The Management of Open Tibial Fractures

Dr. Shadrick G. Lungu (BSc.Hb; MBChB. - UNZA)

Master of Medicine in Orthopaedics (M.Med. (Orth))

Supervisor

Mr. Y. Mulla. M.Ch. (Orth), Liverpool.

Senior Lecturer (University of Zambia)

Co-Supervisor

Mr. A. Gregori. (FRCS, FRCS (Orth), DFM)

A dissertation submitted to the University of Zambia in partial fulfillment of the requirements for the degree of Master of Medicine in Orthopaedics M.Med (Orth)

School of Medicine - 1999

Table of Contents

		Page
1.	Declaration	iv
2.	Dedication	v
3.	Approval	vi
4.	Abstract	vii
5.	Acknowledgement	ix
6.	Abbreviations	xii
7.	List of Tables, Graphs / Charts	xiii
8.	INTRODUCTION	1
9.	STATEMENT OF THE PROBLEM	3
10.	OBJECTIVES	4
11.	RATIONALE	5
12.	LITERATURE REVIEW	6
13.	PATIENTS AND METHODS	47
14.	RESULTS	52
15.	DISCUSSION	71
16.	CONCLUSION	82
17.	RECOMMENDATIONS	84
18.	REFERENCES	85

19. APPENDIX I

20. APPENDIX II

Declaration

I, Shadrick G. Lungu, hereby declare that this dissertation has never been submitted, in part or in full, for a diploma or a degree in any other university.

Date 23/12/99 Candidate Signature ....

I have read this dissertation and approved it for examination.

Date 23/12/99 Signature ....

Supervisor: Mr. Y. Mulla Mch (Orth)

Senior Lecturer (UNZA)

Dedication

… it is past midnight now; Zamiwe (1 year 3 months old), Dalitso (4) and Martha my wife are all asleep. It is difficult to do any work with the former two awake. In the quiet and peace of the night I dedicate this work to Martha and my kids.

June 2, 1998

Approval

This dissertation by Shadrick Gideon Lungu is approved as partial fulfillment of the requirement for the award of the Master of Medicine (Orthopaedics) degree of the University of Zambia.

Examiners:

1. Signature.. Date 23/12/99
2. Signature.. Date 23/12/99
3. Signature.. Date ....
4. Signature.. Date ....

ABSTRACT

No study has been done in Zambia on external fixation of fractures. The objectives of this study therefore are to show the outcome of external fixation of open tibial fractures and whether or not tap water is as effective as normal saline in wound irrigation (lavage).

This study was done at the University Teaching Hospital, Lusaka, and Saint Francis' Hospital, Katete.

Twenty-nine patients, 30 legs, were randomly recruited to the study using pre-labelled proformas as "tap water" (study group) and "normal saline" (control group).

The study group (17 legs) and control group (13 legs) were subjected to a similar line of management except for the type of fluid in wound irrigation. Ten litres of tap water and six litres of saline were used for wound irrigation respectively.

Most patients were managed and followed up by the investigator. Seven of the 29 patients received primary external fixation up to the time of discharge. Nine had plaster casts primarily until they finally healed. The others, however, had a combination of plaster casting and external fixation.

The average age of patients was 27 years with a sex ratio of M:F; 5:1. RTA was the commonest cause of injury. The middle third of the tibia was affected most. Pedestrians suffered open tibial fractures most. Ipsilateral fibular fracture was common.

Complications were equinus deformity of the foot in two legs; maximum limb shortening was 2.5 cm in four legs (types II and III). Five legs of 11 (control) and 9 of 17 (study) suffered superficial wound infection respectively while 1 leg of 11 (control) and 6 of 17 (study) had chronic osteomyelitis.

This study shows that external fixation is a good method of managing open tibial fractures and that large volumes of tap water should be used for wound debridement (in these fractures).

ACKNOWLEDGEMENTS

I wish to acknowledge the effort and valuable advice received from my predecessors in the Department of Surgery, now senior registrars.

I wish to thank Dr C. Sikasote for his personal encouragement and advice. While Dr John S. Kachimba a fellow student, created an atmosphere of competition in the preparation of our respective dissertations. I wish him well, during the preparation of his dissertation, as well as, for the final examination in December 1998.

The Head of the Surgical Department, Professor Krikor Erzingasian, has been instrumental in encouraging and reminding, more than timely, M.Med students (me inclusive) about the need to prepare their dissertation early.

Mr. Alberto Gregori was an inspiration during his attachment to the University of Zambia (at the University Teaching Hospital - School of Medicine). His motivation not only towards his work, but teaching of students also was unequalled. His generous contributions of external fixators, some Plaster of Paris (POP), computer diskette full of literature on open tibial fractures will forever be remembered and acknowledged.

The Head of Orthopaedic section Professor John E. Jellis has provided lots of the literature in this dissertation although he may not be aware about this. His departmental office, also a "library" has up-to-date orthopaedic journals. Although he was not my immediate supervisor, he offered to help with the editing of this dissertation. I thank him with his counter part Mr. Mulla for having been good teachers to me and, of course, to other students.

Mr. Yakub Mulla has supervised me well. I have had "hands on" sessions in many procedures including the management of tibial fractures. He is patient, tolerant and instils confidence in his students.

Ms. Nelicy Hankolwe competently handled the secretarial work. Medical terms are often difficult to spell let alone pronounce by non-medical people. She has done exceptionally well as evidenced by this document.

Mr. Clement Mulenga of the University Teaching Hospital (Virology laboratory) and Dr William Witola of the School of Veterinary Medicine (UNZA) were helpful in analysing the data for me in this work.

I recently attended a joint Conference of the Association of Surgeons of East and Central Africa and the Surgical Society of Zimbabwe in Gweru, from the 17th to 20th of June 1998.

Therefore, I wish to acknowledge the effort and contributions of Dr Jan Rijcken and Dr Jos Vroemen during this conference. Their manual, "Course on the External Fixation of Fractures", is simple and precise to follow. I will forever make maximum use of this copy, manual, to the benefit of myself, other doctors and above all to my patient(s). This manual made me make a few adjustments to this dissertation, which was almost complete.

I wish to thank everyone, including physiotherapists, who have supported me in making this dissertation a reality.

I thank my patients for being patient during the long period of their confinement in POP casts and/or on traction or with metal work in their legs and for following my instructions carefully.

Special thanks go to Ms. Brigitte Veraart who eagerly accepted to proof read this document before its submission to the Head of the Department of Surgery.

ABBREVIATIONS

1.	ESR	-	Erythrocyte sedimentation rate
2.	et al	-	and others
3.	Fig.	-	Figure
4.	Hb	-	Haemoglobin
5.	ISQ	-	In status quo
6.	Lymph	-	Lymphocytes
7.	M/C/S	-	Microscopy, culture and sensitivity
8.	M.Med	-	Master of Medicine
9.	N/A	-	Not Applicable
10.	POP	-	Plaster of Paris
11.	PTB	-	Patella tendon bearing
12.	ROM	-	Range of motion
13.	RTA	-	Road traffic accident
14.	SFH	-	Saint Francis' Hospital
15.	UNZA	-	University of Zambia
16.	UTH	-	University Teaching Hospital
15.	OPD	-	Outpatient department
16.	WBC	-	White blood cells
17.	Y/N	-	Yes or No

LIST OF TABLES, GRAPH / CHART

		Page
1.	Basic Configuration of External fixator Frame	27
2.	Criteria for Primary Amputation	37
3.	The Mangled Extremity Severity Score	39
4.	Aetiology	53
5.	Geographic Location of Fractures	55
6.	Number of Operations	55
7.	Superficial Wound Infection	61
8.	Superficial Wound Infection / Fracture Type	61
9.	Pie chart / Micro-organisms	63
10.	Chronic Osteomyelitis	65
11.	Chronic Osteomyelitis in different Fracture Types	65
12.	Limb Shortening	69
13.	Appendix I	
14.	Appendix II	

INTRODUCTION

In Europe, open fractures are most often seen and treated without delay in a hospital with well-equipped and well-staffed traumatology service and they are operated upon within the shortest possible time[1].

In third world countries, conditions and the availability of health care are completely different. Most of the rural population live far from a health facility and there are only a few hospitals in a country, which offer good surgical care[1]. In most hospitals, open fractures are treated non-operatively either by pin traction or Plaster of Paris (POP), if sterile pins and/or POP are available[1].

Not much is known about the outcome of open fracture management when tap water is used during wound debridement and irrigation, though a study by Angeras et al (1992)[3] showed that irrigation of wound with sterile saline was not superior than using tap water[3]. Given restricted resources and manpower, one of the objectives of this study is to find cheaper and practical ways of treatment of open tibial fractures to reduce on morbidity and mortality.

This paper therefore looks at the outcome in the use of external fixators in open tibial fractures, at the University Teaching Hospital and St. Francis' Hospital, using tap water for one study group and sterile saline for another.

STATEMENT OF THE PROBLEM

Zambia has a population of approximately ten million inhabitants, with only six Orthopaedic Surgeons. Government health budgetary allocations to the University Teaching Hospital have progressively been dwindling in the last twenty years. The University Teaching Hospital presents its yearly budget to the government. The government then approves how much money it shall give the institution (University Teaching Hospital). In the last three years the government approved only a fraction of the institution's (UTH) requirements. In the years 1996, 1997 and 1998, the government approved 43.1%, 39.9% and 20.7% respectively of the UTH budget[2]. The government has not even met its obligations fully in these last three years; consequently the purchase of orthopaedic equipment has diminished. Non-expensive, yet effective, means of managing open tibial fractures has therefore become necessary.

OBJECTIVES

1. To determine the effectiveness of tap water in wound irrigation in open tibial fractures compared to normal saline.

2. To determine the outcome of external fixation in the management of open tibial fractures.

RATIONALE

In 1992 Angeras et al[3] published a study entitled: "Comparison Between Sterile Saline and Tap Water for the Cleaning of Acute Traumatic Soft Tissue Wounds". In this study, the microorganisms isolated from tap water were not similar to the infecting agents isolated from the tap water irrigated soft tissue wounds. And the soft tissue wound infection rate in the tap water and sterile saline groups was not significantly different. They therefore concluded that sterile saline should be replaced by tap water for the cleaning of acute traumatic superficial soft tissue wounds.

Literature in this regard, as concerns orthopaedics, is limited. No study on this topic within Zambia or indeed East and Central Africa has been published. It is against this background that we decided to explore wound irrigation with tap water in open tibial fractures during wound debridement.

LITERATURE REVIEW

The tibial diaphysis is the most commonly fractured long bone. Its relatively subcutaneous position, and the large proportion of high energy that it sustains, means that the tibia also has the highest incidence of open fractures and associated compartment syndrome[4,5]. The tibial shaft, particularly in its lower half, does not possess a very abundant blood supply, so union of fractures often presents a problem; delayed and non-union are not uncommon[6]. Both the extent of the soft tissue injury and the amount of comminution, is directly related to the level of energy, which caused the fracture[7]. Gustilo, et al (1984) first quantified the importance of soft tissue damage as an important predictor of infection and poor outcome and this has since been confirmed[7].

Angeras et al (1992)[3] showed that irrigation of wound with sterile saline was not superior than using tap water[3].

Mechanism of injury and pathology

The damage that is associated with soft tissue injury to an extremity is the result of a high-energy impact between an object and the limb. The amount of energy dissipated during this collision is determined by the equation, $E = MV^2/2$; where E is the kinetic energy, M is the mass, and V^2 represents the square of the speed[8].
A high-velocity gunshot generates approximately 2000 foot-pounds of energy[8], and on contacting the object the limb absorbs energy and then releases it in an explosion that comminutes bone and creates a soft tissue shock wave. This shock wave strips the periosteum. If the shock wave is substantial, it will tear apart the skin, creating an open fracture as well as a momentary vacuum that sucks adjacent foreign material into the depths of the limb. Therefore, the obvious dimension of the wound[8] cannot determine the amount of deep-tissue contamination.

Blistering, contusions, crushed areas of skin and burns reflect the transfer of a large amount of energy to the limb[9].

Twisting force causes spiral fracture of both leg bones at different levels; an angulatory force produces transverse or short oblique fracture usually at the same level. With an indirect injury, one of the bone fragments may puncture the skin; a direct injury crushes or splits the skin over the fracture.

Classification

Classification of an open fracture facilitates the description of the severity of the injury among physicians, and it can provide useful guidance for treatment as well.

The classification of an open fracture is based on a number of factors, including the mechanism of injury; the vascular status of the extremity; the size of soft tissue crush or loss; the extent of comminution; the amount of bone loss; the degree of periosteal stripping; and the degree of bacterial contamination[8]. The final classification of an open fracture should be delayed until the time of initial operative debridement, as many of these factors cannot be assessed fully before that time[9].

Most widely accepted and quoted wound description is that of Gustilo et al[5,9,10,11]. As originally described by Gustilo and Andersen in 1976, this classification divided fractures into types I, II and III. With its revision in 1984, the classification sub-divided type III injuries into III A, III B, and III C[9,11].

Type I

A type I fracture is a low energy with minimal soft-tissue damage and a small (less than one centimeter) wound; the fracture typically occurs as an inside-to-out puncture from an underlying spike of bone. Typically there is slight comminution of the bone and a low level of contamination[5,9,10].

Type II

Type II fracture represents a transition between the low-energy type I and the high-energy type III fractures. Type II fractures may have associated lacerations, one to ten centimeters long, slightly or moderately comminution, and no or slight periosteal stripping of the bone fragments[5,9]. There is also a moderate level of bacterial contamination[5]. These wounds must be thoroughly explored and all dead tissues excised. Primary closure is not advisable - delayed primary closure is safer[10].

Gustilo stated that adequate debridement (removal of unhealthy tissue) is the single most important factor in the attainment of a good result after the treatment of an open fracture[8].

Type III

The most severe pattern of fractures is type III. Gustilo et al, defined type III A open fractures as those having adequate coverage with soft tissue despite extensive soft tissue lacerations or flaps or injuries reflecting high-energy trauma, such as extensive osseous comminution, a segmented fracture pattern, or extensive soft tissue injury (irrespective of the size of the wound) or a combination of any of these[9]. Open fractures that occur in an environment that predisposes to extensive bacterial contamination such as a barn yard setting, or a public waterway, are also classified as type IIIA. Unlike type IIIA that has adequate soft tissue cover, type IIIB has skin loss and periosteal stripping and type IIIC has neurovascular injury. A Type IIIC is associated with a vascular injury that requires repair for survival of the limb.[10] All high velocity injuries are classified IIIB or IIIC - although the wound may be small the internal damage is severe.[9] The incidence of infection in Types I to III ranges from 1% to 30%.

Many of the fractures are caused by blunt trauma, and the risk of complications is directly related to the amount and type of soft-tissue damage[4,10].

Other classification systems for open fractures are available. The AO/ASIF classification for soft tissue injuries uses a combination of the alpha-numeric fracture classification system and an IMN system wherein the injury to the integument (I); muscle (M) and nerve (N) is each judged independently. This classification system has several potential benefits for clinical research, however, it is cumbersome in clinical practice[9]. The Hannover open fracture classification system, developed by Sudkamp et al[9], is based on a point-scale system for bone injury, soft tissue injury, vascular injury and contamination. Open fractures are classified as type I through type IV[9].

In contrast to these other classifications, Gustilo's classification has gained widespread support because it is of prognostic value[8].

Fracture Displacement

The greater the initial displacement of the bone, the worse the prognosis[10]. Extensive soft tissue injury, loss of bone or skin, and bone comminution also has poor prognosis[10]. In the United Kingdom, shortening of more than 1 cm should not be acceptable, except in severe injuries with extensive bone loss[10].

Lateral Shift: The displacement of the distal fragment is described in relation to the position of the proximal fragment (e.g. when there is 50% lateral shift, only half of the bone is in contact on an antero-posterior radiograph). The greater the lateral shift, the less bone contact there will be and the slower the fracture will unite. Lateral shift of up to 50%, however, is compatible with normal limb function[10].

Angulation: Describes the direction in which the distal fragment is pointing (measured in degrees)[4]. No more than 5 degrees of varus or valgus angulation is acceptable; greater angulations will result in abnormal stresses on the knee and ankle, and the development of post-traumatic osteoarthritis. Up to 10 degrees of antero-posterior angulation is tolerated without functional problems, because the deformity is in the plane of motion of the ankle[10]. Anterior bowing is, however, cosmetically distressing, whereas substantial posterior bowing is not acceptable[10]. Dietz and Merchant[12] assessed the amount of angulation that is compatible with good long-term function and the avoidance of osteoarthrosis by evaluating a group of patients at an average of twenty-nine years after a fracture of the tibia. Clinical and radiographic outcomes were unaffected by the amount of anterior, posterior, varus or valgus angulation. Their data, however, suggest those angular deformities of less than 10 to 15 degrees were well tolerated over the long term with respect to the development of osteoarthrosis. However, there is data to indicate that, as the level of deformity approaches the distal third of the tibia, even a minor degree of malalignment can affect the ankle joint[12]. The malalignment alters the biomechanics of the ankle joint by increasing the total area of contact, which results in regions of increased pressure where the residue contact occurs[12]. This increased pressure may cause increased shear stresses on the articular cartilage in the areas of high stress and the shear stresses may result in premature osteoarthrosis of the joint[12].

ROTATION

Rotation is difficult to assess on a radiograph, but can be determined clinically by comparing the injured leg with the sound leg[10].

Initial Assessment and Resuscitation

In the emergency room, the initial attention should be given to resuscitation and assessment of the patient according to the guidelines of Advanced Trauma Life Support (ATLS)[6,9].

Specific assessment of the extremities other than to control active haemorrhage should be part of a secondary survey. The orthopaedist must be aware of other injuries because severe pulmonary, intra-abdominal, or head injuries may limit the extent of initial debridement and stabilization that can be performed acutely for the open tibial fracture[9]. Concomitant fractures of the long bones and unstable fractures of the posterior part of the pelvis ring associated with haemodynamic instability should be stabilized within the first twenty-four hours after the injury whenever possible[7]. Radiographs of the chest and pelvis and lateral radiographs of the cervical spine are made[8].

Clinical Features

The physical examination should include a thorough inspection and palpation of the extremities. Occult open fractures may be missed if the examining physician does not elevate the extremity and inspect it circumferentially[9]. A log - roll should be done to examine the back of the patient[9].

The initial examination should include assessment of the neurovascular status, the soft tissue injuries and osseous deformity. The vascular status can be documented by palpation of pulses, examination for capillary refill, and notation of the colour of the limb and the presence of bleeding from open wounds[4,9]. Any osseous deformity should be evaluated. Olson[9] states that legs that have a gross rotation deformity or angular deformity or both, at the site of a tibial fracture should be realigned promptly in an anatomical position, however, Apley[4] et al (1993) stated that movement of the fracture should not be attempted, but the patient is asked to move his toes.

Associated deformity of the foot, ankle, knee or femur should also be noted. Pulses should be documented before and after alignment[4]. The pulses often improve with realignment; persistently diminished pulses may indicate a vascular injury and the need for arteriographic or Doppler evaluation. Gross motor function and sensibility of the foot and leg should be documented whenever possible[9]. The presence or absence of plantar sensation can be an important factor in the determination of whether limb salvage procedure is the best treatment for a severe injury[9].

Often, soft tissue injuries can be assessed only superficially in the emergency room. Knowledge of the history of the injury and its location is often helpful when determining the extent of soft tissue damage and the level of contamination[9].

Gross contamination with soil, grass or other foreign materials should be noted. The dimension and location of all open wounds should be recorded. A photograph of the open wound helps document its characteristics. For Type II and Type III open fractures, copious irrigation with 5,000 to 10,000 millilitres of normal saline or distilled water is recommended[11]. Superficial foreign bodies, such as leaves and grass that are immediately accessible should be removed from the wound before it is covered. The surgeon should take care to use sterile techniques so as not to increase contamination of the wound during the initial inspection phase[9].

A clean sterile dressing should be applied to the wound and should not be removed until the patient is taken to the operating room[9]. The limb should be placed in a well-padded plaster splint in grossly normal alignment[9].

Timing of Surgery: An open tibial fracture is an operative emergency[9]. The primary treatment is early operative debridement and stabilisation of the bone[9]. Radiographs will help to show what type of a fracture it is, whether comminuted, spiral, short oblique, or any other type.

Treatment

Prophylactic antibiotic treatment has an important role to play in the management of open fractures of the tibia. It must be remembered that all open fractures are contaminated and that an infection will develop unless necrotic tissue is debrided adequately[11]. *Clostridium tetani,* an anaerobic gram-positive rod, is found in soil, dust and animal faeces. Because it produces potentially fatal neurotoxin, patients must be given prophylaxis against tetanus[8,9,10,11]. If a patient is uncertain about his/her history of tetanus immunization or has had less than 2 doses should receive tetanus/Diphtheria toxoid and tetanus immunoglobin[11]. If there is history of immunization with two doses, the patient receives tetanus/Diphtheria toxoid only (and tetanus immunoglobin if the wound.is more than twenty-four hours old)[9,11]. This toxoid is made of a combination of tetanus and diphtheria. If the patient has however, received three or more doses in the past he does not receive any prophylaxis against tetanus unless the last dose was more than five years earlier[9,11].

Clostridium perfringens, an anaerobic gram-positive bacterium, release several endotoxins that result in rapid myonecrosis, vessel thrombosis and if inadequately treated rapid death[11]. If the injury is farm or soil related or has a severe crush component, or if vascular compromise is present, penicillin G (two to four million units given intravenously every four to six hours) must be added[11].

The management of severe open fractures is embodied in the following words:

(1) antibiotic

(2) debridement

(3) stabilization

(4) delayed closure and

(5) rehabilitation[4,9].

Early therapeutic intravenous administration of antibiotics is associated with a decreased rate of infection and thus should begin in the emergency room. The literature recommends using cephzolin for covering gram positive organisms or a loading dose, followed by 1g post operatively as a routine for all open fractures[8,9,11]. Coverage for gram negative organisms, typically with an aminoglycoside[9,11], is used for open fractures with more extensive soft tissue injury or extensive contamination, or both. In an experimental study on rabbit models, Warlock[13], illustrates that the effect of the antibiotic persists even when the initial dose is delayed for four hours after bacterial inoculation in the open tibial fracture site. Most surgeons favour a short course of antibiotics, but this may be extended in complex open wounds[10,11]. To decrease bacterial counts in traumatic wounds, debridement and irrigation with sterile saline is the normal treatment[3]. And gentle irrigation cannot remove large numbers of bacteria[3].

Olson[9] states that in his pulsed lavage with several different types of irrigation solution bacterial counts decreased compared with those associated with standard irrigation with use of a bulb syringe. Recently investigators have found that antiseptic solutions of hydrogen peroxide, Betadine (Povidone iodine) solution and Betadine scrub are toxic to osteoblasts in culture at concentrations used clinically, while bacitracin in normal saline solution had no similar toxic effects.

Bewes[14] divides wound irrigation into "social toilet" and "surgical toilet". During the "social toilet", this requires litres of water. He states that: "one might think that sterile saline would be the right solution for this purpose but I have noticed that when people use sterile saline they consciously or unconsciously use less fluid than when using plain water, and it is volume that counts at this stage, not sterility." He also states that tap water is perfectly acceptable for this purpose, which is to wash away the gross contamination and so "dilute" the organisms in wound to below dangerous levels[3,14].

It is important to note that the lavage must be done by pouring clean fresh water, letting it run continuously over the wound from above, and allowing it to drain into a basin on the floor[14]. Scrubbing the wound with a brush repeatedly dipped in a basin of water nearby is very bad practice - the water in the basin just gets dirtier and dirtier as the "toilet" proceeds[14].

In practice it may take many litres of fluid to get the wound visibly clean of ingrained mud and dirt and the job cannot be done properly with less[14]. A systematic debridement is performed. All necrotic skin, fascia, and tendon are excised. Muscle is evaluated on the basis of the four C's; contractility, colour, consistency, and capacity to bleed[8]. Muscle that does not contract, disintegrates to touch, is pale or discoloured or fails to bleed when cut must be excised[8]. Not infrequently, entire muscle bellies have to be removed. Care must be taken throughout the debridement procedure to protect the neurovascular structures. The most common error made at the time of initial debridement is underestimation of the amount of muscle damage[8]. Debridement of an open tibial fracture involves operative exploration of the wound or wounds to define the zone of injury, removal of devitalized tissue and use of pulsed lavage to achieve additional mechanical debridement of the wound[9].

It must be remembered that presence of an open fracture does not preclude the development of a compartment syndrome, and fasciotomy of the compartment or compartments containing structures that may have been damaged by the injury through the open fracture should be performed routinely as part of the initial debridement[9]. However, some workers recommend that fasciotomy of all four compartments should be reserved for injuries with extensive soft tissue swelling and increased intracompartmental pressures (to within twenty to thirty millimeters of mercury [2.66 to 4.00 kilo pascals] of the diastolic blood pressure)[9].

Sanders et al[8] states that, because disagreement remains about the correct pressure at which a fasciotomy should be performed, the surgeon must maintain a high index of suspicion and perform fasciotomies as necessary in the operating room during the debridement phase. It is better to err on the side of performing an unneeded fasciotomy than to not do a needed fasciotomy[8].

Debridement

Adequate debridement and early assessment of the soft tissue defect are necessary so that appropriate soft tissue coverage can be provided within the first one to two weeks[15]. When the soft tissue portion of the injury is addressed promptly and definitively and then allowed to heal completely, secondary osseous reconstruction may proceed with fewer complications[15].

The Bone

The ends of the principal fragments must be washed and cleaned of debris. Free-floating cortical fragments represent potential sequestra and should be removed. Bone fragments that have reasonable soft tissue attachments should be maintained[8]. Once irrigation and debridement has been completed, the bone is stabilized. Stabilization of the fracture also stabilizes the soft tissues.
Immobilization of the bone in its anatomical position restores alignment to the neurovascular and muscular structures. Stable fixation of the fracture decreases dead spaces and minimizes problems such as pain, oedema, stiffness and osteopaenia[8]. Finally, fixation of the

fracture permits mobilization of the patient[8]. The absence of motion at the fracture site minimizes pain, and elimination of the need for skeletal traction, minimizes respiratory complications and difficulties with regard to nursing care. Stable fixation also permits easier transportation of the patient and facilitates access to the wound during subsequent operations[8].

Fracture Stabilisation

Cast Immobilization

Closed reduction and plaster immobilization is the most common treatment administered in the United Kingdom[10]. Reduction is obtained by manipulation under anaesthesia. An image intensifier is useful during reduction[10]. Before the recent popularity of functional and cast bracing, cast immobilization in a long-leg cast had not changed significantly since its introduction at the time of the Napoleonic wars. Cast immobilization is most suitable for young patients who have sustained a low-velocity injury requiring about 12 weeks' treatment[5].

External Fixation, Biomechanics and Bone healing

External fixation for fracture stabilization has been known since the last century, beginning with the idea of the long bones[16].

Over the past two decades, the more rigid fixators, such as the multibar Hoffmann fixator, have been superseded by more elastic, single, unilateral devices. These newer fixators, such as the Orthofix dynamic axial fixator, are sufficiently rigid to provide skeletal stability in unstable fractures, yet posses a facility for rapid conversion to a dynamic system. This permits axial movement patella claw of Malgaigne in 1843[16]. In 1897 Parkill described the first external device for the fixation of on loading, while maintaining sufficient rotational and anteroposterior stability, and when applied at the appropriate time stimulates callus formation. A progressive increase in load transmission across the fracture (i.e. 'dynamization') can be achieved with other types of fixators by sequential dismantling of two-plane frames -

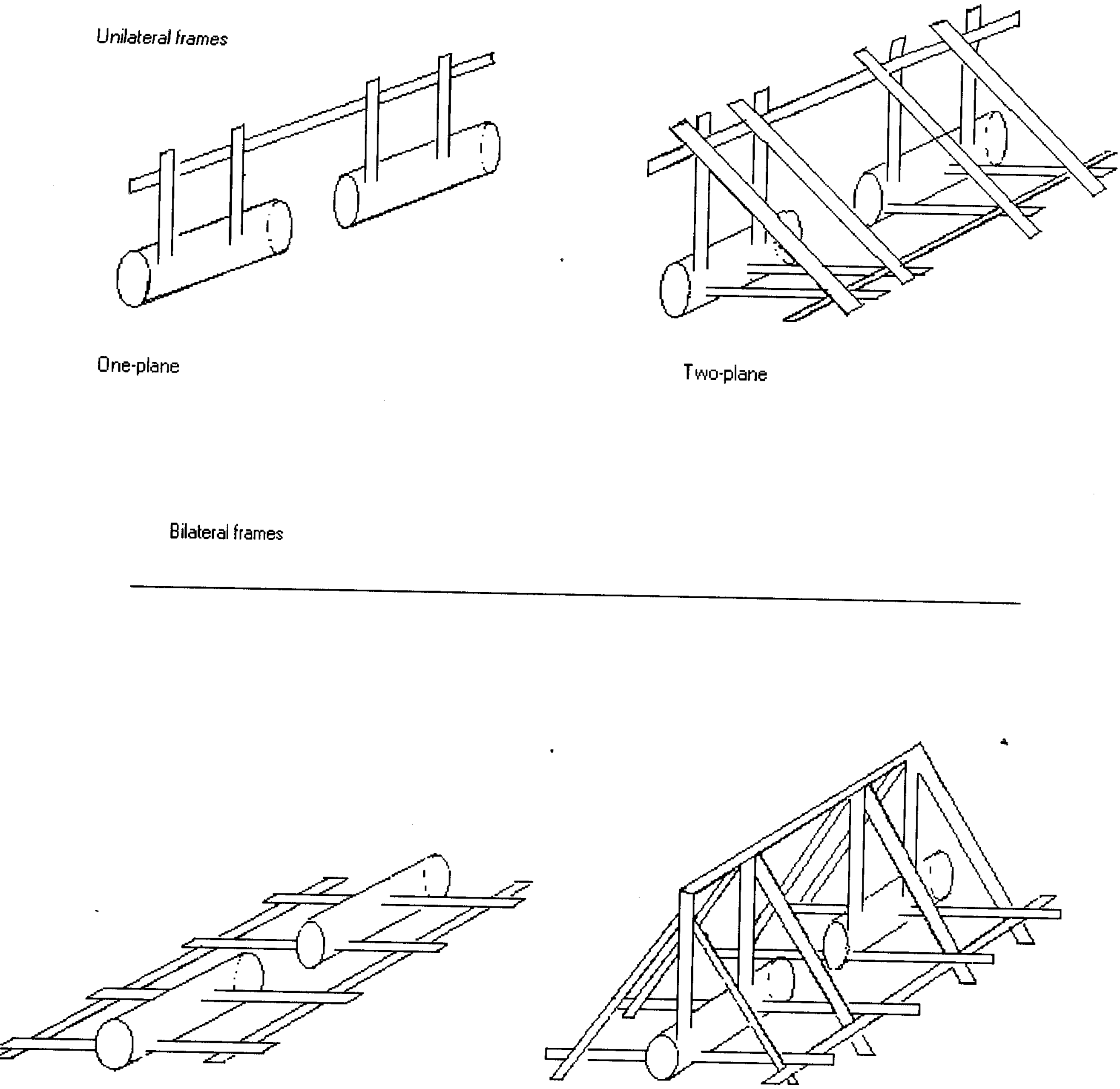


Fig. 1: *The four basic configurations of external fixator frames*[16]

(*Pearse MF et al, Surgery. The Medicine Group*) moving the longitudinal rod away from the bone and loosening the central pin articulations in half-frames.

Primarily in open fractures or in fractures with severe tissue injury, external fixation is now the accepted choice of treatment[16] and also for infected fractures, pseudoarthroses and infected pseudoarthroses[18] as well as infected non-union. Their use allows optimal soft tissue management and prevents early movement at the fracture site[9,18,19]. Primary stabilization of such fractures with internal fixation devices (conventional plate or reamed nail) has shown high complication rates[17].
Early application of the fixator will allow prevention and control of infection[18,20]. It simplifies nursing in the patients with multiple injuries and facilitates healing of soft tissues[16]. Because early application of the fixator has such an important role in preventing infection it should be done at the hospital nearest the scene of the accident, so it is important that district hospitals are equipped to undertake external fixation of open fractures[18].

Current external fixators normally use Steinmann pins or Schanz screws, which are inserted through the bone and which connect the bone to the outside instrumentation namely the clamps and rods, (see fig. 1 above). The implants are attached at a distance from the fracture site to allow easy access for the management of soft tissue injury, stability for the healing of these tissues and rigid early fracture fixation which allows for patient mobilisation.

When used alone, in the treatment of new fractures, external fixators have a high incidence of delayed union and non-union[10]. External fixation is biomechanically less stable compared with internal fixators or plates and screws and is primarily used for injuries with severe soft tissue damage. In this respect, external fixation should be thought of as self - contained traction device, which usually is applied for temporary skeletal or joint stabilisation. However, some trauma centers continue to employ external fixation as the definitive method of treatment for selected fractures[8,20]. Management of Type IIIC tibial fractures, by open reduction and internal fixation is associated with a higher amputation rate than either external fixation or simple splintage, particularly for upper tibial injuries[23]. External fixation is recommended as the method of choice for the stabilisation of the skeletal type IIIC injury[18].

The positioning of the pins is critical. Surgeons should be aware that further surgical intervention will almost certainly be required in a type III, and should therefore ensure that position of the pins does not interfere with later surgery[9].

If the transfixation pins remains in place for a long time, intrinsic problems with the external fixator are likely to arise[17]. The main problems are pin loosening, pin track infection and osseous healing disturbances (non-union, delayed union and malunion).

Interestingly, the same classical problems have always been associated with external devices[16], although efforts have been made to solve them, for example by determining the mechanical properties of different frames[16], preloading pins axially or radially[16] to prevent pin loosening and infection, and dynamisation of the fracture site for optimisation of healing conditions after primary rigid stabilisation[16].

Pins of the external fixator are known to lose their tight fit within bone with time[16]. This complication is of less importance in respect to the concomitant loss of fixation stability than to the link between loss of stable anchorage and related pin track infection[16]. Pin loosening has been observed to occur in up to 60% of the pins in clinical practice[16]. Implant loosening is probably due to micromotion and instability of the implant, leading to bone resorption rather than mechanical overload[16].

Optimal purchase at the pin thread-bone interface can only be achieved by avoiding thermal necrosis during drilling; extremely high tissue temperatures can be generated by drilling which cause cell necrosis[17,21]. Metthews and others (1984) stated that thermal injury results from heat generated during the insertion process itself and is probably the cause of ring sequestra[22]. Pre-drilling a slightly smaller hole than is needed is recommended, using either a hand drill (brace) or a low speed, high torque power drill through a drill sleeve to prevent soft tissue damage[17,20,22]. Damage to the bone can easily occur during pin insertion with cracking or further splitting of the bone. Stresses at the pin - bone interface can be extremely high particularly in unstable fractures, and may lead to osteolysis and pin loosening[20]. With unilateral frames, such stresses may be reduced by increasing the number of pins[19,20] reducing the distance between the bone and the longitudinal rod, attaching a second rod to the same pins and adding a second half-frame at 90^0 to the first one[19,20]. The Pins are available in a variety of sizes from 3 mm to 6 mm. Increasing the size of the pin increases the strength of fixation to the bone but the size appropriate to the particular bone should always be chosen[17]. The design of the pin tip is very important, tips that provide for effective clip elimination being associated with much lower temperatures. In order to obtain maximum pin - bone strength, the pins should be spread as far apart as possible and inserted into strong cortical bone[17].

Dynamising the fixator (that is allowing axial loading) restores cortical contact in stable fractures and thereby reduces the pin - bone stress[17].

If the pin in the bone loosens due to bone resorption, the periosteal side and the endosteal side of the bone are connected. This is a problem when transcutaneous infection is present - the pin then provides a path whereby a minor superficial infection can lead to deep bone infection, pin track infections, osteitis, and osteomyelitis[16]. The situation is even more complicated because in the case of pin loosening the probability of transcutaneous infection is increased[16]. Not only are these infections undesirable in themselves, but they are even more pernicious when the infection is in the medullary cavity and a revision from the external fixation to medullary nailing is necessary. In this case a medullary infection would be a severe problem.

Care should be taken to ensure that there is no skin tension at the entry site of the pins. Daily cleaning of the pin sites with saline followed by an application of povidone iodine cream is recommended[20].

The external fixator is retained until the fracture is "sticky" and may then be replaced by a cast[4,16]. Partial weight bearing is permitted. The cast is removed only when the fracture is consolidated[4].

The quality of a fixator is often judged on the basis of its stiffness. For many years, maximal stiffness was considered essential. However, the positive experience of recent years with so called "bio-logical" fixation has shown that for some indications a more flexible implant is more advantageous for fracture healing[22]. Clinical experience has shown that the very rigid forms of external fixation have a greater incidence of delayed and non-union[20]. The decisive factor is the atraumatic technique and the preservation of the blood supply to the fracture fragments as opposed to exact reduction and stabilisation using stiff implants[22].

The results of external fixation are independent of the type of frame employed[24]. Good results depend on good surgical technique, early full thickness flap cover and understanding of the basic principles of external fixation, rather than on the use of a specific fixator[24].

Pinless Fixators - External fixators with pincer type clamps have been designed, which grip the outer surface of the cortex only. Use of these pincers may reduce the incidence of pin track sepsis, which is the major complication of external fixators[10]. The origin of these pin track infections lies in the conventional transosseous pin fixation, which perforates the bony cortex and exposes the medullary cavity to bacterial invasion. A reduced infection rate may be achieved by changing either the medullary implant (reamed to unreamed) or the external fixator[21]. One solution is to alter the way in which the

external stabiliser is fixed to the bone[22]. The basic idea of the pinless fixator was to produce a stable, temporary, minimally invasive fixator for severe tibial fractures which guarantees a safer conversion to the medullary nail[22].

Once the soft tissue wound is clean, closure within five to seven days after the injury is ideal[4,8,9]. This can be accomplished with delayed primary closure, split thickness skin - grafting, local flaps, or vascularized free tissue transfer. If this treatment is successful, the surgeon has transformed a massively contaminated, open fracture into a clean, closed fracture that requires only bone and joint reconstruction[8].

Because most open wounds of the tibia are antero - medial, a bone graft placed away from the area of damaged soft tissue is ideal. This allows union by bridging between the fibula and the remaining part of the tibia[9]. Grafting at the time of wound closure is not recommended because this increases the possibility that the graft will dissolve or become secondarily infected[8]. Rather, postero-lateral grafting is recommended at approximately four weeks after wound closure. If flap coverage is required, bone grafting is delayed until the flap has stabilised, generally six to

eight weeks later[8]. The bone graft may take three to six months to consolidate sufficiently to permit weight bearing[8]. If a defect is larger than 7.6 cm the surgeon should consider alternative techniques, such as free fibular transfer or bone transport by the Ilizarov method[8].

Amputation

The incidence of amputation in type IIIC is very high and reflects the severity of injury[24]. Candle and Stern, 1987, reported a 78% overall amputation rate in type IIIC tibial fractures and Hausen, 1987, has highlighted the considerable morbidity associated with attempted salvage of these severe injuries[21].

CRITERIA ACCORDING TO LANGE ET AL[9].

Protocol for primary amputation (type IIIC tibial fractures)

A. Absolute indications

1. Anatomically complete disruption of the posterior tibial nerve in adults.
2. Crush injuries with warm ischaemia > 6 hrs.

B. Relative indications

1. Serious associated poly-trauma
2. Severe ipsilateral foot trauma
3. Anticipated protracted soft-tissue and osseous reconstruction

Decision-making variables in limb salvage

A. Patient

1. Age
2. Chronic disease
3. Occupation considerations
4. Patient and family desires

B. Extremity

1. Mechanism of injury
2. Fracture pattern
3. Arterial / venous injury (location)
4. Neurological status (anatomical)
5. Injury status of ipsilateral foot
6. Ischaemia zone after revascularization

C. Associated

1. Magnitude of associated injury (Injury Severity Score)
2. Severity and duration of shock
3. Warm ischaemia time

Table I.

Decision - Aiding Scales

Lange et al[9], proposed a protocol based on absolute and relative indications for amputation (Table I.)[8]. The occurrence of one absolute indication or two relative indications warranted amputation[8]. Unfortunately, only a minority of cases fit these criteria, and the relative indications were extremely subjective and required considerable experience to determine[8].

Helmet et al has a modified version (index) for predicting amputation rates[9] and this is called the Mangled Extremity Severity Score (MESS)(Table II.below). A score of 7 points or more is 100% predictive of amputation. At the moment, the basis on which to make sound, defensible and reasonable decision for primary amputation is still insufficient.

The MESS score and Lange's absolute and relative indications should be used to determine the possible need for amputation. Patient and family conferences (perhaps with an amputee present) are required, and a frank discussion should take place. Then a joint decision can be made in the best interests of the patient[8].

TIME MANGLED EXTREMITY

TYPE	CHARACTERISTICS	INJURIES	POINTS	SCORE
Skeletal soft –tissue group				
1	Low energy	Stab wounds, simple closed 1 fractures, small – caliber gunshot wounds	_	
2	Medium energy	Open or multiple-level fractures dislocations, moderate crush injuries	2	_
3	High energy	Shotgun blast (close range) 3 high – velocity gunshot wound	_	
4	Massive crush	Logging, railroad, oil ring accidents	4	_
			Subtotal	_
Shock group				
1	Normotensive	Blood pressure stable in field and op. room	0	_
2	Transient hypotension	Blood pressure unstable in field but responsive to intraven. fluids	1	_
3	Prolonged hypotension	Systolic blood pressure < 90 mm Hg in field hypotension and responsive to intraven. fluids only in op. room	2	_
			Subtotal	
Ischaemia group (points double if ischaemia > 6 hours)				
1	None	Pulsatile leg without signs of ischaemia	0	_
2	Mild	Diminished pulses only	1	_
3	Moderate	No pulse by Doppler, sluggish capillary refill, paraesthesias, diminished motor activity	2	_
4	Advanced	pulses, cool, paralyzed and numb	3	_
			Subtotal	
Age group				
1	<30 years		0	_
2	30-50 years		1	_
3	> 50 years		2	_
Total mangled Extremity severity score			Subtotal _	
			Total	_

Table II

Complications

Early

Infection: The incidence of infection in open tibial fractures is reported to be 10 to 20 times higher than in other open skeletal injuries[25]. It varies from 2% for Type I and II injuries (Gustilo and Andersen 1976), to over 50% for Type III. Even small perforations should be treated with respect and debridement carried out before the wound is immobilised. Large lacerations require wound excision, and the wound should be left open until the risk of infection has passed[4]. Russell et al, however, believe that there is no place for primary closure of any open tibial fracture[26].

Post-traumatic wound infection is now the most common cause of chronic osteitis[4]. This does not necessarily prevent the fracture from uniting but union will be slow and the chance of refracturing is increased[4].

The wound becomes inflamed and starts draining seropurulent fluid, a sample of which may yield a growth of staphylococci or a mixed infection (bacteria)[4].

Even if bacteriological examination is negative, if the clinical features are suggestive the patient should be kept under observation continuously and treatment with intravenous antibiotics begun[4].

Infected non-union is the most serious complication of a tibial fracture. Management depends on wound toilet, fracture stabilization and bone grafting[10]. The wound must be opened and all dead tissue and bone excised; metal implants must be removed.

The external fixator produces the necessary immobilization for infection control, and eliminates the risk of implanting a plate into an infected bed. The wound is inspected after 2 weeks and any residual dead or infected tissue excised. If the wound is healthy, the fracture site is bridged with cancellous graft taken from the iliac crest. The external fixator may be left in place, or, if the wound is very clean, a plate may be applied[10].

Soft Tissues

Firm bandaging can sometimes prevent fracture blisters - due to elevation of the superficial layers of skin by oedema. They should be covered with a dry sterile dressing[4].

Plaster Sores

Occur where skin presses directly onto bone. They should be prevented by padding the bony points and molding the wet plaster so that pressure is distributed to the soft tissues around the bony points[4].

While a plaster sore is developing the patient feels localized burning pain. A window must immediately be cut in the plaster, or warning pain quickly abates and skin necrosis proceeds unnoticed[4].

Torn Muscle Fibers

Unless the muscle is actively excised the torn fibers may become adherent into untorn fibers, capsule or bone; if adhesions have been allowed to develop, lengthy rehabilitation will be necessary after the fracture has consolidated. The fracture and the torn muscles both need treatment; it is better to serve two sentences concurrently than consecutively[4].

Vascular Injury

Fractures of the proximal half of the tibia may damage the popliteal artery - this is an emergency of the first order requiring exploration[4]. The effects vary from transient diminution of blood flow to profound ischaemia, tissue death and peripheral gangrene. The patient may complain of paraesthesia or numbness in the toes. The injured limb is cold and pale and the pulse is weak or absent.

If a vascular injury is suspected an angiogram or Doppler ultrasound examination should immediately be performed; if it is positive, emergency treatment must be started without further delay. If angiogram is not possible the limb must be explored on clinical grounds.

Late

Delayed union and Non union

Union time depend on the severity of the original fracture, and it is therefore impossible to specify an exact time at which union may be said to be delayed[10].

According to de Boer (1995), true non-union occurs when a pseudoarthrosis is formed between the fracture ends; this is uncommon in the tibia[10]. The term is usually applied to fractures, which have not united within 9 month of injury.

Hypertrophic Non union

There is abundant callus formation but persistence of the fracture line on the radiograph[11]. It is treated by preventing movement at the fracture site, using a long leg cast, a locked-in transmedullary nail, an external fixator or, exceptionally, a plate. If internal fixator is used, bone grafting will not be necessary[10].

Atrophic Non union

There is little or no callus formation. The most common cause is lack of vascularity of the fracture ends caused by the accident or by inadequate surgery. Immobilization of the fracture ends alone does not lead to union - additional cancellous bone grafting is needed. The treatment of choice is probably interlocked intramedullary nailing and grafting, but the results of any treatment tend to be disappointing[10].

The Future

Ultrasound

There is considerable experimental evidence in animal models to suggest that ultrasound applied to a new fracture increases the rate of healing. .Human trial results are awaited[10].

A non-invasive method of electrical stimulation of healing in ununited fractures of the tibia by pulsed magnetic field has been evaluated, and the results are encouraging and this form of treatment warrants further investigation[27]. An extensive study is now being conducted in various centres in Canada[27].

Rehabilitation

Early functional rehabilitation should be a key part of the treatment of open fractures of the tibial shaft. Physical therapy programmes to emphasize the range of motion of the knee and ankle are critical in the first few weeks after the injury[9]. The patient should be encouraged to maintain good muscle tone, even if non-weight - bearing or only toe - touch weight - bearing is allowed. Patients who have axially stable fracture patterns can begin bearing weight immediately[9], whereas those who have an axially unstable fracture pattern should delay weight bearing until the first callus is seen[9]. Patients who have a fracture with segmental bone loss should not be allowed to bear weight on the affected extremity until there are radiographic signs of incorporation of the bone graft (callus)[9].

Radiographs, if possible, should be taken regularly in the first three weeks, to determine whether loss of position has occurred[9].

PATIENTS AND METHODS

Twenty nine patients (thirty legs; one patient had bilateral tibial fractures) were included in the study. The patients were admitted to the University Teaching Hospital, Lusaka, through the five general surgical units or admitted to St. Francis' Hospital in Katete, Zambia. Permission from heads of these Units and hospital Superintendent respectively, was sought and granted. Patients from St. Francis' Hospital were included in the study because the Investigator worked there during 6 months of the study period.

Questionnaire

Data collection form the patient for surgery was facilitated by the use of a proforma (questionnaire) - see Appendix I. Patients were randomly grouped with these using pre labelled questionnaires, either "Tap water" or "Normal saline". This was done at the initial debridement (operation) regardless of the severity of the injury.

Tap water was used for wound irrigation, during debridement, in the study group with 17 legs. Normal saline, however, was used in the 13 legs in the control group. More than 10 litres of tap water were used in the study and 6 litres of normal saline in the control group. Anti-tetanus toxoid was administered to all the patients included in this research work.

External fixation

Aseptic technique was observed during debridement and external fixation. Pins were inserted into the bone after pre-drilling of the bone. The distance between the pins was 2cm. Pins were placed well away from the wound. Most of the fixators used three pins on each side of the fracture - proximal and distal to the fracture site. The connecting rod (external fixator) was placed a few centimeters away from the skin (enough space to allow a flat hand to pass under the rod) - see Appendix II; Fig. 2.

Wounds/Pin sites

Wounds were cleaned daily, at least twice per day. The nurses always did the morning wound cleaning using normal saline. The patient himself/herself or his/her relative did the second wound cleaning. Both the patients and nurses cleaned pin sites alike. These sites were cleaned as many times as possible with methylated spirit soaked swabs.

Perioperative Management

Parenteral antibiotics, metronidazole, benzyl penicillin and gentamycin were administered to all the patients, pre-operatively, in the anaesthetic room. These antibiotics were continued for five more days with only a change to oral metronidazole postoperatively. The dose of the above stated antibiotics was the same in all the patients. Intramuscular injection of pethidine (1mg/kg) was administered every 4 to 6 hours to all patients post operatively. After 48 hours post surgery, patients received oral ibuprofen 400mg 8 hourly (in adults) and up to 500mg of paracetamol every 8 hours (in children). Analgesics were given regularly for five days, and whenever necessary thereafter.

Depending on the microscopy, culture and sensitivity results appropriate antibiotics were administered to the patients who developed infection.

An informed written consent was obtained from the patient for the surgical operation.

The other materials used included a hose pipe (for tap water irrigation), cotton wool, Plaster of Paris, various external fixators including Orthofix, Hoffmann's, Hugh's and an improvised "K nail-POP" external fixator (Appendix II; Fig. 4). A pinless external fixator, was also employed.

Patients were taught how to clean and look after their pin sites if they had an external fixator applied.

At discharge from hospital, a patient will have bought his or her own wooden crutches. St Francis' hospital supplied crutches free of charge to patients treated at that hospital.

Follow up

Patients were reviewed in the outpatient department a month after discharge from the ward. The evidence of radiological union determined removal of the external fixator. Following external fixator removal some patients required a further period of limb support with POP. If there were no other particular problems, patients were reviewed every three months until the final discharge from OPD.

Statistical data analysis

The instrument used in the data analysis in this dissertation is from C - Stat for Windows (computer statistical package). The analysis was done at 95% level of confidence[31].

Ethical Clearance

The study involved human subjects, clearance was therefore sought and obtained from the Research and Ethics Committee of the School of Medicine at the University of Zambia.

RESULTS

A total number of 29 patients (30 legs) were included in the course of the study. One of the patients had bilateral tibial fractures (see Appendix II; Fig. 8). The average patient age was 30 (youngest was 10 years old and oldest 54). Twenty-five patients were males while 5 were females (M:F; 5:1).

Aetiology of fractures

In 28 legs the cause of the fracture was stated. The results are as shown in Table III below. The commonest cause of these fractures was road traffic accident (RTA).

Aetiology	No. of legs
RTA: Pedestrians	12
Passengers/drivers	05
Unspecified	04
Motorcycle	01
Assault	02
Sport (football)	01
Gunshot	01
Fall	01
Tree fell on patient	01
Total	**28**

Table III. Aetiology

Type of fracture

Type I fractures (according to Gustilo-Andersen classification), occurred in 2 patients; Type II in 10 patients; Type IIIA in four 4 patients; Type IIIB in 14 patients. One patient had bilateral Type II fractures. There was no patient with a Type IIIC fracture.

The lower third of the tibia was fractured in 9 of the legs, middle third in 10 legs and the upper third was in six legs. Junctional fractures occurred in two legs, between lower/middle thirds and middle/upper thirds respectively. Others were segmental fractures. The sites of these fractures were determined radiologically.

Site	Legs fractured
Upper 1/3 Mid 1/3 Lower 1/3 Upper/mid 1/3 Mid/lower 1/3 Segmental	6 10 9 1 1 3
TOTAL	**30**

Table IV: Geographic Location of Fracture

Fracture Geometry

The radiological pictures also revealed the type of fracture the tibia sustained. Comminuted fractures were the commonest type (see Appendix II; Fig. 1). These included segmental fractures, compression wedge fractures (butterfly fractures) and a combination with transverse fractures. Comminution occurred in 18 legs while oblique fractures occurred in 4 and transverse fractures in 4 legs. Short oblique fractures were seen in 4 legs.

Other Injuries

The ipsilateral fibula was fractured in 80% of the legs. Other injuries included soft tissue lacerations. One patient suffered head injury, while another a ruptured spleen (splenectomy was done) and had a retroperitoneal haematoma. One patient, however, did not suffer other injuries apart from the open tibial fracture.

Period between Injury and Initial Management

Two patients arrived in theatre within one hour of the injury. Eleven patients had their initial management, within six hours of the injury. The longest period was more than 72 hours. The mean time to initial hospital (theatre) treatment was 9 hours, (p - value 0.001).

Of the 30 legs 13 were irrigated (at debridement) with normal saline while 17 with tap water (6 and 10 litres respectively).

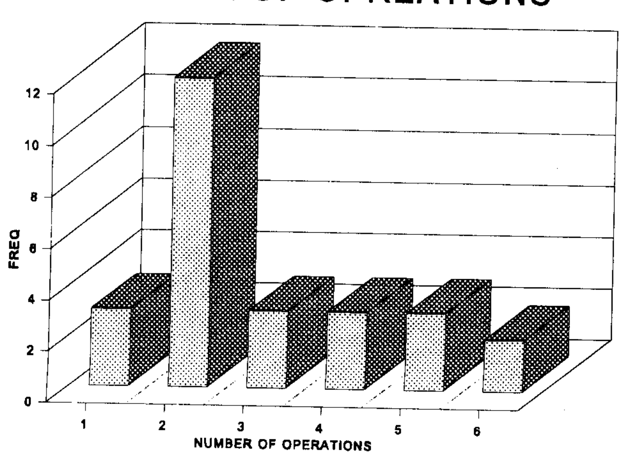
Operations

Various operations were done. In seven patients primary external fixation was carried out while in nine patients Plaster of Paris casts were done primarily. In one patient who had fractures of his ipsilateral tibia and femur, the treatment of these fractures was done by trans-calcaneal and trans-tibial skeletal traction respectively, initially, and later a below knee Patella Tendon Bearing (PTB) cast. The rest had a combination.

Two operations, per leg, were done on average. The minimum number was one, and maximum six. Twelve legs were operated on twice, while two legs were operated on six times. Two legs with types IIIA and IIIB respectively, had six operations each.

The operations, including external fixation, were done by the author except one external fixation and three others were done by a Consultant (St. Francis' Hospital) and a Registrar (University Teaching Hospital) respectively.

NUMBER OF OPREATIONS



Graph I.

Three patients received blood (transfusion). One of these had a ruptured spleen with retroperitoneal haematoma. This patient had autotransfusion (two units of blood from his peritoneal cavity).

Superficial Wound Infection

Superficial wound infection in both the study (tap water) and control (normal saline) groups were as shown in Table V below. Data was complete in 28 legs as regards superficial wound infection.

Patients in the control (normal saline) group suffered superficial infection in 5 legs out of eleven while the tap water group had 9 legs with infection and eight without infection (Table V). Infection was therefore present in 14 of the 28 legs analysed.

Infection	N. Saline	Water	Total
Yes	5	9	14
No	6	8	14
Total	**11**	**17**	**28**

Table V: Superficial wound infection.

Infection	I	II	IIIA	IIIB	Total
Yes	1	3	2	8	14
No	1	9	1	3	14
Total	2	12	3	11	28

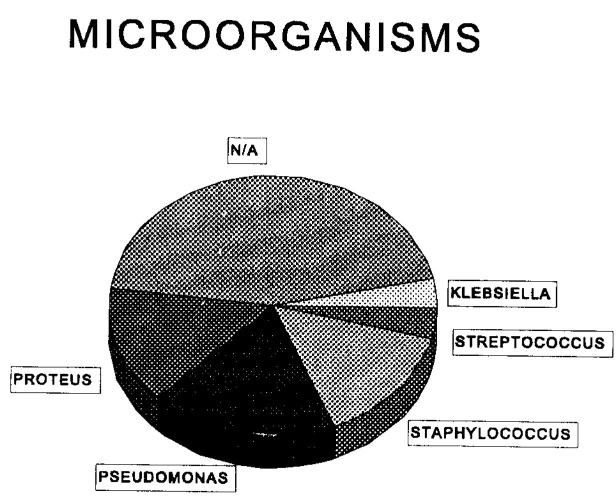
Table VI: Superficial wound infection/Fracture Type

Of these infected wounds, one was Type I; three legs of Type II; two legs of Type IIIA and 8 legs with Type IIIB fractures (Table VI).

Superficial wound infection was commonest in the severely injured (Type III) legs (see Table VI).

The pie chart below illustrates the microorganisms that were isolated from the infected wounds in both the groups. In the study group *Staphyloccocus aureus* was isolated from 2 legs; *Streptoccocus species* from 2 legs too; *Diphtheroidis species* from 1 leg and *Klebsiella species* from 1 leg. None of these microorganisms was isolated from the tap water used in the wound irrigation.

In the control group, on the other hand, Proteus was isolated from 3 legs and Staphyloccocus aureus from 2 legs.


MICROORGANISMS
N/A
KLEBSIELLA
STREPTOCOCCUS
STAPHYLOCOCCUS
PSEUDOMONAS
PROTEUS

Pie chart I.

Chronic Osteomyelitis

In these 28 legs chronic osteomyelitis occurred as shown in Table VII below. Chronic osteomyelitis in different fracture types was as shown in Table VIII.

In the tap water group (17 legs), six had chronic osteomyelitis, while in the control group (saline group) 1 out of 11 legs had this complication. There was no statistical difference in the outcome in the two groups ($p>0.05$) (see discussion).

CHR.OSTEOMYELITIS	N.SALINE	WATER	TOTAL
NO YES	10 1	11 6	21 7
TOTAL	11	17	28

Table VII: Chronic Osteomyelitis

CHR.OSTEOMYELITIS	I	II	IIIA	IIIB	TOTAL
NO YES	2 0	11 0	2 1	6 6	21 7
TOTAL	2	11	3	12	28

Table VIII: Chronic Osteomyelitis in Different Fracture Types

Pin Tract infection

In all the patients that were treated with external fixation (whatever the type) six pins were used per leg. Out of 114, 3 pins had pin tract infection. Also a patient with a calcaneal pin had pin tract infection.

Fracture Healing

Fracture healing occurred in all the legs except one, which suffered non-union. This was a Type IIIA fracture complicated with chronic osteomyelitis. The minimum period of fracture healing was 44 days, the maximum being 217 days and the average was 91 days (13 weeks).

Date of Discharge

The minimum hospital stay was 9 days; maximum was 111 days in the 23 recorded patients. The mean being 42 days.

Knee flexion

Knee flexion was satisfactory in both groups. Fifty eight percent (58.3%) of all the knees had full range of motion. Twelve percent (12.4%) had range of motion between 101° to 130° and twenty nine percent (29.3%) of knees had a range of motion up to 90° to 100°.

Ankle Stiffness

Twenty of the 31 legs had data recorded about the ankle. Of these 20, 2 ankles suffered stiffness in equinus (10 degrees of fixed plantar flexion). These two patients had severe open tibial fractures (Types IIIA and IIIB respectively).

Limb shortening

The legs that suffered limb shortening are as shown in Table IX below. Shortening was commonest in the Type IIIB fractures. One leg (Type IIIB suffered 0.5 cm shortening); two legs (Types II and IIIB) suffered 1.0 cm shortening; four legs (two Types II and two Types IIIB) suffered 2.0 cm shortening while another four legs (one Type II and three

Types IIIB) suffered 2.5 cm shortening. There was no shortening in the Type I fractures. Limb shortening was commoner in the severe Type III injuries.

SHORTENING	LEGS
0.5cm 1cm 2.5cm 2cm NO	1 2 4 4 13
TOTAL	**24**

Table IX: Limb Shortening

All the legs healed with the feet in a neutral position. Six of the legs suffered varying degrees of anterior angulation. The worst being 15° of anterior angulation while the least was 4 degrees. The average was 8.6 degrees of anterior angulation.

No posterior angulation occurred in any limb. Medial angulation occurred in 3 legs. The worst being 22 degrees while the least was approximately 5 degrees with an average of 12 degrees.

DISCUSSION

Age/Sex

The average age in the study of open tibial fractures from 1981 to 1986 by Russell[26] et al was 28.5 years. This study looked at types I to III open tibial fractures. This average age is similar to what our results show. However, Rankin et al[19], in their Early Experience with External Fixation study, from Bulawayo, Zimbabwe, the average age was 33.3 years. Many studies have shown that males suffer open tibial fractures more often than females[1,19,25,26,28]. In this study the male to female ratio was 5:1.

In a study by Court - Brown et al, transfixation pins were infected in 25% of cases with Type IIIA fracture, while there was pin infection in 50% of cases with type IIIB.

In another study, by Rankin et al[19], however, no pin tract infection was experienced in the 15 patients treated with external fixators.

The pin infection in our study compared well with the study by Rankin et al. I think this good result is largely due to the active participation by patients in cleaning the pin sites. Patients were taught how to do this, so as to cut down on morbidity, as regards pin infection.

Literature shows that the causes of open tibial fractures are the same but vary from region to region. However, the major cause of open tibial fractures is RTA[6,19]. In this study more than half of the fractures (22 legs) were secondary to RTA and the majority of patients were pedestrians. Only one patient was a motor cyclist.

Antti et al[29], found that the commonest site of fractures in the tibia was the lower 1/3. Out of 93 tibial shaft fractures treated by nailing, 40 were in lower 1/3 while 39 were in middle 1/3. This study, however, shows that the middle 1/3 was injured more often than the lower and upper 1/3.

Infection rates in Type III tibial fractures are reported to be much higher than those for Grade I and II fractures: Gustilo et al (1990) had infection rates of Grades I, II, and III of 0% to 2%, 2% to 7% and 10% to 50% respectively[7,26]. The same authors also found a large difference between Grade IIIA and Grade IIIB fractures, with infection rates of 4% and 52% respectively, but these cases were not treated by early flap coverage[26].

Five legs in the control group had superficial infection and 9 in the tap water group. Out of the total number of 28 patients in whom no infection/infection was recorded 14 legs had infection.

The largest number of infected legs (wounds) was seen in the Type III open fractures of the tibia. Type IIIC fractures, however, was not included in this study because none were seen. The amputation rate in Type IIIC fractures is about 78% in centers that do vascular surgery[21,24]. Possibly because of lack of specialised facilities, skilled manpower and delays in presenting to hospital, there is a 100% amputation rate at the University Teaching Hospital. This would explain why Type IIIC fractures were not included in this study. These results, however, compare well with others reported in literature[26].

In a study, "Treatment of Open Fractures: A Prospective Study", by Benson et al[25], the most common aerobes were *Staphylococcus epidermidis*, *Corynebacterium spp.*, *micrococcus spp.*, and Bacillus, five times in a total of 116 specimens. A variety of aerobic Gram negative bacilli were encountered. The most common were *Escherichia coli* and *Eisterobacter agglomeraus* (four times)[25].

In another study by Court-Brown et al, *Staphylococcus aureus, Pseudomonas aeruginosa* and *Escherichia coli* were the common pathogens in the open fractures of the tibia. This study also has shown similar types of microorganisms causing wound infection.

Straight leg raising was possible in 18 of the injured lower limbs within nine days postoperatively. This was irrespective of the severity of the fracture but was dependent on how early the physiotherapy was instituted. Delayed definitive treatment and physiotherapy gave way to muscle weakness (wasting), particularly of the quadriceps group. Within 16 days of operation, 21 of the thirty injured patients were able to straight leg raise. Of these, almost half of them were able to mobilize out of bed within this period. The mean difference between time to mobilize in bed and out of bed was 9 days. The patients on average were out of bed within one week of limb immobilization (fracture fixation).

The average healing time of fractures in a study by Gershuni et al[28], was 9.9 months (range; 3 to 23 months). While Court-Brown et al[24], had the following time to union: Type IIIA (6.6 months); Type IIIB (11.8 months) and Type IIIC (15 to 17.5 months). In this study the average time to healing (both groups) was 91 days (3 months), the minimum and maximum being 44 days (1.5 months) and 217 days (7.2 months) respectively. These results compare well with the standard teaching that fractures of adult lower limbs take, on average, 3 months to heal.

The average stay in hospital was directly proportional to the severity of the injury. In Type I the hospital average stay was 24.5 days; Type II (32.4 days) Type IIIA (43.3 days) while Type IIIB was 52.2 days. This is in support with the prognostic nature of the Gustilo - Andersen's classification. The more severe the injury the more the complications and the longer the hospital stay. Court-Brown et al[24], studied Type III fractures and found a mean hospital stay of 71.6 days for Type IIIA and 75.1 days for Type IIIB. Comparing the above stated results and ours it is evident that our patients were discharged out of hospital much earlier despite lack of home care.

Knee flexion and extension in the patients was satisfactory (from 90 - 100°), good (from 101° to 130°) and excellent for a range of motion more than 130°. All the patients had a full range of motion in extension. These good results were largely because of early, persistent and close physiotherapy monitoring. There were, however, two ankles out of the 20 analysed that suffered from stiffness in equinus. Both those patients had severe fractures (Types IIIA and IIIB) in the lower 1/3. One of the two had in fact a segmental Type IIIA fracture. The proximal fracture, in this particular patient, healed well. At the time of writing up this report this patient was re-admitted to the hospital because the distal fracture did not unite. This same site had discharging sinuses secondary to chronic osteomyelitis. Amputation was being considered. In these two patients, their initial treatment involved calcaneal pin skeletal traction.

Diezt and Merchant stated that as the level of deformity approaches the distal third of the tibia even minor degree of malaligment could affect the ankle[12].

Twenty-four of the fractured tibiae had comminution and were Type IIIB fractures. This follows then that, the more severe the fracture, the higher the risks of limb shortening. This again is in agreement with the prognostic value of the Gustilo - Andersen's classification.

All the limbs healed well with the feet in the neutral position (without medial or lateral rotation). This good result was due to regular clinical examination. The injured leg was clinically aligned. The big toe was aligned in relation to the ipsilateral patella and the anterior superior iliac spine, and also relative to the uninjured side. If the rotation, internal or external were noted, this was corrected at the initial operation or subsequent one upon observing this morbidity.

One patient suffered 15° of anterior angulation. This patient had ipsilateral fracture of the femur as well. A head of one general surgical unit discharged him, prematurely before the fracture was sticky or had healed. The reason for this early discharge from hospital was because the nursing staff were on strike. When the Investigator saw this patient later, in the outpatient clinic, the fracture had healed with the above stated degree of deformity. He has since been lost to follow up.

Another patient suffered medial angulation of 22°. This patient had a segmental fracture. The proximal fracture caused this angulation. The range of motion at the knee, however, was excellent. This patient had suffered head injury as well. During the initial operation (external fixation) bone alignment was acceptable. While on the ward postoperatively, the injured leg as well as the other limbs were tied to his bed because he was restless. The alignment of the fracture segments was disturbed. Re-alignment was subsequently done in theatre under sedation. Immediate postoperative radiographs showed good reduction. The investigator, however, left to go and work in another hospital (as part of the postgraduate training programme), therefore, follow up was not possible for 6 months. Corrective osteotomy at a later stage had been planned in case of further displacement. The mean anterior and medial angulations were 12.1° and 8.6° respectively. Both these results fall within the normal range on angulation according to Diezt and Merchant[12].

Chronic osteomyelitis is a common complication of open fractures. This complication was recorded in 7 of all the legs, and the majority of the injured legs belonged to the Type III group of fractures. This complication occurred in 6 legs in the tap water group and 1 leg in the saline group. This data was analysed by chi-squared testing at 95 percent level of confidence, and there was no significant statistical difference in this complication in both the study and control groups ($p>0.05$). No deep infection was recorded in both the control and study groups with fracture Types I and II. The high rate of infection both superficial and deep (osteomyelitis infection in Type III fractures) was largely due to the severity of the injuries (see table)

In the study group 9 legs developed superficial infection whereas 5 legs in the control group had this complication. A large number of infections were recorded in the Type IIIB fractures. Statistical analysis reviewed, in this regard, that there was no significant statistical difference in the outcome between the two groups in terms of superficial wound infection ($p>0.05$). These results compare very well with the infection rate observed by Court - Brown et al[24]. In their study, osteomyelitis occurred in 35.7% of cases with Type IIIB fractures. Gershuni et al, also observed a deep infection rate of 38%[29].

Radiography

In 18 legs there was radiological evidence of comminution, including wedge compression and segmental fractures. Of all the open fractures 18 had severe soft tissue damage. Rankin et al[19], concluded, that in compound fractures of the tibia the vicious combination of a badly comminuted fracture with major skin and soft tissue damage has taxed the orthopaedic mind. This statement is true and being reflected here by our above stated findings.

The presence of a fibula fracture in association with the tibial fracture often indicates an unstable fracture as well as a high-energy mechanism of injury[12]. In our study over 24 of the tibial fractures were associated with an ipsilateral fibular fracture. High-energy injuries are more severe and less likely to be treated successfully with a cast[12]. In this study 22 of the fractures were secondary to RTA and at least 16 fractures were treated with one form of external fixation or another. Nine legs were purely treated with plaster casts.

CONSTRAINTS

1. Failure on part of my sponsors, Zambia Consolidated Copper Mine Limited, to fund this dissertation.

2. Equipment, e.g. hand-drills, in the University Teaching Hospital theatres, was and is in a deplorable state. This made operations on some patients extremely difficult.

3. Communication and cooperation with some General Surgical Units was inadequate consequently some patients were lost to follow up.

CONCLUSIONS

1. Tap water is as effective as normal saline in wound irrigation during surgical wound debridement. Large volumes, not less than 10 litres, of tap water must however be used.

2. Results have shown that external fixation of severe open tibial fractures is an effective method of fracture management in the two institutions (University Teaching Hospital and St. Francis' Hospital) despite the constraints experienced.

3. The commonest cause of open tibial fracture was road traffic accidents, and pedestrians were the commonest casualties.

4. Pin tract infection was not common in this study probably because of the special care taken during the whole study period. This may not be the true reflection of pin site care at the University Teaching Hospital and St. Francis' Hospital.
5. Tibial comminution, with ipsilateral fracture of the fibula, suggests severe injury due to high impact.

6. *Pseudomonas spp.* and *Staphylococcus aureus* were the commonest pathogens causing wound infection.

RECOMMENDATIONS

1. Registrars in general surgical units, even at district hospitals, must be able to apply external fixators in patients with severe open tibial fractures. This is because they attend to these patients earlier than the orthopaedic teams.

2. Surgeons (including registrars) must be familiar with and pay attention to principals and details of external fixation to avoid high morbidity and mortality.

3. Patients with external fixators should be involved in their pin site care to achieve the minimum possible pin tract infections.

4. Basic tools, such as a hand-drill, must be available and in good working condition to facilitate easy and proper application of external fixation devices.

5. Copious amounts of tap water should be used for thorough wound debridement even when normal saline is available.

REFERENCES

1. Steiner AK, Kotisso B. Open Fractures and Internal fixation in a major African Hospital. *Injury* 1996; **27 (9)**: 625-630.

2. University Teaching Hospital (Board of Management). Accounts Department. 1998.

3. Hall Angeras A, Brandberg A, Falk A, Seeman T. Comparison between Sterile Saline and Tap Water for the cleaning of Acute Traumatic Soft Tissue Wounds. *European Journal of Surgery* 1992; **158**: 347-350.

4. Apley AG, Solomon L. Systems of Orthopaedics and Fractures. 17th Edition. Butterworth - Heinemann, Oxford, 1993; pp. 535, 689, 693.

5. Tytheleigh-Strong G, Margaret M, Mc Queen. Fractures of the Tibial Shaft. *Surgery,* The Medicine Group 1996; 229-235.

5. Hughes S. A New Short Textbook of Orthopaedics and Traumatology. Edward Arnold. A division of Hodder & Stoughton, 1989. London.

7. Tornetta III P, Bergman M, Watnik N, Berkowitz G, Stener J. Treatment of Grade IIIB Open Tibial fractures: A prospective Randomised Comparison of External Fixation and Non - reamed locked nailing. *Journal of Bone and Joint Surgery 1994;* ***76-B:*** 13-19.

8. Sanders R, Swiontkowski M, Nunley J, and Speigel P. The Management of Fractures with Soft Tissue Disruption. *Journal of Bone and Joint Surgery* 1993; **75-A**: 778-789.

9. Olson SA. Open Fractures of Tibial Shaft. *Journal of Bone and Joint Surgery* 1996; **78-A**: 1428-1435.

10. de Boer P. Fractures of the Tibial Shaft. *Surgery.* The Medicine Group 1995;

11. Gustilo RB, Merkow RL, Templeman D. The Management of Open Fractures. *Journal of Bone and Joint Surgery 1990;* **72-A**: 299-304.

12. Watson TJ. Current Concepts Review: Treatment of Unstable Fractures of the Shaft of the Tibia. *Journal of Bone and Joint Surgery* 1994; **70 A**:1575-1584.

13. Warlock P, Slack R, Harvey L, Mawhinney R. The Prevention of Infection in Open Fractures. An Experimental Study of the effect of antibiotics therapy. *Journal of Bone and Joint Surgery* 1998; **70 A**: 1341-7.

14. Peter PC. How I do it: the difficult open tibial fracture. *Medicine Digest* 1990; **16 (2)**: 3-7.

15 Fisher MD, Gustilo RB, Varecka FT. The Timing of Flap Coverage, Bone grafting and Intramedullary Nailing in Patients who have a Fracture of the Tibial shaft with extensive Soft tissue injury. *Journal of Bone and Joint Surgery* 1991; **73 A**:1316-21.

16. Stene GM, Frigg U, Swiontkowski M. Biochemical evaluation of the Pinless External Fixator. *Injury* 1992; **23 (I)**: 9-11, (AO/ASIF Scientific Supplement).

17. Pearse MF, MacEachern AG. External fixation. *Surgery* The Medicine Group 1991; 2153-2158.

18. Rijcken JM. Use of the External fixator. *The Proceedings of the Association of Surgeons of East Africa* 1992; **15**: 7-8.

19. Rankin CK. Early Experience with External fixation. *The Proceedings of the Association of Surgeons of East African* 1983; **6**: 79-86.

20. Ackroyd CE. External fixation of fractures. *The Proceedings of the Association of Surgeons of East Africa* 1987; **10**: 72-75.

21. Metthews LS, Green AC, Goldstein SA. The Thermal Effects of Skeletal Fixation - Pin insertion in bone. *Journal of Bone and Joint Surgery* 1984; **66-A**: 1077-1083.

22. Remiger AR. Mechanical properties of the Pinless External Fixator on Human Tibiae. *Injury* 1992; **23 (I)**: 25-42. (AO/ASIF Scientific Supplement).

23. Howard PW, Making GS. Lower Limb Fractures with associated Vascular Injury. *Journal of Bone and Joint Surgery* 1990; **72 B**: 116-120.

24. Court-Brown CM, Wheelweight EF, Christie J, Mc Queen MM. External Fixation for Type III Open Tibial Fractures. *Journal of Bone Joint Surgery* 1990; **73 B**: 801-803.

25. Benson DR, Riggins SR, Lawrence MR, Hoeprich PD, Huston AC, Harrison JA. Treatment of Open Fractures: A Prospective Study. *The Journal of Trauma* 1993; **23 (1)**: 25-30.

26. Russell GG, Henderson R, Arnett G. Primary or Delayed closure for open tibial fractures. *Journal of Bone and Joint Surgery* 1990; **72-B**: 125-8.

27. Cullen MC, Roy DR, Crawford AH, Assenmacher J, Levy SM, Wen D. Open Fracture of the Tibia in Children. *Journal of Bone and Joint Surgery* 1996; **78-A**: 1039-1046.

28. Haas WG, Watson J, Morrison DM. Non Invasive Treatment of Ununited Fractures of the Tibia using Electrical Stimulation. *Journal of Bone and Joint Surgery* 1980; **62 B**: 465-470.

29. Gershuni DH, Halma G. The A-O External Skeletal Fixation in the Treatment of Severe Tibia Fractures. *The Journal of Trauma* 1983; **23 (11)**: 986-990.

30. Alho A, Ekeland A, Stromsoe K, Folleras G, Thoresen OB. Locked Intermedullary Nailing for Displaced Tibial Shaft Fractures. *Journal of Bone and Joint Surgery* 1990; **72-B**: 809-9.

31. Holman RR, Kennedy I. C - Stat for Windows, Chi-square. Cherwell Scientific Publishing Ltd., Oxford. United Kingdom. 1993. 60-61

APPENDIX I

EXTERNAL FIXATION OF OPEN TIBIAL FRACTURES IN ZAMBIA.

Surname:.........................Initials:....................
Hospital No...................... Age.........Sex:..........
Occupation:.........................Survey No..................
Address:...
....
Next of kin and address:...................................
...

HISTORY:
DATE & Time of injury:...
Injured side:....... L/R/Both
Description of injury:..
....
....
GUSTILO ANDERSON (Type)...................................
Cause of injury:(RTA, assault, etc):.......................
Other injuries (specify):....................................
....
....
....
Site: Upper 1/3; Upper/Mid; Mid 1/3; Mid/Lower; Lower 1/3
Segmental
Pre-op INVESTIGATIONS

Date:........... Hb:......... WBC:...........ESR:................

X-ray:...

....

Wound swab: m/c/s:...

DATE/TIME:..............**INITIAL MANAGEMENT** (1st 24hrs.).........

....

....

OPERATION NOTES: DATE:....................TIME...............

Surgeon:.....................Assistant :....................

Anaesthesia:...................Anaesthetist:.................

Pre-op antibiotics:
Gentamycin.............(Dose)...........IM/Stat

X-Pen...................(Dose)............IV/Stat

Flagyl...................(Dose)............IV/Stat

Wound washed with : Running tap water............ (ml)

Normal saline....... (ml)

Surgical Procedure :...................................

....

....

....

Blood transfusion:..... Y/N

POST OPERATION
Rx : Elevation, Antibiotic (specify).......................

Analgesia (specify)...................................

Others...

Date:......Blood Hb:.... WBC:.... (total) Lymph....% ESR:.....

Complications: Fever within 2 weeks (above 38 deg.) ....

Wound healing: normal / delayed / infection.

Wound infection: Y/N If yes give details :.................

Others:..

....

Fracture healing (X-ray) :.......................................

Other comments:..

....

Pin infection..........................Y/N.....................

If yes give details..

Number of Operations...

Lifting leg Date:...

Out of Bed:..

DATE OF DISCHARGE..

GUSTILO-ANDERSON CLASSIFICATION OF OPEN TIBIAL FRACTURES

Type I Small clean puncture wound;
Little soft tissue damage; no crushing and not comminuted fracture.

Type II Wound more than 1cm. long;
Not much soft tissue damage (moderate damage);
No more than moderate crushing.

Type III Extensive skin, soft tissue and neuro-vascular damage;
Considerable comminution.

Type IIIA Fracture can be covered by soft tissue;

B Fracture can not be covered by soft tissue;
periosteal stripping and comminuted.

C Arterial injury.

N.B. All high velocity injuries are classified III B or III C

CLINICAL FOLLOW UP AT 1 MONTH

Date:.............Name/Age/Sex:................File No:.......

Symptoms:..

....

....

Knee Flexion:.................Ankle Flexion:...............
Extension:.............. Extension:...........

Leg External Rotation:............Degrees
Internal Rotation:............Degrees
Neutral ....Degrees

Leg Length
R Side..............L Side.........................

Clinical Union Y/N

Infection Y/N If yes

M/C/S...
....
....

Radiographs
ISQ.........Healing......................................
Other comments...
....
Anterior angulation ....degrees
Posterior angulation ....degrees
Lateral angulation ....degrees
Medial angulation ....degrees

Other complications:.......................................
....

CLINICAL FOLLOW UP AT 3 MONTHS

Date:.............Name/Age/Sex:................File No:.......

Symptoms:..

....

....

Knee Flexion:................Ankle Flexion:..............
Extension:.............. Extension:................

Leg External Rotation:............Degrees
Internal Rotation:............Degrees
Neutral ....Degrees

Leg Length
R Side..............L Side........................
Clinical Union Y/N

Infection Y/N If yes

M/C/S..

....
....

Radiographs
ISQ.........Healing...........Other comments......
Anterior angulation ....degrees
Posterior angulation ....degrees
Lateral angulation ....degrees
Medial angulation ....degrees

Other complications:..................................
....

CLINICAL FOLLOW UP AT 6 MONTHS

Date:.............Name/Age/Sex:................File No:......

Symptoms:..

....

....

Knee Flexion:................Ankle Flexion:..............
Extension:.............. Extension:................

Leg External Rotation:............Degrees
Internal Rotation:............Degrees
Neutral ....Degrees

Leg Length
R Side...............L Side.........................
Clinical Union Y/N

Infection Y/N If yes
M/C/S...
....

Radiographs
ISQ..........Healing..........Other comments........
Anterior angulation ....degrees
Posterior angulation ....degrees
Lateral angulation ....degrees
Medial angulation ....degrees

Other complications:.....................................
....

CLINICAL FOLLOW UP AT 9 MONTHS

Date:.............Name/Age/Sex:................File No:.......

Symptoms:...

....

....

Knee Flexion:................Ankle Flexion:..............
Extension:.............. Extension:................
Leg External Rotation:............Degrees
Internal Rotation:............Degrees
Neutral ....Degrees

Leg Length
R Side...............L Side.........................
Clinical Union Y/N

Infection Y/N If yes

M/C/S...
....
....

Radiographs

ISQ..........Healing..........Other comments........
Anterior angulation ....degrees
Posterior angulation ....degrees
Lateral angulation ....degrees
Medial angulation ....degrees

Other complications:...
....

CLINICAL FOLLOW UP AT 12 MONTHS

Date:.............Name/Age/Sex:................File No:.......

Symptoms:...

....

....

Knee Flexion:................Ankle Flexion:..............
Extension:.............. Extension:................

Leg External Rotation:............Degrees
Internal Rotation:............Degrees
Neutral ....Degrees

Leg Length

R Side................L Side........................

Clinical Union Y/N

Infection Y/N If yes

M/C/S...
....
....

Radiographs

ISQ..........Healing............Other comments......
Anterior angulation ....degrees
Posterior angulation ....degrees
Lateral angulation ....degrees
Medial angulation ....degrees

Other complications:...
....

APPENDIX II

Fig. 1: An example of a comminuted fracture

APPENDIX II

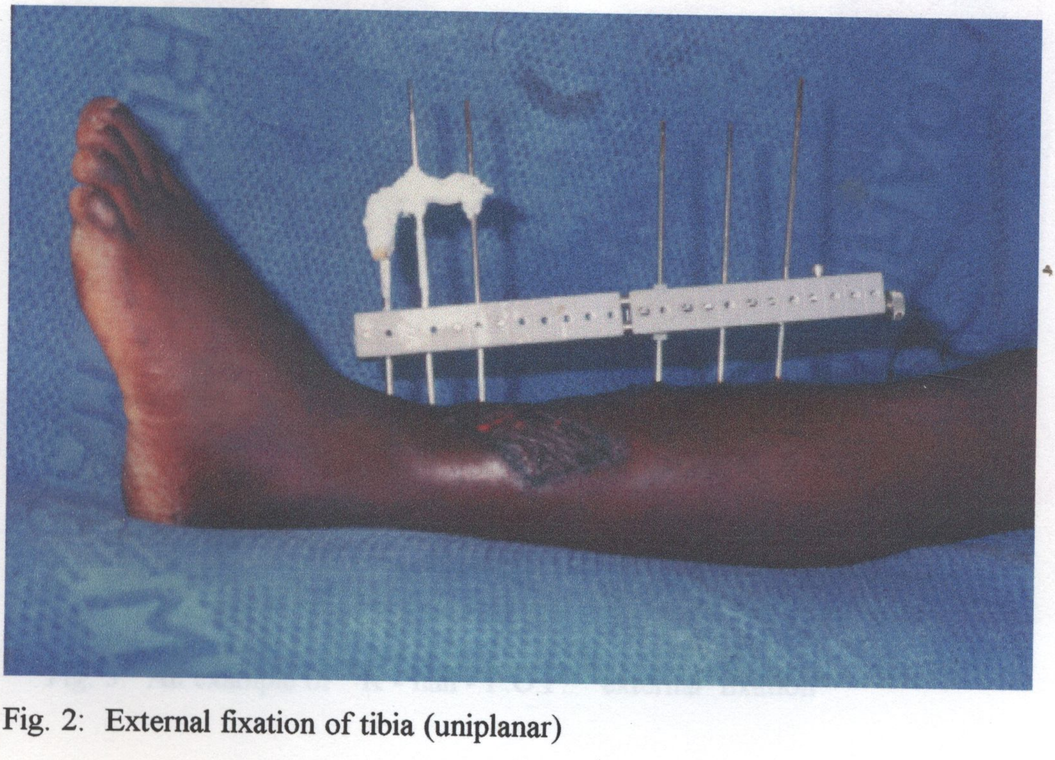


Fig. 2: External fixation of tibia (uniplanar)

APPENDIX II

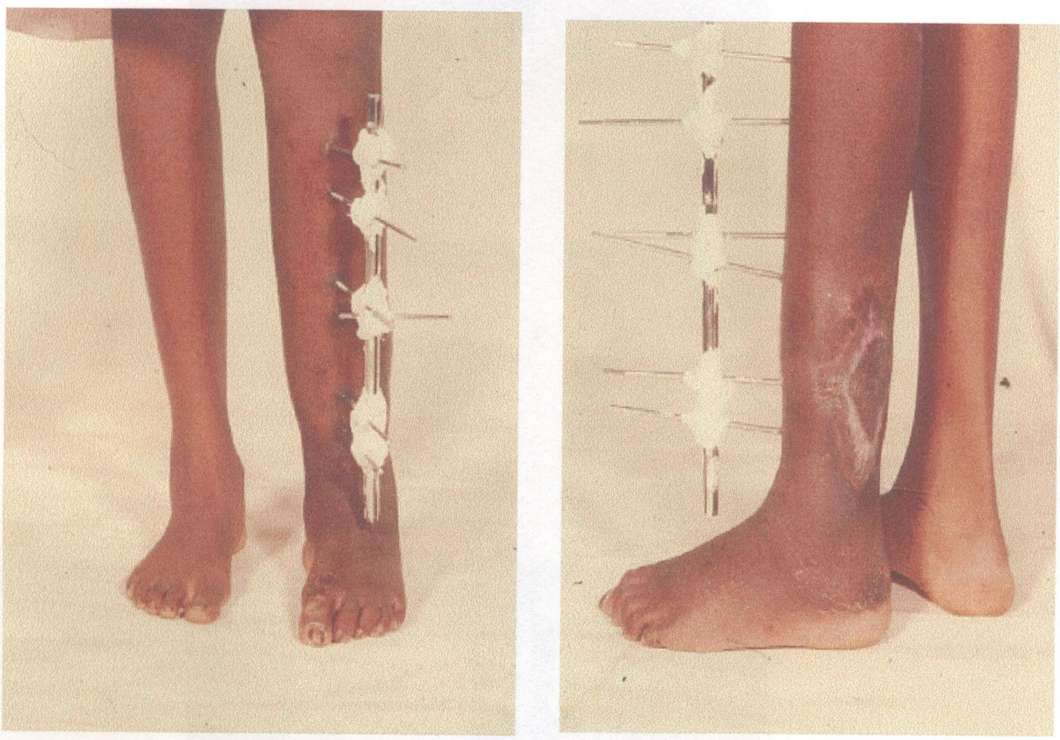


Fig. 3: An example of "K - nail - P.O.P." external fixation

APPENDIX II

Fig. 4: A patient mobilising with a "K - nail -P.O.P." external fixator

APPENDIX II

Fig. 5: Bilateral open tibial fractures

APPENDIX II

Fig. 6: Healed split skin graft

APPENDIX II

Fig. 7: Example of open tibia fracture (left leg) following full recovery

APPENDIX II

Fig. 8: A patient fully weight bearing