractures. *Indian J Orthop*, *42*(4), 377–386.

Davis, M. L., Della Rocca, G. J., Brenner, M., Cribari, C., Cryer, G., Ficke, J. R., Hartsock, L., Henley, M. B., Henry, P. D. G., Jenkins, D. H., Klein, J., Kozar, R., Nathens, A. B., Olson, S. A., Wandling, M., Wiggins-Dohlvik, K., Wolinsky, P., & Ziran, B. H. (2015). Best practices in the management of traumatic. *World Journal of Emergency Surgery*, *14*(1), 1–9.

Dellinger, P. E., Caplan, E. S., Weaver, L. D., Wertz, M. J., Droppert, B. M., Hoyt, N., Brumback, R., Burgess, A., Poka, A., Benirschke, S. K., Lennard, S. E., & Lou, S. M. A. (1988). *Duration of Preventive Antibiotic Administration for Open Extremity Fractures From the Departments of Surgery (PATIENTS AND METHODS Patients were enrolled at three centers (Harborview Medical*. *123*(1), 333–339.

Depypere, M., Morgenstern, M., Kuehl, R., Senneville, E., Moriarty, T. F., Obremskey, W. T., Zimmerli, W., Trampuz, A., Lagrou, K., & Metsemakers, W. J. (2020). Pathogenesis and management of fracture-related infection. *Clinical Microbiology and Infection*, *26*(5), 572–578.

Enninghorst, N., McDougall, D., Hunt, J. J., & Balogh, Z. J. (2011). Open tibia fractures: Timely debridement leaves injury severity as the only determinant of poor outcome. *Journal of Trauma - Injury, Infection and Critical Care*, *70*(2), 352–357.

Enweluzo, G. ., Adekoya–Cole, T. ., Mofikoya, B. ., Giwa, S. ., & Badmus, O. O. (2015). Morbidity of Open Tibia Fractures in Lagos, Nigeria. *East and Central African Journal of Surgery.*, *20*(2), 37–43.

Fernandes, M. de C., Peres, L. R., de Queiroz Neto, A. C., Lima Neto, J. Q., Turíbio, F. M., & Matsumoto, M. H. (2015). Open fractures and the incidence of infection in the surgical debridement 6 hours after trauma. *Acta Ortopedica Brasileira*, *23*(1), 38–42.

Foote, C. J., Tornetta, P., Reito, A., Al-Hourani, K., Schenker, M., Bosse, M., Coles, C. P., Bozzo, A., Furey, A., & Leighton, R. (2021). A Reevaluation of the Risk of Infection Based on Time to Debridement in Open Fractures: Results of the GOLIATH Meta-Analysis of Observational Studies and Limited Trial Data. *The Journal of Bone and Joint Surgery. American Volume*, *103*(3), 265–273.

Geurts, J., Hohnen, A., Vranken, T., & Moh, P. (2017). Treatment strategies for chronic osteomyelitis in low- and middle-income countries: systematic review. *Tropical Medicine and International Health*, *22*(9), 1054–1062.

Glaudemans, A. W. J. M., Bosch, P., Slart, R. H. J. A., IJpma, F. F. A., & Govaert, G. A. M. (2019). Diagnosing fracture-related infections: can we optimize our nuclear imaging techniques? *European Journal of Nuclear Medicine and Molecular Imaging*, *46*(8), 1583–1587.

Govaert, G. A. M., Glaudemans, A. W. J. M., Ploegmakers, J. J. W., Viddeleer, A. R., Wendt, K. W., & Reininga, I. H. F. (2018). Diagnostic strategies for posttraumatic osteomyelitis: a survey amongst Dutch medical specialists demonstrates the need for a consensus protocol. *European Journal of Trauma and Emergency Surgery*, *44*(3), 417–426.

Govaert, G. A. M., Kuehl, R., Atkins, B. L., Trampuz, A., Morgenstern, M., Obremskey, W. T., Verhofstad, M. H. J., McNally, M. A., & Metsemakers, W. J. (2020). Diagnosing Fracture-Related Infection: Current Concepts and Recommendations. *Journal of Orthopaedic Trauma*, *34*(1), 8–17.

Graan, D., & Balogh, Z. J. (2022). Microbiology of fracture related infections. *Journal of Orthopaedic Surgery*, *30*(3), 1–11.

Griffin, M., Malahias, M., Khan, W., & Hindocha, S. (2012). Update on the Management of Open Lower Limb Fractures. *The Open Orthopaedics Journal*, *6*(1), 571–577.

Guerra, M. T. E., Gregio, F. M., Bernardi, A., & Castro, C. C. de. (2017). Infection rate in adult patients with open fractures treated at the emergency hospital and at the ULBRA university hospital in Canoas, Rio Grande do Sul, Brazil. *Revista Brasileira de Ortopedia (English Edition)*, *52*(5), 544–548.

Gustilo, R. ., & Anderson, J. . (1976). Prevention of infection in the treatment of one thousand and twenty-five open fractures of long bones. retrospective and prospective analyses. *J Bone Joint Surg Am*, *58*(4), 453–458.

Hailu, S., & Mengesha, M. G. (2020). *Prevalence of Delayed Presentation of Open Long Bone Frac- Ture Prevalence of Delayed Presentation of Open Long Bone Frac-*. *58*(January 2021), 200–204.

Henriksen, N. A., Meyhoff, C. S., Wetterslev, J., Wille-Jørgensen, P., Rasmussen, L. S., & Jorgensen, L. N. (2010). Clinical relevance of surgical site infection as defined by the criteria of the Centers for Disease Control and Prevention. *Journal of Hospital Infection*, *75*(3), 173–177.

Herman, T. F., & Bordoni, B. (2022). Wound Classification. *StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing*. https://pubmed.ncbi.nlm.nih.gov/32119343/

Hoff, W. S., Bonadies, J. A., Cachecho, R., & Dorlac, W. C. (2011). East practice management guidelines work group: Update to practice management guidelines for prophylactic antibiotic use in open fractures. *Journal of Trauma - Injury, Infection and Critical Care*, *70*(3), 751–754.

Hu, Q., Zhao, Y., Sun, B., Qi, W., & Shi, P. (2020). Surgical site infection following operative treatment of open fracture: Incidence and prognostic risk factors. *International Wound Journal*, *17*(3), 708–715.

Hull, P. D., Johnson, S. C., Stephen, D. J. G., Kreder, H. J., & Jenkinson, R. J. (2014). Delayed debridement of severe open fractures is associated with a higher rate of deep infection. *The Bone & Joint Journal*, *96-B*(3), 379–384.

Hulley, S. B., Cummings, S. R., Browner, W. S., Grady, D. G., & Newman, T. B. (2013). Designing Clinical Research. In *Replication and Evidence Factors in Observational Studies* (14th ed.). Lippincott Williams & Wilkins.

Ibrahim, D. A., Swenson, A., Sassoon, A., & Fernando, N. D. (2017). Classifications In Brief: The Tscherne Classification of Soft Tissue Injury. *Clinical Orthopaedics and Related Research*, *475*(2), 560–564.

Isaac, S. M., Woods, A., Danial, I. N., & Mourkus, H. (2016). Antibiotic Prophylaxis in Adults With Open Tibial Fractures: What Is the Evidence for Duration of Administration? A Systematic Review. *Journal of Foot and Ankle Surgery*, *55*(1), 146–150.

Islam, M. S., Islam, S. S., Parvin, S., Manjur, M., Islam, M. R., Halder, R. C., Islam, M. S., Rahaman, S. K., Hoque, M., Faruque, M. O., & Haque, A. K. M. N. (2022). Current pathogens infecting open fracture tibia and their antibiotic susceptibility at a tertiary care teaching hospital in South East Asia. *Infection Prevention in Practice*, *4*(1), 100205.

Kalande, F. M. (2018). Treatment outcomes of open femoral fractures at a county Hospital in Nakuru, Kenya. *East African Orthopaedic Journal*, *12*(2), 52–55.

Kang, H. J., Kwon, Y. M., Byeon, S. J., Kim, H. N., Sung, I. H., Subramanian, S. A., & Kim, S. J. (2023). Trends and Risk Factors for Surgical Site Infection after Treatment of the Ankle Fracture: National Cohort Study. *Journal of Clinical Medicine*, *12*(13).

Khatod, M., Botte, M. J., Hoyt, D. B., Meyer, R. S., Smith, J. M., & Akeson, W. H. (2003). Outcomes in open tibia fractures: Relationship between delay in treatment and infection. *Journal of Trauma*, *55*(5), 949–954. =

Kigera, J., & Shamim, M. (2012). Antibiotic Prescription Patterns in the Management of Open Fracutres at Mulago Hospital in Kampala. *East and Central African Journal of Surgery*, *17*(1), 47–50.

Kirkwood, B. R., & Sterne, J. A. C. (2003). *Essential Medical Statistics* (2nd ed.). Blackwell Science.

Kironde, E., Sekimpi, P., Kajja, I., & Mubiri, P. (2019). Prevalence and patterns of traumatic bone loss following open long bone fractures at Mulago Hospital. *OTA International: The Open Access Journal of Orthopaedic Trauma*, *2*(1), e015.

Kisorio, J. (2023). *Standard Operating Procedure For Adult Antibiotic Prophylaxis in Orthoperdic Surgery, Moi Teaching and Referral Hospital.* (MTRH/SOP/SURG/ORTHO/AAP/003).

Kombate, N. K., Walla, A., Akloa, K., Amakoutou, K., Bakriga, B., Ayouba, G., Dellanh, Y. Y., Abalo, A., & Dossim, A. M. (2017). Epidemiology of Open Limb Fractures in a Country with Low-Income. *Open Journal of Orthopedics*, *07*(11), 356–361.

Kortram, K., Bezstarosti, H., Metsemakers, W. J., Raschke, M. J., Van Lieshout, E. M. M., & Verhofstad, M. H. J. (2017). Risk factors for infectious complications after open fractures; a systematic review and meta-analysis. *International Orthopaedics*, *41*(10), 1965–1982.

Kouassi, K. J. E., Manon, J., Fonkoue, L., Detrembleur, C., & Cornu, O. (2021). Treatment of open tibia fractures in Sub-Saharan African countries: a systematic review. *Acta Orthopaedica Belgica*, *87*(1), 85–92.

Lack, W. D., Karunakar, M. A., Angerame, M. R., Seymour, R. B., Sims, S., Kellam, J. F., & Bosse, M. J. (2015). Type III Open Tibia Fractures: Immediate Antibiotic Prophylaxis Minimizes Infection. *Journal of Orthopaedic Trauma*, *29*(1), 1–6.

Lasanianos, N. G., Kanakaris, N. K., & Giannoudis, P. V. (2015). Open fractures. In P. V. Giannoudis, N. G. Lasanianos, & N. K. Kanakaris (Eds.), *Trauma and orthopaedic classifications* (pp. 487–493). Springer.

Latha, T., Anil, B., Manjunatha, H., Chiranjay, M., Elsa, D., Baby, N., & Anice, G. (2019). MRSA: The leading pathogen of orthopedic infection in a tertiary care hospital, South India. *African Health Sciences*, *19*(1), 1393–1401.

Li, J., Wang, Q., Lu, Y., Feng, Q., He, X., Li, MD, Z., & Zhang, K. (2020). Relationship Between Time to Surgical Debridement and the Incidence of Infection in Patients with Open Tibial Fractures. *Orthopaedic Surgery*, *February*, 1–9.

Lingaraj, R., Santoshi, J. A., Devi, S., Najimudeen, S., Gnanadoss, J., Kanagasabai, R., & Kanungo, R. (2015). Predebridement wound culture in open fractures does not predict postoperative wound infection: A pilot study. *Journal of Natural Science, Biology and Medicine*, *6*, S63–S68.

Macharia, J. T. (2020). Determination of Bacterial Isolate Profiles, their Antimicrobial Susceptibility Patterns and Trends of Antibiotic Use In Patients with Open Fractures Submitted in partial fulfillment of the requirements for Master of Medicine Degree in Orthopedic Surgery. In *Thesis dessertation*. Univertsity of Nairobi.

Malhotra, A. K., Goldberg, S., Graham, J., Malhotra, N. R., Willis, M. C., Mounasamy, V., Guilford, K., Duane, T. M., Aboutanos, M. B., Mayglothling, J., & Ivatury, R. R. (2014). Open extremity fractures: Impact of delay in operative debridement and irrigation. *Journal of Trauma and Acute Care Surgery*, *76*(5), 1201–1207.

Matos, M. A., Lima, L. G., & de Oliveira, L. A. A. (2015). Predisposing factors for early infection in patients with open fractures and proposal for a risk score. *Journal of Orthopaedics and Traumatology*, *16*(3), 195–201.

Melvin, S. J., Dombroski, D. G., Torbert, J. T., Kovach, S. J., Esterhai, J. L., & Mehta, S. (2010). Open tibial shaft fractures: I. Evaluation and initial wound management. *Journal of the American Academy of Orthopaedic Surgeons*, *18*(1), 10–19.

Messner, J., Papakostidis, C., Giannoudis, P. V., & Kanakaris, N. K. (2017). Duration of Administration of Antibiotic Agents for Open Fractures: Meta-Analysis of the Existing Evidence. *Surgical Infections*, *18*(8), 854–867.

Metsemakers, W. J., Morgenstern, M., McNally, M. A., Moriarty, T. F., McFadyen, I., Scarborough, M., Athanasou, N. A., Ochsner, P. E., Kuehl, R., Raschke, M., Borens, O., Xie, Z., Velkes, S., Hungerer, S., Kates, S. L., Zalavras, C., Giannoudis, P. V., Richards, R. G., & Verhofstad, M. H. J. (2018). Fracture-related infection: A consensus on definition from an international expert group. *Injury*, *49*(3), 505–510.

Metsemakers, W. J., Morgenstern, M., Senneville, E., Borens, O., Govaert, G. A. M., Onsea, J., Depypere, M., Richards, R. G., Trampuz, A., Verhofstad, M. H. J., Kates, S. L., Raschke, M., McNally, M. A., Obremskey, W. T., Metsemakers, W. J., Obremskey, W. T., McNally, M. A., Athanasou, N., Atkins, B. L., … Zimmerli, W. (2020). General treatment principles for fracture-related infection: recommendations from an international expert group. *Archives of Orthopaedic and Trauma Surgery*, *140*(8), 1013–1027.

Metsemakers, W. J., Onsea, J., Neutjens, E., Steffens, E., Schuermans, A., McNally, M., & Nijs, S. (2017). Prevention of fracture-related infection: a multidisciplinary care package. *International Orthopaedics*, *41*(12), 2457–2469.

Morgenstern, M., Kühl, R., Eckardt, H., Acklin, Y., Stanic, B., Garcia, M., Baumhoer, D., & Metsemakers, W. J. (2018). Diagnostic challenges and future perspectives in fracture-related infection. *Injury*, *49*(June), S83–S90.

Mundi, R., Chaudhry, H., Niroopan, G., Petrisor, B., & Bhandari, M. (2015). Open Tibial Fractures: Updated Guidelines for Management. *JBJS Reviews*, *3*(2), 1–7.

Nana, T. C., Pius, F., Martin, N. M., Mbongnu, M., Movuh, D. S., Bombah, M. F., Henry, N., Ngunde, J. P., & Chichom-Mefire, A. (2021). Epidemiological and Clinical Pattern of Open Fractures of Long Bones of the Lower Limbs in the South-West Region of Cameroon: A 5-Year Review. *Open Journal of Orthopedics*, *11*(09), 278–287.

Nanchahal, J., Nayagam, S., Khan, U., Moran, C., Barrett, S., Sanderson, F., & Pallister, I. (2009). Standard for the management of open fractures of the lower limb. *British Orthopaedic Association and British Association of Plastic Reconsructive and Aesthetic Surgeons*, 8–24.

Nåsell, H., Ottosson, C., Törnqvist, H., Lindé, J., & Ponzer, S. (2011). The impact of smoking on complications after operatively treated ankle fractures-a follow-up study of 906 patients. *Journal of Orthopaedic Trauma*, *25*(12), 748–755.

Nicolaides, M., Vris, A., Heidari, N., Bates, P., & Pafitanis, G. (2021). The effect of delayed surgical debridement in the management of open tibial fractures: A systematic review and meta-analysis. *Diagnostics*, *11*(6), 1–16.

Nyamosi, I. R. (2019). *Outcomes of Open Long Bone Fractures in Patients Treated With External Fixators At Moi Teaching and Referral Hospital , Eldoret , Kenya*. Mmed Thesis. Moi University.

Obremskey, W. T., Metsemakers, W.-J., Schlatterer, D. R., Tetsworth, K., Egol, K., Kates, S., & McNally, M. (2020). Musculoskeletal Infection in Orthopaedic Trauma. *Journal of Bone and Joint Surgery*, *102*(10), e44.

Odatuwa-Omagbemi, D. O. (2019). Open fractures: Epidemiological pattern, initial management and challenges in a sub-urban teaching hospital in Nigeria. *Pan African Medical Journal*, *33*, 1–8.

Olesen, U. K., Pedersen, N. J., Eckardt, H., Lykke-Meyer, L., Bonde, C. T., Singh, U. M., & McNally, M. (2017). The cost of infection in severe open tibial fractures treated with a free flap. *International Orthopaedics*, *41*(5), 1049–1055.

Olsen, L. L., Møller, A. M., Brorson, S., Hasselager, R. B., & Sort, R. (2017). The impact of lifestyle risk factors on the rate of infection after surgery for a fracture of the ankle. *Bone and Joint Journal*, *99-B*(2), 225–230.

Ondari, J. N., Masika, M. M., Ombachi, R. B., & Ating'a, J. E. (2016). Unblinded randomized control trial on prophylactic antibiotic use in gustilo II open tibia fractures at Kenyatta National Hospital, Kenya. *Injury*, *47*(10), 2288–2293.

Ovaska, M. T., Makinen, T. J., Madanat, R., Huotari, K., Vahlberg, T., Hirvensalo, E., & Lindahl, J. (2013). Risk factors for deep surgical. *Journal of Bone and Joint Surgery - Series A*, 348–353.

Patzakis, M. J., & Wilkins, J. (1989). Factors influencing infection rate in open fracture wounds. *Clinical Orthopaedics and Related Research*, *243*, 36–40.

Peduzzi, P., Concato, J., Kemper, E., Holford, T. R., & Feinstein, A. R. (1996). A simulation study of the number of events per variable in logistic regression analysis. *Journal of Clinical Epidemiology*, *49*(12), 1372–1378.

Penn-Barwell, J. G., Murray, C. K., & Wenke, J. C. (2012). Early antibiotics and debridement independently reduce infection in an open fracture model. *Journal of Bone and Joint Surgery - Series B*, *94 B*(1), 107–112.

Roddy, E., Patterson, J. T., & Kandemir, U. (2020). Delay of Antibiotic Administration Greater than 2 Hours Predicts Surgical Site Infection in Open Fractures. *Injury*, *51*(9), 1999–2003.

Rupp, M., Walter, N., Brochhausen, C., & Alt, V. (2024). Fracture related Infection - Challenges in definition and diagnosis. *Journal of Orthopaedics*, *49*(March), 38–41.

Russell, G. G., Henderson, R., & Arnett, G. (1990). Primary or delayed closure for open tibial fractures. *Journal of Bone and Joint Surgery - Series B*, *72*(1), 125–128.

Saiz, A. M., Stwalley, D., Wolinsky, P., & Miller, A. N. (2022). Patient Comorbidities Associated With Acute Infection After Open Tibial Fractures. *Journal of the American Academy of Orthopaedic Surgeons Global Research and Reviews*, *6*(9), 1–6.

Scharfenberger, A. V., Alabassi, K., Smith, S., Weber, D., Dulai, S. K., Bergman, J. W., & Beaupre, L. A. (2017). Primary Wound Closure after Open Fracture: A Prospective Cohort Study Examining Nonunion and Deep Infection. *Journal of Orthopaedic Trauma*, *31*(3), 121–126.

Schenker, M. L., Yannascoli, S., Baldwin, K. D., Ahn, J., & 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*, *94*(12), 1057–1064.

Setiawati, R., & Rahardjo, P. (2019). Bone Development and Growth. In *Osteogenesis and Bone Regeneration*. IntechOpen.

Shah, A., Judge, A., & Griffin, X. L. (2022). Incidence and quality of care for open fractures in England between 2008 and 2019 a cohort study using data collected by the trauma audit and research network. *Bone and Joint Journal*, *104 B*(6), 736–746.

Shaker, J. L., & Deftos, L. (2023). Calcium and Phosphate Homeostasis. *Endocrine and Reproductive Physiology*, 77-e1.

Shier, D., Butler, J., & Lewis, R. (2016). *Chapter 7: Skeletal System. Hole ' S Anatomy & Physiology* (14th ed.). McGraw-Hill Education.

Singh, J., Rambani, R., Hashim, Z., Raman, R., & Sharma, H. K. (2012). The relationship between time to surgical debridement and incidence of infection in grade III open fractures. *Strategies in Trauma and Limb Reconstruction*, *7*(1), 33–37.

Smolle, M. A., Leitner, L., Böhler, N., Seibert, F. J., Glehr, M., & Leithner, A. (2021). Fracture, nonunion and postoperative infection risk in the smoking orthopaedic patient: A systematic review and meta-analysis. *EFORT Open Reviews*, *6*(11), 1006–1019.

Sop, J. L., & Sop, A. (2022). Open fracture management. *In: StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing*.

Šromová, V., Sobola, D., & Kaspar, P. (2023). A Brief Review of Bone Cell Function and Importance. *Cells*, *12*(21).

Srour, M., Inaba, K., Okoye, O., Chan, C., Skiada, D., Schnüriger, B., Trump, M., Lam, L., & Demetriades, D. (2015). Prospective evaluation of treatment of open fractures: Effect of time to irrigation and debridement. *JAMA Surgery*, *150*(4), 332–336.

Stevenson, M. C., Slater, J. C., Sagi, H. C., Bedoya, F. P., & Powers-Fletcher, M. V. (2022). Diagnosing Fracture-Related Infections: Where Are We Now? *Journal of Clinical Microbiology*, *60*(2), 1–9.

Su, N., Yang, J., Xie, Y., Du, X., Chen, H., Zhou, H., & Chen, L. (2019). Bone function, dysfunction and its role in diseases including critical illness. *International Journal of Biological Sciences*, *15*(4), 776–787.

Sun, S., Yang, G., Zhang, Y., & Liu, Y. (2024). Risk factors for surgical site infections following open reduction and internal fixation in patients with tibial plateau fractures. *International Wound Journal*, *21*(3), 1–7.

Suzuki, T., Inui, T., Sakai, M., Ishii, K., Kurozumi, T., & Watanabe, Y. (2023). Type III Gustilo–Anderson open fracture does not justify routine prophylactic Gram-negative antibiotic coverage. *Scientific Reports*, *13*(1), 1–8.

Szymski, D., Walter, N., Alt, V., & Rupp, M. (2022). Evaluation of Comorbidities as Risk Factors for Fracture-Related Infection and Periprosthetic Joint Infection in Germany. *Journal of Clinical Medicine*, *11*(17).

Thakore, R. V., Francois, E. L., Nwosu, S. K., Attum, B., Whiting, P. S., Siuta, M. A., Benvenuti, M. A., Smith, A. K., Shen, M. S., Mousavi, I., Obremskey, W. T., & Sethi, M. K. (2017). The Gustilo–Anderson classification system as predictor of nonunion and infection in open tibia fractures. *European Journal of Trauma and Emergency Surgery*, *43*(5), 651–656.

Thomas, D. C., Tsu, C. L., Nain, R. A., Arsat, N., Fun, S. S., & Sahid Nik Lah, N. A. (2021). The role of debridement in wound bed preparation in chronic wound: A narrative review. *Annals of Medicine and Surgery*, *71*(September), 102876.

Thuita, M. J., Chumo, S. F., & Muthike, G. E. (2021). A prospective study of bacterial isolates profile in infected open fractures. *African Journal of Microbiology Research*, *15*(4), 183–188.

Tissingh, E. K., Marais, L., Loro, A., Bose, D., Ferguson, J., Morgensten, M., & McNally, M. (2022). Management of fracture-related infection in low resource settings: how applicable are the current consensus guidelines? *EFORT Open Reviews*, *7*(6), 422–432.

Tornetta, P., Della Rocca, G. J., Morshed, S., Jones, C., Heels-Ansdell, D., Sprague, S., Petrisor, B., Jeray, K. J., Del Fabbro, G., Bzovsky, S., Bhandari, M., Guyatt, G. H., Walter, S. D., Schemitsch, E. H., Anglen, J., Bosse, M., Liew, S., Sancheti, P., McKay, P., … Patil, A. (2020). Risk Factors Associated With Infection in Open Fractures of the Upper and Lower Extremities. *Journal of the American Academy of Orthopaedic Surgeons Global Research and Reviews*, *4*(12), 1–8.

Twagirayezu, E., & Bonane, A. (2008). Open fractures I Rwanda: The Kigali experience. *East and Central African Journal of Surgery*, *13*(1), 77–84.

van den Kieboom, J., Bosch, P., Plate, J. D. J., IJpma, F. F. A., Kuehl, R., McNally, M. A., Metsemakers, W. J., & Govaert, G. A. M. (2018). Diagnostic accuracy of serum inflammatory markers in late fracture-related infection. *Bone and Joint Journal*, *100B*(12), 1542–1550.

Vasenius, J., Tulikoura, I., Vainionpää, S., & Rokkanen, P. (1998). Clindamycin versus cloxacillin in the treatment of 240 open fractures. A randomized prospective study. *Annales Chirurgiae et Gynaecologiae*, *87*(3), 224–228.

Weber, D., Dulai, S. K., Bergman, J., Buckley, R., & Beaupre, L. A. (2014). Time to initial operative treatment following open fracture does not impact development of deep infection: A prospective cohort study of 736 subjects. *Journal of Orthopaedic Trauma*, *28*(11), 613–619.

Wesson, H. K. H., Stevens, K. A., Bachani, A. M., Mogere, S., Akungah, D., Nyamari, J., Masasabi Wekesa, J., & Hyder, A. A. (2015). Trauma systems in Kenya: A qualitative analysis at the district level. *Qualitative Health Research*, *25*(5), 589–599.

Whittle, A. P. (2017). *Chapter 53. General Principles of Fracture Treatment. Campbell's Operative Orthopaedics.* (17th ed.). Elisevier.

Wilkins, J., & Patzakis, M. (1991). Choice and duration of antibiotics in open fractures. *Orthopedic Clinics of North America*, *22*(3), 433–437.

Wilson, A. P. R., Sturridge, M. F., Treasure, T., & Grüneberg, R. N. (1986). a Scoring Method (Asepsis) for Postoperative Wound Infections for Use in Clinical Trials of Antibiotic Prophylaxis. *The Lancet*, *327*(8476), 311–312.

World Health Organization. (2018). *Protocol for surgical site infection surveillance with a focus on settings with limited resources*. https://www.who.int/publications/i/item/protocol-for-surgical-site-infection-surveillance-with-a-focus-on-settings-with-limited-resources

Zalavras, C. G. (2017). Prevention of Infection in Open Fractures. *Infectious Disease Clinics of North America*, *31*(2), 339–352. https://doi.org/10.1016/j.idc.2017.01.005

Zhang, Z., Liu, P., Wang, W., Wang, S., Li, B., Li, J., Yang, B., Li, M., Li, Q., Yang, H., Huang, Z., & Liu, L. (2022). Epidemiology and Drug Resistance of Fracture-Related Infection of the Long Bones of the Extremities: A Retrospective Study at the Largest Trauma Center in Southwest China. *Frontiers in Microbiology*, *13*(July), 1–9.

Zheng, X. Q., Huang, J., Lin, J. liang, & Song, C. L. (2023). Pathophysiological mechanism of acute bone loss after fracture. *Journal of Advanced Research*, *49*, 63–80. https://doi.org/10.1016/j.jare.2022.08.019

APPENDICES

APPENDIX I: TIME FRAME

	2023				**2024**				**2025**	
	Feb to May	May to Jun	Jun to Jul	Jul to Nov	Jan to Sep	Oct to Nov	Dec to Apr	May to Aug	Sep to Dec	
Proposal Writing										
Proposal Presentation										
IREC Submission										
IREC Corrections										
Collection of Data										
Data Entry and Analysis										
Report Writing										
Submission										
Defence										

APPENDIX II: BUDGET

BUDGET ITEM	**QTY**	**UNIT (Kenya Shillings)**	**TOTAL AMT (Kenyan Shillings)**
Equipment			
Reams of Plain papers	8	650.00	5,200.00
storage	3	300.00	900.00
Pens	1 box of 50	600.00	600.00
Storage pen drive	2 / 2G each	1,500.00	3,000.00
Total			**9,700.00**
Proposal development			
Plagiarism index check	1	800.0	800.00
Printing and binding documents	8 copies	1,000.00	8,000.00
Total			**8,800.00**
Personnel			
Biostatician services	1	35,000.00	35,000.00
Total			**30,000.00**
Thesis development			
Plagiarism index check	1	5,000.00	5,000.00
Printing and binding documents	8 copies	1,500.00	12,000.00
Total			**17,000.00**
IREC Approval			**1,000.00**
Communication			**25,000.00**
TOTAL			**136,500.00**
Miscellaneous cost (10% of costs)			**13,650.00**
GRAND TOTAL			**100,150.00**

APPENDIX III: CONSENT FORM

STUDY TITLE: THE OCCURRENCE OF INFECTION IN OPEN LONG-BONE FRACTURES AMONG ADULT PATIENTS AT MTRH.

Introduction

I am Dr. Kesentseng Kemang, a post-graduate candidate in the Orthopaedics and Rehabilitation department at Moi University. As part of studies, I am conducting a study focused on identifying factors linked to infection in adult patients diagnosed with open fractures of long bones at MTRH.

Nature of study

If you or your dependent consent to be part of this study, we will inquire about how and when you got injured, operation and antibiotics used. Questionnaire will be used to collect such information and then you will be followed up for up to 3 months after surgery. More information will be collected when you visit the clinic for check-up.

Benefits of the study

While there are no immediate personal advantages for you as a participant, your involvement in this study will be significant in developing guidelines and policies. These outcomes will ultimately result in improved healthcare services the hospital provides to benefit the community as a whole.

Harm of the study

There is no harm expected in participating in this study.

Privacy and confidentiality:

Any information collected from you or your dependent will be confidential and solely utilized for this research. Your name will not be included in any data

collection instruments. All physical documents and computerized records will be securely stored, protected by access codes, and kept under lock and key

Rights to decline or retract participation in the study

Taking part in this research is entirely optional and you can drop out from it at any point you wish to do so.

Please don't hesitate to contact **Dr. Kesentseng Kemang** via mobile phone at **0114622208** in case of any inquiries or concerns about the study.

After carefully reading and receiving an explanation of the information stated above, I, Mr./Mrs./Miss _____, acknowledge that participating in this study is voluntary and I hereby provide my consent to be involved in the study.

I am aware that I can discontinue from participating in the study at any point with no negative consequences or harm.

Patient's sign.: _____ Date _____

Principal investigator's sign.: _____ Date _____

APPENDIX IV: QUESTIONNAIRE

Serial no: …… IP no: …….

Residential address: ……. Mobile no: ……

Section A: Demographic Data and Medical Hostpry

Age: …… years

Gender: [ ] Male [ ] Female

Education: [ ] Primary [ ] Secondary [ ] Tertiary [ ] None

Occupation: …….

Smoking history: [ ] Smoker [ ] Non Smoker

Co-morbidities: …….. …….

Section B: INURY STATUS

Date and time injury: …….

Mechanism of injury:

[ ] Road traffic accident [ ] Assault [ ] Fall [ ] Work-related injury

[ ] Sports [ ] Others (specify)…….....

SECTION C: HOSPITAL PRESENTATION

Time of presentation from injury:

[ ] < 6 hrs [ ] 6-12 hrs [ ] 12-24 hrs [ ] 24-48 hrs [ ] > 48 hrs

Diagnosis

Side: Left [ ] Right [ ]

Bone involved:

[ ] Humerus [ ] Both radius & ulna [ ] Radius [ ] Ulna

[ ] Femur [ ] Both Fibula & Ulna [ ]Tibia [ ] Fibula

Pattern of fracture: [ ] Spiral [ ]oblique [ ] Transverse [ ] Comminuted

[ ] **Other (specify)** ……

Gustilo Anderson Classification:

[ ] I **[ ]** II **[ ]** IIIA **[ ]** IIIB **[ ]** IIIC

SECTION D: MANAGEMENT

Time from injury to debridement:

[ ] < 6 hrs **[ ]** 6-12 hrs **[ ]** 12-24 hrs **[ ]** 24-48 hrs **[ ]** > 48 hrs

Antibiotics used:

…….. ……..

…….

Timing of antibiotic from injury:

[ ] < 3 hrs **[ ]** 3 -6 hrs **[ ]** 6-12 hrs **[ ]** 12-24 hrs **[ ]** > 24 hrs

Duration of antibiotic use :_____

Duration of surgery: _____

Experience of Surgeon:

[ ] Consultant **[ ]** Resident (specify year:_____)

Fracture stabilization

[ ] Back-slab **[ ]** Full cast with a window **[ ]** External- fixation

[ ] Intermedullary (IM) nailing **[ ]** Plate and screws **[ ]** Other, Specify**…….**

Wound closure after Debridement: [ ] Yes **[ ]** No

SECTION E: FOLLOW-UP (2 weeks, 6 weeks, & 3 months)

Table 2: CDC Criteria data collection tool for surgical wound infection (Adopted from WHO)

Superficial Infection [ ]	**Deep Infection [ ]**
[ ] Pus draining from the superficial incision. **OR** **[ ]** Organism(s) identified (if culture done) **OR** **[ ]** A superficial incision deliberately opened **AND** **[ ]** pain or tenderness, swelling; redness; or hot to touch. **OR** **[ ]** Clinician diagnosis of infection	**[ ]** Pus draining from the deep incision. **OR** **[ ]** A deep incision deliberately opened or aspirated by surgeon **AND** **[ ]** Organism(s) identified (if culture done) **AND** **[ ]** Fever (>38°C) **OR** localized pain **OR** tenderness. **OR** **[ ]** Abscess or signs indicating of infection
Culture result: …….. **Date of specimen collection:** …… **Organism(s) identified:** …… **Antibiotic sensitivity or resistance:** ……	

APPENDIX V:IREC APPROVAL

MTRH/MU-INSTITUTIONAL RESEARCH AND ETHICS COMMITTEE (IREC)

MOI TEACHING AND REFERRAL HOSPITAL
P.O. BOX 3
ELDORET
Tel: 33471//2/3

MOI UNIVERSITY
COLLEGE OF HEALTH SCIENCES
P.O. BOX 4606
ELDORET
Tel: 33471/2/3

Reference: IREC/614/2023
Approval Number: 0004586

10th November, 2023

Dr. Kesentseng Kemang,
Moi University,
School of Medicine,
P.O. Box 4606-30100,
ELDORET-KENYA.

Dear Dr. Kemang,

FACTORS ASSOCIATED WITH THE OCCURRENCE OF INFECTION IN OPEN LONG-BONE FRACTURES AMONG ADULT PATIENTS AT MOI TEACHING AND REFERRAL HOSPITAL

This is to inform you that ***MTRH/MU-IREC*** has reviewed and approved the above referenced research proposal. Your application approval number is ***FAN: 0004586.*** The approval period is **10th November, 2023- 9th November, 2024.** This approval is subject to compliance with the following requirements;

i. Only approved documents including (informed consents, study instruments, Material Transfer Agreements (MTA) will be used.
ii. All changes including (amendments, deviations, and violations) are submitted for review and approval by ***MTRH/MU-IREC***.
iii. Death and life threatening problems and serious adverse events or unexpected adverse events whether related or unrelated to the study must be reported to ***MTRH/MU-IREC*** within 72 hours of notification.
iv. Any changes, anticipated or otherwise that may increase the risks or affected safety or welfare of study participants and others or affect the integrity of the research must be reported to ***MTRH/MU-IREC*** within 72 hours.
v. Clearance for export of biological specimens must be obtained from ***MOH at the recommendation of NACOSTI*** for each batch of shipment.
vi. Submission of a request for renewal of approval at least 60 days prior to expiry of the approval period. Attach a comprehensive progress report to support the renewal.
vii. Submission of an executive summary report within 90 days upon completion of the study to ***MTRH/ MU-IREC.***

Prior to commencing your study; you will be required to obtain a research license from the National Commission for Science, Technology and Innovation (NACOSTI) https://oris.nacosti.go.ke and other relevant clearances from study sites including a written approval from the CEO-MTRH which is mandatory for studies to be undertaken within the jurisdiction of Moi Teaching & Referral Hospital (MTRH) and its satellites sites.

Sincerely,

PROF. E. WERE
CHAIRMAN
INSTITUTIONAL RESEARCH AND ETHICS COMMITTEE

cc	CEO	-	MTRH	Dean	-	SOP	Dean	-	SOM
	Principal	-	CHS	Dean	-	SON	Dean	-	SOD

APPENDIX VI:HOSPITAL APPROVAL (MTRH)

An ISO 9001:2015 Certified Hospital

MOI TEACHING AND REFERRAL HOSPITAL

Telephone: (+254)-0532033471/2/3/4
Fax: 0532061749
Email: ceo@mtrh.go.ke/ceosoffice@mtrh.go.ke

NANDI ROAD
P.O. BOX 3-30100
ELDORET,KENYA

Ref: ELD/MTRH/R&P/10/2/V.2/2010

14th November, 2023

Dr. Kesentseng Kemang,
Moi University,
School of Medicine,
P.O. Box 4606-30100,
ELDORET-KENYA.

FACTORS ASSOCIATED WITH THE OCCURRENCE OF INFECTION IN OPEN LONG-BONE FRACTURES AMONG ADULT PATIENTS AT MOI TEACHING AND REFERRAL HOSPITAL

You have been authorised to conduct research within the jurisdiction of Moi Teaching and Referral Hospital (MTRH) and its satellites sites. You are required to strictly adhere to the regulations stated below in order to safeguard the safety and well-being of staff, patients and study participants seen at MTRH.

1. The study shall be under Moi Teaching and Referral Hospital regulation.
2. A copy of MTRH/MU-IREC approval shall be a prerequisite to conducting the study.
3. Studies intending to export human bio-specimens must provide a permit from MOH at the recommendation of NACOSTI for each shipment.
4. No data collection will be allowed without an approved consent form(s) to participants unless waiver of written consent has been granted by MTRH/MU-IREC.
5. Take note that data collected must be treated with due confidentiality and anonymity.

The continued permission to conduct research shall only be sustained subject to fulfilling all the requirements stated above.

The approval period is 14th November, 2023 – 13th November, 2024.

14/11/2023

DR. WILSON K. ARUASA, *MBS, EBS*
CHIEF EXECUTIVE OFFICER

MOI TEACHING AND REFERRAL HOSPITAL
CEO
APPROVED
14 NOV 2023
SIGN.....
P. O. Box 3-30100, ELDORET

c.c. - Senior Director, Clinical Services
- Director, Nursing Services
- HOD, HRISM

APPENDIX VII:NACOSTI LICENSE

REPUBLIC OF KENYA

NATIONAL COMMISSION FOR SCIENCE,TECHNOLOGY & INNOVATION

Ref No: **459923**

Date of Issue: **12/December/2023**

RESEARCH LICENSE

This is to Certify that Dr.. Kesentseng Kemang of Moi University, has been licensed to conduct research as per the provision of the Science, Technology and Innovation Act, 2013 (Rev.2014) in Uasin-Gishu on the topic: FACTORS ASSOCIATED WITH THE OCCURRENCE OF INFECTION IN OPEN LONG-BONE FRACTURES AMONG ADULT PATIENTS AT MOI TEACHING AND REFERRAL HOSPITAL for the period ending : 12/December/2024.

License No: **NACOSTI/P/23/31847**

459923

Applicant Identification Number

Director General
NATIONAL COMMISSION FOR SCIENCE,TECHNOLOGY & INNOVATION

Verification QR Code

NOTE: This is a computer generated License. To verify the authenticity of this document, Scan the QR Code using QR scanner application.

See overleaf for conditions

THE SCIENCE, TECHNOLOGY AND INNOVATION ACT, 2013 (Rev. 2014)
Legal Notice No. 108: The Science, Technology and Innovation (Research Licensing) Regulations, 2014

The National Commission for Science, Technology and Innovation, hereafter referred to as the Commission, was the established under the Science, Technology and Innovation Act 2013 (Revised 2014) herein after referred to as the Act. The objective of the Commission shall be to regulate and assure quality in the science, technology and innovation sector and advise the Government in matters related thereto.

CONDITIONS OF THE RESEARCH LICENSE

1. The License is granted subject to provisions of the Constitution of Kenya, the Science, Technology and Innovation Act, and other relevant laws, policies and regulations. Accordingly, the licensee shall adhere to such procedures, standards, code of ethics and guidelines as may be prescribed by regulations made under the Act, or prescribed by provisions of International treaties of which Kenya is a signatory to
2. The research and its related activities as well as outcomes shall be beneficial to the country and shall not in any way;
   i. Endanger national security
   ii. Adversely affect the lives of Kenyans
   iii. Be in contravention of Kenya's international obligations including Biological Weapons Convention (BWC), Comprehensive Nuclear-Test-Ban Treaty Organization (CTBTO), Chemical, Biological, Radiological and Nuclear (CBRN).
   iv. Result in exploitation of intellectual property rights of communities in Kenya
   v. Adversely affect the environment
   vi. Adversely affect the rights of communities
   vii. Endanger public safety and national cohesion
   viii. Plagiarize someone else's work
3. The License is valid for the proposed research, location and specified period.
4. The license any rights thereunder are non-transferable
5. The Commission reserves the right to cancel the research at any time during the research period if in the opinion of the Commission the research is not implemented in conformity with the provisions of the Act or any other written law.
6. The Licensee shall inform the relevant County Director of Education, County Commissioner and County Governor before commencement of the research.
7. Excavation, filming, movement, and collection of specimens are subject to further necessary clearance from relevant Government Agencies.
8. The License does not give authority to transfer research materials.
9. The Commission may monitor and evaluate the licensed research project for the purpose of assessing and evaluating compliance with the conditions of the License.
10. The Licensee shall submit one hard copy, and upload a soft copy of their final report (thesis) onto a platform designated by the Commission within one year of completion of the research.
11. The Commission reserves the right to modify the conditions of the License including cancellation without prior notice.
12. Research, findings and information regarding research systems shall be stored or disseminated, utilized or applied in such a manner as may be prescribed by the Commission from time to time.
13. The Licensee shall disclose to the Commission, the relevant Institutional Scientific and Ethical Review Committee, and the relevant national agencies any inventions and discoveries that are of National strategic importance.
14. The Commission shall have powers to acquire from any person the right in, or to, any scientific innovation, invention or patent of strategic importance to the country.
15. Relevant Institutional Scientific and Ethical Review Committee shall monitor and evaluate the research periodically, and make a report of its findings to the Commission for necessary action.

National Commission for Science, Technology and Innovation(NACOSTI),
Off Waiyaki Way, Upper Kabete,
P. O. Box 30623 - 00100 Nairobi, KENYA
Telephone: 020 4007000, 0713788787, 0735404245
E-mail: dg@nacosti.go.ke
Website: www.nacosti.go.ke