UNIVERSITY FOR DEVELOPMENT STUDIES
SCHOOL OF MEDICINE

BACTERIAL INFECTION IN SURGICAL WOUND AFTER ORTHOPEDICS TRAUMA SURGERY AT THE TAMALE TEACHING HOSPITAL IN THE NORTHERN REGION OF GHANA

BY

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DECLARATION

By submitting this thesis for the Master of Philosophy in Clinical Microbiology, I, FREDRICK GYILBAGR, hereby declare that it is entirely my own original work and does not, to the best of my knowledge, contain any material that has already been published by someone else or accepted for the award of any other university degree, with the exception of those cases in which proper textual acknowledgment has been made.

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DEDICATION

I sincerely dedicate this work to almighty God, for His grace, peace, love and encouragement towards the completion of this work. I equally dedicate it to all my friends and loved ones for their encouragement.

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All thanks to the almighty God for the strength and encouragement to enable me to go through this journey. I do recognize the work of my supervisors, Dr. Willams Walana and Professor Alexis D.B. Buunaaim, who guided me through the entire project. Their time and input were valuable in writing this important document.

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LIST OF ABBREVIATIONS

ASA	American Society of Anesthesiologist
ATCC	American Type Culture Collection
AMR	Antimicrobial Resistance
CDC	Center for Disease Control
CLSI	Clinical And Laboratory Standard Institute
CBC	Complete Blood Count
DNA	Deoxyribonucleic Acid
ESBL	Extended Spectrum Beta Lactamases
FBC	Full Blood Count
HB	Hemoglobin
NLR	Neutrophils Lymphocytes Ratio
ORIF	Open Reduction and Internal Fixation
OTP	Orthopedic Trauma Patient
PCR	Polymerase Chain Reaction
KSB	Potassium Solubilizing Bacteria
SSI	Surgical Site Infection
TTH	Tamale Teaching Hospital

OTS	Orthopedic Trauma Surgery
WBC	White Blood Cells
ZN	Ziehl Neelsen

ABSTRACT

Background: Orthopedic trauma surgery (OTS) can result in surgical site infections (SSIs), and the repercussions include prolonged and increased cost of treatment. This study sought to investigate surgical site infection after orthopedics trauma surgery. **Methods:** A prospective cohort study was conducted at the Tamale Teaching Hospital from September 2023 to August 2024. Data on demographics, comorbidities, preoperative, intra-operative, and postoperative parameters were collected from patients, medical records, and the operation report. Samples were collected from patients suspected of SSI, and cultured for bacterial isolation, identification and antimicrobial resistance characterization. Univariate and multivariate logistic regression analyses were used to identify the independent risk factors of surgical site infection. P-value <0.05 was considered statistically significant. Surgical site infection was defined following the Center for Disease Control and Prevention (CDC) criteria. **Results:** A total of 210 patients were enrolled, of which 6.7% (14) developed SSIs, including 1.0% (2) deep and 5.7% (12) superficial SSIs. The study reported a maximum and minimum age of 86 years and 0.67 years (8 months), respectively. The median age (Interquartile range) reported in this study was 35.5 (18 - 47). The incidence rate of SSI in open fractures and closed fractures in this study was 3.3% (7) and 2.9% (6), respectively. According to multivariate regression analysis, blood transfusion before surgery (p=0.034; OR=3.53; 1.10 – 11.33), was identified as an independent risk factor of SSI following OTS. Out of 19 specimens, 14(73.68%) were culture-positive, yielding 22 isolates. *Pseudomonas aeruginosa* 5 (22.73%) was the most common bacterial isolate, followed by *Klebsiella* spp. 4 (18.18%). ESβL-positive isolates were 3(23.08%). PCR confirmed the expression of CTXM and SHV genes by two *Klebsiella* spp., and the CTXM gene by *Proteus vulgaris*. **Conclusion:** The study reported the incidence rate of SSI after OTS to be 6.7% (67 per 1000 surgical operations) within one year. Blood transfusion before surgery was identified as an independent risk factor of SSI following OTS. ESβL-positive isolates were 3(23.08%). PCR confirmed the expression of CTXM and SHV genes by two *Klebsiella* spp., and CTXM gene by *Proteus vulgaris*.

CHAPTER 1
INTRODUCTION

1.1 GENERAL INTRODUCTION

Surgical site infections (SSIs) are among the most dominant complications of orthopedics trauma surgery and remain a significant global issue for patients who have undergone any form of orthopedic surgery (Leaper & Edmiston, 2017; Starčević et al., 2015). Surgical site infection (SSI) appears 30 days after surgery or a year after the use of an implant (Sarangi & Padhi, 2019). In orthopedic trauma surgery, surgical site infections can result in a variety of clinical, economic, and societal repercussions, including an extended hospital stay, increased rates of morbidity and mortality, a higher risk of readmission and reoperation, a high cost of treatment, and an array of undesirable outcomes (Bhat et al., 2018; Najjar & Saleh, 2017). The risk of developing an infection following implant fixation is predicted to be between 0.5% and 30% (0.5–2% in the case of closed fractures and up to 30% in the case of open fractures (Lakshminarayana et al., 2013). The infection can present as superficial SSI, deep SSI, and organ/space, which involves the underlying bone or the implant (Leaper & Edmiston, 2017).

The Centers for Disease Control and Prevention (CDC) categorizes SSI into three classifications (Berríos-Torres et al., 2017). These encompass superficial SSIs, restricted to the skin and subcutaneous tissue, organ or space SSIs connected to human organs and body cavities, and deep incisional SSIs that impact the layers of muscle and fascia. With incidence rates ranging from 0.4 to 30.9 per 100 surgical patients and an overall incidence rate of 118 per 100 surgical patients, SSI remains one of the most prevalent healthcare-associated illnesses in low- and middle-income countries (LMICs) (Rickard et al., 2020). These rates are significantly higher than those seen in developed countries, which range from 1.2% to 5.2% (Maki & Zervos, 2021).

The situation of SSIs in low and middle-income countries, including Ghana, has been exacerbated by the development of bacteria that are resistant to drugs, including methicillin resistance *Staphylococcus aureus* and other bacterial strains, suboptimal implementation of infection prevention (IP) and control guidelines, and the absence of antibiotic stewardship guidelines (Asaad & Badr, 2016; Isik et al., 2015). Antimicrobial resistance (AMR) poses a significant threat to the effective prevention and treatment of a growing array of infections

caused by microorganisms that have become resistant to standard antimicrobials, emerging as a major public health issue of the 21st century (Moyo et al., 2023). In reality, the morbidity and mortality rates of patients who have experienced SSIs are significantly influenced by infections caused by bacterial strains (El-Saed et al., 2020). The misuse of antibiotics is particularly pressing in the context of antibiotic resistance in bacteria (Prestinaci et al., 2015). Bacteria responsible for common or serious diseases have progressively evolved resistance to each new antibiotic introduced to the market over several decades. Given this reality and the inevitability of antibiotics in Orthopedic trauma surgery (OTS), it is crucial to implement measures to avert a worldwide healthcare crisis (Dhingra et al., 2020).

In addition, a dirty hospital surrounding has been found to increase the likelihood of surgical patients developing SSI, in addition to intrinsic and procedure-related risk factors (Bucataru et al., 2023). This is due to the potential for a contaminated environment that serves as a breeding ground for pathogens. Immunocompromised patients may develop SSI as a consequence of bacterial wound contamination during surgery (Mathobela, 2018). The cost and complication of treating SSIs are exacerbated by the introduction of environmental bacterial strains that are resistant to antibiotics (Mathobela, 2018).

The most apparent signs and symptoms of SSIs are purulent discharge from the incision or the area around the insertion site of a drain, as well as the spread of cellulitis from the wound. In general, infection is detected by a pyrexia, increased pain or fever with tenderness, increased white blood cell count, and dehiscence at the incision site (Ameyaw, 2014). Positive culture drainage and a clinician's diagnosis of diseases with a prescription for antibiotics are additional indicators of infection (Robicsek et al., 2008).

Surgical site infections account for over one-third of postoperative fatalities worldwide. In order to prevent this, it is advisable to actively monitor environmental organisms to provide the infection control and surgical teams with the necessary surveillance data regarding the pattern of SSIs (Barlean et al., 2019). The AMR of the majority of these environmental infections is unique and varies based on the environment. (Bengtsson-Palme et al., 2018). To enhance the healthcare system's infection prevention and control measures, including surveillance and monitoring of antibiotic resistance, as well as the appropriate use of antibiotics and alternative therapies, this project was initiated to ascertain the incidence,

associated risk factors, and antibiotic resistance patterns of bacterial isolates from infected wounds following OTS.

1.2 PROBLEM STATEMENT

Patients who require orthopedic trauma surgery, particularly those involved in motor or car accidents, may arrive with various injuries in addition to fractures. The aftereffects of these conditions necessitate prolonged hospitalization, admittance to the intensive care unit (ICU), and blood transfusions, which are frequently necessary. Surgical site infections can result in septic arthritis, chronic osteomyelitis, and osteoarthritis, particularly after Open Reduction and Internal Fixation (ORIF) of fractures (Everhart et al., 2017). Patients who developed surgical site infections experience a higher incidence of reoperations and a decline in their functional outcomes (Patel et al., 2016). Although surgical advancements have been achieved, surgical site infections (SSIs) continue to be a global issue, contributing to increased mortality and morbidity rates among hospitalized patients (Rickard et al., 2020). Surgical site infections are linked to a substantial increase in the financial burden on patients, which includes reoperation and readmission, hospital management costs, increased disability-adjusted life years, increased treatment costs, and an increased burden on the country as a whole (Jenks et al., 2014).

Treatment of SSIs is hampered by the emergence of microbial-resistant bacteria, which are hard to control (Iskandar et al., 2019). Antibiotic-resistant bacteria have grown and spread as a consequence of antibiotic abuse and overuse (Serwecińska, 2020). These resistant bacteria possess genetic mutations that confer the ability to survive antibiotic exposure, thereby rendering the antibiotics ineffective in eliminating them (Fymat, 2017). Additionally, keeping up with the evolution of resistance is challenging because it is costly and time-consuming to produce new antibiotics (Andersson et al., 2020). Therefore, effective methods to manage SSIs and stop the spread of antibiotic resistance are urgently needed.

Bacteria that produce expanded-spectrum beta-lactamases (ESβL) comprise a significant cohort of bacterial agents that are of concern in the context of antimicrobial resistance (AMR). This resistance to pathogens is mediated by microorganisms that produce β-lactamases—enzymes capable of hydrolyzing β-lactam antibiotics, thereby inactivating their antimicrobial properties (De Angelis et al., 2020). In recent research, over 500 beta-

lactamases have been identified (Dyatlov et al., 2015; Ibrahim et al., 2016). Beta-lactamases are widely distributed globally and are predominantly secreted by Gram-negative bacteria, particularly those belonging to the CTX-M-15 family.

Due to the rapid rise in motor vehicle and motorbike accidents, the Northern Region of Ghana is experiencing the effects of nationwide trends such as overpopulation, urbanization, and industrialization (Jack et al., 2021). According to the annual surgical records from the orthopedic trauma Surgical Ward of the Tamale Teaching Hospital, the number of surgeries performed has shown a consistent increase over recent years, with 495 cases reported in 2020, 685 cases in 2021, and 719 cases in 2022. This upward trend in surgical procedures presents a growing concern, as inadequate management may contribute to increased rates of morbidity and mortality. Despite the increase in the number of surgical cases, there is limited documentation on surgical site infections (SSIs) following orthopedic and trauma surgeries (OTS) at the hospital. Specifically, data on the incidence of SSIs, associated risk factors, and their antibiotic resistance profiles remain sparse. Given these gaps, this study aims to address the lack of comprehensive information on SSIs following OTS and to investigate the antimicrobial resistance (AMR) patterns and mechanisms associated with these infections.

1.3 JUSTIFICATION

Surgical site infection (SSI) can be disastrous in orthopedic practice, as it can lead to the dreaded chronic osteomyelitis, decreased functional outcomes, and increased the cost of care significantly (Kalinzi, 2018). Implementing infection prevention strategies like improved surveillance and antibiotic prophylaxis can be made easier by better understanding the risk factors for bacterial infections in surgical wounds. Additionally, understanding the most frequent bacteria that cause infections in surgical wounds can aid in developing treatment plans and selecting the best antibiotics. By assessing the risk factors and establishing preventive methods, the incidence of SSIs can be decreased, resulting in cost savings.

Surgical site infection can result in a high rate of morbidity and mortality. Assessing the risk factors and creating prevention and treatment measures can improve patients' outcomes. Therefore, this study was conducted to gather information on local incidence of

bacterial infection, risk factors linked to the incidence, common bacterial pathogens, and resistant genes related to SSI.

Such information would help create management guidelines for SSIs and organize surveillance, prevention, and control of this class of illnesses. Policymakers can also use the data to build a fundamental framework for a broader nationwide surveillance study.

1.4 RESEARCH OBJECTIVES

1.4.1 AIM

The main aim of the study was to determine bacterial infection in surgical wound after orthopedic trauma surgery at the Tamale Teaching Hospital (TTH) in the Northern Region of Ghana..

1.4.2 SPECIFIC OBJECTIVES

The specific objectives of this study were to:

1. Assess the incidence and risk variables linked to SSI following orthopedic trauma surgery
2. Identify the different bacterial pathogens and their antimicrobial susceptibility patterns associated with SSI.
3. Determine specific genes that code for ESβL production from surgical wounds following orthopedic trauma surgery.

1.5 RESEARCH QUESTIONS

1. What are the incidence and risk factors related to operative site infections after orthopedic trauma surgery?
2. What are the different bacterial pathogens and their antimicrobial susceptibility patterns associated with SSI?
3. What are the specific genes that code for ESβL production from surgical wounds following orthopedic trauma surgery?

1.6 RESEARCH HYPOTHESIS

The bacterial pathogens isolated and their antimicrobial resistance patterns will align with those reported in existing literature.

1.7 CONCEPTUAL FRAMEWORK

Patient-related factors and surgery-related factors (independent or changeable variables) either directly or through interplay influence the dependent variable, postoperative surgical site infection following trauma orthopedic surgery.

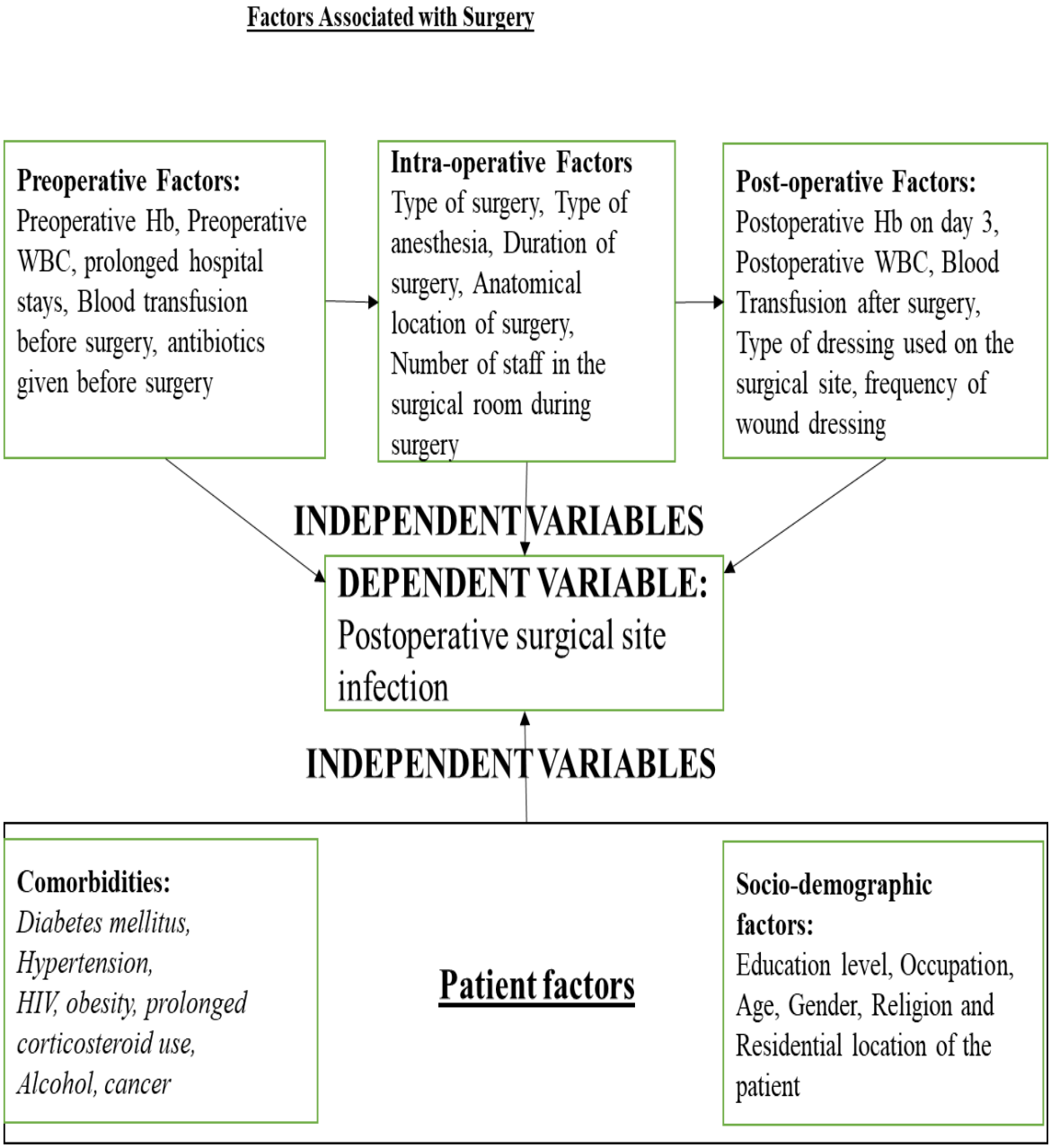

Figure 1.1 Conceptual Framework on risk factors for Post-Operative Surgical Site Infections following trauma orthopedic surgery; Researcher's view

CHAPTER 2
LITERATURE REVIEW

2.1 INTRODUCTION

Infection is an invasion and growth of microorganisms in body tissues, which may not be detectable or lead to local cellular injury as a result of toxins, antigen-antibody response, competitive metabolism, or intracellular replication (Childs & Murthy, 2017). If untreated, wounds lead to escalating tissue damage and ultimately result in the demise of the host (Dumville et al., 2016).

Surgical site infections (SSIs) are characterized as infections that manifest at the surgical wound within 30 days post-surgery or one year if an implant remains in situ (Townsend et al., 2016). Surgical site infections constitute 14–16% of all nosocomial infections among inpatients and rank as the third most frequently reported nosocomial infection (Aktuerk et al., 2020). They have been shown to lead to hospital stays that are, on average, 2 weeks longer and to increase healthcare costs by over 300% (Ansari et al., 2019). In orthopedic trauma patients, SSI is particularly detrimental, potentially leading to diminished functional results or paralysis (McQuillan et al., 2018). The incidence varies markedly among surgical techniques, facilities, patients, and physicians (Ban et al., 2017). Notwithstanding advancements in infection control and surgical methodologies, these infections remain a significant problem even in hospitals equipped with state-of-the-art equipment (Heffernan & Fox, 2014). The incidence of infections at the surgical site (SSIs) among surgical patients can attain 20%, contingent upon the surgical process, the monitoring criteria employed, and the data collection standards (Pawłowska et al., 2019).

Surgical site infection following OTS can significantly diminish a patient's quality of life. They are linked with considerable morbidity, financial strain on patients and healthcare providers, and extended hospitalizations. Secondary consequences of SSIs encompass revision surgery, protracted wound healing, and heightened antibiotic consumption, all of which substantially affect patients and the financial burden of healthcare (Onyekwelu et al., 2017).

2.2 SURGICAL WOUND CLASSIFICATION

Previous research categorizes surgical wounds into four classifications (Mukamuhirwa, 2017): The operating wound is free of infection and shows no signs of irritation. These classifications include:

Clean Wound: Typically, clean wounds are sutured; non-penetrating traumatic wounds should be classified in this category if they fulfill the requirements (absence of infection or inflammation).

Clean-Contaminated Wound: This category includes wounds originating from the respiratory, digestive, vaginal, or urinary tracts that exhibit no atypical contamination. This category encompasses procedures related to the monitoring of bile and the appendix, regardless of the presence of infection.

Contaminated Wound: The optimization of sterile techniques in cases of open, fresh, and unintentional wounds, as well as gastrointestinal tract wounds, is particularly challenging. Non-discharge (pus) inflammation, involving injured tissue without confirmed purulent discharge, is classified within this group.

Dirty or Infected Wound: This group includes prior injuries caused by trauma that involve compromised tissue, ruptured viscera, or pre-existing clinical illnesses. According to this concept, the bacterium responsible for the postoperative infection may have previously been residing in the surgical region. "

2.3 CLASSIFICATION OF SURGICAL SITE INFECTION (SSI)

According to a previous study, there are three criteria for surgical site infections, which include superficial incisional SSI, Deep incisional SSI, and Organ/Space SSI (Mukamuhirwa, 2017).

2.3.1 SUPERFICIAL INCISIONAL SSI

This category of surgical site infection manifests within 30 days post-operation, affects the skin and subcutaneous tissue, and meets one or more of the following criteria: Purulent exudate from the incision, irrespective of scientific confirmation (culture); Isolated organisms from aseptically obtained fluid or tissue culture in the wound; Localized pain, edema, erythema, warmth, and a surgically induced shallow incision are indicative of

clinical infection, as is the diagnosis of a superficial incisional surgical site infection (SSI) by a surgeon or accompanying physician (Onyekwelu et al., 2017).

2.3.2 DEEP INCISIONAL SSI

This occurs within 30 days of the operation without an implant, or within one year with an implant, and affects the internal soft tissues, such as fascia or muscle within the incision. One of the following additional criteria is met by the infection, which is directly associated with a surgical procedure: When the patient exhibits at least one of the following clinical infection signs or symptoms, the deep incision undergoes dehiscence or intentional opening by the surgeon. Purulent discharge is observed from the incision, but not from the organ or space at the site. During incision examination, reoperation, or pathological or radiological assessment, a surgeon or attending physician diagnoses a deep incisional surgical site infection (SSI) if an abscess or other infection indicators involving the deep incision are identified, or if localized pain, edema, or fever exceeds 100.4°F, unless cultures are negative (Onyekwelu et al., 2017)

2.3.3 ORGAN/SPACE SSI

SSI relates to any anatomical segment excluding the incision, manifests within 30 days post-surgery without an implant, or within 1 year if an implant is present, contingent upon the infection is associated with the procedure and meeting one of the criteria outlined below Purulent exudate from a drain placed within an organ or cavity (infection at the drain site does not qualify as a surgical site infection); isolated microorganisms from aseptically obtained fluid or tissue from the organ or cavity; detection of an abscess or other signs of infection linked to the deep incision during incision assessment, reoperation, or pathological or radiological analysis; and a diagnosis of an organ/space surgical site infection by a surgeon or attending physician (Onyekwelu et al., 2017).

2.4 SOURCES OF SSI

Pathogens responsible for SSI may arise from either extrinsic or indigenous sources.

2.4.1 ENDOGENOUS SOURCES

Most SSIs are caused by the host's endogenous skin and visceral flora, which contaminate surgical incisions with germs. Contamination occurs after the incision of the skin or hollow viscera (Shanthi, 2015). Examples of this endogenous flora include skin microorganisms such as Staphylococcus aureus and enteric Gram-negative rods like Escherichia coli.

Besides the surgical site, these infections may also originate from remote infective locations (Esposito et al., 2016).

2.4.2 EXOGENOUS SOURCES

The sources encompass the operating room environment, medical personnel, specifically the surgical team, and any instruments introduced into the operating room during a procedure (Dancer et al., 2012; Zhiqing et al., 2018). Contamination arises via patient interactions with the surgical team or other healthcare providers harboring pathogens and from contaminated hospital surfaces, with wounds acting as conduits for infection. Infection may potentially spread from wounds through contaminated hospital surfaces. Streptococci and *Staphylococci species* are exogenous microbiota (Lee et al., 2013; Singh et al., 2014).

2.5 PATHOGENESIS OF SSIs

Environmental bacteria and those from other regions of the skin can infiltrate when the skin's barrier is damaged. The acute inflammatory response and coagulation are activated (Pastar et al., 2013). This facilitates the colonization and proliferation of bacteria in the subcutaneous tissue (Pastar et al., 2013). Upon invasion, pathogenic microorganisms produce virulent factors, including enzymes and toxins, resulting in tissue degradation and acute wound infections (Pastar et al., 2013). Bacterial pathogens employ many strategies in chronic wound infections, such as biofilm formation, quorum sensing, gene acquisition for multidrug resistance, and mutations to enhance virulence factors, to perpetuate their detrimental effects (Piewngam et al., 2020)

Contamination of bacteria in the surgical site is essential for the onset of an SSI. Quantitative research has shown that the occurrence of SSI is markedly increased when a surgical site is contaminated with more than 105 bacteria per gram of tissue (Bhatta et al., 2016). Nevertheless, the presence of foreign material at the site may significantly reduce the quantity of contaminating bacteria required to induce infection (Damani et al., 2014). The interplay of four elements dictates the probability that bacterial contamination may lead to surgical site infection (SSI). This encompasses the bacterial inoculum, bacterial pathogenicity, the influence of adjuvants, and host immunity (Fry, 2013).

The virulence of the bacteria and the inoculum size proportionately influence the infection process. Local wound attributes, such as the presence of hemoglobin and foreign bodies like drains, augment bacterial pathogenicity (Fry, 2013). A previous study indicates that most bacteria responsible for surgical site infections produce toxins and possess invasive

characteristics, such as adhesins, which enhance their ability to stick to host cells, invade, colonize, and damage host tissues (Lachiewicz et al., 2015). To shield themselves from the host's immune system and most antimicrobial agents, certain bacterial species can synthesize supplementary polymeric substances or possess a polysaccharide capsule (Hooshdar et al., 2020)

Tumor necrosis factor-alpha, which activates neutrophils for bacterial phagocytosis, is secreted by the host's pro-inflammatory cells to combat the invasion. Furthermore, it induces the release of interleukins and reactive oxygen species, as well as acid hydrolases from lysosomal vacuoles, leading to an inflammatory response and the accumulation of pus-containing necrotic tissue, neutrophils, bacteria, and proteinaceous fluid, accompanied by signs of inflammation (rubor, dolor, calor, and tumor) (Esposito et al., 2016).

2.6 PATHOGENS CAUSING SURGICAL SITE INFECTIONS

Numerous investigations have demonstrated that the distribution of microorganisms identified from surgical site infections has remained consistent throughout the past decade (Abdul-Jabbar et al., 2013; Fan et al., 2014). *Staphylococcus aureus, coagulase-negative staphylococci, Enterococcus species*, and *Escherichia coli* continue to be the most often isolated bacteria (Upreti et al., 2018). A substantial body of research demonstrates that a growing percentage of surgical site infections (SSIs) is attributable to multidrug-resistant bacteria, specifically MRSA and ESBL producers (Bhave et al., 2016; Chaudhary et al., 2017; Seni et al., 2013).

Additionally, previous studies have indicated that *Staphylococcus aureus* was the most prevalent bacteria linked with SSI, followed by *Pseudomonas aeruginosa*, *E. coli*, *Klebsiella species*, *Citrobacter species*, and *Acinetobacter species* (Bajaj et al., 2018; Shinde & Kulkarni, 2017; Sunilkumar & Roopa, 2015; Suryawanshi et al., 2014).). Another investigation revealed that the predominant SSI isolate was *Pseudomonas species* (42.85%), followed by *Klebsiella species* (28.5%) *(Janugade et al., 2016)*.

Additional studies conducted by various researchers identified *Staphylococcus aureus, Escherichia coli, Klebsiella pneumoniae, Enterococcus, Pseudomonas aeruginosa*, and coagulase-negative *staphylococci* as the predominant isolates in post-operative wound infections (Akinkunmi et al., 2014; Alexiou et al., 2017; Amutha & Viswanathan, 2014; Mundhada & Tenpe, 2015; Sawhney et al., 2017).

Assessments of ward surfaces, operating room environments, non-critical healthcare instruments, and bedside surfaces across various hospitals indicated a significant presence of contaminants, including *Coagulase-negative staphylococci, Staphylococcus aureus, Klebsiella species, Pseudomonas species, Aspergillus species, Bacillus species*, and *MRSA*. (Getachew et al., 2018; Matinyi et al., 2018; Weldegebreal et al., 2019; Yuen et al., 2015).

2.7 INCIDENCE OF SSI AFTER TOS

2.7.1 GLOBAL INCIDENCE OF SSI

The global incidence of SSIs in orthopedic procedures varies markedly based on patient demographics, hospital size, surgeon expertise, and surveillance methods (Nussbaum et al., 2018). Tertiary hospitals often have the lowest rates of SSI at 4.6 percent, compared to small (500 beds) and large (>500 beds) teaching hospitals, which had rates of 6.4 and 8.2 percent, respectively (Webster & Alghamdi, 2015).

Infection rates at surgical sites show significant global variability, spanning from 2.6% to 58% (Allegranzi, 2014; Apanga et al., 2014; Bhangu et al., 2018; Kaur et al., 2017; Rosenthal et al., 2013). A previous study predicts that the annual incidence of SSI cases in the United States varies from 160,000 to 300,000, incurring costs between $3.5 billion to $10 billion (Edmiston Jr et al., 2022).

Research from the European Centre for Disease Prevention and Control covering 2013–2014 across 16 European nations indicated 18,364 instances of postoperative wound infection arising from 967,191 surgical procedures. The study indicated that SSI rates varied from 0.6% to 9.5% procedures (Mellinghoff et al., 2023).

The incidence of postoperative infection in various hospitals across India ranges from 10% to 25%. Research indicates that the incidence was 9% in other regions of the country (Dahiya et al., 2016), whereas in Kerala, South India, it was 4.1% (Vijayan et al., 2015).

Furthermore, a CDC assessment on infections associated with healthcare facilities indicated around 157,500 surgical site infections (SSIs) occurred during inpatient procedures in the United States in 2011 (Magill et al., 2014). Germany, England, France, Portugal, and mainland China exhibit SSI incidence rates of 2.2%, 1.6%, 1.4%, 1.6%, and 4.5%, respectively (Fan et al., 2014)

In Ulaanbaatar, the capital of Mongolia, a case-control study investigating the risk factors for sepsis following cesarean sections revealed that wound infection complicated 47.4% (361/761) of patients (Dagshinjav et al., 2017). A retrospective study was conducted on

approximately 211 cases with postoperative SSI at Nizwa Hospital in Oman. The incidence rate at that time was 2.66% (Dhar et al., 2014)

A study from the Department of Infection Control at Zhongda Hospital in China identified several risk factors associated with surgical site infections (SSI), including cancer, diabetes, ASA scores, wound classification, preoperative white blood cell count, type of surgery, intraoperative blood loss, necessity for blood transfusions, duration of the operation, risk index, postoperative drainage, and utilization of gastrointestinal or urinary catheters (Isik et al., 2015).

2.7.2 INCIDENCE OF SSI IN AFRICA

The incidence rates of SSI in Sub-Saharan Africa differ according to several reports (Manyahi et al., 2014b). In a study involving 322 pediatric surgical patients in Nigeria, the rates of surgical site infections (SSIs) were elevated, with emergency procedures exhibiting a rate of 25.8% compared to 20.8% for elective surgeries. The association was not statistically significant (Korol et al., 2013). A comparable study in South Africa revealed a statistically significant link between a high incidence of surgical site infections (SSI) in unclean surgeries (60%) compared to contaminated (27.3%), clean contaminated (19.3%), and clean surgeries (14.3%) (Dramowski et al., 2016).

A study on SSIs conducted in three public hospitals in Cameroon revealed an incidence rate of 9.16%. Superficial infections accounted for 68.18%, whereas deep infections constituted 31.82%; 90% of infected patients presented with open wounds (Mukamuhirwa, 2017).

Research at Thika Hospital in Kenya indicated that cesarean sections constituted 75% of all surgical procedures, which included hernia repairs, laparotomies, hysterectomies, amputations, and appendectomies. Orthopedic and neurosurgical specialties exhibit a significant SSI incidence of 14%, with injuries from contaminated traffic accidents occurring more frequently. Patients operated on by surgeons with vocational training exhibit a 15% higher incidence of surgical site infections (SSI) (Aiken et al., 2013).

The Kenyatta National Hospital in Kenya reported the highest incidence rate of SSI at 36.7%. Kijabe Hospital in Kenya reported the lowest incidence rate of SSI at 5%, reflecting a significant decrease from 9.3% due to a series of post-interventions, which encompassed optimized antibiotic prophylaxis and enhanced operating room practices (Ntumba et al., 2015; Opanga et al., 2017).

A study conducted in Nnewi, Nigeria, found that approximately 12.5% of post-cesarean wound infections occurred. The rate was 20.0% for emergency cesareans and 5% for

elective surgery patients (Onyegbule et al., 2015). A study reported a cumulative total incidence of SSI at Bugando Medical Center in Mwanza of 10.9%, with an incidence rate of 37.5 per 10,000 individuals per day (95% CI, 26.8-52.4) (Mpogoro et al., 2014). A prospective hospital-based study conducted in 2014 at Mbarara Regional Referral Hospital in Southwestern Uganda revealed an overall surgical site infection (SSI) incidence of 16.4%, comprising 5.9% superficial SSIs and 47.1% deep and organ space SSIs each (Lubega et al., 2017)

2.7.3 INCIDENCE OF SSI IN GHANA

The incidence of SSI following orthopedic trauma in Ghana has not yet been established; however, some prevalence data have been reported. Previous research indicates that the prevalence of SSI in Ghana ranges from 39% to 40% (Salia et al., 2024). SSIs account for up to 33% of all hospital-acquired infections (Ameyaw, 2014; Apanga et al., 2014; Labi et al., 2019).

2.8 RISK FACTORS FOR SSI FOLLOWING TOS.

Patients may exhibit varying risk factors for SSIs after orthopedic trauma surgery. These variables encompass both intrinsic (patient-related) and extrinsic (procedure-related) factors. Intrinsic variables encompass age and non-modifiable features such as obesity, smoking, and immunosuppressive medical disorders (Anderson et al., 2014; Triantafyllopoulos et al., 2015). Extrinsic factors encompass the type of surgery performed, its duration, and the hospital environment (Pedroso-Fernandez et al., 2016).

2.8.1 PREOPERATIVE FACTORS OF SURGICAL SITE INFECTION

2.8.1.1 USE OF PROPHYLACTIC ANTIBIOTICS

Routine administration of antimicrobial prophylaxis during basic, clean, non-prosthetic surgery is not recommended. Patients undergoing implant surgery should get prophylactic antibiotics (Kolasiński, 2019). Cefazolin is commonly employed due to its efficacy against both gram-positive and gram-negative bacteria. The standard prophylactic dosage of cefazolin is a single administration (Harris et al., 2015). Clindamycin should be used as the primary option for patients with an allergy to β-lactam antibiotics. Vancomycin is the primary treatment for MRSA (Mohammad Ghazavi et al., 2014).

Multiple post-operative doses of surgical antibiotic prophylaxis do not surpass a single dosage in avoiding surgical site infections (Swinbourne, 2023). Despite numerous studies associating the timing of postoperative antimicrobial prophylaxis with surgical site infections (SSI), the optimal timing for administering prophylaxis remains undetermined

(Swinbourne, 2023). Most recommendations advocate for the use of appropriate antibiotics within 60 minutes of incision (Appelbaum et al., 2024; Swinbourne, 2023).

2.8.1.2 PERIOPERATIVE BLOOD TRANSFUSION

Blood transfusions are commonly employed in orthopedic surgery due to significant incisions and prolonged recuperation periods. Autologous and allogeneic blood are both viable choices for transfusion. A prior study indicates that perioperative allogeneic blood transfusions may lead to surgical site infections (Ponnusamy et al., 2014). Immunomodulation during blood transfusion has heightened susceptibility to surgical site infections, urinary tract infections, and respiratory tract infections. Irradiation can reduce the incidence of diseases, similar to the effects of leukoreduction timing and blood storage duration(Lan et al., 2018).

Most orthopedic research demonstrates that allogeneic transfusion is associated with a heightened risk of infections. A significant dose-dependent escalation in both SSIs and other infections is linked to allogenic blood transfusion (Friedman et al., 2014). Patients who did not receive any transfusion had a decreased overall infection rate compared to those who underwent autologous or allogeneic transfusions (Ponnusamy et al., 2014). Notwithstanding this, the recommendations caution against denying patients' requests for blood and blood products due to the potential for SSIs (Berríos-Torres et al., 2017).

2.8.1.3 LENGTH OF HOSPITAL STAY BEFORE SURGERY

A patient is at an increased risk of bacterial colonization with prolonged hospital stays, regardless of whether it occurs preoperatively or postoperatively (Kelava et al., 2014). Patients with polytrauma have an increased susceptibility to surgical site infections due to prolonged hospitalizations. Polytrauma patients with elevated ISS scores, admitted to the ICU post-ORIF, are at risk of developing surgical site infections due to the severity of their injuries and frequent exposure to invasive treatments (Habibie, 2022). A recent study has demonstrated that multisystem dysfunctions in polytrauma patients admitted to the ICU lead to a more severe catabolic and immunocompromised state, hence elevating the risk of SSIs (Sheikh, 2022).

A study investigating the occurrence of closed fractures post-implant surgery revealed that *Klebsiella species* were the most prevalent, followed by *Pseudomonas aeruginosa*, with an overall surgical site infection rate of 7.09% (Mardirossian, 2022). A cohort study reported *Pseudomonas aeruginosa* as the predominant bacterium with an extended duration of stay, which was associated with SSI after orthopedic trauma surgery (Rajput et al., 2018).

2.8.2 PATIENT-RELATED RISK FACTORS OF SSI

2.8.2.1 CIGARETTE SMOKING

As a vasoconstrictor, nicotine in cigarette smoke can hinder wound healing by reducing the flow of nutrient-rich blood to the surgical site. The inflammatory cascade may be compromised due to diminished blood flow to the injured tissues (Srensen, 2012). The body may be incapable of managing the bacterial incursion due to these events, potentially resulting in SSI (Kong et al., 2017; da Costa et al., 2017; Durand et al., 2013).

2.8.2.2 AGE

Previous research indicates that both young and elderly individuals are at an elevated risk of having SSI postoperatively (Korol *et al*., 2013; Amoran *et al*., 2013; Shah *et al*., 2017; Chu *et al*., 2015). The rationale for age being a predisposing factor for the development of SSIs remains inadequately defined. Factors influencing the wound-healing process in older individuals indicate that an altered inflammatory response contributes to wound infections in this demographic (Gould et al., 2015).

2.8.2.3 GENDER

Previous studies have demonstrated that gender significantly influences the occurrence of postoperative SSI (Abdi et al., 2018; Langelotz et al., 2014; Setty et al., 2014; Takahashi et al., 2018). This element may be associated with sex hormones such as testosterone and estrogen. These hormones can impede wound healing by altering the expression of genes associated with inflammation and epithelialization (Pastar et al., 2014).

2.8.2.4 MALNUTRITION

Malnutrition has been identified as a risk factor for SSI in patients receiving any form of surgery (Tsantes et al., 2020). The patient is susceptible to surgical site infections and unfavorable surgical results due to malnutrition, which disrupts normal immune system function and often leads to inadequate wound healing (Gu et al., 2019). Serum albumin concentrations are utilized to assess nutritional status, with the normal nutritional range being between 3.4 and 5.4 g/dl (Alfargieny et al., 2015).

2.8.2.5 OBESITY

Obesity is characterized by a BMI over 30 kg/m²; overweight is defined as a BMI between 25 and 30 kg/m²; underweight is indicated by a BMI below 18.5 kg/m²; and normal weight is classified as a BMI ranging from 18.5 to 25 kg/m² (Huttunen & Syrjänen, 2013). Obese patients should ideally minimize their weight before surgery since obesity is considered a substantial independent risk factor for SSI (Mukamuhirwa, 2017). Obesity may prolong

surgical procedures due to inadequate vascularization of adipose tissues, leading to insufficient oxygen delivery and compromised immune response (Sangle et al., 2015).

2.8.2.6 DIABETES MELLITUS

A weakened immune system resulting from the pathophysiological effects of diabetes impedes wound healing (Rodríguez-Rodríguez et al., 2022). Research indicates that diminished collagen synthesis and deposition, reduced wound-breaking strength, and modified leukocyte activity are indicators of impaired wound healing in diabetic patients (Van Putte et al., 2016). Diabetic persons exhibit diminished leukocyte chemotaxis, phagocytosis, a reduction in macrophage count inside the wound matrix, and compromised perfusion and tissue oxygenation due to microvascular abnormalities associated with diabetes (Ahmed & Antonsen, 2016). The patient's level of glycemic control may be related to various adverse effects of diabetes. Elevated glucose levels (> 200 mg/dL) in the immediate postoperative period have been associated with a heightened risk of surgical site infection (SSI) due to inadequate glycemic control. The CDC advises that diabetic patients require adequate glucose management during the perioperative phase (Mukamuhirwa, 2017).

Patients with diabetes may experience co-morbid mobility difficulties that increase their risk of surgical infections when the condition is poorly managed. Patients with diabetes who suffer from surgical site infection (SSI) consequences exhibit elevated morbidity and death rates, extended hospitalizations, and increased healthcare expenditures (Wukich, 2015). Individuals without diabetes have a reduced likelihood of developing SSI compared to those with diabetes, contingent upon the type of surgery performed (Mukamuhirwa, 2017).

2.8.3 INTRAOPERATIVE RISK FACTORS OF SSI

2.8.3.1 TYPE OF SURGERY

The trauma orthopedic surgical procedure may be elective or emergent; emergency procedures can increase the risk of surgical site infections due to the absence of standard preoperative preparation (Thelwall et al., 2015).

2.8.3.2 SURGICAL SITE SKIN PREPARATION

Surgical site skin preparation is typically conducted on the patient's unbroken skin in the operating theater prior to surgery, encompassing not just the precise location of the planned incision but also an extended region of the patient's skin. This method seeks to diminish the microbial load prior to the incision of the epidermal barrier. The predominant antiseptic

agents are chlorhexidine (CHG) and povidone-iodine (PI) in alcohol-based formulations, which exhibit a wider range of antibacterial efficacy. Aqueous solutions, primarily comprising iodophors, are also utilized (George et al., 2017).

2.8.3.3 NUMBER OF PEOPLE IN THE OPERATION ROOM

The number of personnel in the operating room and the frequency of door openings during surgery are intraoperative risk factors that may elevate the incidence of surgical site infections (SSI). Research has demonstrated that individuals are the primary contributors of environmental pollution in the operating room (Mora et al., 2016). The justification for restricting personnel and movement in the operating theatre is to reduce the dispersion of bacterial infections from staff skin and air contamination from external sources (Tan et al., 2019). A prior study examined air quality during 30 orthopedic trauma surgeries and demonstrated a favorable connection between airborne microbial levels and the number of individuals in the operating room (Panahi et al., 2012). Traffic in the operating room is significantly elevated during trauma orthopedic procedures, particularly in revision cases, as evidenced by a prior study that assessed the frequency of door openings during initial and revision trauma orthopedic surgeries (Panahi et al., 2012).

A study conducted in 2015 evaluated the influence of surgical staff practices on the incidence of SSI. established a correlation between the number of individuals in the operating room and the rate of SSIs or airborne pollutants, as well as a correlation between the frequency of door openings and airborne bacterial counts (Birgand et al., 2015).

2.8.3.4 DURATION OF SURGICAL PROCEDURE

A study identified prolonged surgical procedures exceeding three hours as a risk factor for the development of surgical site infections (SSIs), with a 24% incidence rate among affected patients (Najjar & Saleh, 2017). A separate study also recognized analogous findings as a risk factor (Mawalla et al., 2011). Additional research indicated that prolonged surgical duration heightens the risk of wound exposure to environmental bacterial contamination (Mundhada & Tenpe, 2015; Najjar & Saleh, 2017). A study revealed an operating duration above three hours as a major risk factor for SSI after spine surgery, increasing the risk of SSI by 1.33 times or more. (Cheng et al., 2017). A study has determined that the risk of SSI after hip increases by 1.58 times if the procedure exceeds 2 hours in duration. (Cheng, 2015). A prior study has determined that every 15-minute extension in surgical duration correlates with a 9% rise in the incidence of deep surgical site infection following initial total knee arthroplasty (Namba et al., 2013).

2.8.3.5 LOCATION OF THE SURGERY

Previous research has identified the surgical site as a significant risk factor for the development of SSI. A prior study determined that surgeries involving seven or more intervertebral levels elevate the risk of SSI in orthopedic spinal procedures by a factor of 3.3 (Olsen et al., 2016). Nonetheless, a surgical procedure on the cervical spine and a procedure at a single vertebral level have been linked to a diminished incidence of surgical site infections in orthopedic spinal surgeries (Olsen et al., 2016). A separate study indicated that surgical procedures for adult spinal abnormalities, including kyphosis and scoliosis, entail longer operative durations than other spine surgeries, rendering them more vulnerable to elevated postoperative infection rates (Schwab et al., 2012).

2.8.4 POSTOPERATIVE RISK FACTORS OF SSI

2.8.4.1 LENGTH OF POSTOPERATIVE STAY

Extended postoperative hospitalizations, as indicated in the literature, are associated with an elevated risk of SSI following orthopedic trauma surgery. A prior study indicated that an extended postoperative hospital stay is a risk factor for Peri-Prosthetic Joint Infection following trauma orthopedic surgery (Gheiti & Mulhall, 2013). Another study indicated that an extended hospital stay can elevate the chance of acquiring Peri-Prosthetic Joint Infection following trauma orthopedic surgery by a factor of 1.09 (Triantafyllopoulos et al., 2018).

2.8.4.2 USE OF PROPHYLACTIC ANTIBIOTICS AFTER SURGERY

The administration of prophylactic antibiotics postoperatively aims to reduce the incidence of SSI; nevertheless, some studies indicate that they may also elevate the risk of such infections. A study has determined that antibiotic prophylaxis with aminoglycosides and the application of antibiotic solution for surgical wound irrigation elevate the incidence of SSIs after orthopedic spinal procedures by 2.7 times for both factors (Najjar & Saleh, 2017). A separate study has advised that antibiotic prophylaxis should not extend beyond the initial 24 hours postoperatively (Gheiti & Mulhall, 2013).

2.8.4.3 BLOOD TRANSFUSION POSTOPERATIVELY

Research indicates that blood transfusions may elevate inflammation and diminish immunity. Moreover, the blood transfusion may induce immunological mobilization, hence elevating the risk of nosocomial infections, especially SSI (Theodoraki et al., 2014). Research has determined that the transfusion of packed red blood cells and platelets elevates the risk of SSIs in orthopedic spinal procedures by 3.4 times (Everhart et al., 2018).

A similar study also identified postoperative transfusion as a significant predictor of SSI after spinal decompression and fusion surgeries. (Veeravagu et al., 2017). Blood transfusion has been recognized as an independent risk factor for Peri-Prosthetic Joint Infection (Gheiti & Mulhall, 2013). A study has indicated that postoperative blood transfusion is a risk factor for Peri-Prosthetic Joint Infection (Daines et al., 2015).

2.8.4.4 INCISIONAL WOUND IRRIGATION AFTER SURGERY

Incisional wound irrigation is commonly performed after the conclusion of surgery prior to wound closure, to reduce the incidence of SSI. Besides serving as a physical cleanser by eliminating debris, bodily fluids, and other contaminants, the irrigation solution is thought to work as a localized antibacterial agent when supplemented with an antiseptic or antibiotic compound. Prominent institutions have formulated several recommendations concerning this topic: A study has demonstrated the advantages of irrigation with an aqueous PI solution in preventing SSI, with no heightened risk of product-related adverse events or iodine toxicity, as corroborated by the meta-analyses undertaken by the CDC (Castel-Oñate et al., 2022). Conversely, another study demonstrated that wound irrigation with an antibiotic solution does not confer advantages over saline solution or no irrigation; thus, it is not endorsed by all major institutions, primarily due to the lack of supporting evidence and the heightened risk of promoting antibiotic resistance associated with this practice (de Jonge et al., 2017; Organization, 2016). A separate investigation indicated that diluted PI maintains bactericidal efficacy without the cytotoxic effects linked to alternative antiseptics (Van Meurs et al., 2014).

2.9 ANTIMICROBIAL RESISTANCE IN SSI AFTER OTS

The resistance of bacterial infections to widely utilized antibiotics and the rise of MDR bacteria is a global challenge that is escalating rapidly, resulting in restricted and costly antibiotic options (Akova, 2016). Antibiotic resistance continues to rise globally despite many efforts to combat it (Organization, 2022). Consequently, infections resulting from these resistant bacteria will persist in causing more severe ailments, treatment failures, extended hospital stays, and higher healthcare expenses (Prestinaci et al., 2015; Shrestha et al., 2018). In trauma orthopedics, postoperative infections are regarded as catastrophic consequences that might result in increased medical costs, extended hospital stays, amputation of the operated limb, readmission, or even death (Lu et al., 2022; Yun et al., 2016). The use of implantation materials during these procedures raises the possibility of

infections, which are notoriously difficult to treat because they create biofilms (Arciola et al., 2018).

In orthopedic surgery, the frequency of SSI varies from one health facility to the other and is related to complications (Olowo-Okere et al., 2018). The predominant organisms linked to surgical wound infections following orthopedic surgery include Staphylococcus aureus, Escherichia coli, Klebsiella spp., Proteus spp., Citrobacter spp., Acinetobacter spp., coagulase-negative Staphylococcus, and Pseudomonas aeruginosa (Godebo et al., 2013). Beta-lactam antibiotics are the predominant agents employed for surgical site infection prophylaxis and treatment; nonetheless, 30% to 90% of these antibiotics are either misapplied or excessively utilized(Mulu et al., 2012).

The extent of bacterial contamination, the virulence, and the antibiotic resistance of the bacteria influence the probability of a surgical site infection (Team, 2019). Preventing most SSI infections is possible (Team, 2019), however, the likelihood of an infection developing relies on factors including the host's age, immunocompromised state, or the AMR of the causing microorganisms (Moradali et al., 2017).

Inappropriate overuse raises selection pressure, favoring the growth of drug-resistant bacteria, complicating and raising the cost of empirical therapeutic decisions, endangering public health, and raising the incidence of SSI worldwide (Li & Webster, 2018). Irrational antibiotic medications and outdated empirical therapy make the disease worse. To reduce the issue, reliable epidemiological data from continuous nosocomial infection surveillance or data from clinical laboratories' antibiotic susceptibility testing (AST) are required (Lim et al., 2021).

2.10 ESBL IN ENTEROBACTERIACAE

ESBLs are enzymes—encoded by genes such as TEM, SHV, CTX-M, and others—that hydrolyze the β-lactam ring of extended-spectrum β-lactam antibiotics (e.g., third-generation cephalosporins like cefotaxime, ceftazidime, ceftriaxone) and aztreonam, rendering these drugs ineffective (Castanheira et al., 2021). The prevalence of ESBL-encoding genes is frequently underestimated due to the challenges in detecting them in clinical laboratory environments, and their incidence varies globally (Castanheira et al., 2021). The prevalence of ESBL-encoding genes produced by bacteria in surgical site infections in Europe and America has been documented to be below 20% (Hoffman-Roberts et al., 2016). The prevalence of ESBL-encoding genes in surgical site

infections in Asia and Africa has been estimated to be as high as 60% (Quan et al., 2016; Storberg, 2014). In Ghana, a Teaching Hospital in Ho has reported the detection of ESBL in 41.5% of *E. coli* isolates. The dominant genotype was TEM, often co-existing with CTX-M and SHV (Kipngeno Tigoi, 2024). Other studies in Ghana have also reported about 50% of ESBL-encoding genes, with the predominant gene variations responsible for ESBL production being SHV, TEM, and CTX-M genotypes (Feglo et al., 2013; Obeng-Nkrumah et al., 2013). Organisms that produce extended-spectrum beta-lactamases have been linked to post-surgical site infections and other surgical site infections (Dhar et al., 2014; Jolivet et al., 2018).

These bacteria share a common resistance mechanism that is mediated by plasmids or produced chromosomally. ESβL enzymes of more than 120 distinct varieties are frequently detected in members of the Enterobacterales family. The primary method of obtaining ESβLs is through horizontal gene transfer, and they provide resistance to oxyimino-cephalosporins (Nagshetty et al., 2021). Penicillin, monobactams, and broad-spectrum cephalosporins are hydrolyzed by a subset of these enzymes, which are designated as mutant derivatives of established plasmid-mediated β-lactamases (TEM/SHV) or mobilized from environmental bacteria (CTX-M) (Viana Marques et al., 2018). Cephamycin and carbapenems do not affect them; however, clavulanic acid inhibits them. Clinicians who are involved in the treatment of infectious diseases that arise from surgical sites may be perplexed by the ongoing expansion of knowledge regarding β-lactamases, as new enzymes with potentially diverse properties are progressively being identified. To facilitate the selection of the most suitable therapy, it may be beneficial to identify these resistant genes and organize the intricate microbiological data into therapeutically meaningful categories from a clinical perspective.

2.11 DIAGNOSIS OF SURGICAL SSI

Manifestations of SSI are contingent upon the location, the classification of the SSI, and, to a lesser degree, the causative agent (Young & Khadaroo, 2014). The onset of the infection is contingent upon the patient's immune response and interaction with the pathogen (Drago et al., 2019). The initial stage in diagnosing a surgical site infection involves a physical examination of the patient to identify symptoms of infection, including erythema, localized edema, discomfort, warmth, and purulent discharge (Thomas et al., 2016). The second and

most crucial phase is the culture and sensitivity testing of wound swab, conducted aerobically or anaerobically, to determine the microbiological profile and antibiogram (Coventry, 2014). Additional pertinent tests may encompass MRI, particularly useful in visualizing soft tissues, including the brain, spinal cord, and other internal organs (Kasliwal et al., 2013).

2.12 PREVENTION AND MANAGEMENT OF SSI

Infection prevention and control in postoperative environments are deemed crucial for all healthcare delivery systems worldwide. The management of postoperative infections imposes significant psychological and financial strain, as patients with SSI exhibit prolonged hospital stays, elevated morbidity and mortality rates, and increased healthcare expenses, including reoperations and readmissions (Tucci et al., 2019). Preventing SSI in orthopedic surgery is a complex challenge, particularly when an implanted biomaterial is involved, necessitating the integration of many strategies before, during, and after the procedure (Schömig et al., 2020). Upon identifying the risk factors for orthopedic SSI, prompt and conclusive measures for their prevention can be implemented.

Passed study advised administering the initial dose of antibiotics within 60 minutes prior to the surgical incision, ceasing prophylactic antimicrobial therapy within the first 24 hours postoperatively, restricting the number of healthcare personnel entering and exiting the operating room to mitigate airborne microbial contamination, and substituting prolonged wound drainage with irrigation (Daines et al., 2015).

Reports indicate that factors influencing wound healing are primarily related to aseptic and surgical methods, suggesting that surgical site infections (SSIs) are predominantly preventable; over fifty percent are expected to be preventable with evidence-based treatments (Copanitsanou et al., 2018). Protocols exist concerning standard precautions for the prevention of surgical site infections; these encompass operating room infrastructure requirements, hand and forearm antisepsis (Berríos-Torres et al., 2017; Loveday et al., 2014), and sterilization processes (Perçin, 2016), and the necessity for annual education of surgical teams (Loveday et al., 2014).

CHAPTER 3
MATERIALS AND METHODS

3.1 STUDY AREA

This study was conducted at the Tamale Teaching Hospital (TTH) in Tamale, Northern Region of Ghana which serves as a referral facility for the Northern, Savana, North-East, Upper East, and Upper West regions.

The hospital also treats patients who have been referred from Togo, Burkina Faso, and Mali (Wahab, 2017). The choice of this medical center was made in response to the considerable number of orthopedic patients it receives, as well as the diverse patient population, resulting in the expansion of motorized transportation in this region of Ghana.

The TTH has a bed capacity of 800 and offers general medicine, surgery, obstetrics and gynecology, pediatrics, orthopedics, ophthalmology, dermatology, psychiatry, and other services. The hospital setup includes specialized departments and sections that are staffed by skilled medical staff and administrative personnel who are dedicated to giving patients high-quality care (Darkom, 2015). In addition to offering clinical services, the TTH is actively engaged in research, advancing knowledge, and promoting healthcare.

The Tamale Teaching Hospital is located within the Tamale Metropolis. Tamale is a Metropolitan Assembly located in the central part of the Northern Region of Ghana. Tamale Metropolis also serves as the regional capital of the Northern Region. It is located 600 km north of Accra. Tamale Metropolis is the third-largest city in Ghana. Most residents of Tamale are Muslims and Dagombas by tribe (Takora et al., 2023). The metropolis has a total area of 750 km2 and a total population of 950,124. It shares boundaries with Savelugu Municipality to the north, Central Gonja Municipality to the south, Mion District Assembly

to the east, and Tolon District Assembly to the west. The metropolis has five (5) municipalities, including Tamale South Municipality, Tamale Central Municipality, Tamale North Municipality, Tamale West Municipality, and Sagnarigu Municipality.

3. 2 STUDY DESIGN

A prospective cohort study was conducted at the TTH from September 2023 to August 2024.

3.3 INCLUSION, AND EXCLUSION CRITERIA

Participants were patients who had undergone surgery in the orthopedic trauma surgical ward. We excluded patients admitted to the orthopedic surgical department but did not undergo any surgery and those who died after surgery. In addition, patients who had their wound infected before surgery (diagnosed by the surgeon and confirmed by culture-positive results) were excluded from this study. Also, patients with incomplete data of medical records by opting out within 6 months were excluded if SSI was not documented before the decision to opt out.

3.3 STUDY POPULATION

Study populations comprise patients who visited the Tamale Teaching Hospital and had undergone surgery at the Orthopedic Trauma Surgical Department

3.4 SAMPLE SIZE DETERMINATION

The sample size was calculated utilizing the Cochrane formula for sample size determination.

$N = z^2pq / e^2$, where $q = (1 - p)$; z = standard normal variate = 1.96 with a 95% confidence interval.

p= incidence of SSIs (13.58%) as reported by a recent study (Olowo-Okereet al., 2017) conducted in Nigeria. e= absolute standard error= 0.05

N =1.962(0.1358(1-0.1358)/0.052 = approximately, 180.

N=180.

By adding 5% of 180 to make up for non-responses, 189 minimum patients were recruited for the study.

3.5 DATA COLLECTION

The instruments for the data collection were in the form of a questionnaire to cover the demographic background of respondents, risk factors associated with SSIs, and blood cell parameters both pre- and post-surgery, as informed by existing literature and anecdotal observations. The questionnaire was based on the objectives of the study; hence, they were designed into themes. This study assessed the demographic characteristics, comorbidities, preoperative risk factors, intraoperative risk factors, and postoperative risk factors of SSI following OTS. The blood cell parameters considered were total WBC count, platelet count, lymphocyte differential count, neutrophil differential count, hemoglobin levels, and neutrophil/lymphocyte ratio (NLR). Patients were scheduled for a periodic review and a follow-up was done for one year for SSI. In addition, acute SSI requiring the patient to reattend the hospital at other time points was recorded. At each follow-up point, assessment of wound healing was done by the surgeon and recorded.

3.6 SAMPLE COLLECTION

Blood samples were obtained from participants into ethylenediamine tetra acetic acid (EDTA) tubes prior to surgery and on the post-of day 3. After collection, all samples are meticulously labeled with patient information and sent to the hematology laboratory at TTH within 30 minutes for complete blood count (CBC/FBC) analysis. Post-operatively, each patient was tracked and assessed for surgical site infection (SSI) over a period of one year. The patients were scheduled for regular (three-month intervals) evaluations during which the surgeon assessed wound healing progress and the occurrence of surgical site infections (SSI). The identification of SSIs was founded on the clinical assessment and diagnosis by

the surgeon according to the CDC (2013) criteria for diagnosing SSIs. Upon confirmation of the diagnosis by the surgeon, the suspected patients undergo wound cleansing with sterile normal saline to reduce skin colonizers before sample collection. The surgeon aseptically collects a wound swab from each patient using a sterile cotton-tipped applicator. Upon collection, all samples are meticulously labeled with patient information and conveyed in Stuart transport media within one hour to the Microbiology Laboratory Department at Tamale Teaching Hospital for culture and sensitivity testing, as well as Ziehl-Neelsen (ZN) staining for acid-fast bacilli.

3.7 LABORATORY INVESTIGATIONS

3.7.1 CULTURE AND SENSITIVITY TESTING

Specimens were cultured on blood agar, chocolate agar, and MacConkey agar utilizing normal bacteriological techniques. Cultures on chocolate agar were incubated at 35-37°C in 5% carbon dioxide (for microaerophilic conditions), while those on blood agar and MacConkey agar were incubated at 35-37°C in ambient air (for facultative anaerobes and obligate aerobes) for 18 to 24 hours. Description of colonies, a Gram stain was conducted on discrete colonies to classify the isolates as Gram-positive or Gram-negative bacteria for subsequent analyses.

3.7.2 ZN (ZIEHL-NEELSEN) STAINING

The Ziehl-Neelsen staining was done on all the specimens for acid-fast bacilli identification. The test procedure included: making triplicate smears of the specimens on microscopic slides and heat fixing the smears over a blue flame. The smears were flooded with carbolfuchsin and heated gently until it produced fumes, and allowed to stand for 5m and washed off gently under tap water. This was followed by decolorization with 20% sulphuric acid for 1-2m. This was followed by flooding the slides with methylene blue dye for 2-3m, and wash with water. The slides were air-dried and examined under oil immersion lens for acid-fast bacilli, which retain the red color of the primary dye, carbolfuchsin (Yerraguntla, 2018).

3.7.3 BACTERIA ISOLATION AND IDENTIFICATION

Gram staining was performed on discrete bacterial isolates to determine their Gram reaction and to facilitate preliminary classification based on cell wall composition and morphological characteristics. Biochemical tests, such as the catalase and coagulase tests, were performed on gram-positive organisms for identification. Whereas, urease test, citrate test, triple sugar iron test, motility test, oxidase test, and indole test were performed on all gram-negative isolates for identification (Kshikhundo & Itumhelo, 2016).

3.7.4 TESTING FOR ANTIMICROBIAL SUSCEPTIBILITY (DISK DIFFUSION)

The Kirby-Bauer disc diffusion method was used for antibiotic susceptibility testing, and the Clinical and Laboratory Standards Institute (CLSI) guidelines (2022) were followed in interpreting the result (Giske et al., 2022). To satisfy the 0.5 McFarland turbidity requirement, a discrete bacterial isolate was inoculated into a sterile broth (normal saline), ensuring a turbid suspension. Compare the bacterial suspension to the 0.5 McFarland standard visually, using a bright light and a white card with contrasting black lines. Once the turbidity is matched, the bacterial suspension is considered to be at a 0.5 McFarland standard, which corresponds to approximately 1.5 x 10^8 CFU/ml. The bacterial suspension was now inoculated into a Muller-Hinton agar plate. After allowing the plates to dry for fifteen minutes, the selected antibiotic discs were aseptically applied. Following a 24-hour incubation period at 35–37°C, the zone of inhibition was measured using a graduated ruler to determine the inhibitory zone widths in millimeters (mm). Tetracycline (30 µg), Doxycycline (30 µg), Erythromycin (15 µg), Clindamycin (2 µg), Ciprofloxacin (5 µg), Levofloxacin (5 µg), Penicillin (10 units), Gentamicin (10 µg), and Trimethoprim/Sulfamethoxazole (23.75 µg) were among the antibiotics used for gram-positive organisms, while Meropenem (10 µg), Amikacin (30 µg), Gentamicin (10 µg), Cefuroxime (30 µg), Ceftazidime (30 µg), Cefotaxime (30 µg), Cefepime (30 µg), Ciprofloxacin (5 µg), Levofloxacin (5 µg), and Piperacillin/Tazobactam (100/10 µg) were used for gram-negative organisms. *Staphylococcus aureus* ATCC 25923, *Pseudomonas aeruginosa* ATCC 27853, and *Escherichia coli* ATCC 25922 were used as control organisms in this experiment. According to the CLSI guidelines, the organisms' susceptibility results were categorized as either sensitive or resistant. The choice of antibiotics selections was based on Clinical and Laboratory Standards Institute guidelines (2022) (Giske et al., 2022).

3.7.5 PHENOTYPIC ESBL SCREENING

For all Enterobacteriales, genes that code for ESβL were tested using a phenotypic confirmatory disc diffusion assay. A standard inoculum (0.5 McFarland) of the test isolate was used to inoculate the Mueller-Hinton agar (MH). Genes that code for ESBL were tested against third-generation cephalosporines, ceftazidime (30µg) and ceftazidime-clavulanic acid (30µg/10 µg). An increase in zone diameter of ≥5 mm in the presence of clavulanic acid, as compared to that of ceftazidime alone, was interpreted as an ESβL producer.

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Table 3.1 Target genes screened for purposes of ESBL

GENES	SEQUENCE	PRODUCT LENGTH	PURPOSE
PER-F	ATGAATGTTCATTATAAAAGC	926	ESBL
PER-R	TTAATTTGGGCTTAGGG		ESBL
CTX M-F	GCGATGGGCAGTACCAGTAA	392	ESBL
CTX M-R	TTACCCAGCGTCAGATTCCG		ESBL
SHV-F	TCAGCGAAAAACACCTTG	472	ESBL
SHV-R	TCCCGCAGATAAATCACCA		ESBL
TEM-F	ATGAGTATTCAACATTTCCG	861	ESBL
TEM-R	TTACCAATGCTTAATCAGTGAG		ESBL
VEB-F	CGACTTCCATTTCCCGATGC	642	ESBL
VEB-R	GGACTCTGCAACAAATACGC		ESBL

3.7.6 DNA EXTRACTION FROM BACTERIAL ISOLATES USING RADI PREP DNA EXTRACTION KITS

Bacterial cells were aseptically collected from isolated colonies on a solid culture plate using a sterile inoculating loop. The cells were suspended in an appropriate volume of a lysing buffer and homogenized to form a uniform bacterial suspension. Following centrifugation, 200 µL of the bacterial pellet or resuspended cells was transferred into 250

µL of Potassium Solubilizing Bacteria (KSB) buffer, in accordance with the manufacturer's instructions (KH Medical, Germany). A 20ul of proteinase K (100ug/ml) was added and 5ul of carrier molecule, vortexed for 10s, and incubated at 56ºC for 10m. After the addition of 359ul of absolute ethanol and vortexing for 10s, the content was transferred into a spin column, centrifuged at 12000g for 1 min, and the flow-through discarded. A 500ul of KSW1 was added to the column and centrifuged for 1 minute at 12000g, discarding the flow through. This was repeated with a 500ul of KSW2. A 70ul of KSE buffer was added to the spin column, incubated for 1 minute at room temperature, and centrifuged for 1 minute at 12000g to elute the DNA. The extracted DNA was assessed for purity and concentration (Chennai Technologies, India), 1.8 – 2.0 purity range, and 20ng – 50ng concentration range, before being used for PCR (Mafakheri et al., 2022).

3.7.7 PCR AMPLIFICATION OF ESBL GENES AND ELECTROPHORESIS

Well-labeled PCR tubes were dispensed with 12.5 µL PCR master mix, 0.5 µL each of forward and reverse primers, and 50ng of DNA template added, and then topped up with nuclease-free water to make a total reaction volume of 25ul. PCR amplification was performed using a thermal cycler under the following conditions: initial denaturation at 94°C for 3 minutes, followed by 40 cycles of denaturation at 94°C for 30 seconds, annealing at 60°C for 30 seconds, and extension at 72°C for 30 seconds (Wong et al., 2015).

3.7.8 AGAROSE GEL ELECTROPHORESIS

Amplicon separation was performed using agarose gel electrophoresis. A 1% (w/v) agarose gel was prepared in 1× TAE (Tris-acetate-EDTA) buffer, and electrophoresis was carried out at a constant voltage of 90 V with a current of approximately 80 mA for 30 minutes. DNA bands were visualized under UV illumination following staining with an intercalating dye (ethidium bromide), and gel images were captured.

3.8 DATA ENTRY AND EVALUATION

The data for this study was entered into SPSS version 27 and presented in the form of frequencies, percentages, and cross-tabulations. Chi-square and Fisher's exact tests was employed to determine the associations between the dependent and independent variables.

Additionally, binary and multiple logistic regression analyses were performed to determine factors linked to SSI after OTS. Associations were considered statistically significant at a p-value of less than 0.05 and a 95% confidence range. We employed heat maps and bar graphs to illustrate the antimicrobial resistance patterns against the corresponding organism. Additionally, Microsoft imaging techniques were utilized to delineate the distinct ESβL variations identified. Normality was conducted to ascertain if the data represented a normally distributed population; nevertheless, the results indicated a skewed distribution, signifying that the data was not normally distributed. We employed the Mann-Whitney U test a non-parametric statistical method, to evaluate the differences in the median between the dependent and independent variables. The reference ranges for hemoglobin (Hb) concentrations are delineated as follows: 1). Male: 14-18 g/dL (SI units). Female: 12-16 g/dL (SI units); Pregnant female: >11 g/dL (Pagana et al., 2019).

3.9 ETHICAL CONSIDERATION

The institutional review board of the University for Development Studies approved this study (UDS/IRB/127/23). Authorization for the site was obtained from the Tamale Teaching Hospital and the Department of Surgery (TTH/R&B/SR/283). Participation of patients was entirely voluntary, and informed consent was obtained from them.

CHAPTER 4
RESULTS

4.1 INCIDENCE AND SOCIODEMOGRAPHIC CHARACTERISTICS OF STUDY PARTICIPANTS

A total of 210 patients were recruited for this study. Out of these, 14 (6.7%) developed SSI (5.7% and 1.0% were within 30 days and 6 months, respectively). The study reported a maximum and minimum age of 86 years and 0.67 years (8 months) respectively. The median age (Interquartile range) reported in this study was 35.5 (18 - 47). However, the predominant age groups were between 21 – 30 and 41 – 50 years (18.6% and 19.0% respectively). Regarding gender, males were predominant (68.6%), and majority of the study participants were married (55.7%). Education-wise, 24.3% had tertiary level education, while 19.0%, 12.9%, and 11.4% had respectively primary, JHS, and SHS levels of education. About a third of the study participants are unemployed (31.0%). A greater proportion of the study participants were Muslims (71.4%), 22.9% Christians and 5.7% Traditionalists. Comparatively, Majority of the study participants resided in the rural area (42.4%), followed by 36.7% in the urban and 21.0% peri-urban area, as depicted in **Table 4.1**.

Table 4.2 Sociodemographic characteristics of study participants

Variables	Frequency (n=210)	Percentage (%)
Age categories (Years)		
≤10	27	12.9
11 - 20	35	16.7
21 - 30	39	18.6
31 - 40	33	15.7
40 - 50	40	19.0
>50	36	17.1
Gender		
Male	144	68.6
Female	66	31.4
Marital status		

Married	117	55.7
Single	81	38.6
Divorced	4	1.9
Cohabitation	8	3.8
Educational level		
No education	68	32.4
Primary	40	19.0
Junior High School	27	12.9
Senior High School	24	11.4
Tertiary/Above	51	24.3
Occupation		
Government worker	29	13.8
Private worker	29	13.8
Self-employment	37	17.6
Student	50	23.8
Unemployment	65	31.0
Religious background		
Christians	48	22.9
Muslims	150	71.4
Traditionalist	12	5.7
Residential area		
Urban	77	36.7
Peri-Urban	44	21.0
Rural	89	42.4

4.2 PATIENT-RELATED RISK FACTORS OF SSI AFTER OTS

Patient-related risk factors that predispose to SSI following OTS were examined. The factors considered were demographic data, and health and lifestyle factors such as diabetes mellitus, hypertension, smoking, alcohol use, asthma, congestive cardiac failure, cancer patients, and the American Society of Anesthesiologists (ASA) score. The results revealed

that none of the factors was significantly associated with SSI following OTS (p-value>0.05) as shown in **Table 4.2**. The results however showed that a greater proportion of those who lived in the rural areas (64.3%) developed SSI as compared to the urban and peri-urban settlers. Furthermore, SSI was predominant in participants who did not have formal education (42.9%) compared to various levels of formal education. In addition, about 50.0% of the unemployed patients suffered from SSI as against the other occupational categories.

Table 4.3 Patient-related factors of SSI after OTS.

Variables	Total	Surgical Site Infection Yes (n=14)	No (n=196)	p-value
Age categories (Years)				**0.058**
≤10	27 (12.9)	0 (0.0)	27 (13.8)	
11 -20	35 (16.7)	5 (35.7)	30 (15.3)	
21 - 30	39 (18.6)	4 (28.6)	35 (17.9)	
31 - 40	33 (15.7)	1 (7.1)	32 (16.3)	
41 - 50	40 (19.0)	0 (0.0)	40 (20.4)	
>50	36 (17.1)	4 (28.6)	32 (16.30	
Gender				**0.141**
Male	144 (68.6)	7 (50.0)	137 (69.9)	
Female	66 (31.4)	7 (50.0)	59 (30.1)	
Marital status				**0.817**
Married	117 (55.7)	8 (57.1)	109 (55.6)	
Single	81 (38.6)	6 (42.9)	75 (38.3)	
Divorced	4 (1.9)	0 (0.0)	4 (2.0)	
Cohabitation	8 (3.8)	0 (0.0)	8 (4.1)	
Educational level				**0.165**
No education	68 (32.4)	6 (42.9)	62 (31.6)	
Primary	40 (19.0)	2 (14.3)	38 (19.4)	
Junior High School	27 (12.9)	3 (21.4)	24 (12.2)	
Senior High School	24 (11.4)	3 (21.4)	21 (10.7)	
Tertiary and above	51 (24.3)	0 (0.0)	51 (26.0)	
Occupation				**0.346**
Government worker	29 (13.8)	0 (0.0)	29 (14.8)	
Private worker	29 (13.8)	1 (7.1)	28 (14.3)	
Self-employed	37 (17.6)	3 (21.4)	34 (17.3)	
Student	50 (23.8)	3 (21.4)	47 (24.0)	
Unemployed	65 (31.0)	7 (50.0)	58 (29.6)	
Religious background				**0.413**
Christians	48 (22.9)	2 (14.3)	46 (23.5)	
Muslims	150 (71.4)	12 (85.7)	138 (70.4)	
Traditionalist	12 (5.7)	0 (0.0)	12 (6.1)	
Residential area				**0.227**

Urban	77 (36.7)	3 (21.4)	74 (37.8)	
Peri-urban	44 (21.0)	2 (14.3)	42 (21.4)	
Rural	89 (42.4)	9 (64.3)	80 (40.8)	
Diabetes mellitus				**0.641**
Yes	3 (1.4)	0 (0.0)	3 (1.5)	
No	207 (98.6)	14 (100.0)	193 (98.5)	
Hypertension				**0.646**
Yes	22 (10.5)	2 (14.3)	20 (10.2)	
No	188 (89.5)	12 (85.7)	176 (89.8)	
Smoking				**0.704**
Yes	2 (1.0)	0 (0.0)	2 (1.0)	
No	208 (99.0)	14 (100.0)	194 (99.0)	
Alcohol used				**0.641**
Yes	3 (1.4)	0 (0.0)	3 (1.5)	
No	207 (98.6)	14 (100.0)	193 (98.5	
Asthmatic				**0.704**
Yes	2 (1.0)	0 (0.0)	2 (1.0)	
No	208 (99.0)	14 (100.0)	194 (99.0)	
Congestive Cardiac Failure				**0.789**
Yes	1 (0.5)	0 (0.0)	1 (0.5)	
No	209 (94.5)	14 (100.0)	195 (99.5)	
Cancer Patient				**0.641**
Yes	3 (1.4)	0 (0.0)	3 (1.5)	
No	207 (98.6)	14 (100.0)	193 (98.5)	
ASA Score				**0.958**
ASA 1	179 (85.2)	12 (85.7)	167 (85.2)	
ASA 2	27 (12.9)	2 (14.3)	25 (12.8)	
ASA 3	3 (1.4)	0 (0.0)	3 (1.5)	
ASA 4	1 (0.5)	0 (0.0)	1 (0.5)	

ASA: American Society of Anesthesiologists' physical status classification system.

4.3 BLOOD TRANSFUSION BEFORE SURGERY WAS A MAJOR PREOPERATIVE RISK FACTOR ASSOCIATED WITH SSI AFTER OTS.

This study assessed the preoperative risk factors that predispose patients to SSI following OTS. The factors considered were washing of surgical site with water and soap before surgery, the type of antiseptic used in the skin preparation, whether antibiotics were given before surgery, types of antibiotics that were given before surgery, whether there was blood transfusion before surgery and the types of ABO blood group that was transfused before surgery. However, the only parameter that was linked to SSI was blood transfusion before surgery (p=0.038) but not the type of blood transfused, as shown in **Table 4.3**. Proportion-wise, not washing the surgical site before surgery was associated with 78.6% of SSI, and

savlon/alcohol skin preparation was mostly used by surgeons. The most common antibiotic given to patients before surgery was cefuroxime.

Table 4.4 Preoperative factors associated with SSI after OTS

Variables	Total	Surgical site Infection Yes (n=14)	No (n=196)	p-value
Was the surgical site washed with soap and water before surgery?				**0.765**
Yes	52 (24.8)	3 (21.4)	49 (25.0)	
No	158 (75.2)	11 (78.6)	147 (75.0)	
What antiseptic was used for the skin preparation?				**0.864**
70% Isopropyl alcohol	1 (0.5)	0 (0.0)	1 (0.5)	
Chlorhexidine/Alcohol	3 (1.4)	0 (0.0)	3 (1.5)	
Savlon/Alcohol	206 (98.1)	14 (100.0)	192 (98.0)	
Was antibiotics given before surgery?				**0.789**
Yes	209 (99.5)	14 (100.0)	195 (99.5)	
No	1 (0.5)	0 (90.0)	1 (0.5)	
Types of antibiotics given before surgery				**0.497**
Cefuroxime	202 (96.7)	13 (92.9)	189 (96.9)	
Meropenem	1 (0.5)	0 (0.0)	1 (0.5)	
Ceftriaxone	4 (1.9)	1 (7.1)	3 (1.5)	
Clindamycin	2 (1.0)	0 (0.0)	2 (1.0)	
Blood transfusion before surgery?				**0.038**
Yes	42 (20.0)	6 (42.9)	36 (18.4)	
No	168 (80.0)	8(57.1)	160 (81.6)	
Types of blood groups that was given before surgery				**0.869**
Blood Group A	8 (19.0)	1 (16.7)	7 (19.4)	
Blood Group B	10 (23.8)	1 (16.7)	9 (25.0)	
Blood Group AB	0 (0.0)	0 (0.0)	0 (0.0)	
Blood Group O	24 (57.1)	4(66.7)	20 (55.6)	

4.4 THE ANATOMICAL LOCATION OF THE SURGERY WAS A SIGNIFICANT INTRA-OPERATIVE FACTOR ASSOCIATED WITH SSI AFTER OTS

The current study assessed the intra-operative risk factors that predispose patients to SSI following orthopedic trauma surgery (OTS). The factors considered were types of surgery, types of procedure, types of implants used, whether there was a fracture, types of fracture, classification of open fractures, types of anesthesia given, duration of surgery, anatomical

location of the surgery, and number of staff in the surgical room during surgery. However, the only parameter that was profoundly linked to SSI was the anatomical location of the surgery (p=0.003), as shown in **Table 4.4.** Moreover, among the SSI cases, 92.9% had implants compared to those without implants, 7.1%. In addition, when the number of staff in the surgical room was >9, about 35.7% of such category developed SSI. Among patients whose surgery duration was > 120 minutes, 15.7% of them had SSI, compared to 5.5% and 5.9% in the <60 and 60-120 minutes groups, respectively but was not statistically significant.

Table 4.5 Intra-operative factors associated with SSI after OTS

Variables	Total	Surgical Site Infection Yes (n=14)	No (n=196)	p-value
Type of surgery				**1.000**
Elective	195 (92.9)	13 (92.9)	182 (92.9)	
Emergency	15 (7.1)	1 (7.1)	14 (7.1)	
Type of procedure				**0.119**
Implant used	154 (73.3)	13 (92.9)	141 (71.9)	
No implant used	56 (26.7)	1 (7.1)	55 (28.1)	
Types of implants used				**0.461**
Endoprosthesis	3 (1.9)	0 (0.0)	3 (2.1)	
I. M. Nailing	30 (19.5)	4 (30.8)	26 (18.4)	
Plate and Screw	70 (45.5)	4 (30.8)	66 (46.8)	
External fixation	28 (18.2)	4 (30.8)	24 (17.0)	
Pins and Wires	23 (14.9)	1 (7.7)	22 (15.6)	
Is there fracture?				**0.473**
Yes	172 (81.9)	13 (92.9)	159 (81.1)	
No	38 (18.1)	1 (7.1)	37 (18.9)	
Types of fractures				**0.565**
Open fracture	76 (44.2)	7 (53.8)	69 (43.4)	
Closed fracture	96 (55.8)	6 (46.2)	90 (56.6)	
If open fracture, classification				**0.305**
GA1	2 (2.6)	0 (0.0)	2 (2.9)	
GA2	24 (31.6)	0 (0.0)	24 (34.8)	
GA3A	25 (32.9)	4 (57.1)	21 (30.4)	
GA3B	22 (28.9)	3 (42.9)	19 (27.5)	
GA3C	3 (3.9)	0 (0.0)	3 (4.3)	
Types of anesthesia given				**0.573**
General	83 (39.5)	4 (28.6)	79 (40.3)	
Regional	127 (60.5)	10 (71.4)	117 (59.7)	
Duration of surgery				**0.246**
0 – 60 minutes	55 (26.2)	3 (21.4)	52 (26.5)	
60 – 120 minutes	136 (64.8)	8 (57.1)	128 (65.3)	
>120 minutes	19 (9.0)	3 (21.4)	16 (8.2)	

Anatomical location of the surgery				**0.003**
Upper limb	45 (21.4)	0 (0.0)	45 (23.0)	
Lower limb	137 (65.2)	11 (78.6)	126 (64.3)	
Spine	2 (1.0)	1 (7.1)	1 (0.5)	
Pelvic	6 (2.9)	2 (14.3)	4 (2.0)	
Foot and Ankle	12 (5.7)	0 (0.0)	12 (6.1)	
Clavicle	8 (3.8)	0 (0.0)	8 (4.1)	
Number of staff in the surgical room during surgery				**0.150**
3 – 5 Staff	9 (4.3)	0 (0.0)	9 (4.6)	
6 – 9 Staff	164 (78.1)	9 (64.3)	155 (79.1)	
>9 Staff	37 (17.6)	5 (35.7)	32 (16.3)	

4.5: THE TYPE OF DRESSING USED ON THE SURGICAL SITE AND THE TYPE OF BLOOD GROUP TRANSFUSED POST-SURGERY WERE SIGNIFICANTLY ASSOCIATED WITH POST-OPERATIVE SSI AFTER OTS

The current study assessed the post-operative risk factors that predispose patients to SSI following OTS. The factors considered were whether there was blood transfusion after surgery, types of blood group transfused after surgery, types of dressing used on the surgical site, and the classification of the surgical wounds after surgery. However, the only factors that was significantly associated with SSI were the type of dressing used on the surgical site (p=0.035) and the type of ABO blood group transfused after surgery (p=0.030), as shown in **Table 4.5**

Table 4.6 Post-operative factor associated with SSI after OTS

Variables	Total	Surgical Site Infection Yes (n=14)	No (n=196)	p-value
Was there a blood transfusion after surgery?				**0.797**
Yes	19 (9.0)	1 (7.1)	18 (9.2)	
No	191 (91.0)	13 (92.9)	178 (90.8)	
Which type of blood group was given after surgery?				**0.030**
Blood Group A	6 (31.6)	0 (0.0)	6 (33.3)	
Blood Group B	2 (10.5)	1 (100.0)	1 (5.6)	
Blood Group AB	2 (10.5)	0 (0.0)	2 (11.1)	
Blood Group O	9 (47.4)	0 (0.0)	9 (50.0)	
Which type of dressing was done after				**0.035**

surgery?				
Gauze Only	92 (43.8)	4 (28.6)	88 (44.9)	
Gauze and Saline	45 (21.4)	1 (7.1)	44 (22.4)	
Gauze and Povidone	43 (20.5)	7(50.0)	36 (18.4)	
Gauze and Savlon/Alcohol	30 (14.3)	2 (14.3)	28 (14.3)	
Classifications of the surgical wound after surgery				**0.470**
Clean	84 (40.0)	6 (42.9)	78 (39.8)	
Clean-Contaminated	40 (19.0)	4 (28.6)	36 (18.4)	
Contaminated	61 (29.0)	4 (28.6)	57 (29.1)	
Dirty	25 (11.9)	0 (0.0)	25 (12.8)	

4.6 BLOOD TRANSFUSION BEFORE SURGERY AND TYPES OF DRESSING USED ON THE SURGICAL SITE WERE INDEPENDENT RISK FACTORS OF SSI AFTER OTS.

Univariate and multivariate binary logistic regression analyses was applied to identify independent risk factors that predispose patients to SSI following OTS. The factors considered were gender, residential area, hypertension, types of surgery, types of procedure, whether there was a fracture, types of anesthesia given, duration of surgery, washing of surgical site with soap and water before surgery, blood transfusion before surgery, blood transfusion after surgery and the types of dressing used after the surgery. However, blood transfusion before surgery (p-value=0.035; OR=3.33; 1.09 – 10.20), and type of dressing used on the surgical site (p-value=0.027; OR=4.28; 1.18 – 15.51) were the only factors that showed significant association with SSI after the univariate binary logistic regression analysis. Further, only those with significant association were used to run the multivariate logistic regression analysis. The results confirmed that blood transfusion before surgery is three times more likely to developed SSI (p-value=0.034; OR=3.53; 1.10 – 11.33), and type of dressing used on the surgical site (p-value=0.035; OR=4.08; 1.10 – 15.08) remained significantly associated with SSI and as such identified as independent risk factors of SSI after OTS, **Table 4.6**.

Table 4.7 Predictors of SSI after OTS

Variables	COR (95% CI)	p-value	AOR (95% CI)	p-value
Gender				
Male	1 (Ref)			
Female	2.32 (0.78 – 6.92)	**0.130**		

Residential area				
Urban	1 (Ref)			
Peri-urban	1.18 (0.19 – 7.31)	**0.863**		
Rural	2.78 (0.72 – 10.64)	**0.137**		
Hypertension				
No	1 (Ref)			
Yes	1.47 (0.31 – 7.03)	**0.632**		
Type of surgery				
Elective	1 (Ref)			
Emergency	1.00 (0.12 – 8.21)	**1.000**		
Type of procedure				
No implant used	1 (Ref)			
Implant used	5.07 (0.65 – 39.69)	**0.122**		
Is there fracture				
No	1 (Ref)			
Yes	3.025 (0.38 – 23.86)	**0.293**		
Type of fracture				
Closed fracture	1 (Ref)			
Opened fracture	1.52 (0.49 – 4.73)	**0.468**		
Type of anesthesia used				
Regional	1 (Ref)			
General	0.59 (0.18 – 1.96)	**0.390**		
Duration of surgery (minutes)				
0 - 60	1 (Ref)			
60 - 120	1.08 (0.28 – 4.24)	**0.909**		
>120	3.25 (0.60 – 17.71)	**0.173**		
Was the surgical site washed with soap and water before surgery?				
Yes	1 (Ref)			
No	1.22 (0.33 – 4.56)	**0.765**		
Blood transfusion before surgery				
No	1 (Ref)		1 Ref)	
Yes	3.33 (1.09– 10.20)	**0.035**	3.53 (1.01 – 11.33)	**0.034**
Blood transfusion after surgery				
No	1 (Ref)			
Yes	0.76 (0.09 – 6.16)	**0.798**		
Which type of dressing was used on the surgical site after surgery?				
Gauze and Savlon/Alcohol	1 (Ref)		1 (Ref)	
Gauze and Saline	0.50 (0.05 – 4.61)	**0.541**	0.42 (0.05 – 3.99)	**0.454**
Gauze and Povidone	4.28 (1.18 – 15.51)	**0.027**	4.08 (1.10 – 15.08)	**0.035**
Gauze only	1.57 (0.27 – 9.04)	**0.613**	1.31 (0.22 – 7.80)	**0.763**

4.7: PREOPERATIVE AND POSTOPERATIVE BLOOD PARAMETERS IN PREDICTING SSI FOLLOWING OTS

Out of the 210 patients recruited for this study, 157 had their blood samples taken at different times for preoperative and postoperative (post-of-day 3) CBC analysis. The preoperative and postoperative blood parameters considered were total white blood cell count (WBC), hemoglobin level (Hb), platelets count, neutrophils differential count, lymphocytes differential count, and neutrophil/lymphocyte ratio (NLR). However, preoperative hemoglobin was strongly linked to SSI and as such identified as a predictor of SSI following trauma orthopedic surgery (p=0.019). On the contrary, none of the postoperative parameters were linked to SSI following orthopedic trauma surgery (OTS) (p-values >0.05) as shown in **Table 4.7**

Table 4.8 Preoperative and postoperative blood parameters in predicting SSI following OTS

Variables	SSI (N=14)	No SSI (N=143)	P-value
Preoperative Variables			
Preoperative Hb	10.35 (8.78 – 11.28)	11.30 (9.60 – 12.80)	**0.019**
Preoperative WBC	9.86 (5.48 – 11.32)	8.70 (6.14 – 11.42)	0.397
Preoperative Platelets	224 (173.75 – 268.75)	222 (165 – 299)	0.925
Preoperative Lymphocytes	1.72 (1.42 – 2.95)	2.47 (1.75 – 4.82)	0.826
Preoperative Neutrophils	6.23 (3.09 – 9.10)	4.02 (2.54 – 6.86)	0.510
Preoperative NLR	2.79 (1.73 – 5.90)	1.53 (0.67 – 3.30)	0.363
Postoperative Variables			
Postoperative Hb	9.45 (8.35 – 10.65)	9.60 (8.40 – 11.02)	0.177

Postoperative WBC	8.51 (7.20 – 12.36)	9.34 (7.05 – 11.02)	0.730
Postoperative Platelets	276.50 (196 – 380.25)	307 (207 – 405)	0.683
Postoperative Lymphocytes	2.53 (1.73 – 3.26)	3.21 (2.30 – 4.60)	0.397
Postoperative Neutrophils	5.68 (4.71 – 7.69)	4.95 (3.24 – 7.52)	0.778
Postoperative NLR	2.29 (1.66 – 5.12)	1.66 (0.81 – 2.99)	0.638

Mann-Whitney U test (also called Wilcoxon Rank–Sum test) was used to compare the differences in medians between the two variables and the output are displaced: Median (Interquartile Range) and P-values of <0.05 was considered statistically significant.

4.8 Criteria used in the diagnosis of SSI after OTS

The study revealed that most of the participants who developed SSI experienced no signs and symptoms such as fever, swelling of the site, erythema, and pain and tenderness (85.7%, 92.9%, 64.3%, and 64.3% respectively). All the study participants who developed SSI experienced serous discharge or pus from the site as a clinical sign (100.0%). Most of the participants did not experience a separation of tissues as a clinical sign of SSI. A total of 2 (14.3%) deep and 12 (85.7%) superficial SSIs were identified, **Table 4.8**.

Table 4.9 Criteria used in the diagnosis of SSI after OTS

Variables	Frequency (N=14)	Percentage (%)
fever?		
Yes	2	14.3
No	12	85.7
swelling of the site?		
Yes	1	7.1
No	13	92.9
Erythema?		
Yes	5	35.7
No	9	64.3
Pain and tenderness		
Yes	5	35.7
No	9	64.3
Serous discharge or pus from site?		
Yes	14	100.0

No	0	0.0
Separation of tissues?		
Yes	2	14.3
No	12	85.7
Types of surgical site infection diagnosed		
Superficial SSI	12	85.7
Deep SSI	2	14.3
Organ/Space SSI	0	0.0

4.9: BACTERIAL PROFILE AND ANTIMICROBIAL-RESISTANT PATTERNS

A total of 19 suspected samples (using the CDC criteria) were sent to the laboratory for bacterial culture and Ziehl Neelsen (ZN) staining of Acid-fast bacilli identification, of which 14(73.68%) turned out to be culture-positive, resulting in the isolation of 22 organisms. The remaining samples 5 (26.32%) showed no bacterial growth. There were no Acid-fast bacilli identified. Among the culture positives, 50.0% (7/14) showed monomicrobial growth, and 50.0 % (7/14) showed polymicrobial growth, **Figure 4.1A.** The polymicrobial growth has shown varied groups of organisms which include: 1) *Klebsiella spp* and *Enterococcus spp* 2) *Proteus mirabilis, Proteus vulgaris* and *Providencia rottgeri*, 3) *Citrobacter spp* and *Staphylococcus aureus*, 4) *Morganella morganii* and *Proteus mirabilis*, 5) *Citrobacter diversus* and *Enterobacter spp*, 6) *Klebsiella spp* and *Pseudomonas aeruginosa*, 7) *Klebsiella spp* and *Proteus mirabilis*. Among the organisms isolated, 86.36% (19/22) were Gram-negative bacilli, out of which 13 (68.42%) were Enterobacterales and 6(31.58%) were non-fermenters; 5 (83.33%) were *Pseudomonas aeruginosa* and 1(16.67%) *Pseudomonas* spp.). *Pseudomonas aeruginosa* 5 (22.73%) was the most common organism isolated, followed by *Klebsiella* spp. 4 (18.18%), **Figure 4.1B.** Among the 3 (13.64%) Gram-positive isolates, 2 (66.67%) were *Staphylococcus aureus* and 1 (33.33%) *Enterococci* spp. **Figure 4.1C.** Among the Gram-negatives, antimicrobial resistance was predominantly associated with *Proteus vulgaris*, *Citrobacter* spp., *Klebsiella* spp., *Providencia rottgeri,* and *Morganelle morganii* against the cephalosporines group of antibiotics, **Figure 4.1D**. In the Gram positives, *S. aureus* and *Enterococcus* spp. were resistant to tetracycline and doxycycline. Additionally, *S. aureus* was resistant to penicillin and *Enterococcus* spp. to ciprofloxacin, **Figure 4.1E**.

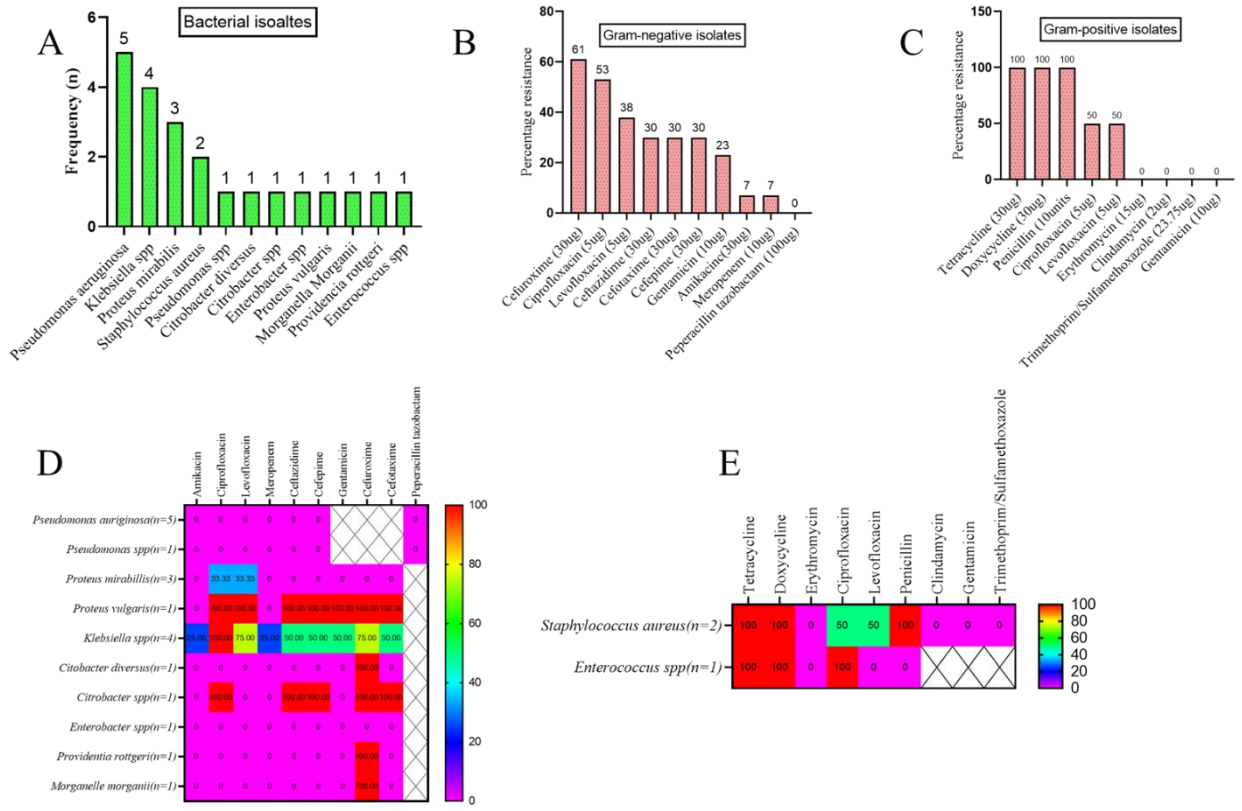

Figure 4.1 Bacterial profile and antimicrobial-resistant patterns.

A: All bacteria isolated; B: Gram-negative bacterial isolates and pattern of AMR; C: Gram-positive bacterial isolates and pattern of AMR; D: Heatmap presentation of antibiotic resistance pattern among the Gram-negative isolates; E: Heatmap presentation of antibiotic resistance pattern among the Gram-positive isolates.

4.10 DISTRIBUTION OF ESBL VARIANTS AMONG ENTEROBACTERALES ASSOCIATED WITH SSI POST-OTS.

A total of 13 (59.1%) Enterobacterales were isolated during the study period. Phenotypic ESβL screening and molecular characterization were investigated to identify possible resistant gene expression. Ceftazidime (30ug) and Ceftazidime/Clavulanic acid (30ug/10ug) was used for the screening. Three isolates (two *Klebsiella* spp. and one *Proteus vulgaris*) were identified as ESβL-positive using both phenotypic screening and molecular characterization. On the contrary, the remaining 10 Enterobacterales tested ESβL-negative to both the phenotypic and molecular methods, **Table 4.9.**

Table 4.10 Distribution of ESβL variants among Enterobacterales involved in SSIs post-OTS.

		Screening Method	
		Phenotypic (ESBL Positive)	**PCR (ESBL Positive)**
Isolates	**Total No.**	**N (%)**	**N (%)**
Klebsiella spp	4	2(50.0)	2(50.0)
Citrobacter diversus	1	0(0.0)	0(0.0)
Citrobacter spp	1	0(0.0)	0(0.0)
Enterobacter spp	1	0(0.0)	0(0.0)
Proteus mirabilis	3	0(0.0)	0(0.0)
Proteus vulgaris	1	1(100.0)	1(100.0)
Morganella Morganii	1	0(0.0)	0(0.0)
Providencia rottgeri	1	0(0.0)	0(0.0)

4.11 MOLECULAR CHARACTERIZATION OF TARGETED ESBLS GENES

This study considered five different ESβL genes for purposes of antimicrobial-resistant identification. The various genes considered, their sequences, and their respective product length (base pairs) are represented in **Table 3.1**. The genomic DNA with marker 1000bp of all the Enterobacterales isolates was tested for the presence of ESβL genes using conventional PCR and agarose gel electrophoresis methods. Two genes (CTXM and SHV) were identified in two *Klebsiella* spp. (**Figure 4.2 A&B**). The CTXM gene was also identified in one *Proteus vulgaris*. Other genes tested, such as PER, TEM, and VEB were not present in any of the bacterial isolates. These isolates were resistant against the cephalosporines group of antibiotics. The three isolates that expressed the ESβL genes (**Figure 4.2D**), were all phenotypical ESβL positive (**Table 4.9**).

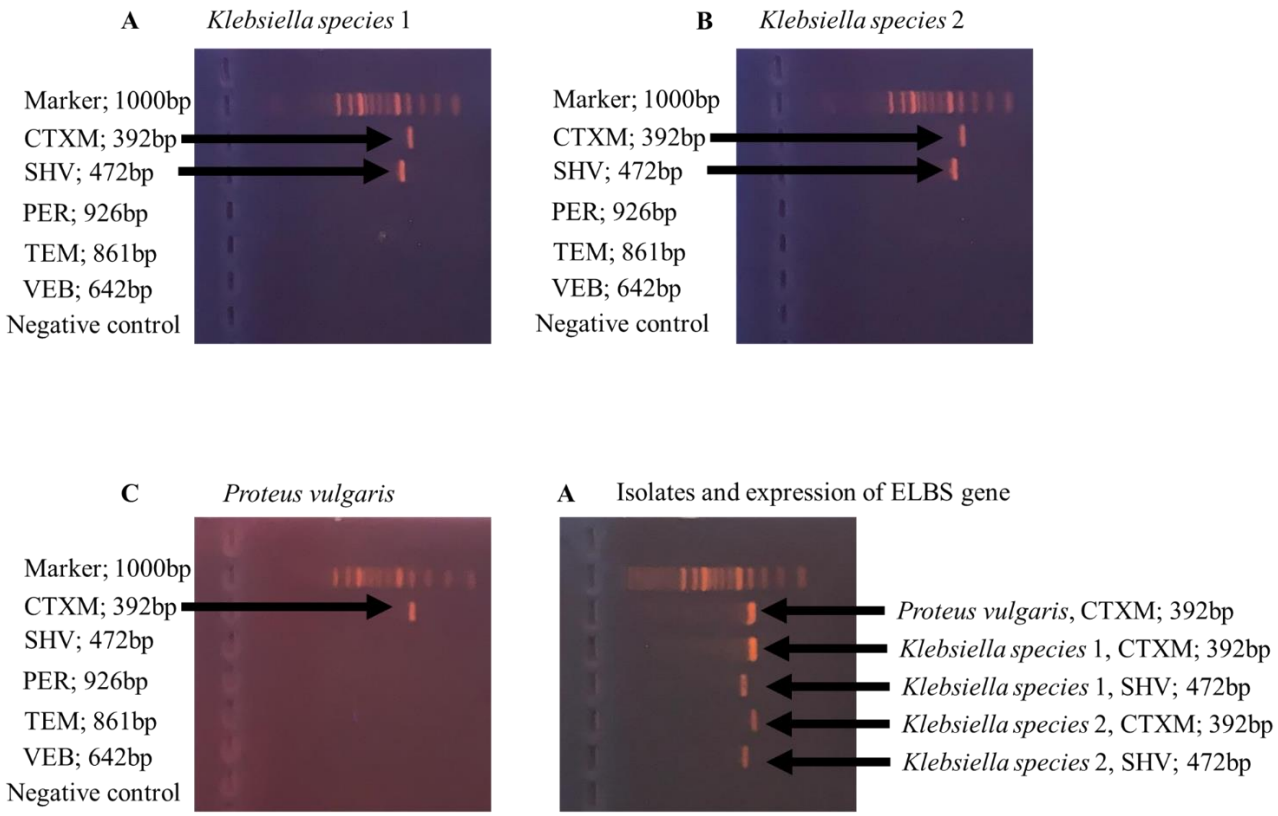

Figure 4.2 Molecular characterization of the ESβL genes by PCR.

(A) Represents the *Klebsiella* specie 1 and the ESβL genes expressed (CTX M, 392bp and SHV, 472bp). (B) Represents the *Klebsiella* specie 2 and the ESβL genes expressed (CTX M, 392bp and SHV, 472bp). (C) Represents the *Proteus vulgaris* and the gene expressed (CTX M, 392bp). (D) Represents the isolates, genes expressed, and their respective base pair. *Klebsiella specie* 1 was resistant to ciprofloxacin, levofloxacin, cefuroxime, ceftazidime, cefotaxime and cefepime but was susceptible to meropenem, amikacin and gentamicin. *Klebsiella specie* 2 also expressed similar resistant patterns to those of *Klebsiella specie* 1. *Proteus vulgaris* was resistant to ciprofloxacin, levofloxacin, gentamicin, cefuroxime, ceftazidime, cefotaxime and cefepime but was susceptible to meropenem and amikacin.

CHAPTER 5
DISCUSSION

5.1 DEMOGRAPHICS AND INCIDENCE OF SSI AFTER TOS

Aseptic precautions at surgical sites during operations do not eradicate the danger of infection, a known consequence in orthopedics. The current study reports an SSI incidence of 6.7% (67 per 1000 surgical procedures) following OTS, comprising 5.7% for superficial infections and 1.0% for deep infections. The incidence of SSI in this study exceeds that reported by other researchers from Saudi Arabia, Indonesia, India, and Belgrade (Al-Mulhim et al., 2014; Radji et al., 2014; Rajkumari et al., 2014; Starčević et al., 2015) . Nevertheless, two studies in Tanzania and Nigeria have reported a greater incidence of SSI (Kisibo et al., 2017; Olowo-Okere et al., 2018). The variations in events may be attributed to discrepancies in sample size, temporal and spatial context of the study, hospital type, surgical team composition, and surgical procedure type (Spencer et al., 2022).

Despite the increased incidence of SSI in the age groups 11-20, 21-30, and beyond 50 years, this observation lacked statistical significance, corroborating earlier findings that age alone does not constitute a risk factor for SSI (Al-Mulhim et al., 2014; Starčević et al., 2015). Nevertheless, additional research emphasized that advanced age is a risk factor for the onset of surgical site infections, likely attributable to age-related comorbidities such as immune system suppression, diminished appetite leading to inadequate nutritional status, and diabetes mellitus (Ikeanyi et al., 2013; Kisibo et al., 2017).

The present analysis revealed a greater proportion of males relative to females (ratio 2.2:1). This can be attributed to the greater involvement of males in outdoor activities and field employment, which increases their risk of accidents resulting in fractures and other related injuries. (Hole, 2014). The preponderance of men among operated patients has been previously demonstrated in research from India, Iran, and South India (Koyagura et al., 2018; Kumar et al., 2017; Mardanpour et al., 2017). The current study reported no significant associations between patient-related risk factors and SSI following OTS. This finding contradicts a publication that showed gender, inadequately managed diabetic mellitus, chronic alcoholism, and ASA Score as independent risk factors for SSI following OTS (Wise et al., 2019).

Blood transfusion before surgery was identified as an independent risk factor of SSI following thoracic outlet syndrome (OTS) procedures. This finding aligns with recent research indicating that blood transfusion prior to surgery is an independent risk factor of SSI (Everhart et al., 2017; Everhart et al., 2018; Najjar & Saleh, 2017). Additional factors, this study also reported other factors including the cleansing of the surgical site with soap and water prior to surgery, the type of solution employed for skin preparation, the administration of preoperative antibiotics, the specific antibiotics administered, and the types of ABO blood group transfused prior to surgery, were evaluated; however, none of these served as predictors of SSI following orthopedic trauma surgery (OTS).

The surgical anatomical site was a crucial intra-operative factor linked to SSI following OTS, consistent with prior research (Brophy et al., 2019; Wise et al., 2019). Contrary to this study, it has been reported that fracture types and operation duration are independent risk factors for SSI (Hu et al., 2020). However, our study observed an increased likelihood of developing SSI with prolonged surgery duration and open fractures, although this was not statistically significant. Additionally, another study identified specific types of open fractures, as classified by the Gustilo-Anderson system, as risk factors (Wise et al., 2019). Moreover, an augmented number of operating room personnel has been identified as a risk factor for surgical site infections (Panahi et al., 2012).

Among the parameters evaluated for post-operative risk, only the type of dressing used on the surgical site and the blood group transfused post-surgery were significantly associated with surgical site infections (SSI). Research indicates that the application of povidone-iodine in surgical site dressings is a predictor of SSI. This is ascribed to the reduced efficacy duration of povidone-iodine, which is inactivated by serum proteins and blood, in contrast to chlorhexidine (Mawalla et al., 2011). Likewise, povidone-iodine irrigation prior to skin closure at the surgical site did not mitigate SSIs (Mahomed et al., 2016). Conversely, studies indicated that the application of povidone-iodine for surgical site dressing significantly decreased the frequency of surgical site infections (Davies & Patel, 2016).

The study concluded that the overall incidence rate of SSI following thoracoscopic surgery (OTS) is 67 per 1000 surgical patients. Blood transfusion prior to surgery and the type of dressing applied to the surgical site post-operation were recognized as independent risk factors for SSI following thoracic surgery. It is essential to implement local strategies to

reduce the incidence of SSI following total organ systems (OTS) procedures, particularly for high-risk patients, including those necessitating pre-operative blood transfusions. A comprehensive multicenter investigation is necessary to determine the impact of blood transfusion on SSI. The role of wound dressing agents in preventing surgical site infections warrants further investigation.

5.2 THE ROLE OF PREOPERATIVE AND POSTOPERATIVE BLOOD PARAMETERS IN PREDICTING THE RISK OF SSI AFTER OTS

This study reported no statistically significant difference between preoperative leukocytes (WBC) and SSI. A similar study conducted in Switzerland reported no significant association between preoperative leukocytes and SSI (Mahmood et al., 2017). In contrast, other studies have found a significant association between pre-operative leukocytes and postoperative infections (Ling et al., 2023; Moghadamyeghaneh et al., 2015). This leukocytosis may result from a pre-existing infection, increasing the risk of SSI postoperatively. It may also be linked to malnutrition or other risk factors that increase the individual's susceptibility to SSI. This study found no significant association between preoperative NLR and SSI. This is in contrast with a study conducted in Turkey, which identified preoperative NLR as significantly associated with SSI (Kahramanoglu et al., 2018).

In this study, postoperative neutrophils, postoperative lymphocytes, and postoperative neutrophil/lymphocyte (NLR) show no significant association with SSI. This is in contrast with a study conducted in Japan (Inose et al., 2020), where these parameters showed a significant association with SSI. Another study also showed that NLR postoperatively could significantly discriminate between SSI and non-SSI groups after orthopedic surgery (Inose et al., 2019). Thus, using NLR would offer some diagnostic utility for the early prediction of SSI after orthopedic surgery (Zhao et al., 2020). Thus, using NLR would offer some diagnostic utility for the early prediction of SSI after orthopedic surgery. However, the results of our study may also indicate that NLR provides no advantage for the early prediction of SSI after orthopedic surgery. A few factors, such as the participants' selection, the sampling time, surgical techniques, implant used, blood loss, surgical complexity, and duration of surgery, could contribute to the variation.

Platelets are diminutive, non-nucleated cellular fragments that are found in the bloodstream, and their functions in blood clotting and hemostasis are well documented (Garraud & Cognasse, 2015). Inherited or acquired abnormalities in platelet count or function may be linked to bleeding issues (Deppermann & Kubes, 2016). Recent studies have emphasized the association of platelets with specific infections and inflammatory illnesses (Celik et al., 2017; Dinc et al., 2015). A prior study suggested that platelet count distribution may serve as a significant supplementary diagnostic tool for identifying SSI following severe orthopedic surgery, therefore minimizing costs and time expenditure (Zhang et al., 2018). The current investigation found no significant correlation between preoperative and postoperative platelet counts and the occurrence of SSI following orthopedic trauma surgery (OTS).

The present study identified preoperative hemoglobin (Hb) as a predictor of SSI following orthopedic trauma surgery (P-value<0.05). This is in line with previous studies, which reported preoperative hemoglobin (Hb) as significantly associated with SSI following trauma orthopedic surgery by (Falsetto et al., 2022; Jans et al., 2014). This could probably be because low hemoglobin levels can reduce oxygen tension and affect collagen formation. This impairs macrophage function and stops the healing process from progressing, increasing the risk of wound infection. Since it produces a less stable scar and favors dehiscence and infection (Castilla et al., 2012). However, a previous study also reported no significant association between preoperative hemoglobin and SSI (Paulino Pereira et al., 2016). The present study identified no significant association between postoperative hemoglobin and SSI following orthopedic trauma surgery (OTS). In contrast, a previous study reported postoperative hemoglobin as a predictor of SSI (Ruiz-Tovar et al., 2013).

5.3 BACTERIAL PROFILE AND ANTIMICROBIAL RESISTANT PATTERNS ASSOCIATED WITH SSI AFTER OTS

Among 210 patients who underwent diverse orthopedic procedures, nineteen (19) samples were collected from those suspected of developing surgical site infections (SSI). Of these, 14 (73.68%) cases exhibited positive cultures, while 5 (26.32%) cases demonstrated no bacterial growth. The positivity rate of culture reported as 73.68% in our study surpassed

the isolation rates of 68.8% in a referral hospital in Uganda (Seni et al., 2013), 71% in Ethiopia (Starčević et al., 2015) and 60.6% in Nepal (Amatya et al., 2015). The elevated proportion noted in this study may be ascribed to the surgical techniques employed, preoperative and intraoperative practices, patient-related variables, environmental influences, and postoperative care. The culture positivity rate in our study is notably lower than 90% in Tanzania (Manyahi et al., 2014a) and 96% in India (Rao et al., 2013). The diversity in culture positive may be ascribed to disparities in infection control and prevention strategies, as well as variables in the examined groups, such as comorbidities, sex, and age.

Pseudomonas aeruginosa was the most prevalent bacterium identified, with 5 occurrences (22.73%), followed by *Klebsiella spp*. with 4 occurrences (18.18%), and *S. aureus* with 3 occurrences (13.04%). This aligns with a previous study that identified *Pseudomonas aeruginosa* (39.13%) as the predominant bacteria isolated, followed by *Klebsiella spp*. (21.73%) (Meng et al., 2020). Our findings diverge from studies where coagulase-negative *staphylococci* were identified as the most infectious microorganisms (Becker et al., 2020; Li et al., 2013), and in others, *S. aureus* was common (Shafizad et al., 2019). The diversity in the isolated species may be ascribed to discrepancies in aseptic techniques employed, the various geographical epidemiology of the causative agents, and variations in the surgical procedures conducted, among other factors.

The Enterobacterales isolated in this investigation exhibited significant resistance to ciprofloxacin and cefuroxime, with resistance rates of 53.85% and 61.54%, respectively. Conversely, all Enterobacterales exhibited high susceptibility to gentamicin, amikacin, and meropenem, with rates of 69.23%, 76.92%, and 92.31%, respectively. *Pseudomonas aeruginosa* and the other *Pseudomonas species* found in this investigation exhibited complete susceptibility. Staphylococcus aureus exhibited complete resistance to tetracycline, doxycycline, and penicillin among Gram-positive organisms. *Enterococcus spp* showed complete resistance to Tetracycline, doxycycline, and ciprofloxacin. Conversely, *Enterococcus spp* exhibited complete susceptibility to penicillin (100%), whereas *Staphylococcus aureus* showed full susceptibility to erythromycin, gentamicin, clindamycin, and trimethoprim/sulfamethoxazole (100% for each).

The majority of patients acquired the infection during their hospital stay, namely after many months of admission, with an incidence of 85.71% (12/14). This may likely come from exposure to the hospital atmosphere and postoperative care. Microorganisms in the hospital environment encounter numerous antimicrobial agents and exhibit significant antimicrobial resistance due to selection pressure (Rothe et al., 2013; Sievert et al., 2013), thereby complicating the therapeutic management of surgical site infections involving these isolates. Resistance to commonly utilized antibiotics, particularly Cefuroxime, which exhibited a 61.54% resistance rate, may be ascribed to the imprudent application of these antibiotics in the absence of evidence regarding the causative agent and antibiogram, as well as the misuse stemming from self-medication with accessible and inexpensive over-the-counter antibiotics. The study underscores the necessity for stringent antimicrobial stewardship and the pursuit of innovative antibiotics, as the considerable prevalence of antibiotic resistance indicates that current antibiotics may become ineffective without timely intervention.

Recent investigations indicate that ESβL-producing bacteria are problematic in numerous healthcare settings (Mohammed & Abass, 2019; Tansarli et al., 2013). Pathogens that code for ESβLs pose a significant public health threat and are difficult to manage therapeutically. Resistant pathogenic infections can transform non-fatal cases into lethal illnesses due to treatment failure (Aruhomukama, 2020; Shan et al., 2015). Bacterial chromosomes contain ESβL-coding genes that can be inherited or transferred via plasmids throughout the bacterial population, indicating the persistence of these resistant strains (Naelasari et al., 2018).

This investigation detected ESβL production (CTXM and SHV genes) in 3 (23.08%) isolates of the Enterobacterales family, specifically in two *Klebsiella spp*. and one *Proteus vulgaris* with the CTXM gene. A prior analysis identified CTXM as the most commonly observed gene responsible for the ESβL phenotype (Egyir et al., 2020). Conversely, research indicates that the predominant ESβL morphologies comprise *Escherichia coli* (25.9%), followed by *Klebsiella pneumoniae* (7%), *Acinetobacter spp*. (2.4%), *Pseudomonas aeruginosa* (2.4%), and *Proteus spp*. (1.2%) (Madhavi & Hanumanthappa, 2021). Kasukurthy and Bathala identified Gram-negative bacilli as the primary pathogens in SSIs, with *K. pneumoniae* (29%) being the most frequently isolated organism, followed by

E. coli (22%) (Kasukurthy & Bathala, 2020). The prevalence of ESβL production among Gram-negative bacilli was 44%, which is comparatively higher than our findings.

CHAPTER 6
CONCLUSIONS AND RECOMMENDATIONS

6.1 CONCLUSION

The study reported the overall incidence rate of SSI after OTS to be 6.7% (67 per 1000 surgical operations). Blood transfusion before surgery and the use of povidone iodine and gauze for dressing after surgery were identified as independent risk factors of SSI following OTS. This study identified low preoperative hemoglobin level as a predictor of SSI following orthopedic trauma surgery**.**

Gram-negative bacteria, particularly *Pseudomonas aeruginosa,* were the dominant isolates from surgical sites after trauma orthopedic surgery. Among the Gram-positives, *S. aureus* was the dominant. ESBL production was seen among 3(23.08%) isolates of the Enterobacterales family, involving CTXM and SHV genes in two *Klebsiella* spp. and CTXM in one *Proteus vulgaris*. The findings of this study highlight the presence of antimicrobial resistance (AMR) among bacterial isolates, with CTX-M and SHV identified as the most prevalent extended-spectrum β-lactamase (ESβL) genes. These results underscore the growing threat of resistant pathogens in clinical settings and emphasize the urgent need for strengthened antimicrobial stewardship and routine surveillance to curb the spread of these resistance mechanisms.

6.2 RECOMMENDATIONS

Local measures that limit the rates of SSI after OTS should be adopted, especially in managing high-risk patients such as those who require pre-operative blood transfusion. Further studies are required to optimize appropriate dressing protocols for various wounds after OTS.

In this study, ESBL-producing organisms were identified among the Enrobacterales. However, strain types could not be identified as a result of the whole genome sequencing not being performed. Future studies in a similar area should include whole genome sequencing.

Multidrug-resistant patterns of ESBLs have serious implications for treatment. Therefore, the detection of phenotypic ESBL routinely should be included in the health facilities' testing system, and AST done to assist in the selection of antibiotics for the treatment of infections. Also, constant monitoring of the resistant trend of organisms to

antibiotics should be incorporated in surveillance systems of the region and the country as a whole.

6.3 LIMITATION OF THE STUDY

The samples used for the study were not subjected to anaerobic conditions to identify if any anaerobic organisms are associated with surgical site infections following orthopedic trauma surgery.

Expanding the sample size could probably have increased the generalizability of this study and data on the experience of the surgeons could have also help to determine if that had an influence on the recorded incidence.

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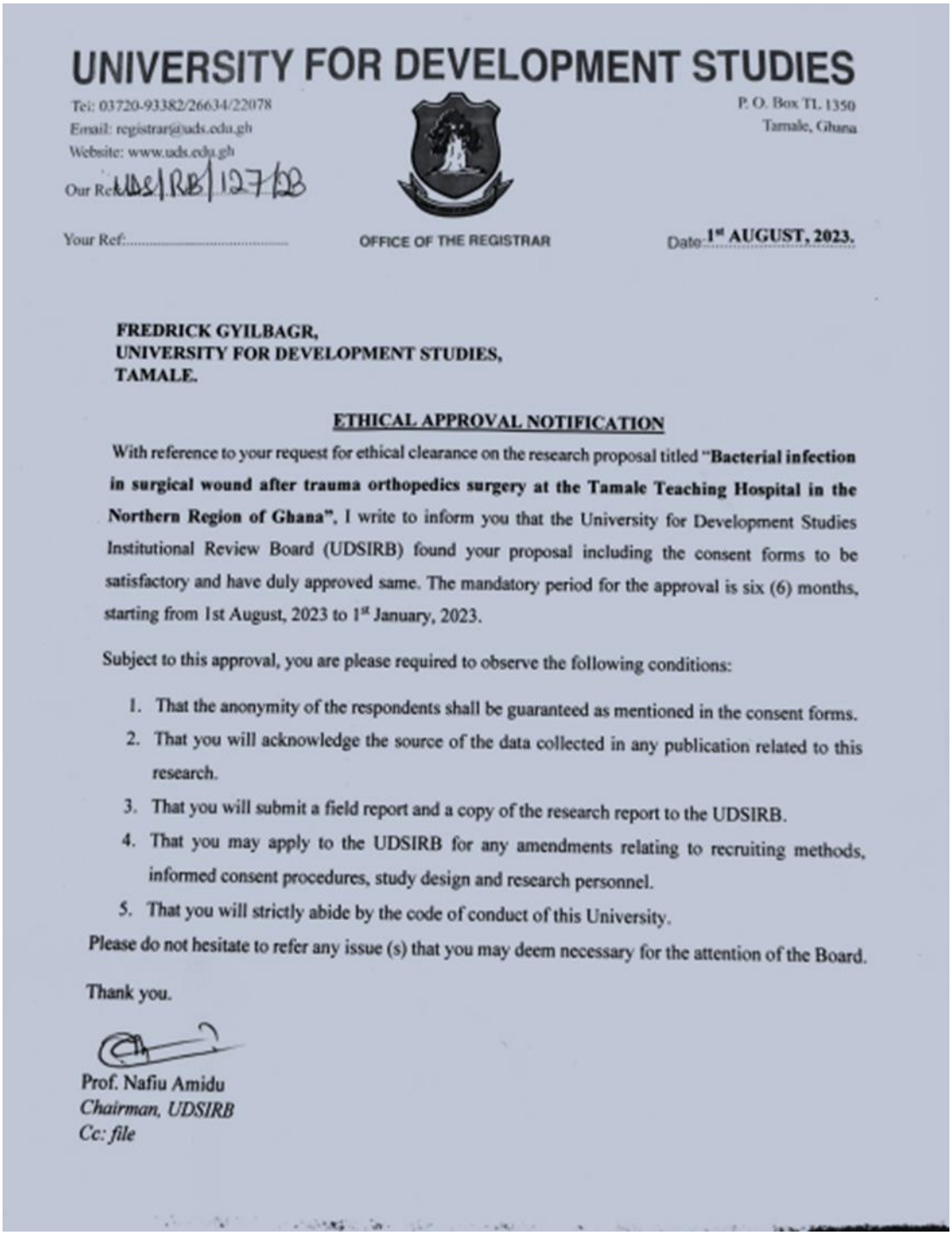
APPENDIX I: ETHICAL APPROVAL



UNIVERSITY FOR DEVELOPMENT STUDIES

Tel: 03720-93382/26634/22078
Email: registrar@uds.edu.gh
Website: www.uds.edu.gh
Our Ref: UDS/RB/127/23

P. O. Box TL 1350
Tamale, Ghana

Your Ref:.....

OFFICE OF THE REGISTRAR

Date: 1st AUGUST, 2023.

FREDRICK GYILBAGR,
UNIVERSITY FOR DEVELOPMENT STUDIES,
TAMALE.

ETHICAL APPROVAL NOTIFICATION

With reference to your request for ethical clearance on the research proposal titled "**Bacterial infection in surgical wound after trauma orthopedics surgery at the Tamale Teaching Hospital in the Northern Region of Ghana**", I write to inform you that the University for Development Studies Institutional Review Board (UDSIRB) found your proposal including the consent forms to be satisfactory and have duly approved same. The mandatory period for the approval is six (6) months, starting from 1st August, 2023 to 1st January, 2023.

Subject to this approval, you are please required to observe the following conditions:

1. That the anonymity of the respondents shall be guaranteed as mentioned in the consent forms.
2. That you will acknowledge the source of the data collected in any publication related to this research.
3. That you will submit a field report and a copy of the research report to the UDSIRB.
4. That you may apply to the UDSIRB for any amendments relating to recruiting methods, informed consent procedures, study design and research personnel.
5. That you will strictly abide by the code of conduct of this University.

Please do not hesitate to refer any issue (s) that you may deem necessary for the attention of the Board.

Thank you.

Prof. Nafiu Amidu
Chairman, UDSIRB
Cc: file

APPENDIX I1: INTRODUCTORY LETTER

UNIVERSITY FOR DEVELOPMENT STUDIES
SCHOOL OF MEDICINE
DEPARTMENT OF CLINICAL MICROBIOLOGY

Tel : +233-50273-2644
E-mail : clinmicrob@uds.edu.gh
Website: www.uds.edu.gh
Tamale, Ghana, West Africa

P. O. Box TL 1883

Date: July 10, 2023

Dear Sir/Madam,

LETTER OF INTRODUCTION: FREDRICK GYIBAGR (21026518)

I write to confirm that **Fredrick Gyilbagr** is an MPhil postgraduate student of this department in the School of Medicine and in his second year of study.

As a requirement of the training programme, he is expected to conduct a research of public health importance and thus submits a proposal on **Bacterial Infection in Surgical Wound after Trauma Orthopedics Surgery at the Tamale Teaching Hospital in the Northern Region of Ghana**, which would be supervised by **Dr. Williams Walana.**

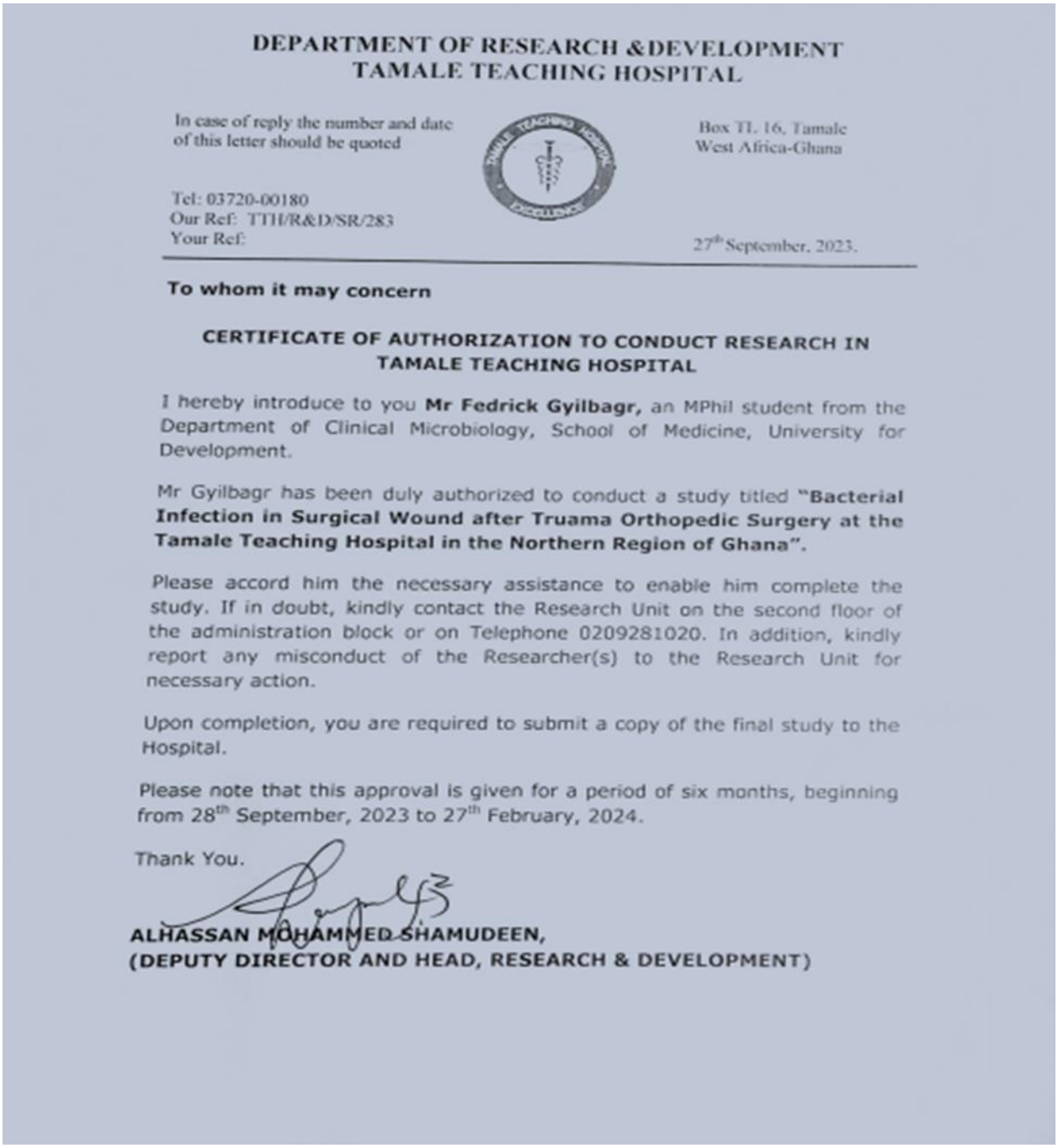
I trust that you would kindly give his proposal the needed consideration.

Thank you.

Dr. Akosua Bonsu Karikari

(Head, Department of Clinical Microbiology)

APPENDIX III: SITE PERMISSION



DEPARTMENT OF RESEARCH &DEVELOPMENT
TAMALE TEACHING HOSPITAL

In case of reply the number and date of this letter should be quoted

Box TL 16, Tamale
West Africa-Ghana

Tel: 03720-00180
Our Ref: TTH/R&D/SR/283
Your Ref:

27th September, 2023.

To whom it may concern

CERTIFICATE OF AUTHORIZATION TO CONDUCT RESEARCH IN TAMALE TEACHING HOSPITAL

I hereby introduce to you **Mr Fedrick Gyilbagr,** an MPhil student from the Department of Clinical Microbiology, School of Medicine, University for Development.

Mr Gyilbagr has been duly authorized to conduct a study titled **"Bacterial Infection in Surgical Wound after Truama Orthopedic Surgery at the Tamale Teaching Hospital in the Northern Region of Ghana".**

Please accord him the necessary assistance to enable him complete the study. If in doubt, kindly contact the Research Unit on the second floor of the administration block or on Telephone 0209281020. In addition, kindly report any misconduct of the Researcher(s) to the Research Unit for necessary action.

Upon completion, you are required to submit a copy of the final study to the Hospital.

Please note that this approval is given for a period of six months, beginning from 28th September, 2023 to 27th February, 2024.

Thank You.

ALHASSAN MOHAMMED SHAMUDEEN,
(DEPUTY DIRECTOR AND HEAD, RESEARCH & DEVELOPMENT)

APPENDIX IV: CONSENT FORM FOR STUDY PARTICIPANTS

Form number…….

Project Title: Bacterial infection in surgical wound after Trauma Orthopedics Surgery at the Tamale Teaching Hospital in the Northern Region of Ghana

Name and Address of Principal Investigator

Fredrick Gyilbagr, Department of Clinical Microbiology, School of Medicine and Health Sciences, University for Development Studies, Tamale.

Introduction

I am a student from the Department of Clinical Microbiology, School of Medicine and Health Science, University for Development Studies-Tamale conducting research on Bacterial infection in surgical wounds after Trauma Orthopedics Surgery at the Tamale Teaching Hospital in the Northern Region of Ghana. All information collected will be treated as confidential and no one can trace any information back to you.

Procedure

The study is targeted at patients who have undergone Orthopedic surgery at TTH. Participation is voluntary. Participants will be made to complete part of the questionnaire and return it to the principal investigator. Participants will also be required to give a 2mL blood sample to the principal investigator. Those who are suspected to have developed SSI, Wound swab samples will be taken from them by the surgeon

Risks and Benefits

Participants may feel uncomfortable with some of the questions and also during the sample collection period, however, they will be helpful for the research and may contribute to evidence base that has the ability to alter treatment regimen for patients with surgical site infection.

Right to refuse

Your consent to participate in this study is voluntary, you are not under any obligation to participate, and you are at liberty to withdraw from this study at any point in time. I will however appreciate it, if you could stay on till the completion of the study.

Anonymity and confidentiality

I assure you that any information given will be used purely for the purpose of this academic research. All information given will not be disclosed to anyone.

Voluntary agreement form for study participants

I have read and understood the content of this consent form. I have been given an opportunity to ask question(s) about the research. I agree to participate as a participant.

Name: ……

Signature: …… Date: ……

Interviewer's statement

I ……., the undersigned, have explained to the subject in the language he/she understands and the participant has agreed to take part in the study.

Signature: …… Date: …….

APPENDIX V: QUESTIONNAIRE

Questionnaire on Bacterial infection in surgical wound after Trauma Orthopedics Surgery at the Tamale Teaching Hospital in the Northern Region of Ghana

Instructions

Please note that you are voluntarily agreeing to participate in this research by completing this questionnaire. You will remain anonymous and your data will always be treated confidentially. You may withdraw from this study at any time. Please complete the questionnaire in full. Mark the appropriate response with a cross or write in the space provided.

SECTION A: SOCIO-DEMOGRAPHICS

1. Age (years)……

2. Gender: 1) Male 2) Female

3. Marital Status:

1) Married 2) Single 3) Divorced 4) Cohabitation

4. Educational levels:

1) No education 2) Primary 3) Junior high School 4) Senior high School 5) Tertiary and above

5. Occupation:

1) Government worker 2) Private worker 3) Self-employed 4) Student 5) Unemployed

6. Religious background

1) Christian 2) Islam 3) Traditionalist 4) Others

7. Residential area

1) Urban 2) Peri-urban 3) Rural

8. Date admitted……

9. Date of operation……

10. Date of discharge…….

11. Phone number…….

12. LHIMS Number……

SECTION B: PATIENTS RELATED RISK FACTORS ASSOCIATED WITH POSTOPERATIVE INFECTIONS

COMORBIDITIES

Variables	Yes	No
13. Diabetes mellitus		
14. Hypertension		

15. Smoking		
16. Alcohol		
17. Long-term steroid use		
18. Cancer patient		
19. Others		

20. ASA Score

1) ASA 1 2) ASA 2 3) ASA 3 4) ASA 4 5) ASA 5 6) ASA 6

21. Class of wound

1)Clean 2) Clean-contaminated 3) Contaminated 4) dirty or infected

22. Duration of hospital stay before surgery…….

SECTION C: SURGICAL FACTORS ASSOCIATED WITH POSTOPERATIVE INFECTION

23. Type of surgery

a) Elective b) Emergency

24. If fracture surgery, type of fracture

1) Open fracture 2) Close fracture

25. If open fracture, classifications

1) GA1 2) GA2 3) GA3A 4) GA3B 5) GA3C

26. Type of anesthesia

1) General anesthesia 2) Regional anesthesia

27. Duration of surgery…….

38. Number of staff in the surgical room during surgery…….

29. Anatomical location of surgery

1)Upper limb 2) Lower limb 3) Spine 4) Pelvic 5) Foot and ankle 6) Others

30. Was the surgical site washed with soap and water before skin preparation?

1) Yes 2) No

31. What solution was used for the skin preparation

1) 70% isopropyl alcohol 2) Chlorhexidine gluconate 3) Savlon/Alcohol

32. Preoperative Hb…….

33. Preoperative WBC…….

34. Preoperative PLT……

35. Preoperative Neutrophils…….

36. Preoperative Lymphocytes…….

37. Preoperative Neutrophils/Lymphocytes Ratio (NLR)…….

38. Was antibiotics given before surgery

1) Yes 2) No

39. If yes to question (36), please indicate the type of antibiotics that was given before surgery……
….

40. Blood transfusion before surgery?

1) Yes 2) No

41. If yes to question (38), please indicate the specific type of blood group that was transfused.

……

SECTION D: POST-OPERATIVE FACTORS ASSOCIATED WITH SURGICAL SITE INFECTION

42. Postoperative Hb on day 3…….

43. Postoperative WBC……

44. Postoperative PLT……

45. Postoperative Neutrophils…….

46. Postoperative Lymphocytes…….

47. Postoperative Neutrophils/Lymphocytes Ratio (NLR)…….

48. Blood Transfusion after surgery?

1) Yes 2) No

49. If yes to question (42), please indicate the specific type of blood group that was transfused

……

50. Which type of dressing is/was used on the surgical site?

1)Gauze 2) Gauze and Saline 3) Gauze and Povidone 4) Others

51. How frequently is the dressing done?.....

52. Type of surgical site infections

1) Superficial 2) Deep 3) Organ/Space

53. Date the infection was identified……

54. At what stage was the infection detected?

1) During hospital stay 2) At Re-admission 3) Routine checking for wound dressing

SECTION E: SIGNS AND SYMPTOMS OF SURGICAL SITE INFECTION OR POST-OPERATIVE INFECTION

55) Fever Yes ( ) No ( )

56) Swelling of site Yes ( ) No ( )

57) Erythema Yes ( ) No ( )

58) Pain or tenderness Yes ( ) No ( )

59) Serous discharge or pus from site Yes ( ) No ( )

60) Separation of the deep tissues Yes ( ) No ( )

61) Diagnosis of superficial/deep/organ incisional surgical site infection by ―clinician‖ Yes ( ) No ( )

62. Culture and sensitivity done? Yes ( ) No ( )

63. If yes to question 49, what is/are the organism(s) isolated?

…….

64. Drugs: Resistant to sensitive to:

1. 1.
2. 2.
3. 3.
4. 4.
5. 5.

APPENDIX VI: DEFINITION OF SSI CLASSIFICATIONS

CDC guidelines categorized the SSI. The CDC categorizes surgical site infections into three classifications (Control & Prevention, 2013). These comprise:

Superficial incision SSI: Infection manifests within 30 days post-operation and affects solely the skin or subcutaneous tissue of the incision.

Deep incisional SSI: Infection manifests within 30 days post-operation if no implant is present, or within one year if an implant is in situ, provided the infection is associated with the surgical procedure and affects the deep soft tissues (e.g., fascial and muscular layers) of the incision.

Organ/Space SSI: An infection manifests within 30 days post-operation if no implant is present, or within one year if an implant is present and the infection is deemed related to the surgery; the infection must involve any anatomical part (e.g., organs or spaces) that was opened or manipulated during the surgical procedure, excluding the incision.