PATTERNS OF OPEN TIBIA FRACTURES AND OUTCOMES OF INTRAMEDULLARY FIXATION USING SURGICAL IMPLANT GENERATION NETWORK NAIL AT MOI TEACHING AND REFERRAL HOSPITAL

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A thesis submitted to Moi University School of Medicine in partial fulfillment of the requirement for the award of the degree of Master of Medicine (Orthopaedic Surgery) at Moi University

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DECLARATION

Declaration by Candidate

This thesis is the author's original work and has not been presented for a degree in any other university/institution. No part of this thesis may be reproduced without prior written permission of the author or Moi University.

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DEDICATION

This work is dedicated to my wife Merilyn and our sons Daniel-John and Adrian – Amos.

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The author did not receive payments or services, either directly or indirectly (i.e., via his or her institution), from a third party in support of any aspect of this work.

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ABSTRACT

Background: Open tibial fractures are common and severe injuries that are frequently complicated by infection. Surgical fixation of these fractures with locked intramedullary nails has been shown to have good outcomes in both developed and low- and middle-income countries alike. With the steady rise in the number of open tibial fractures
(12 treated in 2005 and 36 in 2014) seen at Moi Teaching and Referral Hospital (MTRH) and the proven economic burden of these injuries on the patient, the search for the best method to manage open tibial fractures at MTRH is a priority. The Surgical Implant Generation Network (SIGN) nail is a solid locked intramedullary nail and has been used increasingly in the management of open tibia fractures at MTRH, since its introduction in 2005.Although used in the management of open tibia fractures, the treatment outcomes of the SIGN nail are undocumented.

Objectives: To quantify the treatment outcomes by infection rate and union rate and functional outcome using the Euroquol-5Dimension-3Level instrument following SIGN nail fixation of open tibia fractures in MTRH.

Methods: Adult patients presenting with open tibia fractures that received SIGN nail surgery at MTRH between July 2015 and September 2016 were recruited. The study design was prospective descriptive with each patient followed at 6-week intervals over 6 months and examined for complications. The study was approved by the Institutional Research and Ethics Committee (IREC). Data was collected using a structured interview and clinical examination and analysed using SPSS v 23 and results were presented in tables and charts.

Results: There were 52 patients with 52 open tibial fractures with 3 lost to follow up and 2 with incomplete data. Median age was 29, IQR 23-38. Ninety-one percent of patients were male. Road traffic accidents were the most common cause. The infection rate was 8.5%, with infection present in Grade II and Grade IIIA fractures only. The union rate was 79% at 6 months. The mean index score for EQ5D 3L was 0.905(maximum score is 1.000), with 72% of patients reporting no problems with mobility.

Conclusions: The infection rate following SIGN nail fixation was low and the union rate was high. Majority of patients reported good outcomes.

Recommendations: The SIGN nail is safe and effective for use in grade I to grade IIIA open tibial fractures at MTRH. Further studies into treatment outcomes in Grade IIIB and Grade IIIC fractures needed.

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ABBREVIATIONS AND ACRONYMS

BOA/BAPS   British Orthopaedic Association/ British Association of Plastic

Surgeons

CDC   Centres for Disease Control

EQ5D-3L   Euroqol -5 Dimension 3- Level

FDA   Food and Drug Administration

HRQoL   Health related quality of life

IM   Intramedullary

IREC   Institutional Research and Ethics Committee

LMIC   Low and middle- income country

MTRH   Moi Teaching and Referral Hospital

ROM   Range of motion

RTA   Road Traffic Accident

SIGN   Surgical Implant Generation Network (SIGN Fracture Care

International, Richland, WA, USA)

SOSD   SIGN Online Surgical Database

SSI   Surgical Site Infection

DEFINITION OF KEY TERMS

Intramedullary Nail This is a load sharing implant which acts as an internal splint in the process of fracture fixation. The Surgical Implant Generation Network Nail is used at MTRH to fix open tibia fractures.

Open fracture Open fractures of the tibia are those tibia fractures communicating with the external environment.

Patterns Refers to type, severity, aetiology of open tibia fractures.

Tibia The tibia is a long bone connecting the knee and the ankle joint.

Outcomes This refers to clinical and functional outcome.

CHAPTER ONE

INTRODUCTION

1.1 Background

The tibia is a long bone connecting the knee and the ankle joint. An open fracture of this bone communicates with the external environment (Gustilo & Anderson,1976). Fractures of the tibia constitute the most common open long bone fracture occurring in approximately 2 per 10,000 per year in the developed world (Court-Brown et al.,2012; Court-Brown & McBirnie,1995). There has been an increase in open tibia fractures in low-and middle-income countries (LMIC's) but little published information on their rate of occurrence (Chalya et al., 2012; Johal et al., 2014).

Open tibial fractures are the result of high energy trauma, frequently following a road traffic injury. In Africa, road traffic accidents have been reported to be the leading cause and often affect young males in their economic prime (Ibeanusi& Ekereh,2007; Ifesanya et al.,2010). One regional study found that these injuries had a profound impact on the socio-economic status of the individual and that of the family unit (O'Hara et al., 2016). Open tibial fractures have historically been a challenge to the orthopaedic surgeon because they have been frequently complicated by infection, poor healing and poor patient reported functional outcome (Heckman et al, 2015; Poletti et al., 2017).

Classification of the pattern of injuries according to the system of Gustilo and Anderson at the time of surgical wound management is useful in guiding treatment and predicting outcomes (Melvin et al., 2010a).

The goals of treatment in open tibial fractures are to obtain a healed fracture and a normally functioning limb, with no infection (Russell, 1990).

The management of open fractures has evolved over the centuries and the current established practice is based on a philosophy of early intravenous antibiotic administration, thorough wound debridement and early fracture stabilization (Gustilo et al.,1990). In achieving fracture stability, there has been a progressive change from external fixation to internal fixation with the primary use of nails. Only within the past four decades has primary intramedullary fixation become standard in the management of open tibial fractures (Gopal et al., 2000).

Primary reamed intramedullary nailing in low resource countries has had challenges owing to shortage of trained personnel, inadequate facilities and limited availability of implants (Spiegel et al., 2008). It has also been controversial because of concerns of the risk of intramedullary infection due to placement of a metal implant in an injury considered to be contaminated (Russell et al., 1990).

At Moi Teaching and Referral Hospital (MTRH), the use of nails in managing open tibial fractures began in 2005 with the use of the Surgical Implant Generation Network (SIGN) nail. This solid intramedullary nail has been used in this level one trauma centre in Eldoret, Kenya. It has been provided free of charge and was designed for use in resource poor settings (Feibel & Zirkle,2009).

1.2 Problem Statement

The SIGN intramedullary nail has been used increasingly in the management of open tibia fractures since 2005 at MTRH but the patterns of injury and the treatment outcomes of open fractures using this treatment regimen have not been adequately published.

1.3 Justification

Infection rates, union rates and functional outcomes have been used in orthopaedic literature to measure the safety, efficacy and success of primary intramedullary nailing in open tibia fractures. These outcome measures have not been documented for open tibia fractures managed at MTRH where an increasing number of these injuries are now managed by use of SIGN nail. Documentation of these outcomes and types of open tibial fractures will highlight gaps in management leading to improved management protocols and reduced morbidity from a potentially devastating injury that commonly affects young economically productive males.

1.4 Research Question

What are the documented patterns of open tibia fracture managed by primary intramedullary fixation using SIGN Nail and the associated clinical and functional outcomes at MTRH?

1.5 Objectives

1.5.1 Board objective

To document the patterns of open tibia fracture managed by primary intramedullary fixation using SIGN nail and the associated clinical and functional outcomes MTRH.

1.5.2 Specific Objectives:

1. To determine the types of open tibia fractures treated with the SIGN nail at MTRH.

2. To assess the infection rate of open tibia fractures treated with SIGN nail at MTRH.

3. To measure the union rate of open tibia fractures treated with SIGN nail at MTRH.

4. To evaluate the functional outcomes of fractures treated with SIGN nail at MTRH.

CHAPTER TWO

LITERATURE REVIEW

2.1 INTRODUCTION

The annual incidence of open injuries is 11.5 per 100,000 with 40% occurring in the lower limb, commonly in the tibial shaft (Court-Brown et al., 1998, 2012; Howard, 1997; O'Hara et al., 2014). Open injuries of tibia account for almost 50% of all open injuries and are contaminated and are more prone to infection than other long bones (Littenberg et al., 1998; Patzakis & Wilkins, 1989). They usually result from high-energy injury and are frequently associated with polytrauma, high rates of infection and other complications which may threaten the limb and occasionally life and are generally a therapeutic challenge to the orthopaedic surgeon (Gustilo & Anderson, 1976; Heckman et al., 2015).

Road traffic accidents are the mechanism of injury in more than half (up to 65%) with most of the remainder caused by falls (up to 25%), sports-related injury and direct blows (Court-Brown & McBirnie, 1995, Weiss et al., 2008).

Although sporting injuries are a common cause of closed tibial fracture, they infrequently result in open fractures (<10%) (Muhammad & Goudie, 2013). Similar mechanisms of injury have been described in studies in low middle income countries (Joshi et al., 2009).

Young males are at risk of sustaining this injury and large epidemiologic studies have found up to 60 % of open tibial fractures were high energy types (Gustilo III) (Court-Brown et al.,1998; Weiss et al.,2008).

Similarly, studies in low and middle-income countries show a male preponderance to orthopaedic trauma with road traffic accidents as the leading cause (Hsia et al., 2010; Ifesanya et al. 2010; Kobusingye et al., 2002; Lelei et al.,2009 a; O'Hara et al.,2014)

often due to motorcycle accidents which are abundant and, on the increase (Godina et al.,1991).

These men are in their economic prime and are often the sole breadwinners. There is therefore a socioeconomic impact of open tibial fractures to both the individual and the family unit which can have short and long-term effects on the economy of these countries (Bloom et al.,2004; O'Hara et al., 2016). A few studies from Kenya have also shown the trend of road traffic accidents as the commonest cause, the male propensity in orthopaedic trauma and the economic burden on hospitals (Ayumba et al., 2015; Macharia et al.,2009; Odero, 1997; Odero et al., 2003; Said, 2000).

Recent advances in management, including techniques of wound management and bone stabilization, have resulted in improved outcomes. The intramedullary nail is now the method of choice for stabilizing the open diaphyseal fracture because it controls length and rotation much better biomechanically than other modes of fixation (Heckman et al., 2015).

2.2 Patterns of Open Tibial Fractures and Outcomes

2.2.1Types of open tibia fractures

Open tibial fractures are commonly classified according to the system of Gustilo and Anderson. First proposed in 1976 (Gustilo & Anderson, 1976), this classification was modified to its current form in 1984 (Gustilo et al., 1984).

The original classification described three groups of increasing severity based on the size of the open wound, the degree of its contamination and the extent of soft-tissue injury. The major disadvantage of the original classification was that the grade-III category included a broad spectrum of open injuries of differing severity and, subsequently, of variable prognosis. In the revised form, the grade-III injuries were divided into three subgroups based on the extent of bone exposure, the requirements

for adequate soft-tissue cover of the exposed bone and the need for vascular repair.

Grade I injuries are low energy and are associated with small soft-tissue damage, flaps, or avulsions. Generally, grade II open fractures are moderate-energy injuries, with more soft-tissue involvement than do grade I fractures. Grade III injuries are high-energy wounds. These have been subclassified into categories A, B, and C.

Grade IIIA injuries have extensive soft-tissue damage secondary to high-energy trauma but have adequate soft-tissue coverage. Grade IIIB injures exhibit severe periosteal stripping and bone exposure, often associated with massive contamination. The patient with Grade IIIB injury may require treatment with soft-tissue coverage procedures.

Table 2.2.2.1: Gustilo Classification of Open Fractures (Gustilo & Anderson, 1976; Gustilo et al.,1984)

Gustilo Classification of Open Fractures	
I	Clean wound <1cm in length. Low energy injury.
II	Clean wound > 1cm in length. Moderate energy injury
IIIA	Adequate soft-tissue coverage despite extensive soft-tissue damage,flaps, or high- energy trauma irrespective of the wound size. Severe contamination. Severe comminution or segmental fracture pattern.
IIIB	Inadequate soft-tissue coverage with periosteal stripping, often associated with massive contamination. Requires a free tissue flap or rotational flap to achieve soft tissue coverage.
IIIC	Arterial injury requiring repair

Grade IIIC fractures require vascular repair. The full extent of the injury to the deep soft tissue and its viability is often underestimated on presentation and may not correlate with the size of the skin defect.

The timing of when an open tibia fracture is classified is important. Firstly, the initial classification in casualty department promotes communication between surgeons and determines how the fracture would be managed. Secondly, classifying the fracture at

the end of debridement showed how the injury had evolved. It would not always be possible to evaluate the fracture wound in the emergency room so evaluation following initial debridement was considered the optimal time (Agel et al., 2014; Roberts & Adams, 2013).

Despite the widespread use of the Gustilo classification, interobserver agreement has been reported to be only 60% (Brumback & Jones, 1994). This meant different surgeons arrived at different grades for the same fracture pattern. Also, there was moderate to poor intra-observer variation noted as there was also variation noted by the same surgeon when the same fracture was shown later.

Nevertheless, the Gustilo classification is useful in communicating the severity of open fracture among surgeons and in helping the treating physician predict the outcome of an open fracture. The Gustilo classification system also has prognostic significance; increasing infection rates and worse outcomes are associated with increasing severity of injury. Infection rates range from zero to 2% for grade I fractures, 2% to 10% for grade II fractures, and 10% to 25% for grade III fractures (Gustilo & Anderson,1976; Gustilo, Corpuz et al.,1985, Gustilo, Grunninger et al.,1987; Gustilo, Merkow et al.,1990; Melvin et al., 2010b; Papakostodis et al., 2011; Patzakis & Wilkins,1989).

The AO classification system of open fractures offers a comprehensive method of classifying both bony and soft-tissue injuries. Bony injury is classified according to the standard AO classification scheme; soft-tissue injury is categorized by the damage imparted to three distinct anatomic structures: Skin, muscle and tendon, and neurovascular system. Injury to the skin is further classified as open or closed. This framework enables accurate classification of the fracture and associated soft-tissue injury but is not in common usage and does not predict outcomes such as union, the

requirement for secondary surgery, or infection, nor do they correlate with functional outcomes (Swiontkowski et al., 2000).

2.2.2 Infection Rates

Infection can be superficial or deep. Deep infection involves deep soft tissues and bone and usually requires a procedure for either debridement or removal of the implant. A superficial infection involves superficial soft tissue and resolves with antibiotics.

Table 2.3.2.1.1: CDC Criteria for Deep Surgical Site Infection (Horan et al.,1992)

Centres for Disease Control Criteria for Deep Surgical Site Infection
Surgical site infection occurring within one year of the surgery involving deep soft tissue (muscle and fascial layers as well as one of the following: 1. purulent drainage from a deep incision   2. wound dehiscence or deliberate opening by the surgeon (culture positive or not cultured) in the setting of fever($>38^{\circ}$C) and or localized pain or tenderness   3. abscess or other evidence of infection involving the deep incision found on direct examination, during invasive procedure, or by histopathologic examination or imaging   4. diagnosis of deep incisional SSI by a surgeon

Table 2.3.2.1.2: Centres for Disease Control Criteria for Superficial Surgical Site Infection (Horan et al., 1992)

Centres for Disease Control Criteria for Superficial Surgical Site infection
Infection occurs within 30 days after the operative procedure and involves only skin or subcutaneous tissue of the incision, and at least one of the following is present
1. purulent drainage from the superficial incision   2. Organisms isolated from an aseptically obtained culture of fluid or tissue from the superficial incision.   3. at least one of the following signs or symptoms of infection: pain or tenderness, localized swelling, redness, or heat and superficial incision is deliberately opened by surgeon, unless culture of incision is negative.   4. diagnosis of superficial incisional SSI by a surgeon

In the literature, infection rate refers to the rate of deep infection. Gustilo reported an infection rate was 1.9% in Grade I injuries, 8% in grade II, but increased to 41% in grade III injuries (Gustilo & Anderson, 1976; Gustilo et al., 1985). The incidence of infection in open tibial fractures has been shown to directly correlate with the amount of soft tissue injury (Gustilo et al., 1990). Some authors have shown grade I injuries to have rates of infection between 0 to 2 %, grade II between 2-10% and grade III overall 10 to 25% (Gustilo et al.,1987; Melvin et al., 2010b; Papakostodis et al.,2011; Patzakis & Wilkins,1989).

The high energy nature of open tibial fractures results in extensive soft-tissue injury and devitalization of bone, and the increased risk of infection that predispose these fractures to impaired healing. Increasing Gustilo grades represent higher energy of the injury absorbed by bone and soft tissue of the limb and may explain the increased rates of infection with more severe Gustilo grades that have been reported.

According to Kindsfater et al., (1995) in their retrospective review of 25 grade II and 25 grade III open tibia fractures, deep infections seemed to occur months after initial injury with grade III deep infections occurring at an average of 4.8 months after surgery. Gustilo and Anderson (1976) in their landmark study found that infections were usually evident during the first month after surgery, the majority being recognized during the first 7 days. Some authors including Gaurav et al., (2017) also record the number of superficial infections in their studies on open tibia fractures.

2.2.3 Union rates of open tibial fractures

Fracture healing is the one of the goals of treatment when using intramedullary nailing in open tibia fracture. The increased risk of infection as well as the devitalization of bone in these injuries affect the progress of fracture healing. While

there is lack of consensus among orthopaedic surgeons on the assessment of fracture healing (Corrales et al., 2008), these definitions have been used:

i.   Union. Fracture union was assumed when bone healing occurred without any other surgical intervention apart from the index procedure or early planned bone grafting (Papakostidis et al., 2011) within 6 months of surgery. It was assessed on x-ray and clinically.

ii. Delayed Union: This was when bone healing did not occur within 6 months.

iii. Non-Union: This is bone healing delayed beyond 12 months with no evidence of healing for the previous 3 months or a bone gap in excess of 3cm following intramedullary nailing.

iv. Malunion: This was bone healing in deformity exceeding 10° in any plane following intramedullary nailing.

Giannoudis et al., (2006) in a systematic review of reamed tibia nails in 187 open tibia fractures found a union rate of 97%, 6% malunion rate with 15.5% needing bone grafting procedures proving the safety and superiority of this method of skeletal fixation even in open tibial injuries.

2.2.4 Functional outcomes

In clinical research there is increasing interest in evaluating the physical and psychosocial consequences for the injured. Also, there is growing consensus among clinicians that the potential impact on 'quality of life' is of paramount concern to the patient following injury after a major road traffic accident (Derrett et al.,2009).

One such measure is the EuroQol (The EuroQol Group, 1990).The EuroQol-5D-3L (EQ- 5D) instrument is used to assess health-related quality of life (HRQoL) (Brooks, 1996). The EQ-5D is sensitive to change in fracture populations, and is valid and

reliable for phone administration (Derrett et al., 2009; Hung et al., 2015) and has been used in some studies in trauma (Eliezer et al.,2017 ;Gopal et al., 2004; O'Hara et al.,2016).

The EQ-5D measures health status among five dimensions. Mobility, self-care and participation in usual activity, pain or discomfort and anxiety and depression. Within each dimension a patient selects one of three responses: (1) no problems (2) some problems (3) extreme problems. There are 245 possible EQ-5D health states (5^3 health states). These can be valued to derive an index score of a specified health state (Derrett et al., 2009). A patient with a health state profile of "no problems" in all five dimensions (i.e. 1, 1, 1,1,1) was allocated an index score of 1.00. A patient who reported "moderate problems" in the dimensions of usual activities and pain or discomfort (i.e. 1,1,2,2,1) had an index score of 0.79. (1.00 = Full health; 0 = Dead; some health states are allocated index scores worse than dead) (Dolan, 1997). It has been used in some regional studies on tibia fractures and femur and has been validated.

2.3 Theoretical and Conceptual Framework

2.3.1History of intramedullary nailing in open tibial fractures

Intramedullary nails are now the method of choice for stabilizing the open tibia shaft fracture because it controls length and rotation much better biomechanically than other fixation modalities. It also offers the advantages of avoiding further disruption of soft tissue and periosteum and may potentially allow for immediate post-operative weight- bearing. Further, because the incision and nail insertion occur remotely from the open wound, there is lower likelihood of the nail being contaminated and colonized by bacteria (Heckman et al., 2015; Mundi et al., 2015).

Although primary nailing is ideal in grade I, grade II and even grade III (when

debridement is thorough) tibia fractures, it was considered unacceptable even four decades ago for fear of increased risk of infection (Heckman, 2015; Schmidt & Swiontkowski, 2000). External fixators had been the treatment of choice in stabilizing open tibial fractures as they provided fracture stability with adequate wound management and soft tissue care until more orthopaedic surgeons became concerned with their complications (Babhulkar & Raza,2008; Court-Brown et al.,1991).

Gerhard Kuntscher, from Germany, is credited with developing the intramedullary nail during world war II but little is published on the results his early tibia nails (Bong et al,2006).

It was Lottes who first reported results using a flexible intramedullary nail in open tibia in the 1950's (Lottes,1954) and published an infection rate of 7.3% in 204 open tibia fractures (Lottes,1974).Other authors years later also reported good results with Kuntscher nails in a small series of open tibia fractures but noted problems in controlling axial rotation in fractures of the proximal and distal shaft (D'Aubigne et al.,1974; Zucman & Maurer,1969). To solve this problem, Kempf et al., (1985) added interlocking screws that could be inserted through the bone and nail, above and below the fracture site and the interlocking nail was born.

In the largest reported series of nailing of grade I tibia fractures, Klemm and Borner (1986) reported an infection rate of 6% which was higher than 0-1% range reported by Gustilo and Anderson (1976) for the same injury and explained why intramedullary nailing of open tibial fractures was not recommended 1980's.

Court-Brown et al. (1990), happy with the results of locking intramedullary nails in femur fractures, decided to adopt locked intramedullary nails in treating closed and grade I open tibia fractures and had excellent results with an infection rate of between 0 and 2%. This led them to extend the use of locking intramedullary nails to grade II

and III open tibia fractures as they were dissatisfied with the results of external fixators in grade III fractures.

In a subsequent prospective study, Court brown et al., (1991) studied 41 grade II, IIIA and IIIB tibia fractures and had infection rates in grade II, grade IIIA and IIIB of 7%,0% and 23% respectively.

Experience in the use of intramedullary nails grew with several authors publishing results of nailing in even more severe open tibia fractures. Robinson et al., (1995) reported a 20% infection rate in 30 IIIB tibia fractures and Keating et al., (2000) published 17.5% infection rate in 55 IIIB tibia factures.

Primary nailing of open tibia fractures became popularized when Kakar & Tornetta (2007) demonstrated low infection rates in a prospective study of 143 open tibia fractures. They concluded that good results were possible with immediate tibia nailing and meticulous soft tissue management.

In LMICs, more authors are publishing their experience with primary nailing in the more severe IIIA and IIIB injuries. In India, Singh et al., (2011) reviewed retrospectively 103 grade III open tibia injuries and showed a 14% infection rate and 94% union rate (88% within 6 months).

2.3.2 SIGN nail in open tibia fractures

Primary intramedullary nailing in open tibial fractures has been problematic in low and middle-income countries owing to a shortage of trained personnel, inadequate facilities and limited availability of implants (Spiegel et al.,2008) and concerns of the risk of intramedullary infection (Russell et al.,1990).

This resulted in one American charity producing implants that are Food and Drug Administration (FDA, United States) approved and for use in LMICs free of cost in an effort to create 'equality in fracture care' (Zirkle, 2008).

The Surgical Implant Generation Network (SIGN) managed by SIGN Fracture Care International, Richland, Washington has grown at a remarkable pace since its inception in 1999. SIGN Fracture Care International is a non-profit organization from the USA which has been doing charitable work in some tertiary hospitals in Kenya since 2005   by providing intramedullary (IM) nails free of charge (Lelei et al., 2009; Soren, 2009).

The SIGN nail is a solid, stainless-steel, intramedullary implant designed for poor-resource settings without power instrumentation, fluoroscopy, or fracture tables. It was developed for the treatment of long bone fractures in LMICs and has been placed in over 130,000 patients worldwide and used extensively in disaster relief settings. The same nail is used to treat fractures of tibia, femur (antegrade and retrograde), and humerus (Feibel & Zirkle, 2009; Zirkle,2008).

Since the beginning, each SIGN nail surgery has been reported to the SIGN headquarters to assess inventory needs and provide feedback. Initially, this was accomplished through email, which was cumbersome and time consuming. In 2003, the SIGN Online Surgical Database (SOSD) was developed with the capability to upload and view postoperative x- rays. This made it possible to provide immediate feedback to surgeons after each case. In addition, it was recognized that the database could include data from follow-up visits and thereby allow monitoring of clinical outcomes(Shearer et al., 2009; SIGN, 2017).

There have been very few studies reporting results of SIGN nailing and fewer still that have been published on open tibial nailing (Stephens et al., 2015).

Young et al., (2011) reviewed over 17,000 tibial fractures in developing countries that were treated with the SIGN IM nail and reported an infection rate of 6.9%. In another study, Young et al., (2013) found the risk of infection using SIGN nail in the setting

of open fractures was in the range of 4 and 7%. The overall follow-up rate was 23.1 % in this study and highlighted the problem of postoperative follow-up in performing quality orthopaedic research in developing countries (Gosselin et al.,2009).

Shah et al., (2004) from Nepal published a retrospective series of 32 open tibial shaft fractures treated with SIGN nailing. At a minimum follow-up of 8 months they reported 4 delayed unions, 1 nonunion, and 1 deep infection, all of which eventually achieved a satisfactory result.

Shah et al., (2004) used the SIGN nail in the primary nailing of 36 open tibia fractures in a population ranging in age from 15- 54 years and minimum follow up of 8 months. Nine (25%) were grade III fractures. They had a deep infection rate of 2.9% overall with zero deep infection in IIIA and grade I tibial fractures. The only deep infection was in a grade IIIB fracture. They noted the use of preliminary external fixators but were converting to SIGN nail within 2 weeks.

More recently, Ali et al., (2017) in Bangladesh, managed 12 grade IIIB open fractures with SIGN IM nail and early flap coverage (within 72 hours of injury) and reported 1 superficial infection and no deep infection.

In a recent conference paper, Shahab (2017) retrospectively reviewed the results of SIGN nail in open tibia fractures in low and middle-income countries and reported an overall infection rate of 10.8% and a union rate of 72%.

Lelei et., al (2009) first started using the SIGN nail in 2005 at MTRH, a level one trauma centre in Eldoret, a key educational centre in Kenya (Kenya Information Guide,2015).
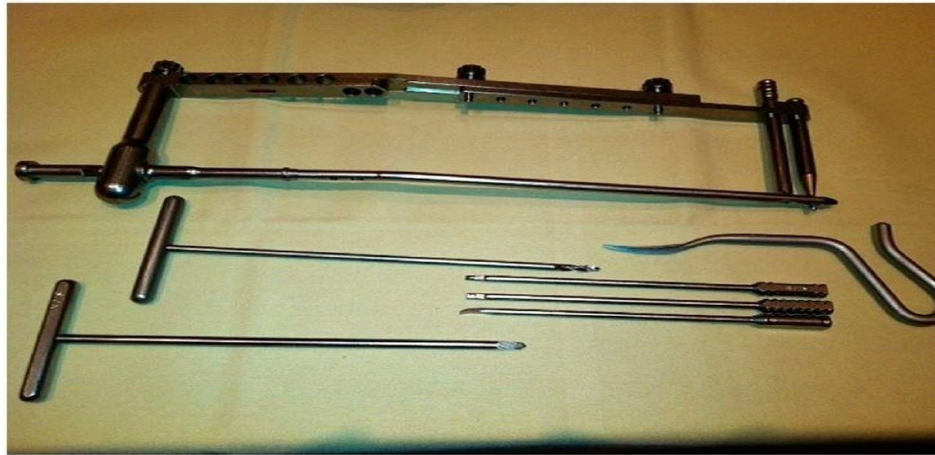
Figure 2.5.1: The SIGN IM nail and instruments. The SIGN IM nail is a solid, stainless-steel nail with a 9-degree proximal bend and 2 proximally and distally interlocking screws, intended for management of fractures in tibia, femur, and humerus for low resource settings.

Figure 2.3.1: The SIGN IM nail and instruments Adapted from Feibel & Zirkle (2009).

2.3.3 Determinants of outcome

The risk of complications in an open tibial fracture are known to be increased by both patient and injury factors (Lack et al., 2015).

Patient factors like diabetes, HIV status, and smoking have been associated with delayed union as well as a higher rate and increased severity of infections. Smoking in particular has been associated with an increased rate of flap failure, delayed union, and nonunion (Aderinto & Keating, 2008; Harrison et al., 2004; Harvey et al.,2002; O'Brien & Denton,1994). Age above 65 has also been reported as a risk factor for increased infection (Rajasekaran et al., 2006).

The Gustilo Anderson classification has been noted by several studies to determine the highest risk of infection and poor healing and to be the key prognostic indicator of outcome (Gustilo & Anderson,1976; Gustilo et al.,1984; Khatod et al.,2003; Naique et al.,2006; Rajasekaran et al.,2006; Sungaran et al.,2007). Inadequate debridement or debridement after 12 hours from injury (especially in grade III open tibia fractures, time interval between injury and administration of prophylactic antibiotics beyond 3

hours are all reported determinants of infection (Patzakis & Wilkins,1989; Rajasekaran et al.,2006).

2.3.4 Other clinical outcomes-These are hardware failure (loosening of a screw or nail breakage), reoperation (additional procedures needed to achieve union or treat complications), compartment syndrome and amputation.

Compartment Syndrome: Open tibial fractures may damage one or more compartments of the limb, but the severe swelling may result in compartment syndrome of the other intact compartments of the same limb (McQueen & Gaston, 2000).

Compartment syndrome may arise in open tibial fractures. Acute compartment syndrome occurs when pressure rises within a confined space in the body, resulting in a critical reduction of the blood flow to the tissues contained within the space. Without urgent decompression, tissue ischemia, necrosis, and functional impairment occur (Heckman, 2015).

In the previously mentioned systematic review by Giannoudis et al., (2006), they reported a 3% hardware failure with 15.5% requiring bone grafting procedures and 31.6% reoperation proving the effectiveness of the reamed intramedullary nail.

2.3.5 History of Management of Open Tibia Fractures

The principles of treatment have evolved over centuries and a lot of advancements were made during the treatment of war injuries. Tscherne grouped the evolution into 4 eras of life preservation, limb preservation, infection control and restoration of function (Heckman et al., 2015).

2.3.5.1 The Ancient Period

The ancient Egyptians in early writings were the first to recognize that open fractures were to be covered. "Whenever there is a gaping wound, such as that inflicted by the mouth of a crocodile it should be covered with meat' (Breasted, 1930).

In ancient Greece, circa 400 BC, amputation was the treatment of choice. Hippocrates said that "not to reduce an open fracture is to incur the reproach of ignorance; to reduce it is to increase the chance of death" He recommended wound lavage with wine solutions and unguents before the application of special bandages (Harkness, 2009; Poletti et al., 2017).

There are early monographs of authors in ancient china on orthopaedic trauma. Lin, a Taoist priest of the Tang dynasty (618-907AD) wrote of open fractures that the wound must be extended with a sharp knife, washed with boiled water and finally the fracture reduced at operation. The wound may or may not be sutured depending on the situation. The limb was then wrapped in tough silk. External ointments were then applied (Harkness, 2009; Poletti et al., 2017). In Roman times, a Greek physician called Galen (129-199AD) continued to manage open fractures by the method of Hippocrates (Wangensteen & Wangensteen, 1978).

2.3.5.2 The middle Ages

The French surgeon Ambroise Pare was the first to recognize the problem of contamination and advocated the removal of devitalized bone and soft tissue. During the renaissance period, this young surgeon summarized his extensive wartime experience in treating open fractures in 1545.He recommended. "The skin must forth with be enlarged so that there may be free passage for both pus and matter, as also for other things the wound may contain, and it will be easier to place the bones back to

their natural position. If there be any strange bodies, as pieces of wood, iron, bones, bruised flesh, congealed blood, or the like, whether they come from without or within the body" (Harkness, 2009; Heckman et al., 2015).

The term debridement was coined by Desault, a French surgeon in Napoleon's army. This term literally meant the unbridling of a horse but now has come to mean a form of wound management where the wound is surgically extended, and all necrotic and foreign material removed. This occurred in the 18th century where the principle of management was summarized as 'Lose a limb and save a life'. In the absence of antibiotics, aseptic wound techniques, mortality from gangrene and sepsis was very high (Harkness, 2009).

2.3.5.3 The Modern Age

World war I could be described the beginning of the era of preservation of life. Survival was improved with the implementation of resuscitation, thorough wound debridement, stabilization and avoiding immediate wound closure.

Survival continued to improve through world war II with the availability of antibiotics (penicillin) and even newer antibiotics during the Korean war (sulphonamides). The availability of antibiotics and the knowledge of the benefits of aggressive debridement and early soft tissue techniques (Scully et al.,1956; Trueta & Barnes,1940) ushered in the era of infection control.

The 1970's marked the beginning of the era of limb preservation. There were refinements in the principles and techniques of external fixation allowing complex fracture patterns to be rapidly stabilized. In the field of plastic surgery, there were new developments in wound coverage techniques allowing large soft tissue defects to be addressed by techniques such as microvascular free tissue transfer.

Throughout 1980's, external fixators had been the treatment of choice in stabilizing open tibial fractures as they provided fracture stability with adequate wound management and soft tissue care. More orthopaedic surgeons became concerned with their complications (Babhulkar & Raza,2008; Court-Brown et al.,1991). In the 90's came the development of locked intramedullary nails which have proved to be a very useful technique in the stabilization of the open fractures(Court-Brown et al.,1991).

The principles of treatment of open fractures were undergoing constant refinement. Landmark works which emerged in this era were that of Gustillo and Anderson (1976) which placed importance on the wound in open fractures and stressed the need for early cover. The principle of "fix and flap" emerged as it was realized that infections were mostly hospital acquired (Godina,1986).

Improvement in treatment outcomes of open tibia injuries has occurred when it came to be recognized that care for these open injuries lay not only with one specialty, but that success lay with a multi-disciplinary approach. The orthoplastic approach has now been coined, where orthopaedic surgeons work together with plastic surgeons from the stage of debridement onwards and is now the standard of care in trauma centres in the developed world (BOA/BAPS, 1993; Court-Brown et al.,1997).

The care of the open tibial fracture is now in the "*Era of Functional Restoration."* Surgeons have come to realize that limb salvage is not the only aim. Patients are often dissatisfied with a painful, deformed or disfigured limb and may opt for a secondary amputation after a prolonged salvage procedure (Rajasekaran et al., 2006; Rajasekaran et al., 2009; Rajasekaran & Sabapathy,2007).

The future of treating open tibial injuries will focus on understanding the factors affecting the healing of bone and soft tissue at the molecular and genetic level. This

would allow for individualized treatment plans (Heckman et al., 2015).

2.3.6 Management of Open Tibia Fractures

2.3.6.1 Priorities in treatment

The priorities in treatment are to first to save life, then to save the fractured limb and then to restore limb function. Saving a limb without adequate function can be worse than to have an early amputation and limb fitting rehabilitation. Open fractures are high energy injuries and are associated in 30% of cases with multiple system injury and need to be managed initially according to ATLS protocols (American College of Surgeons Committee on Trauma, 2004; Gustilo et al., 1990). This involves an adequate initial evaluation, including resuscitation, detailed history of the injury and photo documentation to help the assessment of soft-tissue damage and contamination (Giannoudis et al.,2006; Heckman et al.,2015).

2.3.6.2 Goals of treatment

The goals of treatment of an open tibial fracture are the prevention of infection, healing of the fracture and restoration of the function of the limb.

Despite the growing body of literature surrounding the treatment of open tibial shaft fractures, several crucial aspects in the surgical management of these patients remain equivocal and thus varied across the global orthopaedic community (Petrisor et al., 2008).

2.3.6.3 Treatment of open tibial fractures

There are four aspects of management that are central to the operative treatment of open tibial shaft fractures: (1) irrigation and debridement techniques, (2) antibiotic prophylaxis, (3) fracture stabilization, and (4) wound management. Types of fracture will be referred to by their Gustilo and Anderson classification.

2.3.6.4 Wound Irrigation and Debridement Techniques

In their original paper Gustilo and Anderson stated, "There is universal agreement that open fractures require emergency treatment, including adequate debridement and irrigation of the wound". Although the details of irrigation are debated, the role of debridement is clear: "Adequate debridement is the single most important factor in the attainment of a good result in the treatment of an open fracture" (Gustilo & Anderson,1976).

There are several issues regarding the irrigation and debridement of open tibial shaft fractures that are currently controversial. The true urgency of initial surgery has been called into question, as well as the optimal techniques of irrigation remain equivocal (Mundi et al.,2015).

Most current guidelines recommend that debridement be performed within 6 hours of injury (Melvin et al., 2010b) and this has become the standard of care even though evidence to support this practice is lacking (Court-Brown et al.,1997; Singh et al., 2012).

Several retrospective series have demonstrated no significant difference in infection rates for patients who undergo initial surgery before or after the six-hour mark after injury or presentation, including those patients with grade-III fractures (Khatod et al., 2003; Tripuraneni et al., 2008).These findings have been validated in a meta-analysis, in which a pooled analysis of fourteen prospective and retrospective studies demonstrated no significant difference in overall infection rates between late and early debridement (odds ratio, 0.91 favouring late debridement; 95% confidence interval [CI], 0.70 to 1.18). The time threshold for defining late versus early debridement in this analysis was based on the varying definitions set by the individual studies,

although the majority used a six-hour threshold (Schenker et al.,2012).

Fittingly, an assessment of national practice trends across the United States and involving 6099 patients with open tibial fractures demonstrated that 42% of patients waited longer than six hours for initial surgery after arriving at the hospital. Factors associated with delayed treatment included patient characteristics (e.g., severe head or thoracic injury or presentation after 6:00 pm) and hospital characteristics (e.g., level-I trauma centre or university hospital) (Namdari et al.,2011).

Ultimately, in the absence of evidence from randomized trials, formal irrigation and debridement within 6 hours after injury remains the historically established recommendation of care. The effect of debridement done after 24 hours is less clear. Although debridement should be done as soon as possible, studies seem to indicate that the thoroughness of the debridement is more important than the timing (Werner et al.,2008). However, there is a growing recognition that delayed surgery for less severe fractures (grade I) may be an acceptable practice as long as debridement is performed as a priority procedure no later than the morning after admission (Melvin et al., 2010b). Irrigation is used to supplement systematic and thorough debridement in removing foreign material and decreasing bacterial load. Despite its importance and the frequency with which irrigation is employed, there is a relative shortage of high-quality literature regarding the optimal solution, volume, additive, and method of irrigation for open tibia fractures. As a result, there are variations of irrigation solutions, pressure and volume from which to select from, including normal saline solution with or without additives (antiseptics, antibiotics, delivered at low or high pressure.

Some animal studies indicate that increasing the volume of irrigation improves the removal of bacteria and debris; however, the optimal volume has not been determined. Based on the widespread availability of 3-litre bags of normal saline, Anglen (2001) recommended using 3 litres of irrigation for grade I fracture, 6 Litres for grade II fracture, and 9 litres for grade III fracture.

Some surgeons use saline alone. An international survey of 984 orthopaedic surgeons who assessed practice preferences for irrigation techniques of open fractures found no global consensus on the preferred choice of irrigation solution or pressure.

Although the predominant preferences were normal saline solution alone and low-pressure irrigation, only 71% of respondents endorsed these practices (Petrisor et al., 2008).

There are recent randomized clinical trials that are providing further insight into the relative efficacy of these irrigation techniques. Anglen (2005) randomized 400 patients with open fractures of the lower extremity (111 tibial shaft fractures) to irrigation with either castile soap or antibiotic (bacitracin) solution and found no significant difference regarding infection risk between the two agents (13% castile soap versus 18% bacitracin). There was, however, an increased risk of wound-healing failure with the antibiotic solution (4% castile soap versus 9.5% bacitracin).

The Fluid Lavage of Open Wounds (FLOW) study is an international, multicentre, 3 x3 x2 randomized trial that has recruited over 2500 patients to evaluate the efficacy of high- pressure, low-pressure, and bulb-syringe lavage as well as normal saline solution versus castile soap solution(Flow Investigators, 2010). The initial pilot study of 111 patients suggested that low pressure lavage may reduce reoperation rates due to infection, nonunion, and wound-healing problems but that ultimately the final

results of this landmark trial will provide more definitive guidance (FLOW Investigators, 2011).

The importance of meticulous irrigation and debridement of open fracture wounds in reducing infection risk are universally accepted (Melvin et al., 2010b). Beyond this uncontested matter, however, strong recommendations for specific solutions or irrigation pressures for the management of open tibial shaft cannot be made (Mundi et al., 2015).

2.3.6.5 Antibiotic Prophylaxis

Infection is a known complication related to open fractures, as open injuries are prone to microbial contamination (Gustilo et al.,1984). Open tibia fractures are reported to be ten to twenty times prone to infection than other open long bone injuries (Patzakis & Wilkins,1989). In the absence of antibiotic prophylaxis, infection occurs in approximately 24% of open fractures (Patzakis et al.,1983). Numerous studies have been carried out over the years, investigating the role of antibiotic prophylaxis in the setting of open fractures. A Cochrane review of randomized trials (n = 913 patients) demonstrated a pooled relative risk reduction of 59% for acute infection in patients with open fractures treated with prophylactic antibiotics. It was concluded that for every thirteen patients treated with prophylactic antibiotics, one acute infection would be prevented (Gosselin et al., 2004).

Although the merits of administering systemic antibiotic prophylaxis are well established, there are few randomized trials that have added to knowledge regarding the urgency of administration, the necessary duration of treatment, and the optimal regimen of antibiotic therapy (Mundi et al., 2015).

As per accepted practice, antibiotic prophylaxis should be commenced as early as possible after injury. Timely antibiotic administration has been identified as the most important factor in reducing the risk of infection. Patzakis and Wilkins (1989) conducted a study that underlies the recommendation that antibiotics must be administered within 3 hours to significantly reduce infection risk in open injuries. In their case-control study of more than 1100 open fractures, antibiotics administration more than three hours after injury was associated with 1.63 times greater odds of infection in comparison with treatment within the first three hours after injury.

It has been recommended that both grade-I and grade-II open fractures require antibiotic coverage for twenty-four hours after wound closure (Hoff et al.,2011; Jaeger et al.,2006). For grade-III injuries, it is suggested that antibiotic administration continue for seventy- two hours after injury but no longer than twenty-four hours after wound closure (Hoff et al., 2011; Jaeger et al., 2006).

As demonstrated by Dellinger et al., (1988) in their blinded randomized trial comparing a one-day course of antibiotic prophylaxis to a five-day course, there is no clear benefit to prolonged antibiotic prophylaxis in preventing fracture site infections in open fractures, including those of grade-III severity.

With regard to specific antibiotic selection, there is strong evidence supporting coverage against gram-positive organisms for all open fractures, typically with a first-generation cephalosporin unless specific contraindications exist (e.g., allergy) (Hoff et al,2011; Melvin et al.,2010b; Patzakis et al.,1974).

Additional coverage against gram negative organisms is indicated for grade-III injuries, and the use of an aminoglycoside has been suggested by Hoff et al., 2011. The best- available evidence in the form of randomized trials, however, has not

conclusively validated the optimal regimen. In a randomized study by Patzakis et al., (2000), antibiotic prophylaxis treatment of grade-III open fractures with a combined regimen of cefamandole and gentamicin substantially reduced infection rates compared with prophylaxis with ciprofloxacin alone (infection rate, 7.7% versus 31%, respectively). It must be noted that the sample size of patients with grade-III injuries was relatively small (n = 52) and that significance was not reached despite the magnitude of difference in infection rates.

Sorger et al., (1999) were unable to substantiate such a low infection rate in their randomized trial, as 10% to 25% of patients with grade-III open fractures (n= 20) developed an infection despite prophylaxis with a similar antibiotic course consisting of cefazolin and gentamicin.

Other antibiotic options for grade-III open fractures have also been explored in randomized trials. Prophylaxis with use of a third-generation cephalosporin (cefotaxime) alone for grade-II and grade-III open tibial fractures was evaluated in an earlier trial by Johnson et al., (1998). Despite a considerably lower infection rate with cefotaxime compared with cefazolin in grade-III fractures (infection rate, 18% versus 37%, respectively), the effect size was statistically insignificant because only twenty-seven patients with such high-grade injuries had been recruited.

Vasenius et al., (1998) further underscored the need for appropriate gram-negative coverage of grade-III injuries in a randomized trial that demonstrated unacceptably high infection rates when clindamycin or cloxacillin was used alone for antibiotic prophylaxis. Local delivery of antibiotics has also drawn the interest of researchers in recent years, as antibiotic-laden polymethylmethacrylate cement beads have been demonstrated to improve antibiotic delivery at the target site (Melvin et al., 2010b).

In their retrospective review of 1085 open fractures, Ostermann et al., (1995)

demonstrated a significant reduction in infection rate (acute and chronic) for grade-III injuries with use of systemic antibiotics in conjunction with tobramycin-impregnated cement beads as compared with systemic prophylaxis alone (infection rate, 6.5% versus 20.6%, respectively; p, 0.001). This significance was not found in lower grade injuries.

However, a recent meta-analysis of twenty-one studies demonstrated a significantly lower deep-infection risk with use of local antibiotic administration as an adjunct to systemic antibiotics across all types of open tibial fractures treated with intramedullary nailing. The effect was most pronounced for grade-III injuries, which demonstrated a pooled infection risk of 2.4% (95% CI: 0.0% to 9.4%) with an adjunct local antibiotic as compared with 14.4% (95% CI: 10.5% to 18.5%) with systemic prophylaxis alone (odds ratio, 0.17; p value not reported)(Craig et al., 2014).

2.3.6.6 Fracture Stabilization

Options for stabilization following open tibial shaft fracture include either internal fixation or external fixation. Internal fixation may be performed with plates (e.g., dynamic compression plates or limited contact dynamic compression plates) or with an intramedullary nail (Mundi et al., 2015).

External fixation may be either definitive or temporary (e.g., preceding a second-stage internal fixation procedure). The standard of care for open tibial shaft fractures has evolved considerably over the past several decades.

2.3.6.6.1 Internal Fixation -Plating: There is both biologic and clinical rationale that favors the plating of open tibial shaft fractures over alternative options. First, external fixation is cumbersome and not convenient for the patient. Among internal fixation devices, plating does not risk further injury to bone that is likely already denuded of periosteum (especially in higher-grade open fractures), whereas intramedullary nailing has the potential to further compromise the intraosseous blood supply and lead to osteonecrosis (Schemitsch et al.,1995).

Arguments against plating have focused on the possibility of chronic infection and resultant infectious non-union, as the inert surface of a metal plate could provide a medium for bacterial growth to flourish. Evidence from clinical studies has largely fallen against plating. Therefore, this option is no longer recommended in the primary treatment of open tibial shaft fractures (Melvin et al., 2010).

2.3.6.6.2 Intramedullary Nailing

Clinical studies have largely upheld the superiority of intramedullary nailing in terms of improved fracture-healing and reduced risk of deep infection. Kakar and Tornetta III (2007) performed a prospective longitudinal cohort evaluation of 143 grade-I to grade-III open tibial shaft fractures that were managed with unreamed tibial nailing. All fractures received irrigation, debridement, and closure within fourteen days postoperatively. These authors found an overall low incidence of deep infections (3%) and implant failures (3.5%). Although this study lacked a comparator group, the results were better than those quoted in the literature on plating. However, the investigators reported a high incidence of ipsilateral ankle stiffness (21%), knee pain (20%), and fracture-site pain despite union (21%).

Inan et al., (2007) compared circular wire external fixation with unreamed tibial nails in a randomized trial of grade- IIIA open tibial shaft fractures. They reported a

significantly shorter time to union (nineteen versus twenty-one weeks, respectively; p = 0.04) and fewer knee contractures (0% versus 10%, respectively value not reported) in favor of the unreamed tibial nails. They were unable to detect any significant difference in the number of deep infections.

In another randomized trial, Henley et al., (1998) compared half-pin external fixators to unreamed tibial nails in grade-II, grade-IIIA, and grade- IIIB open tibial shaft fractures. The use of an intramedullary nail resulted in better alignment and fewer reoperations, with no significant difference in infection rates.

A systematic review that indirectly compared reamed nails to external fixators has also demonstrated a decreased risk of reoperation with the use of intramedullary nails (Bhandari et al., 2000). Overall, the evidence supports the use of intramedullary nailing (either reamed or unreamed) over both plating and external fixation for open tibial shaft fractures based on lower reoperation rates and faster time to fracture union. If used in place of plating, there is a reduced risk of deep infection as well.

2.3.6.6.3 Reamed versus Unreamed Nailing

Surgeons have the option of reaming the intramedullary canal of the tibial shaft prior to nail insertion. Reaming before nailing allows for insertion of a larger diameter intramedullary nail with resultant greater stability. However, reaming can disrupt the endosteal bloody supply through thermal injury, physical disruption of blood vessels, increased intramedullary pressure, and fat-emboli occlusion of blood vessels (Schemitsch et al., 1995).

Unreamed techniques require smaller nails and therefore result in comparatively less stability but preserve the endosteal blood supply. The latter consideration is potentially important when periosteum has been denuded during the initial injury. Thermal necrosis during reamed nailing can also lead to increased rates of

postoperative infection and other complications (Leunig & Hertel, 1996).

Bhandari et al., (2000) conducted a systematic review that identified two studies that compared reamed and unreamed nails for the treatment of open tibial shaft fractures. They were unable to demonstrate significant superiority of one technique over the other in the context of open fractures.

Subsequently, the Study to Prospectively Evaluate Reamed Intramedullary Nails in Patients with Tibial Fractures (SPRINT) investigators randomized 1319 patients to either reamed or unreamed intramedullary nailing; 406 of these patients had an open fracture, and 137 of these fractures were grade-III injuries. Reamed nailing was shown to be superior in the closed fracture group but not in the open fracture group, which trended instead in the opposite direction but did not reach significance (Bhandari et al.,2008). Therefore, neither the reamed nor the unreamed nailing technique has proven superior in the treatment of open tibial shaft fractures.

2.3.6.6.4 External Fixation

Owing to a lack of evidence supporting superiority of external fixation over intramedullary nailing, as well as patient discomfort and the high incidence of pin-track infections, definitive external fixation is generally not a highly recommended treatment option. However, external fixation can still be an appropriate option for certain injuries. For instance, orthopaedic surgeons may use external fixation for severely contaminated grade-IIIA and grade-IIIB fractures that are associated with severe bone loss (Sen et al., 2004). However, improvements in soft-tissue reconstruction techniques and infection control have largely changed the practice of definitive external fixation in favour of intramedullary nailing.

There remains, however, a strong role for temporary external fixation in the management of severely contaminated tibial shaft fracture in association with

extensive soft-tissue injury. The literature has demonstrated acceptable results for open tibial shaft fractures that are treated sequentially with external fixation followed by intramedullary nailing (Antich-Androver et al.,1997; Blachut et al.,1990; Maurer et al.,1989; McGraw & Lim,1988).

Bhandari et al., (2005) conducted a systematic review of both tibial and femoral fractures managed with intramedullary nailing secondary to external fixation. The vast majority of tibial fractures in the analyzed studies were open fractures. They found that tibial shaft fractures treated with a shorter duration of external fixation (i.e., fewer than twenty-eight days) had a relative risk reduction of 83% (n = 263) for infection (p, 0.001). Following removal of the external fixator, tibial shaft fractures in which there was a shorter interval between the time of fixator removal and the time of intramedullary nailing (i.e., fewer than fourteen days) had a relative risk reduction of 85% (n = 268) for infection (p , 0.001). Therefore, external fixators should be used for a short duration, and the interval between removal and internal fixation should be less than fourteen days. Some surgeons have advocated near-immediate conversion, with a very short interval (i.e., less than ten days) if there are concerns pertaining to pin-track infection (Melvin et al.,2010b; Ueno et al.,2006).

2.3.6.6.5 Wound Management

An optimal time for wound closure of open tibial shaft fractures has yet to be established, although primary closure under specific circumstances is warranted (Heckman et al., 2015). In a retrospective cohort study of ninety-five open tibial fractures (grade I to grade IIIA). Hohmann et al., (2007) found no significant difference in infection rates between patients who underwent primary closure (4% average infection rate) and patients who underwent delayed closure (2% average infection rate with wound closure at a mean of nine days from the time of initial

debridement). It is important to note that only seven fractures were grade-III injuries, with the study primarily including less severe, isolated injuries of the tibia.

There is, however, further evidence endorsing primary closure in grade-III fractures. In a prospective, noncomparative series of 173 patients with grade-IIIA and grade-IIIB open fractures treated with primary closure, Rajasekaran et al., (2009) found that 87% of patients had "excellent" result, which collectively entailed fracture union, primary wound-healing with no or marginal necrosis, and no infection. However, stringent criteria for primary closure were utilized in this study, including no skin loss, debridement within twelve hours of injury, stable skeletal fixation during primary surgery, skin apposition without tension, and no sewage or organic contamination, among other criteria.

In general, primary closure has been suggested for grade-I to grade-IIIA tibial fractures when adequate viable soft tissue allows for tension-free closure and the patient has undergone meticulous debridement of the injury along with timely antibiotic prophylaxis. Intraoperative cultures after debridement have demonstrated poor yield in predicting subsequent infection and should not dictate the timing of wound closure (Mundi et al., 2015).

For fracture wounds requiring flap coverage, location of the injury, size of the defect, and zone of injury must collectively be assessed to determine if rotational or free flap coverage is optimal. Typically, fractures in the proximal two-thirds of the tibia are treated with rotational muscle flaps, whereas fractures in the distal third of the tibia require treatment with free flaps (Melvin et al., 2010b). In a study of 174 patients with an open fracture in the distal third of the tibia, Yazar et al., (2006) found that free muscle flaps were comparable with free fasciocutaneous flaps with respect to flap survival, bone healing, and infection rates.

Negative pressure wound therapy has attracted much attention as a method of providing provisional coverage for such wounds not amenable to primary closure. Stannard et al., (2009) randomized fifty-eight patients with severe open fractures requiring serial debridement to coverage with either negative pressure wound therapy or saline-solution- soaked dressings. The predominant fracture type included in this study was that of the tibia (42%), and 92% of the injuries were of grade-III severity. The study found that there was a significant reduction in total infection rate (acute and late combined) with negative pressure therapy, although this estimate lacked precision as demonstrated by a wide confidence interval (relative risk [RR] = 0.20; 95% CI = 0.045 to 0.874). Furthermore, when acute and late infections were assessed independently, no significant difference was detected, likely due to insufficient study power.

Irrespective of the use of negative pressure wound therapy, flap closure of open tibial fracture wounds should not be delayed beyond seven days after injury, as the risk of subsequent infection and other complications increases with time (Bhattacharyya et al.,2008; D'Alleyrand et al.,2014; Melvin et al.,2010b).

A recent systematic review evaluating open fracture wounds that required flap coverage corroborated the importance of early coverage. In a pooled analysis of seven studies-six of which specifically studied open tibial fractures- early coverage was associated with a significant reduction in infection risk (RR = 0.31; 95% CI = 0.18 to 0.53).

Surprisingly, several of these studies employed an aggressive early flap-coverage practice (less than seventy-two hours after injury) (Wood et al., 2012). In the absence of any randomized trials, however, the true efficacy of such aggressive timing for coverage remains to be explored.

2.3.6.6.6 Conclusion

Open tibial shaft fractures are a common yet challenging injury for the orthopaedic surgeon to manage. Several paramount strides have been made in establishing evidence- based treatment strategies for these patients, as study findings have endorsed the need for meticulous irrigation and debridement, prompt antibiotic prophylaxis, and primary wound closure under the appropriate circumstances.

Furthermore, stabilization techniques of tibial shaft fractures have evolved considerably, with current evidence demonstrating superior outcomes with either reamed or unreamed intramedullary nailing for definitive management.

Nevertheless, there remains a need for additional high-quality evidence to clarify the efficacy of specific techniques and treatment practices under the umbrella of these accepted treatment areas.

Through large-scale randomized trials, the answers to such fundamentally important questions can hopefully be answered such that a global consensus on optimizing all aspects of management for these patients is reached.

CHAPTER THREE

METHODOLOGY

3.1 Study Site

The study was carried out at Moi Teaching and Referral Hospital (MTRH) casualty, orthopaedic clinics and orthopaedic wards. The Hospital is one of two referral hospitals in Kenya and is located along Nandi Road in Eldoret town (310 kilometers Northwest of Nairobi the capital city of Kenya), Uasin Gishu County, in the North Rift region of Western Kenya.

MTRH immediate catchment area population is approximately 16.24 million, from the former Nyanza Province (5.39 million), North Rift (5.50 million) and the former Western Province (5.35 million) ("Kenya Census Report," 2010). The hospital receives patients as referrals from other Hospitals or institutions within or outside Kenya for specialized health care. It also provides facilities for medical education for Moi University and for Research either directly or through other co-operating health institutions ("MTRH," 2017).

The Accident and Emergency Department receives a high number of cases of road accidents and assaults in the neighbouring communities as well as the high patient check-ins and referrals from Western Kenya Region, and from South Sudan and eastern Uganda.

The bed capacity is 1000 beds and orthopaedic cases constitute 7.1% (51 beds). Due to its wide catchment area, the department experiences high bed occupancy of between 100%-150 %, this leads to overstraining of the available resources.

There are orthopaedic department is staffed by full time consultant orthopaedic surgeons who are familiar with SIGN nail surgery.

3.2 Study Design

This was a prospective descriptive study investigating clinical and functional outcomes of using SIGN nail in open tibia fracture.

3.3 Study Population

All adult patients aged 18 and over admitted to MTRH, Eldoret, Kenya with an open tibial shaft fracture that was treated by SIGN IM nail during the study period.

3.4 Study Period

Eligible patients were recruited in the period 1st July 2015 to 30th September 2016.

3.5 Eligibility

3.5.1 Inclusion criteria

Adult patients admitted to MTRH within the study period with an open tibia shaft fracture and who had their fracture stabilized primarily by use of SIGN IM nail.

3.5.2 Exclusion criteria

1. Patients with polytrauma.

2. Patients with pathologic tibia fractures.

3. Patients with mal/nonunion of pre-existing tibia fractures.

4. Bilateral open tibial fractures in an attempt to keep fracture population as homogeneous as possible.

5. Open tibial fractures extending into the knee or ankle joint or within 5cm of them.

6. Open tibial fractures more than 3 weeks old prior to admission or debrided in another facility.

3.6 Sampling Technique

A purposive sampling technique was used. Consecutive patients who met the inclusion criteria were include in the sample.

3.6.1 Sample Size Determination

$$n = \frac{Z^2\, \hat{p}\,(1-\hat{p})}{e^2}$$

Sample size was calculated based on Fisher's exact formula (Casagrande,1978).

Where

n = desired sample size (population >10,000) i.e. population greater than 10,000

Z = the standard normal deviate usually set at 1.96 or simply 2.00
which correspond to 95% confidence level.

p = estimated characteristic of the study population (50% / 0.5
since no national prevalence)

q = 1 − p

d = the minimum error (degree of accuracy desired), which is usually

set at 5% or 0.05 Therefore

$= (1.96)^2$ x 0.5 x 0.5

$= (1.96)^2$ x $(0.05)^2$

= 0.9604 x 0.0025

= 384.16

= 384

Since the population was less than 10,000 the following formula was used to

determine the desired sample size.

$$nf = \frac{n}{1+\frac{n}{N}}$$

Where

nf = the desired sample size (N<10,000) i.e. population less than 10,000

n = the desired sample size (384)

N = total population (target) <10,000

According to the hospital records office, 47 open tibias were nailed in 2013 at MTRH. (N)= 47

Therefore $nf = \dfrac{384}{1+\frac{384}{47}}$

$$= \dfrac{384}{1+8.17} \; = 42$$

3.7 Data Collection

Clinical and demographic information was collected using a questionnaire based on the SIGN questionnaire done by the author and a trained assistant following patient consent.

3.8 Follow Up

At the time of enrolment, the phone number of each patient, as well as two additional phone numbers of friends or family were recorded in the event that the primary phone number was no longer in service at the time of follow-up. Study patients were informed in advance that they would need to return for follow-ups at set time points and educated about the benefits of the research. Regular contact by phone was kept maintaining motivation to keep follow-up in-person appointments at time points 2 weeks (for suture removal), 6 weeks, 12 weeks, 18 weeks and 24 weeks from SIGN IM nail surgery (for radiologic and clinical evaluation) using the SIGN follow-up

questionnaire. During these visits x-rays were checked for union and implant complications and wounds checked for signs of infection. X-rays were checked at the 6 week,18 week and 24 week time- point and when deemed necessary. Any complications were recorded, and appropriate advice given. Follow-up interview and examinations were done by the author. The time points are standardized and allowed identification of outcomes of interest.

Final follow-up was done at six months post-surgery and included an assessment of the the patient quality of life using the Euroqol questionnaire (Brooks, 1996). Follow-up also ended if a patient had the nail removed at a secondary operation due to a complication.

3.9 Standard Operating Procedures

In this descriptive study, there was no formal protocol. All patients were treated by orthopaedic residents and orthopaedic consultants in the casualty department, orthopaedic outpatient clinics and in the MTRH theatre. Patients were treated in accordance with the orthopaedic department standard of care.

1. All patients received emergent evaluation for life-threatening injury by the trauma surgical team or emergency department medical officer accordance with ATLS protocols.

2. All patients received intravenous antibiotics and tetanus prophylaxis on arrival at the casualty department.

3. The choice of antibiotics depended on availability and the discretion of the treating physician.

4. After initial splinting of the limb, the patient underwent emergent irrigation and debridement, which included surgical extension of wounds, sharp excision of

devitalized and/or contaminated soft tissue and bone.

5. All study patients received antibiotics received antibiotics within 30 mins of induction of anaesthesia.

6. Fracture stabilization was obtained by primary nailing with a SIGN nail either at the first debridement procedure or at a second or third follow up procedure by the discretion of the surgeon.

7. The fractures were graded by the operating surgeon corroborated by the author through inspection of the wound, report of the wound in notes and examination of the x-rays after debridement according to the criteria of Gustilo and Anderson (Gustilo & Anderson,1976; Gustilo et al.,1984).

8. Wound closure was achieved at the time of nailing by primary closure (closure of the wound at the time of initial debridement and nailing), secondary closure (closure at a second or subsequent debridement procedure within 3 weeks of injury including skin graft) at the discretion of the treating surgeon

9. The standard sign technique for tibia (including hand reaming) was used in fixing all fractures (Feibel & Zirkle,2009)

10. Post-operative protocol: Early mobilization was encouraged, and range of motion exercises started from the first post-operative day. Instructions about weight bearing were discretional to the operating surgeon. A patient was prescribed non-weight bearing, partial weight bearing or full weight bearing. Patients stayed in hospital for 2- 3 days depending on their progress. Post-operative dressings were removed 2–3 days after surgery. On discharge, the patients were given either a walker or crutches and instructed to follow-up in 2 weeks for suture removal.

3.10 Evaluation Criteria.

The outcome measures of interest were deep infection rate, union rates, EQ5D index

score at 6 months was used to assess the patient's evaluation of their quality of life. Other clinical outcome measures were full weight bearing status, delayed union, deformity, hardware(implant) failure, and reoperation for any reason.

Functional outcome was measured using a standardized assessment of health-related quality of life, the Euroqol. Another functional outcome measure of interest was knee stiffness at 6 months.

3.10.1 Definition of terms

1. Radiological union was defined as the presence of bridging callus on at least two orthogonal radiographic views (Blachut et al.,2005).

2. Clinical union was defined as the ability to bear full body weight and ambulate painlessly (Corrales et al.,2008).Delayed union referred to fractures which had not united radiologically by 6 months post-surgery.

3. The union rate was determined by calculating the number of radiologically united fractures as a proportion of the fractures with complete follow-up at 6-month post – surgery and was used as a measure of effectiveness of the implant.

4. Infection was determined according to CDC criteria for infection and assessed within 6 months of SIGN nail surgery. The infection rate was the number of deep infections within 6 months of surgery expressed as a proportion to the number of included patients. It was a proxy for implant safety.

Superficial incisional surgical site infections were diagnosed according to CDC criteria.

1. Clinical Outcome: This included malalignment or deformity and referred to any deformity in any plane more than 10 degrees and measured with an AO Trauma goniometer.

2. Another outcome was hardware failure which was any complication from failure of the implant and included nail breakage or screw loosening.

3. All-cause reoperation which referred to any reason for re-operating an open tibia fracture following the use of SIGN nail within 6 months. It included procedures for debridement, nail removal or adjustment. This was another measure of success of the implant.

4. Full weight-bearing status at 6 months was a measure of clinical union.

5. Functional outcome was measured using the EuroQol instrument and assessed health-related quality of life (HRQoL). The questionnaire includes five dimensions of overall health: mobility, self-care, ability to perform usual activities, pain/ discomfort, and anxiety/ depression. An index value from these five dimensions was calculated used Eq5D calculator (The EuroQol Group, 1990).

3.11 Data Management and Statistical Analysis

The data was entered on an excel spreadsheet on a password protected computer and exported and analyzed using SPSS version 23.0 software(IBM_Corp, 2016). The findings were presented in frequency distribution tables graphs and charts. Descriptive statistics were performed for all continuous variables of interest using the mean and standard deviation or the median and interquartile range depending on the distribution of data. Counts and proportions were used for all nominal data.

3.12 Ethical Considerations

The research proposal was reviewed and approved by the Institute of Research and Ethics Committee at Moi Teaching and Referral Hospital and Moi University (IREC 1290). Patient confidentiality was observed throughout the research. No patient was refused treatment if they refused to participate in this study.

3.13 Limitations

1. The study was a prospective case series without a comparison group. It lacked a comparator group blinded or independent assessment of outcomes.

2. Sample size was small and so susceptible to spurious findings-small changes in the number of outcome events could substantially alter the percentage of infections reported and possibly the significance of results.

3. More than one person doing surgery with different levels of skill. This could have impacted weight-bearing instructions which in turn could have affected fracture union. It was mitigated by the fact that all surgeons were familiar with the SIGN technique.

CHAPTER FOUR

RESULTS

4.1 Introduction

A total of 52 patients with 52 open tibia fractures were recruited between July 2015 and September 2016. These fractures were treated with the use of a SIGN intramedullary nail and each followed for 6 months. Three were lost to follow up and 2 had incomplete data (as they came for only one follow-up) and in all 5 cases, could not be reached by phone to arrange follow-up.

There were 47 patients with complete data for analysis giving a follow up rate of 90% (47/52)
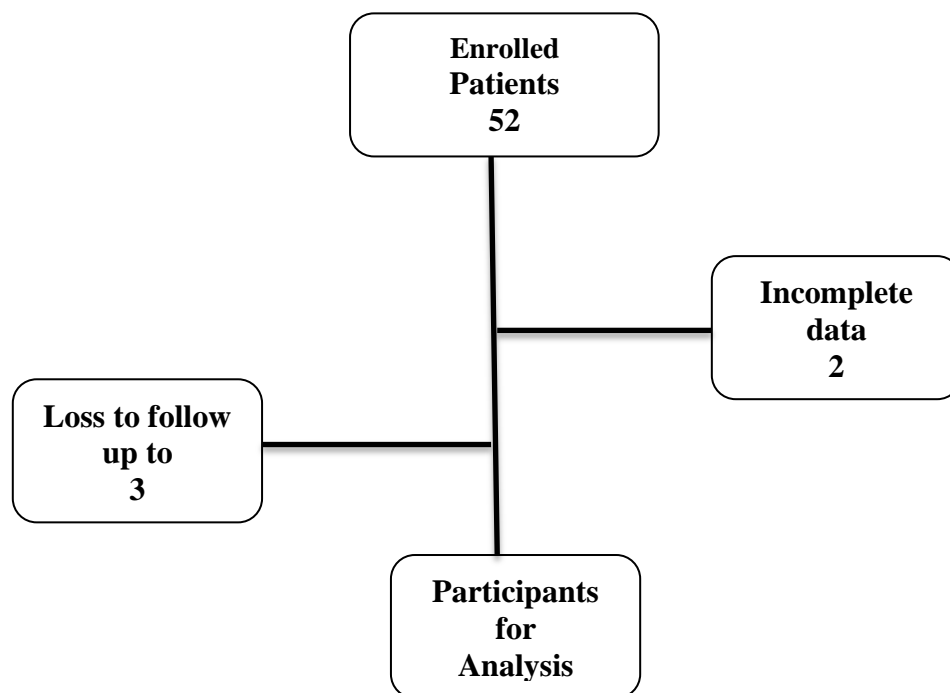
Figure 4.1.1: Recruitment of participants

There were 4 deep infections, 5 superficial infections,2 malalignments,37 unions and 1 nail breakage within the follow-up period of 6 months. Five nails were removed in total. Four nails were removed for deep infection and 1 for malunion

Only seven (7/47,15%) received antibiotics within 3 hours of injury, with the majority (28/47,59.6%) receiving antibiotics within 6 hours of injury. Floxapen was the most commonly administered antibiotic followed by ceftriaxone.

Only 4.2% (2/47) had a debridement within 6 hours, with most (44.6%, 21/47) debrided between 12 and 24 hours after injury.

Majority (17/47,36%) received SIGN nail after 72hours with only 34% (16/47) of fractures fixed within 24 hours. One fracture was fixed within 12hours.

Only 16 (34%) had primary wound closure, the rest by secondary closure, of which 11(23.4%) had a skin graft. No rotation or free flaps were used to achieve skin cover in all cases. Seventeen (36.2%) achieved closure after 72hours from injury.

4.2 Demographics

The age range in years for the study population was 18- 84 with a median age of 29 and an inter quartile range of 24 to 42 years. Fifty seven percent were 30 years and below, 4.3% over 65 years and 78.7% within the age range 18-45.

Forty three of the forty-seven participants (91.5%) were male with a male to female ratio of 10.7:1.

Most were single (59.6%), had achieved secondary school level of education (61.7%), were farmers by occupation (40.4%) and smokers (17/47,36.2%).

Table 4.2.1: Patient Characteristics

Patient Characteristics	
Characteristic	Frequency(Percentage)
No. of Patients	
Total no.	47
Sex	
Male	43(91.5)
Female	4(8.5)
Age(y)	
Median	28.9
Range	18-84
IQR	24-42
Marital Status	
Single	28(59.6)
Married	19(40.4)
Education	
Primary	16(34)
Secondary	29(61.7)
Tertiary	2(4.3)
Occupation	
Farmer	19(40.4)
Student	7(14.9)
Motorcycle Rider	5(10.6)
Other	16(34.1)
Smoking	
Yes	17(36.2)
No	30(63.8)
Associated Injury	
Yes	9(19.1)
No	38(80.9)
Medical Conditions	
Yes	2(4.3)
No	45(95.7)

Medical comorbidities were present in 2 (4.3%, both HIV positive) and associated injuries sustained in other regions of the body present in 19.1%.

Table 4.2.2: Age Categories

Age Category	Frequency	Percent
<=30 years	27	57.4
31-40 years	6	12.8
41-50 years	7	14.9
51-60 years	5	10.6
>65 years	2	4.3
Total	47	100.0

4.3 Aetiology and Fracture Patterns

Road traffic accidents were the commonest mechanism of injury (74.5%) followed by physical assault in 7 cases (14.9%). Falls occurred in 2 cases (2.8%). Other mechanisms made up 7.8% of participants and this comprised a work place accident, a sport injury and a single case of gunshot injury.

Grade III A fractures were the commonest fracture pattern to receive intramedullary nailing (40.2%) followed by Grade II injuries (34%) and Grade I injuries (25.6%) in descending order of frequency. No grade IIIB or IIIC injuries were treated by SIGN nail during the study period.

Twenty-nine (61.7%) of the fractures were in the tibial mid-shaft.

Table 4.3.1: Fracture Classification

Fracture Classification	
	Frequency (%)
Gustillo Classification	
Gustilo I	12(25.6)
Gustilo II	16 (34.0)
Gustilo IIIA	19 (40.4)
Gustilo IIIB	0 (0)
Gustilo IIIC	0 (0)
Total	47(100)
AO Classification (42-)	
A1	5(10.6)
A2	14(29.8)
A3	10(21.3)
B1	6(12.8)
B2	4(8.5)
B3	3(6.4)
C1	0(0)
C2	5(10.6)
C3	0(0)
Total	47(100)

Table 4.3.2: Fracture Patterns by Location and Mechanism of Injury

Descriptive (Fracture Location)	Frequency (%)
Proximal	5(10.6)
Middle	29(61.7)
Distal	8 (17.1)
Segmental	5 (10.6)
Total	47 (100)

Mechanism of Injury	
Road Traffic Accident	35(74.5)
Physical Assault	7(14.9)
Fall from height	2(2.8)
Other	3(7.8)
Total	47(100)

4.4 Infection Rate

Table 4.4.1 Infection rates

Infection	Gustilo grade	I	II	IIIA	IIIB	IIIC	Total
Superficial infection		0	0	5	0	0	5
Deep infection		0	1	3	0	0	4
Infection rate (%)		0/12 (0)	1/16 (6.25)	3/19 (15.8)	0/0 (0)	0/0 (0)	4/47 (8.5)

There were five superficial infections and four deep infections during the 6-month follow-up period. Three (60%) of the superficial infections progressed to deep infections.

Two of them resolved with antibiotic therapy and wound dressings. They occurred at an average of 3.6 weeks (range 3-4 weeks) from surgery.

The four deep infections were seen at a mean of 8.3 weeks (range 4-11weeks) following SIGN IM fixation. Three involved Grade IIIA pattern fractures and 1 involved grade II fracture pattern.

Three of the four deep infections were initially superficial and subsequently became deep. One deep infection was deep from onset and occurred four weeks post-surgery. The SIGN nail was removed in each case of deep infection and replaced with an external fixator device.

The infection rate was calculated as total number of deep infections divided by the total number of participants with complete follow up data expressed as a percentage.

Total number of participants with complete data = 47

Total number of deep infections = 4

Infection rate = 4/47 x 100

= 8.51%

When considered by Gustilo grade, which is a measure of injury severity, there were no infections in grade I injuries, one in grade II injuries and three in grade IIIA fractures.

There was an infection rate in grade I fractures of 0% (0/12),6.25% (1/16) for grade II injuries and 15.80% (3/19) for grade IIIA fractures. No grade IIIB or IIIC fractures received a SIGN nail.

Of those with deep infections, none received antibiotics within 3hours,2 (50%) received antibiotics within 6 hours and all received antibiotics within 12 hours of injury. In open tibia fractures with deep infection, 75% (3/4) had surgical debridement done within 6 to 12 hours of trauma.

4.5 Union Rate

The union rate was determined as measure of how many fractures had achieved radiologic union by x-ray by the fourth follow-up visit at 24 weeks following SIGN nail fixation for open tibia fracture.

Total no of fractures radiologically united at 24 weeks = 37

The union rate = total number of fractures radiologically united at 24 weeks/ total number of fractures in the study.

$$=37/47$$

$$= 78.7\%$$

The union rate by Gustilo grade was as follows: grade I (91.7%,11/12), grade II (81.2%,14/16) grade IIIA (63.1%,12/19).

All those that had superficial infections united.

Eighty-seven percent (41/47) of patients had achieved full weight bearing status at 6 months after surgery.

Table 4.5.1: Union by Gustilo grade

Gustilo Grade	I	II	IIIA	Total
Union Rate (%)	11/12(91.7)	14/16(81.2)	12/19(63.1)	37/47(78.7)
Full Weight Bearing (%)	11/12(91.7)	14/16(81.2)	14/19(73.7)	39/47(83.0)

Table 4.5.2: Time to Union by Gustilo grade

Gustilo I (Time to union in wks.)	Radiologic Union Frequency	Clinical Union Frequency
12-16	8	10
17-19	3	1
Gustilo II (Time to union in wks.)		
12-16	10	8
17-19	3	4
20-24	1	2
>24	2	2
Gustilo IIIA (Time to union in wks.)		
17-19	4	13
20-24	8	1
>24	5	5

About two-thirds of grade I fractures had united within 16 weeks whilst just over half of grade II fractures had united by this same time. Majority (42%,8/19) grade IIIA fractures united between 20-24 weeks.

4.6 Other Clinical Outcomes

Other clinical outcomes noted were malalignment, all-cause re-operation and hardware failure. Two (4.3%) patients had malunion, five (10.6%) required additional operation for debridement and nail removal. Four were for deep infection,1 for nail breakage, and 1 for malunion. One nail broke, giving a failure rate of 2.1% (1/47).

Table 4.6.1: Clinical Outcomes

Clinical outcome	Total	Grade I	Grade II	Grade IIIA
Infection(Deep)	4	0	1	3
(Superficial)	5	0	1	4
Full Weight Bearing	39	11	14	14
Delayed Union	10	1	2	7
Malalignment (>10)	2	1	0	1
Nail breakage	1	0	1	0
Reoperation	5	1	1	3

4.7 Functional Outcome

The functional outcome was measured using the EQ5D-3L tool. The mean index score amongst the 47 fractures was 0.905 using the EQ5D-3L calculator, which used an algorithm to calculate an index score from the individual domains of the EQ5D-3L.

For Grade I, Grade II and Grade IIIA fractures, the mean index scores were 0.93, 0.89, and 0.912 respectively.

The mean index score for fractures with deep infections was 0.54.

Only 82.3% (39/47) of patients reported no problems with mobility, with 91.5% (43/47) reported no problems with self-care. With respect to return to usual activities, only 80.9% (38/47) had resumed usual activity with 72% (34/47) indicated they had no pain or discomfort and 87.2% (41/47) reported no anxiety.

Knee range of motion was another parameter of functional outcome with 15% (7/47) unable to flex the knee beyond 90degrees. Grade II and IIIA made up the majority with functional knee impairment at 6 months post-surgery.

Table 4.7.1: Functional Outcomes

Functional Outcome (Gustilo Grade)	I	II	IIIA	Overall
Mean EQ5D Index Score	0.93 ±0.11	0.89 ±0.24	0.91±0.14	0.91±0.18
Stiff Knee (ROM < 90°)	1/12(8%)	3/16(19%)	3/19(16%)	7/47 (15%)
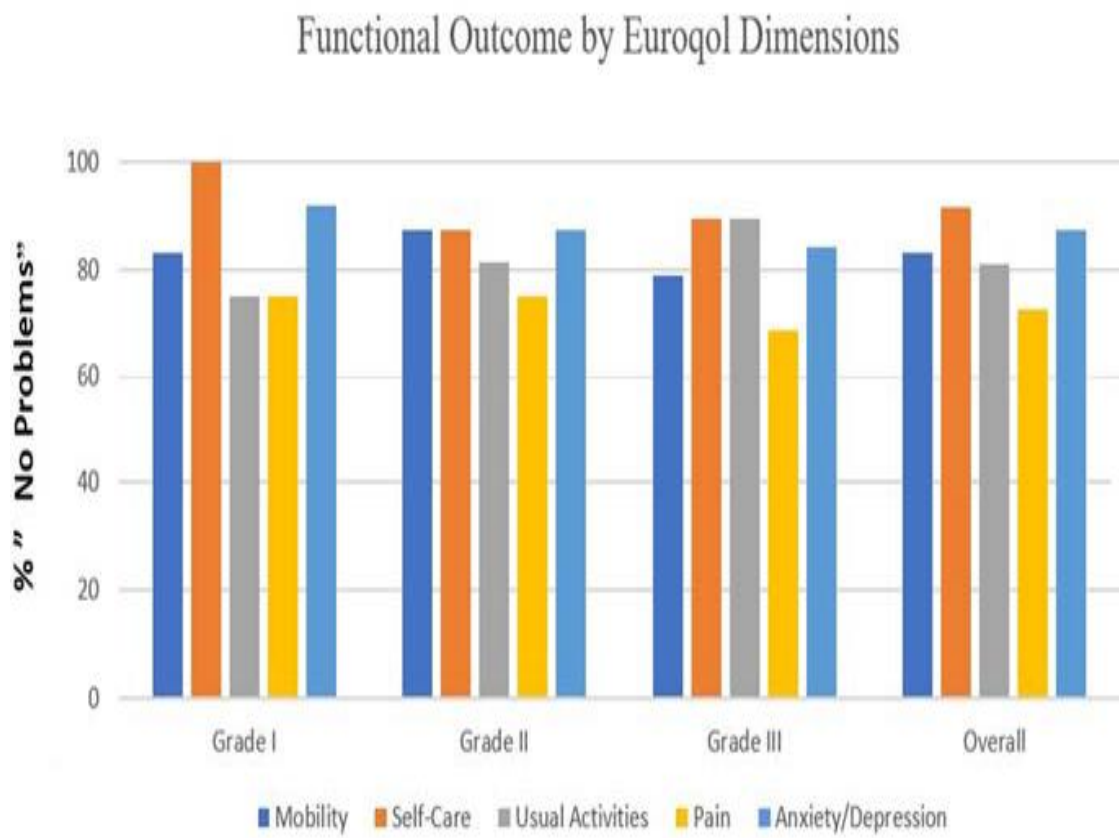
Figure 4.7.1: Functional Outcome by Euro qol Dimensions

CHAPTER FIVE

DISCUSSION

5.1 Introduction

In this descriptive case series of 47 patients with open tibia fracture treated by primary nailing using the SIGN intramedullary nail, a high follow-up rate of 90% was noted. This is remarkable because data available on the SIGN online database indicates the follow up rates for the MTRH SIGN program and the average for SIGN programs in hospitals around Kenya is 39.22% and 33.96% respectively (SIGN, 2017).

This high follow-up rate could be attributed to clear and sustained communication with the patient about the benefits of the study at recruitment and telephone calls to remind each patient for their upcoming appointment and its benefits to them.

Follow-up is a well-known obstacle to quality research in orthopaedics in LMICs like Kenya. Follow-up evaluation is often cost-prohibitive for patients [who live on a few dollars (US) per day]. Patents miss work, arrange transportation over sometimes long distances to the hospital, and pay for the clinic visit and x-rays according to Shearer et al., (2009).

5.2 Demographics

The age group most affected was less than 30 (57.4%) followed by the 41-50 (14.9%). The extremes of age in the study population (less than 20 and over 70) were least affected. This concurs with studies that have reported the disproportionate burden of orthopaedic trauma in the age category 18 -45 in a low-and middle-income country (LMIC) (Hsia et al., 2010; Kobusingye et al., 2002).

Farmers were the occupation most affected, followed by students. Eldoret is the administrative capital of Usain Gishu County. The main economic activities in this county are large scale wheat and maize farming, dairy farming and horticulture. Eldoret is also an important education centre and a crucial transport corridor linking Kenya to Uganda and South Sudan ("Kenya Information Guide," 2015).

There was a male preponderance with a male to female ratio of 10.7:1 which concurred with an earlier study by Lelei et al.,(2009) which had a ratio of 9.2:1.The male gender is considered more active and has increased labour participation and more inclined to engage in risky behaviour such as using unsafe means of transportation according to Bloom et al.,2004 and O'Hara et al., 2014.

Road traffic accidents (RTA) were the commonest cause of injury followed by physical assault. This agreed with the earlier MTRH study of open tibia fractures which also had road traffic accidents as the leading cause but differed because gunshot wounds were the second common cause. The study considered open fractures of both the tibia and femur with 60% of them being open femur fractures. Also, the study covered the period of electoral violence in Kenya, in which Eldoret was considered the epicenter according to Lelei et al., (2009) and could explain the proportion of gunshot injury seen in that study. In this current study, almost three quarters of injury were caused by RTA followed by physical assault, falls and some sports related injury. This concurred with the findings of a large epidemiological analysis by Court-Brown et al., (1995) which found that RTA's were the mechanism of injury in more than half of all open tibial shaft fractures, with most of the remainder caused by falls, sports related injuries, and direct blows. Other studies on open tibia fractures have also shown a similar trend (Joshi et al., 2004).

The age group 18 – 45 comprised more than three-quarters of study population. This concurs with local studies which have reported RTA's to affect young economically productive males. According to Odero et al., (2003), 75% of road traffic injuries involve economically active adults and Odero (1997) and Said (2000) have described the propensity for the young population to be involved in non-fatal crashes in Kenya. Casualties affected by road traffic injuries make up 45- 50% of all admissions to surgical wards in Kenya and as a result place a high demand on hospital resources according to Macharia et al., 2009 and Odero et al., 2003. The health of the economically productive young male is vital to the economic growth of a LMIC like Kenya in both the short term and long term as they are often the sole bread winners for a family of dependents as documented by O'Hara et al.,2014.

5.3 Fracture Patterns

Gustilo IIIA was the commonest (40.4%) fracture type to be nailed in this study. Open tibial fractures are high energy injuries and a considerable proportion are associated with severe soft tissue injuries. Court Brown and McBirnie (1995) found 60% of open tibia shaft fractures were Gustillo III in their large epidemiological study. This reflected an increased use of intramedullary nailing in the management of more severe fracture patterns compared to earlier studies at MTRH as documented by Lelei et al., 2009a.

The middle shaft was the commonest location injured. This is in agreement with a recent conference paper on the use of SIGN nail in open tibia fractures in LMIC's by Shahab,2017.

5.4 Infection Rate

The rate of deep infection in this study was 8.51%. This fell within the generally accepted range for open tibia fractures of 3-25% according to the British Orthopaedic Association (BOA/BAPRAS., 2009). The overall infection rate is also lower than that reported for SIGN nail used in open tibia fractures in LMIC's according to Shahab, (2017). In this retrospective review of the SIGN online surgical database (SOSD) covering 176 patients in 49 developing countries; he reported an infection rate of 10.8%.

It is difficult to determine the infection rates from the study of Lelei et al., 2009a. One deep infection was noted in an open tibia fracture but its Gustilo grade as well as the total number of open tibia operated was unclear. It was a retrospective review in a patient population that mostly had open femur fractures, which are biologically different from open tibia fractures as documented by Littenberg et al.,1998.

The infection rate when stratified by Gustilo grade increased progressively from no deep infection in grade one fractures to 6.25% in grade II fractures and increased, by a factor of approximately 2.5, to 15.8% in grade IIIA fractures. These rates fell within the range reported by numerous authors when stratified by Gustilo grade and are given as follows: Grade I (0-2%), Grade II (2-10%) and Grade III (10-25%) (Gustilo &Anderson, 1976; Gustilo & Corpuz, 1985; Gustilo & Grunninger, 1987; Gustilo & Merkow, 1990; Melvin et al.,2010; Papakostodis, 2011; Patzakis & Wilkins, 1989) and demonstrated the direct correlation between severity of soft tissue injury (Gustilo grade) and incidence of infection as documented by Gustilo et al.,1990.

This concurs with studies by Khatod et al., (2003) and Sungaran et al., (2007) which reported Gustilo grade as the most important prognostic indicator for the development

of infection in open tibial fractures.

In this study, 17(36.2%) were smokers with no infection reported at 6 months post-surgery. This contrasts with the study by Aderinto and Keating, (2008) who showed smoking to be associated with increased number of infections in patients with open tibial fractures.

HIV was the only comorbidity documented in the current study population and was reported in two patients who were both on antiretroviral treatment. One was a grade IIIA and the other was a grade II injury and no infection was reported within 6 months. This could be because both cases were on retroviral therapy. A positive HIV status has been associated with a rise in the number and severity of infections when compared with such fractures in patients who were HIV negative as documented by Aderinto & Keating, 2008. Infection rates of 71% to 100% were reported in two series of open tibial fractures in HIV-positive patients by Harrison et al., 2004 and O'Brien & Denton, 1994.

Although all patients in this study received prophylactic antibiotics after injury, only 7 (14.9%) patients in current study received antibiotic prophylaxis within 3 hours with the majority receiving within 12 hours of injury. In addition, of those with deep infections, none received antibiotics within 3 hours of injury. Among the more severe grade IIIA fractures, only 1 received antibiotics within 3 hours of injury and no infection was reported within 6 months for this fracture. The reason for antibiotic administration beyond 3 hours could be explained by a combination of transport delay by patients and a lack of availability of drugs. Patzakis and Wilkins (1989) identified timely antibiotic administration as the most important factor in reducing the risk of infection. In their case control study of more than 1100 open fractures, giving antibiotics more than 3 hours after injury was associated with 1.63 times greater odds

of infection in comparison with treatment within the first three hours of injury. Regarding antibiotic type, the most commonly documented antibiotic given at initial care for open tibia fractures at MTRH was flucloxacillin. Ceftriaxone was the second most commonly administered antibiotic and was given in the more severe grade III fractures. Addition of an aminoglycoside was rarely added for grade IIIA injuries. The choice of antibiotics was mainly due to availability and the discretion of the admitting staff, possibly owing to a lack of a written antibiotic policy. There is currently no conclusive evidence in the form of a randomized clinical trial that validates an optimal regimen for open tibia fractures as documented by Mundi et al., 2015. There is however evidence for coverage against gram positive bacteria in open fractures with a first-generation cephalosporin by Court-Brown & McBirnie, 1995, Melvin et al., 2010 and Patzakis (1974).

Furthermore, the addition of an aminoglycoside has been suggested by Hoff et al., 2011 and a randomized study by Patzakis et al., 1974. It is however not conclusive as the sample size in these studies was small and significance could not be reached. Other studies like that of Sorger et al., (1999) could not substantiate the results of Patzakis et al., 1974.

In this study, only 3(6.4%) had SIGN nailing done within 24 hours of injury. Among the grade IIIA fractures, only 1(1/19,5.3%) was nailed within 12 hours. A combination of late presentation, the need for a repeat debridement was often the cause for delay in nailing. Occasionally, the SIGN nail was not available and so surgery was postponed to a later date after initial debridement. This contrasts with a study by Singh et al., (2011) in India where primary intramedullary nailing of open tibia fractures within 12 hours of injury. The majority (75%) of the fractures in their study comprised the more severe grade IIIB fractures, with grade IIIA fractures

constituting only 20.5% of the study population and plastic surgery was involved where flap coverage was needed. They reported an infection rate of 14% which is remarkable because it is lower than that recorded in this study in a more severe fracture population.

In this study, only 4.2% (2/47) met the currently accepted standard of care of debridement done within six hours of injury, with no infections reported in these fractures. Most fractures were debrided between 12 and 24 hours. Of those with deep infection,3(75%) were debrided after 24 hours and concurs with the growing recognition by orthopaedic surgeons according to Melvin et al., (2010) that delaying debridement after 24 hours is not recommended. It must be noted that there are several retrospective studies that have demonstrated no significant difference in infection rates for those patients who undergo debridement before or after the six-hour mark including studies by Khatod et al., (2003) and Tripuraneni et al., (2008) but more randomized trials are needed to bring more clarity.

Thirty-four percent had primary closure and the rest secondary closure and no free rotation flaps were used in fractures as there were no IIIB. Grade IIIB fractures require flap closure and are usually deemed too contaminated for primary nailing at MTRH. There is currently no working collaboration between the plastic surgery and orthopaedic department and it is doubtful whether the experience with flaps for complex trauma cases exists. Grade IIIB tibia fractures are managed on external fixators with some eventually requiring amputation. There are now reports by Bhandari et al., (2005) and Melvin et al., (2010b) demonstrating low infection rates in grade IIIB fractures treated by initial external fixation followed by conversion to locked intramedullary nailing within 28 days. This could expand the current indications for SIGN nails to include grade IIIB fractures. The knowledge and

experience of personnel trained and experienced in doing flaps must be present. Ali et al., (2017) in Bangladesh used a protocol of primary nailing with SIGN nail in 12 grade IIIB open tibia fractures and reported no deep infections. All cases received flap coverage within 72 hours of injury and 83% were debrided within 12 hours of trauma.

No wound management adjuncts were used in this current study as they are either currently unavailable, or their usage has not been popularized. Local delivery of antibiotics through antibiotic impregnated cement (which is available in MTRH) as an adjunct to systemic antibiotic has been demonstrated in met- analysis by Craig et al., (2014) to significantly lower deep infection risk, with the effect being more pronounced for grade III fractures. This has implications for lowering the infection rates in grade III open tibia fractures at MTRH as grade IIIA fractures, which constituted 40% of this study, contributed 75% of the deep infections.

A systematic review by Bhattacharyya et al., (2008) have advocated the use of negative pressure wound therapy which reduces the need for flaps and may be suitable in settings where collaboration between plastic surgery and orthopaedics is not yet optimal or where experience by plastic surgeons in severe soft tissue injuries is lacking. Close collaboration between orthopaedics and plastic surgery departments has led to significant reduction in infection rates in the management of severe grade III injuries according to Gopal et al., (2000).

5.5 Union Rate

Thirty-seven open tibia fractures united by radiographic criteria within 6 months given a union rate of 78.7%. This contrasts with a union rate of 72% reported Lelei et al., (2009) when using SIGN nail in open tibia and femur fractures at MTRH where the predominant fracture type was open femur (Sample size 43).

In the current study,40% (19/47) open tibia were Grade III pattern. This was a higher proportion of grade III fractures compared to 25% (9/36) Grade III tibia in a study by Shah et al., 2004. In this retrospective case series in Nepal, 36 open tibia fractures were fixed primarily using the SIGN nail and reported a union rate of 86.1%(31/36) within 6 months and a mean time to union of 22 weeks. Relatively higher union rates could also be attributed to early antibiotic administration, aggressive soft tissue management including collaboration with plastic surgeons for early wound coverage. All patients in the study by Shah et al. (2004) were nailed within 12h.

When considering timing of surgery for the more severe grade III fractures in this study, only one grade IIIA tibia fracture was nailed within 12 hours of injury, and 3(10.5%) were nailed within 24 hours. Delays in patient arrival, waiting times for theatre space and the need for repeat debridements were some of the reasons why early debridement and nailing could not done at MTRH.This has support from a study in MTRH by Ayumba et al., 2015. Another possibility for delay in nailing is that most of the initial debridement procedures in the MTRH study were not performed by the most experienced surgeon on the team and done mostly late nights when a less experienced theatre team was available. This would result in the need for a repeat debridement and delay.

When stratified by Gustilo grade, the union rates were 91.7%, 81.2% and 63.2% for grades I, II, IIIA respectively. This concurred with a meta-analysis by Papakostidis et al., (2011) in which union rates fell from grade I through to grade IIIB for open tibial fractures treated by reamed intramedullary nailing. They also estimated a range for union rates stratified by Gustilo grade as follows: grade I (91-100%), grade II (40-95%) and grade IIIA (21-91%). Gustilo grade is a good predictor of outcome and increasing grade represented increasing severity of bony injury, which in the tibia that has a precarious blood supply, resulted in reduced union rates and increased rates of delayed union and non-union according to several works by Gustilo & Anderson, 1976; Gustilo & Grunninger,1987; Gustilo & Merkow,1990; Melvin et al., 2010a and Papakostidis et al., 2011.

HIV was the only comorbidity and was reported in two patients who were both on antiretroviral treatment. One was a grade IIIA and the other was a grade II injury. Their fractures each went on to unite within 6 months without infection. HIV status has been associated with delayed union as documented by Aderinto & Keating,(2008) and also demonstrated a trend towards non-union when compared with such fractures in patients who were HIV negative.

Some studies in developed countries have reported union rates much higher than that reported in this study. Giannoudis et al. (2006) reviewed the literature on open tibia fractures and found a 97% (53% were grade III) union rate following reamed intramedullary nailing from four studies which included one prospective randomized trial. A total of 187 open tibia were reviewed (16% IIIA, 27% IIIB) and most (37%) had soft tissue coverage between 24 and 72 hours of injury and 15% needing bone grafting to achieve healing in contrast to this study where no fracture received additional bone grafting procedure.

A study giving similar union rates as this study was Shahab (2017) who reported a 72% union rate (126/176) with 81% (143/176) of these able to weight bear within 6 months.   It was a retrospective review of the SIGN online database (SOSD) for open tibia fractures using SIGN nail in 22 LMIC. It must be noted that 35% were grade III fractures (28%IIIA, 7%IIIB).

5.6 Functional Outcome

In this study, functional outcome was assessed by the Euroqol tool where an index value of 1.00 represented the perfect state of health and 0 represented death. Grade I injuries had the best mean index score and grade II, surprisingly, had better mean index scores than the more severe Grade IIIA fractures. Grade II fractures had fewer infections and fewer delayed unions than grade IIIA but had a case of a severe infection and another with implant breakage which disproportionately lowered the mean score for this fracture pattern. If the score for the patient with the severe grade II infection was excluded, the mean index score became comparable to that of grade I fractures, highlighting the impact of infection on quality of life of the patient.

Gopal et al., (2004) in a study on the functional outcomes in severe (grade III) open tibia fractures to assess the "fix and flap strategy" reported a mean index value EQ5D index score of 0.68. This score was lower than the mean index score on this study and could be explained by the fact that the study population was more severe IIIB and IIIC tibia fractures which received a regimen of radical debridement, immediate stabilization and early soft tissue cover.

In this study, when considering the domains of the EQ5D, the number of patients expressing no problems in each domain decreased as Gustilo grade increased highlighting the importance of this classification even on predicting patient reported quality of life.

5.7 Associations

Using bivariate analysis between demographic characteristics and outcomes, the following were found: There was no evidence of statistical significance between age, gender, marital status, education level and deep infection (p>0.05) or union (p>0.05).

Using the same analysis, Smoking was not associated with deep infection (39.5% versus 0.0%, p >0.05). This is surprising given the strong correlations between smoking and deep infection and delayed union cited in previous sections.

There was similarly no evidence of statistical significance from the data to link HIV infection with deep infection or delayed union (p>0.05).

Most surprising was that although deep infection rates showed a trend towards increase with worse Gustilo grade classification, the correlation did not approach significance (p>0.05).

Participants who were diagnosed with deep infection had statistically significantly lower functional outcome score compared to those who were not diagnosed with deep infection, mean: 0.54 (SD: 0.22) versus. 0.94 (SD: 0.13), p <0.001. Deep infection affected significantly the health-related quality of life for patients receiving SIGN nail fixation.

Efforts therefore must be targeted towards measures that are known to reduce infection rates in the strive to improve the management of SIGN nail fixation of the open tibial fracture at MTRH.

CHAPTER SIX

CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

Open tibia fractures treated by primary SIGN nailing in MTRH were most commonly grade IIIA pattern and involved the tibial midshaft. Road traffic accidents were the most frequent cause and males were 10 times more affected than females.

The short term overall deep infection rate at six months following primary SIGN intramedullary nailing was low. Infection rates increased from Grade I through to Grade IIIA. Most patients did not receive antibiotics in the recommended period and no local antibiotics were used.

The overall union rate was higher than previous reports. SIGN nailing is effective for grade I to IIIA open tibia fractures at MTRH.

The functional outcomes were excellent with over 75% reporting "no problems" with mobility.

6.2 Recommendations

1. SIGN nail can be used in Grade I to Grade IIIA open tibia at MTRH.

2. Traffic safety health promotion on radio and television targeted at males like wearing helmets if on a motorbike, and seat belts if in a vehicle on discharge from hospital open tibial following injury.

3. Every effort should be made to install protocols that would result in lowered infection rates including written antibiotic policy for administering prophylactic antibiotics in open tibia fractures admitted to MTRH stating the recommended choice of antibiotic, dosage, urgency and duration of treatment for harmonized practice. It should also include the use of localized antibiotic delivery in the severe

IIIA fractures

4. Every effort should be made to improve union rates including regular resident training on techniques of thorough debridement and flaps that can be used to promote early soft tissue cover, including the use of new technologies like negative wound pressure therapy that have been shown to improve union rates in IIIA tibia fractures. Additionally, Collaboration between orthopaedics and plastic surgery departments in providing joint care for severe open tibia fractures.

5. Every effort should be installed to improve fuctional outcomes including measures stated above to reduce infection and further studies to understand the use of SIGN nails in grade IIIB and IIIC fractures.

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APPENDICES

Appendix I: Consent Form

My name is Daniel-John Lavaly and I am a student at Moi University School of Medicine. I am conducting a study on the patterns of open tibia fractures and outcomes of SIGN intramedullary nailing in open tibia fractures at MTRH. SIGN intramedullary nail is a tool used in open fracture surgical treatment.

I will ask you some questions regarding your fracture and the surgical treatment using SIGN nail that you will receive at Moi Teaching and Referral Hospital. I will also ask you some questions about your socio demographic characteristics.

Your participation in the study will in no way change the treatment plan that your doctors deem is fit for you. This study will not put you at any risk; no immediate benefit will accrue to you.

Information gathered will be treated with utmost confidentiality; your identity will be protected. The information obtained will be used to improve the patients at our facility with open tibia fractures and may be published in medical journals and/or presented in scientific symposia.

The Moi University Ethics and Research Committee has approved this study.
For any question or clarification, please do not hesitate to contact me Daniel-John Lavaly on 0716205571 or contact the chairperson of IREC, Moi Teaching and Referral Hospital
P.O Box 3-30100 Eldoret.

May I proceed with the questions? Yes/ No.

Respondent's signature…………………Date ………………

Appendix II: Assent Form

Title of Study: Patterns Of Open Tibia Fractures And OUTCOMES OF INTRAMEDULLARY NAILING USING SURGICAL IMPLANT GENERATION NETWORK NAIL AT MOI TEACHING AND REFERRAL HOSPITAL

Investigator: Daniel-John Lavaly

Research Staff: Daniel-John Lavaly

Why are we doing this study?

We are doing a research study about outcomes in open tibia fractures treated by SIGN nail.

Why am I being asked to be in the study?

We are inviting you to be in the study because you have an open tibia fracture which was treated by SIGN nail.

What if I have questions?

You can ask questions if you do not understand any part of the study. If you have questions later that you do not think of now, you can talk to me again or ask your nurse to call me on 0716205571.

If I am in the study what will happen to me?

If you decide that you want to be part of this study, you will be asked to answer a short questionnaire, have a quick exam of your leg and we will be in touch by telephone to arrange your follow -ups.

Will I be hurt if I am in the study?

There are some things about this study you should know. You will not be hurt in this study

Will the study help me?

If you are in the study, it may not help you to get better or benefit you. The study may help us to understand how safe and ho effective is your treatment and to make improvents.

I have to be in this study?

You do not have to be in this study, if you do not want to be. If you do not want to be in this study, we will tell you what other kinds of treatments there are for you. If you

decide that you do not want to be in the study after we begin, that is Okay too. Nobody will be angry or upset. We are discussing the study with your parents and you should talk to them about it too.

What happens after the study?

When we are finished this study we will write a report about what was learned.

This report will not include your name or that you were in the study.

Assent:

If you decide you want to be in this study, please print/write your name. If you decide that you do not want to be in the study, even if you have started in the study, then all you have to do is tell: ………….

I,   (Print your name) would like to be in
this research study.

                                              (Date of assent)

                                              (Name   of   person   who   obtained
assent)

                                              (Signature of person who obtained
assent and
       Date)

                                              (Local Principal Investigator name)

                                              (LPI signature and Date)

Appendix III: Questionnaire

Patient code……………………

PART A: PATIENT CASE INFORMATION

1. Age

2. Sex: ☐Male ☐ Female

3. Date of injury

4. Marital status (*Choose one*): [1]Married ○ [2]Divorced ○ [3]Single ○[4] Widow(ed)

5. ○ [5] Separated ○

6. Level of Education (*choose one*):

    [1]○Primary [2]○Secondary[3]○Tertiary [4]○University

7. Occupation (*write down*):

8. Do you have any other injuries?

9. Do you suffer from any other medical condition?

[1] Yes   [2] No   If yes which condition (write down)

    _____

10. Address

11. Phone no.

 PART B: SURGERY INFORMATION

12. Sugery date?

13. Antibiotics used? ☐Yes ☐ No

14. If Yes, how long from time of injury?   Hours   ☐   Days   ☐

15. Name of antibiotic

16. Duration of coverage   hours   ☐   days   ☐

17. Surgery comments

PART C Fracture Information

18. Fracture side   Left ☐   Right ☐

19. Location of fracture Proximal ☐ Middle ☐   Distal ☐   Segmental ☐

20. AO classification?

21. Type of fracture?

GustilloI   ☐

GustillloII   ☐

Gustillo IIIA   ☐

Gustillo IIIB   ☐

Gustillo IIIC   ☐

22. What caused the fracture of the Tibia?

[1] Road Traffic Accident

[2] Fall from a height

[3] Physical Assault

[4] Work related injury

[5] Gunshot

[6] Others (*state*) _____

23. Time from injury to debridement ?   hours   days

24. Previous Exo Fix   Yes   No

25. If yes, how long was exo fix in place?   Days

26. If yes, how long between the removal and SIGN nail placement

27. Method of reaming   None   Hand

Name: _____

Appendix IV: Follow-Up Questionnaire

Patient Code

1. Infection?   Yes   No

2. If yes,   Superficial   Deep

3. If yes,   Duration of infection?   Weeks

4. Partial weight bearing   Yes   No

5. Full weight bearing   Yes   No

6. Healed by Xray?   Yes   No

7. Knee flexion > 90degrees   Yes   No

8. Any implant failure?   …..Yes   …No

9. Any deformity?   …..Yes   ……No(Under 10 degrees)

10. If yes,   ALIGNMENT   > 10 deg varus   >10 deg valgus

>10 deg varus   >10 deg valgus

                ROTATION   > 30 deg

11. Comments

Appendix V EQ5D 3L Questionnaire (Swahili Version)

Kwa kuweka alama ya vema kwenye kisanduku kimoja katika kila fungu hapo chini, tafadhali onyesha maelezo yapi yanaelezea vizuri zaidi hali ya afya yako kwa leo.

Uwezo wa kutembea

Sina tatizo katika kutembea	❑
Nina matatizo kiasi katika kutembea	❑
Siwezi kutembea kabisa	❑

Uwezo wa kujihudumia

Sina tatizo kujihudumia mwenyewe	❑
Nina matatizo kiasi katika kujisafisha au kuvaa mwenyewe	❑
Siwezi kujisafisha wala kuvaa mwenyewe	❑

Shughuli za kila siku*(mfano: kazi, kusoma shuleni/chuoni, kazi za nyumbani, shughuli za kifamilia au starehe)*

Sina tatizo katika kufanya shughuli zangu za kila siku	❑
Nina matatizo kiasi katika kufanya shughuli zangu za kila siku	❑
Siwezi kabisa kufanya shughuli zangu za kila siku	❑

Maumivu/Kutojisikia vizuri

Sina maumivu au sina kutojisikia vizuri	❑
Nina maumivu kiasi au najisikia vibaya kiasi	❑
Nina maumivu makali au najisikia vibaya sana	❑

Hali ya afya nzuri
kabisa inayoweza
kufikirika

Wasiwasi/mnyong'onyeo

Sina wasiwasi au mnyong'onyeo ❑

Nina wasiwasi kiasi au mnyong'onyeo kiasi ❑

Nina wasiwasi sana au nina mnyong'onyeo sana ❑

Ili kuweza kukusaidia wewe kusema kama hali yako ya kiafya ni nzuri au mbaya, tumechora **kipimo** kinachofanana na kipima joto. Hali nzuri kabisa unayoweza kufikiria

 imewekewa alama ya 100 (mia moja) na hali mbaya kabisa unayoweza kufikiria imewekewa alama ya 0 (sifuri).

Sasa tungependa utuambie sehemu katika kipimo hiki ambapo ungeiweka hali yako ya afya leo. Tafadhali fanya hivi kwa kuchora mstari kutoka kwenye kisanduku hapo chini hadi kwenye sehemu yoyote katika kipimo ukionyesha jinsi hali ya afya yako ilivyo nzuri au mbaya kwa leo.

Hali ya afya yako kwa leo

100

9●0

8●0

7●0

6●0

5●0

4●0

3●0

2●0

1●0

0
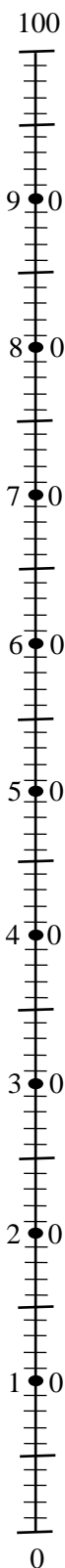
Hali ya afya
mbayakabisa
inayoweza
kufikirika

Appendix VI: Eq5d (English Version)

By placing a tick in one box in each group below, please indicate which statements best describe your own health state today.

Mobility

I have no problems in walking about ☐ ☐

I have some problems in walking about ☐ ☐

I am confined to bed ☐

Self-Care

I have no problems with self-care ☐ ☐

I have some problems washing or dressing myself ☐ ☐

I am unable to wash or dress myself ☐

UsualActivities *(e.g.work,study,housework,familyorleisureactivities)*

I have no problems with performing my usual activities ☐ ☐

I have some problems with performing my usual activities ☐ ☐

I am unable to perform my usual activities ☐

Pain/Discomfort

I have no pain or discomfort ☐ ☐

I have moderate pain or discomfort ☐ ☐

I have extreme pain or discomfort ☐

Anxiety/Depression

I am not anxious or depressed ☐ ☐

I am moderately anxious or depressed ☐ ☐

I am extremely anxious or depressed ☐

UK(English)©1990EuroQolGroupEQ-5D™isatrademarkoftheEuroQolGroup

Appendix VII: Eq5d Index Calcultor

EQ-5D index calculator

This model estimates the EQ-5D index score for a given health state defined by the user. Index scores are based on general population valuation surveys that used TTO or VAS methods in various countries as presented in the book: *Szende, Oppe, Devlin (ed.): EQ-5D Value Sets: Inventory, comparative review, and user guide.*

Please enter health state description:

Mobility	1
Self-care	2
Usual activities	2
Pain/Discomfort	2
Anxiety/Discomfort	1

Select country/survey of interest: Kenya

	TTO Score	VAS Score
Kenya	0.698	Not available

Results for all countries/surveys:

	TTO Score	VAS Score
Belgium	Not available	0.650
Denmark	0.713	0.521
Finland	Not available	0.586
Germany	0.800	0.642
Japan	0.670	Not available
Netherlands	0.729	Not available
New Zealand	Not available	0.631
Slovenia	Not available	0.614
Spain	0.682	0.634
UK	0.656	0.637
USA	0.748	Not available
Zimbabwe	0.698	Not available
Europe	Not available	0.635

Appendix VIII: IREC Approval Letter

INSTITUTIONAL RESEARCH AND ETHICS COMMITTEE (IREC)

MOI TEACHING AND REFERRAL HOSPITAL
P.O. BOX 3
ELDORET
Tel: 33471/2/3
Reference: IREC/2014/143
Approval Number: 0001290

MOI UNIVERSITY
SCHOOL OF MEDICINE
P.O. BOX 4606
ELDORET
2nd October, 2014

Dr. Daniel-John Lavaly,
Moi University,
School of Medicine,
P.O. Box 4606-30100,
ELDORET-KENYA.

INSTITUTIONAL RESEARCH &
ETHICS COMMITTEE
0 2 OCT 2014
APPROVED
P.O. Box 4606-30100 ELDORET

Dear Dr. Lavaly,

RE: FORMAL APPROVAL

The Institutional Research and Ethics Committee has reviewed your research proposal titled:-

"Patterns of Open Tibia Fractures and Outcomes of Intramedullary Fixation Using Sign Nail at Moi Teaching and Referral Hospital."

Your proposal has been granted a Formal Approval Number: **FAN: IREC 1290** on 2nd October, 2014. You are therefore permitted to begin your investigations.

Note that this approval is for 1 year; it will thus expire on 1st October, 2015. If it is necessary to continue with this research beyond the expiry date, a request for continuation should be made in writing to IREC Secretariat two months prior to the expiry date.

You are required to submit progress report(s) regularly as dictated by your proposal. Furthermore, you must notify the Committee of any proposal change (s) or amendment (s), serious or unexpected outcomes related to the conduct of the study, or study termination for any reason. The Committee expects to receive a final report at the end of the study.

Sincerely,

PROF. E. WERE
CHAIRMAN
INSTITUTIONAL RESEARCH AND ETHICS COMMITTEE

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

Appendix IX: IREC Continuing Approval

INSTITUTIONAL RESEARCH AND ETHICS COMMITTEE (IREC)

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

MOI UNIVERSITY
SCHOOL OF MEDICINE
P.O. BOX 4606
ELDORET
Tel: 33471/2/3

Reference: IREC/2014/147
Approval Number: 0001290

2nd October, 2015

Dr. Daniel-John Lavaly,
Moi University,
School of Medicine,
P.O Box 4606-30100,
ELDORET-KENYA.

02 OCT 2015

Dear Dr. Lavaly,

RE: CONTINUING APPROVAL

The Institutional Research and Ethics Committee has reviewed your request for continuing approval to your study titled:-

"Patterns of Open Tibia Fractures and outcomes of Intramedullary Fixation Using Sign Nail at Moi Teaching and Referral Hospital".

Your proposal has been granted a Continuing Approval with effect from 2nd October, 2015. You are therefore permitted to continue with your study.

Note that this approval is for 1 year; it will thus expire on 1st October 2016. If it is necessary to continue with this research beyond the expiry date, a request for continuation should be made in writing to IREC Secretariat two months prior to the expiry date.

You are required to submit progress report(s) regularly as dictated by your proposal. Furthermore, you must notify the Committee of any proposal change (s) or amendment (s), serious or unexpected outcomes related to the conduct of the study, or study termination for any reason. The Committee expects to receive a final report at the end of the study.

Sincerely,

PROF. E. WERE
CHAIRMAN
INSTITUTIONAL RESEARCH AND ETHICS COMMITTEE

cc: Director   -   MTRH
        Dean   -   SOM
        Dean   -   SPH
        Dean   -   SOD
        Dean   -   SON

Appendix X: STUDY TIMETABLE

Activity	Duration	Time Frame
Overall period	24 months	July 2015 – September 2016
Conceptualization of idea	1 month	January 2014-January 2015
Literature Review	1 month	February 2014-January 2015
Proposal development	3 months	March - June, 2014
Submitting to IREC for Approval	1 month	July 2014
Soliciting for funds	2 months	October 2014 – December 2014
Data collection	8 months	July 2015 – March 2017
Data Analysis	2 months	March 2017 – September 2017
Thesis write up	2 months	August 2017 – December 2017
Defense	2 months	August 2018
Document cleaning	1 month	March 2017
Final report	1 month	September 2018

Appendix XI: BUDGET

ITEM	COST (Ksh)
Research assistants (2)	150,000
X-rays imaging	56,400
Biostastician	50,000
Stationery and Printing costs	16,000
SUBTOTAL	**272,400**
Contingency(10% subtotal)	27,240
TOTAL	**299,640**