MANAGEMENT OF OPEN FRACTURES OF THE LOWER EXTREMITY. HOW VACUUM SEALING TECHNIQUE AND EXTERNAL FIXATION AFFECT THE OUTCOME.

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CERTIFICATION

The undersigned certify that he has read and hereby recommend for acceptance by the University of Dar es salaam a dissertation entitled:
Management of open fractures of the lower extremity. How vacuum sealing technique and external fixation affect the outcome, in partial fulfilment of the requirements for the degree of Master of Science Orthopaedic and Traumatology.

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Date: Dec 13th '97

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DEDICATION

I dedicate this dissertation to my wife Sarah N. Mboya and my children Lilian N. Mboya and Loveness N. Mboya for their support, love, understanding, and great patience during my long absence while persuing my training in Orthopaedics and Traumatology.

ABSTRACT

TITLE: Management of open fractures of the lower extremity. How vacuum sealing technique and external fixation system affect the outcome.

SUBJECT: Patients with fractures of the lower extremity in whom thorough wound debridement, copious irrigation, vacuum sealing application and external fixation was the main stay of treatment.

OBJECTIVE: To study and analyse the quality of various operative management of soft tissues and skeletal injuries of the lower extremity.

SUMMARY:

Amputation has been the main stay of treating open fractures up to the middle of the 19th century. This had resulted in considerable disability and great missery,especially in developing countries in terms of poor rehabilitation, and problems of prosthesis procurement. High infection rate, prolonged healing times and hospital stay, have greately hindered a normal life in victims with severe open fractures. Technology development in the western community today, has tremendously revolutionised open fracture treatment not only from amputation to limb salvage but also development of methods which prevent or lower infection rate, achieve short healing time short, duration of hospital stay, as well as short occupational re-intergration time.

Among 116 patients studied at the Traumatology department of the University of Ulm Germany, about 90% were treated by serial vacuum sealing after standard and serial debridement with thorough irrigation. Prophylactic antibiotic (cefuroxime) was administered to all patients and external fixation

was performed in 30% of patients, of which 16% were the Ilizarov ring fixation. Under the above protocol, the overral amputation rate was as low as 6%. It is concluded that the above protocol of open fracture treatment is associated with a high rate of limb salvage, low complication rate, short healing time and short duration of hospital stay. That undeniable fact outweighs the relatively expensive procurement of such surgical material necesary to establish this important protocol at the Muhimbili Orthopedic Institute.

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1. INTRODUCTION

1.1 DEFINITION

An open fracture is one in which there is a break in the skin and underlying soft tissue and this leads directly into or communicates with the fracture and its hematoma[35, 43]. "Compound fracture" is a non specific term and it is now rarely used[43]. Sometimes the diagnosis of an open fracture can pose a problem because the wound may be a considerable distance from the fracture site[38,47]. However when a wound occurs in the same limb segment as a fracture, the fracture should be considered open until proved otherwise[46]. The prognosis in open fractures is determined primarily by the amount of devitalised soft tissue and by the level and type of bacterial contamination[10, 33, 46]. These two factors are the primary determinants of the outcome.

1.2 HISTORICAL PERSPECTIVE

Over the issuing centuries an open fracture meant not only amputation but also death from sepsis [10,43,55,140,229]. The surgery of open fractures remained until the middle of nineteenth century, as the surgery of amputation[54].Amputation itself carried a very high mortality rate usually from haemorrhage and sepsis. In 1842, Malgaine[147] found that the overall mortality rate for amputation was 30%, whereas for major amputation was 52%, and for the thigh alone 60%. In the Franco-Germany war of 1870 to 1871 the mortality rate for all open fractures was 41%[43]. In the American civil war of

1860-1865, of the 30,000 amputations carried out the mortality rate for thigh amputations was 54%, and 34% for leg amputations, giving an overall mortality rate of 26%[49,55]. Muhimbili Medical Centre, department of Orthopaedic and Trauma admits about 5,000 patients per year, (annual report 1995). Of these, 98 (2%) of the cases are due to open fractures. This carry high mobidity rate including high infection rate[161].

Until the 16th century, red hot iron and boiled oil of eder were used as the means of controlling haemorrhage and infection after amputation[10,46]. Ambroise Pare`[174] in 1564 described ligation of a bleeding vessel after amputation, whereas Le Petit [63], in 1718 described the use of tourniquet and claimed such intervention to have reduced the mortality rate for amputation of lower limbs from 75% to 25%.

Parallel to the above development is tissue debridement. Debridement as an important component in open fracture surgery, had its advocates as early as the 15th and 16th century. That is the time, Brunschwig and Botelo[10,43], advocated removing the nonviable tissue from wounds that had poor progress. In the same 16th century, Guy de Chauliac[64] ,started on such school of thought, and taught the enlargement of open and contaminated wounds to encourage drainage. Pierre Desault[43,46] in the 18th century established the modern concepts of debridement, and it is he who coined the term "debridement." Larrey[43] ,Desault`s pupil extended the principle and included the issue of timing. The sooner debridement is done, he contended, the better the result.

Although amputation as a primary means of treatment of open fractures was practised for quite a considerable period, some surgeons were dissatisfied with this mutilating and disabling procedure.[10] Thinking in terms of limb conservation, it was Pare`[175,230] who in 1564 documented for the first time a successful conservation of a limb following an open fracture. He described an injury of his own leg, sustained after being kicked by his horse. The fact that Pare` continued to insist on conservative management of his own fracture rather than amputation, he was marking the beginning of the major change in this field. Pare[175],adviced,that if there be any strange bodies, whether from without or within must be removed, otherwise no union is to be expected. The wound must then forthwith be enlarged to provide free drainage and is held open by rolls of linen.

Later on, the excellent pioneering work of Lister, Pasteur, Koch, and Semmelweis[10,43,54], established another major step toward limb salvage. They introduced not only antisepsis, asepsis, and antibiotics, but also a more progressive understanding of bacterial contamination and cross infection. Moreover, the Galenistic school of thought that antiseptics or antibiotics might circumvent the need to leave the wounds open and heal uneventfully was then greatly heightened, but still that remained highly controversial[46].That is because,when antisepsis was used alone e.g. in the Franco - Prussian war of 1870-1871 it absolutely failed[228] .Antibiotics alone were used in the korean war, but again this was disappointing[49,84].This was attributed to the fact that principles of debridement were very fast forgotten or

abandoned[10].Therefore in different military theatres, the primacy of debridement and the Hippocratic school of thought,that means debriding the wound and leave it open had to be relearned [49,229].To be sure, an open wound may heal despite the technically inadequate debridement but a closed wound seldom can, even when aided by antibiotics or antiseptics[140,228].However, it seems now that the two major schools of thought are finally brought together. The wound that is inadequately debrided and left open, (Hippocratic school) may benefit from an appropriate antibiotic (Galenistic school) administered at the appropriate time[43,140]. All the techniques developed during the past century are important but none was as difficult to learn or as easy to neglect as the art of debridement, and this is also true as we match towards the 21st century[10,107].

In addition to the above basic precepts the Hippocratic physicians recognised that, fracture stabilisation influence the ultimate outcome of open fractures [140,229].Technology explosion in the last three decades has lead to the development of multiple implants both for external and internal fixation[10,167].However, the significance of this application is the precise indication according to technical ability of the surgeon, degree of soft tissue injuries, level of contamination,fracture configuration, general patient`s condition, and social economic aspect[10,18,32,167].

Along with the above development, the importance of soft tissue coverage is progressively better understood.[196,205] Delayed primary wound closure or coverage as well as the use of flaps have been well established.

Brown,[26] Gustilo,[105,107] and Connelly[53] advocated early soft tissue coverage. Godina[97], had 80% of his tissue transfers done on the day of injury, and achieved an infection rate as low as 1.5%, attested to his skill in radical debridement.

Furthermore, the continued understanding of fracture patterns and soft tissue damage has resulted into the development of the modern comprehensive open fracture classification[10,33,43,172].The modified classification worked out by Gustilo and co-workers is the most widely accepted and quoted[10,33,43,104].The critical factors in this classification are the degree of soft tissue injury and contamination.Very often the two factors are forgotten or neglected and too much emphasis is put on wound size.

Finally, both medical and surgical discoveries such as debridement techniques, microbiologic theory of infection, high technique of fracture stabilisation, and techniques of wound coverage, have brought about tremendous revolution in operative management of open fractures with skeletal injury[10,43,167].Therefore whereas once upon a time society witnessed unprecedented death toll and higher rate of limb amputation as a measure of open fracture treatment, our major focus today which is also the focus of this study is to look into management methods that;[32,35,46,104,107,221] prevent infection rate, achieve short healing time,short hospital stay, and finally restore early limb function and patient`s activity level. The analysis of how application of the vacuum sealing and external fixation influence these parameters is

carried out.The study consist of two parts. Part one deals with introduction and review of literature, while part two addresses the present study.

2. REVIEW OF LITERATURE

2.1 AETIOLOGY AND MECHANISM

2.1.1 General Aspect

The questions to when, where, and how the injury occurred have a direct bearing on the orthopaedic intervention and its timing[33,67].A patient with open tibial fracture who underwent a two hour extraction from an automobile accident, would be at a higher risk of developing compartment syndrome than a patient with similar injuries who was admitted within 15 minutes of injury.Furthermore,a patient admitted after more than 6 hours post injury runs a very high risk of infection and the line of management is different from that of a patient who is attended less than 6 hours after injury[89].

The answer to where the injury occurred is equally important, especially with respect to possible contamination[68]. A victim of a farm yard accident might be at a higher risk for infection than a victim of a motor vehicle accident[106].Likewise wounds incurred in a tornado are virtually contaminated by finely dispersed soil which fills the air[43,106].Closing such wounds is likely to lead to serious infection including clostridial sepsis[231].

Probably the most important question concerns how the injury occurred, that is about the magnitude and direction of force or energy,that

caused the injury[10,4].The essential equation that represents the application of a violent force to the human body is expressed as $K=MV^2/2$, where M represents mass and V the velocity of the wounding force[43].The kinetic energy is a measure of how much energy can be absorbed by body tissues[195]. The kind of tissue injuries that occur vary in relation to the source of the kinetic energy. It doesn`t make any difference whether the body itself is in motion and the offending agent is stationary, or both the body and the agent are in motion[43].For example when a car strikes a pedestrian, an open fracture of tibia is produced. It is to be remembered that the force that brought about the fracture of the tibia is usually transmitted across the muscle belly in the calf even though the integument at that point had often remained intact[43].The fractured bone ends are deflected anteriorly against an area of poor musculature creating an open wound, but virtually the posterior musculature or soft tissue is often devascularised and contaminated[49]. The energy level of a 20 mph bumper injury is many times that of a high velocity gunshot wound[43,105],see table 1.

Table 1:

Shows energy levels of the tibia from various mechanisms of injury.

Mechanisms	Dissipated energy (ft-lb.)
Fall from a side walk	100
Skiing injury	300-500
High velocity gunshot wounds	2,000
Motorcycle injury	80,000
Automobile bumper collision at 20 mph	100,000

Modified from Gustilo[107] and Findlay[84]

Very often a limb is caught in a violent compressive force as it is the case when a motorcycle rider catches his leg between his machine and a car in a sideswipe collision[84,228]. Sometimes the visible wound is small but radiographs may reveal a wide separation between the tibia and fibula. Such separation denotes a very serious soft tissue injury with impending compartment syndrome[43]. This tip off in the x-ray should alert the clinician to take immediate measures in order to prevent problem.

2.1.2 Gunshot Injuries

In sharp contrast to automobile accidents, a missile is a dense body of comparatively small mass but in accordance with the formula $K=MV^2/2$, the missile achieves a state in which the energy dissipated is highly

magnified[1,190,222].Most low velocity weapons such as civilian handguns, fire bullet at a velocity of 200-300 m /sec,whereas high velocity ones fires at 800-1000 m / sec[1,70] .There are mainly 3 factors or mechanisms that determine the magnitude of tissue damage inflicted by a bullet[71,194,238].

(a).Laceration and Crushing,

(b) Shock Waves, and

(c) Cavitation.

As the missile penetrates any media the material in its path is crushed and forced apart. This is a characteristic of a low velocity missile. Shock waves are usually seen with high velocity missiles.[70] This affect areas relatively distant from the actual missile track. The input compresses the medium infront of the bullet, and this region moves away as a **"Fluid wave"** of spherical form. Cavitation is the third mechanism of tissue damage.[43,231,242] This is seen predominantly with high velocity missiles as well. As the missile penetrates, it accelarates the medium forward and sideways from its path with such force that the particles because of their inertia, continue moving for an appreciable time after the missile has passed. This expands the track of the missile in a cavity called **"Temporary or momentary cavity"** because it collapses quickly. It leaves a zone of injury whose dimension and extent of damage depends on the density of the medium and amount of energy transferred by the missile.[43,242] Lungs are less dense and contains compressible air so they suffer least, as opposed to the liver or muscles which have higher density and incompressible fluid.[231,242] The amount of damage is also inversely

proportional to the elasticity of the tissue.[242] Because the skin, is so elastic high velocity bullets may leave tiny entrance and exit wounds thus masking the actual injury. Along the missile track, it is a macerated track called the **"Permanent cavity."**Both permanent and momentary cavities are at sub-atmospheric pressure and will suck air and material in from both ends.[43] It has been conclusively demonstrated that the heat generated by the bullet does not render it sterile.[43,72,92,239] Therefore by definition, missile fractures are contaminated fractures. Fragments of bones and sometimes fragments of bullets, very often act as secondary missiles. They may tumble around in the tissues and cause injury to the blood vessels and nerves.[43,72,238]

2.1.3 Shotgun Injury

Shotgun injuries are unique because of the shape and multiplicity of the pellets in the shell, and because of their rapid changes in impact velocity depending on target distance[71,229,238].They tend to scatter at target point, but initially they move from gun barrel in a rather dense group called"shot cloud." If they are fired at a very close distance while still quite closely packed, their collective impact may be somewhat like that of a high velocity bullet[242].However,each pellet has so much less kinetic energy than a bullet, and it is rapidly expended as target distance increases. Thus many such injuries, most of them inflicted at long range (more than 7.0m), rarely penetrate the deep fascia[1].The old style wadding shell is extremely irritative to tissues and incites a severe inflammatory reaction when left in

situ[43,190,204,206,238]. The modern plastic plug is less damaging. However all kinds of wadding must be looked for especially in close range wounds. There are many other examples of how injury is incurred but these few should make a point.

2.2 VASCULAR ANATOMY OF MUSCLE

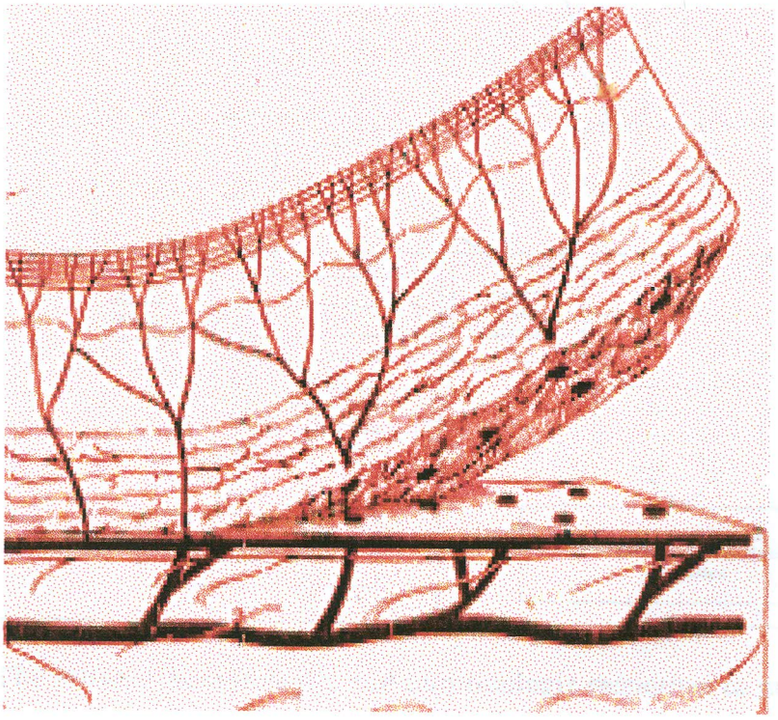
Recognition of the reconstructive potential of soft tissue territories vascularised in an axial orientation has lead to the conceptualisation and utilisation of axially supplied muscle, musculocutenous, and fasciocutaneous for both local and free donor sites.[34] (See table 2). For example,each head of the gastrocnemius is supplied by a single vascular pedicle (sural artery) which enters proximally.[82,149,151] This allows for a very proximal rotation axis to cover defects in the proximal third of the tibia.[34] The distribution of the muscle bulk of the soleus allows its rotation for defects in the middle third of the tibia. The muscles in the deep posterior compartment of the leg are very limited in utility for rotation and tibial coverage[34].

Pattern of muscle blood supply, a key for the soft tissue reconstruction (Mathes and Nahai.[149])

Table 2 shows classification of the vascular anatomy of muscles

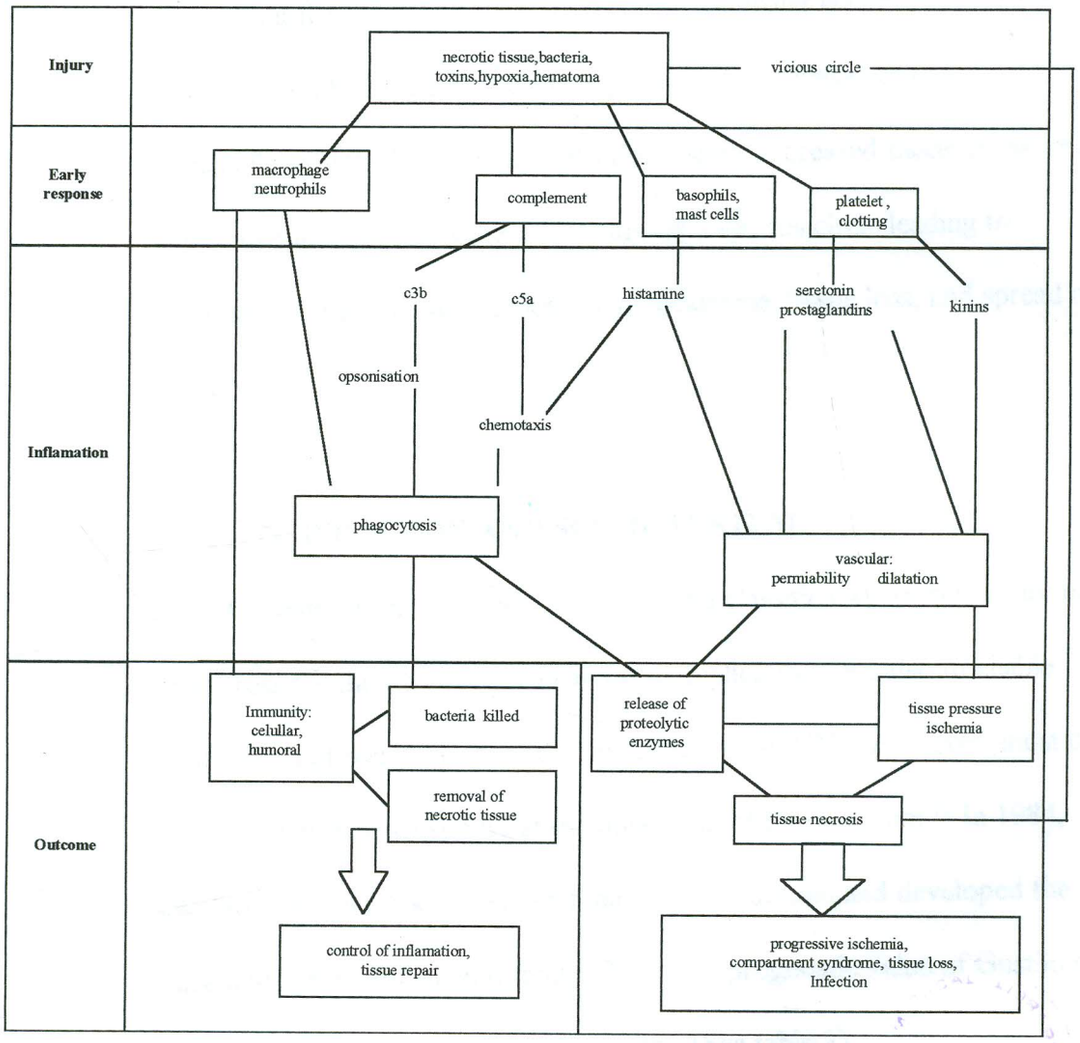
Type	*No of pedicle*	*Examples of muscles*	*Reliability for local or remote transfer*
I	One	Lateral and medial gastrocnemius, and tensor fascia lata	Excellent
II	One or two	Soleus, Peroneus longus and brevis, Gracilis, Vastus lateralis, Biceps femoris, abductor hallucis, and flexor digitorum brevis.	Good
III	Two	Rectus abdominis, Gluteus maximus and Seratus anterior.	Good
IV	Multiple	Extensor digitorum longus, Extensor hallucis longus, flexor digitorum longus.flexor hallucis longus, Satorius and Tibialis anterior.	Fair (very limited)
V	One	Latissimus dorsi, and Pectoralis major.	Excellent

The skin and subcutaneous region of the leg have a dermal and subdermal plexus, that are supplied predominantly by vertically oriented perforators from underlying muscle and fascia[108]. The perforators in turn receive blood from axially supplied muscle as mentioned above. The blood supply of the skin flap harvested for transplantation is considerably compromised because the perforators are transected as opposed to a muscle flap aimed for microvascular anastomosis[33,241] (figure 1).



2.3 PATHOPHYSIOLOGY OF MUSCULOSKELETAL INJURY

Figure 2 The inflammatory sequel in musculoskeletal trauma.[10]



The cellular, hematologic, and immunologic responses to injury leading to repair or further tissue destruction

If the soft tissue injury is minor, or if thorough debridement and antibiotic agents have been instituted to control most of the necrotic, foreign material, and bacteria, then the inflammatory response is controlled and tissue repair ensues.[10,51,81] With massive injuries or severe contamination, the

macrophages cannot deal with the bacterial load. They die and release lysosomal or other proteolytic enzymes which cause further necrosis of the surrounding tissues.[51] This deleterious effect is further enhanced by release of mediators of inflammation and subsequent vascular dilatation and permeability.[10,167] This together with the ensuing increased tissue pressure and muscle ischaemia, (see figure 2) propagates a vicious circle leading to progressive inflammation, compartment syndrome, tissue loss, and spread of infection.

2.4 CLASSIFICATION AND SCORE SYSTEM

2.4.1 Classification: The mojar purpose of a classification system is not only to address the therapeutic and prognostic implications but also to enable comparison of results in scientific publications.[33,43,107.214] However, most of such systems lack sensitivity at the upper end of the spectrum.[10] In 1984, Gustilo and Co-workers revised their previous system and developed the most accepted system for open fractures.[33,104] The prognostic value of Gustilo and Co-worker system is significantly greater. (See table 3)

Table 3: Classification of open fractures according to Gustilo and Co-workers 1984

Grade	*Wound*	*Level of contamination*	*Soft tissue injury*	*Bone injury*
1	< 1 cm long	Clean	Minimal	Simple transverse or short oblique fracture.
2	> 1 cm long	Moderate	Moderate crushing component	minimal comminution
3A	Usually > 10 cm	High	severe crushing component	moderate comminution.soft tissue coverage of bone possible
3B	Usually > 10 cm	High	Very severe loss of coverage. periosteal stripping	Severe comminution Bone coverage poor. usually require soft tissue reconstruction surgery
3C	Usually > 10 cm	High	Very severe loss of coverage. plus vascular injury requiring repair	bone coverage poor. usually require soft tissue reconstruction surgery

Amputation ,farm yard injuries,fractures occurring in highly contaminated environment, high velocity gun shot wounds, close range shotgun wounds, high energy trauma, segmental fractures, and fractures with loss of bone , irrespective of the size of the wound all automatically are considered as a grade III open fracture.[43,104]

From table 3 above; a type I wound is caused by a low energy injury and is usually less than 1 cm long. It is usually caused by a bone piercing from the inside outward rather than a penetration injury.

A type II wound is greater than 1 cm in length and has a moderate amount of soft tissue damage. These are generally outside inside injuries.

A type III wound result from a high energy outside to inside injury with extensive soft tissue devitalisation. It is generally greater than 10 cm and the fracture is widely displaced or comminuted. Type III wounds are further classified as follows:[104]

III-A: Is an open fracture in which there is limited stripping of the soft tissue and periosteum from bone,and bone coverage does not present any major problems.

III-B: Is an open fracture in which there is extensive stripping of soft tissue and periosteum from bone, and where devitalisation or loss of soft tissue requires plastic reconstructive procedures for closure.

III-C: Is an open fracture in which there is a major vascular injury requiring repair for salvage of the extremity.

2.4.2 The Mangled Extremity Severity Score:

Several investigators have now tried to address the dilemma between sacrificing a potentially useful limb and the time consuming resource intensive salvage of a functionally useless extremity[99,111,83,88,134,159].Johansen[88] and colleagues, Gregory[99] and associates each developed a detailed score system called The Mangled Extremity Severity Score **"MESS"** and **(NISSSA)** respectively in order to predict the need for amputation. (See table 4 and 5 below)

Table 4 Mangled Extremity Severity Score (MESS)

A SKELETAL/ SOFT TISSUE INJURY	POINTS
low energy injury	1
medium energy injury	2
high energy injury	3
very high energy injury	4
B LIMB ISCHAEMIA	
pulse reduced, or absent,but perfusion normal	1*
pulseless, parasthesia, diminishing capillary refill	2*
cool, paralysed, insensate, numb	3*
C SHOCK	
systolic BP always greater than 90 mmHg	0
hypotensive transiently	1
persistent hypotension	2
D AGE	
< 30	0
30 -50	1
> 50	2

*** Score doubled for ischaemia greater than 6 hours**

The above score is relatively simple, easily applicable, and readily reproducible and still shows high Positive Predictive Value.[10] A score of great than or equal to 7 is 100% accurate in predicting a need for amputation [164]

Table 5: MANGLED EXTREMITY SYNDROME GRADING SYSTEM [99,86]

(NISSSA)

A: Injury Severity Score	
0-25	1
25-50	2
>50	3
B: Integument	
Guillotine	1
Crush/ Burn	2
Avulsion/ Degloving	3
C: Nerve	
Contusion	1
Transection	2
Avulsion	3
D: Vascular	
Transected	1
Thrombosed	2
Avulsed	3
Vein drainage	1
E: Bone	
Simple	1
Segmental fracture	2
Segmental comminuted fracture	3
Segmental comminuted fracture with a bone loss < 6 cm^+ (add 1 point for bone loss > 6)	4
Segmental comminuted fracture intra-articular or extra-articular with bone loss <6 cm	5
Segmental fracture intra-articular or extra.articular with bone loss > 6 cm	6
F: Lag Time *	
G: Age (years)	
40-50	1
50-70	2
>70	3
H: Pre-existing disease	1
I: Shock	2
A Score of less than 20 points suggests that salvage should be attempted. Conversely, amputation should be done if the score is more than 20 points	

*** one point for every hour > 6**

2.5 TREATMENT

2.5.1 PHILOSOPHY AND CONCEPTS

From the fact that fractures with major soft tissue disruption occur in association with injuries to other parts of the body, the surgeon must consider such injuries in the context of polytrauma recognising the patient as a whole[10,32,33,43]. Care of this patient is categorised and carried out in three phases[10]. The acute phase that includes resuscitation and identifying life threatening conditions, wound debridement, fracture stabilisation, soft tissue reconstruction, and restoration of muscle function and joint motion. The second phase is the reconstructive phase that addresses the problem of treatment such as infection, non-union, malalignment etc. The third one is the rehabilitative phase that focuses on the patient`s psychosocial and vacational rehabilitation.

While in the past only few patients returned to work before one and half to two years, at present clinicians or surgeons are striving to see the patients back at the work place and recreational pursuits before the first anniversary of the injury[10,43]. To achieve such goals, the patient`s course of treatment and recovery is planned right at day one of injury, and the three treatment phases are no longer carried out sequentially as it used to be but are overlapped, and on discharge from hospital the patient has gained some mobility and is enrolled in a well structured and monitored program of outpatient clinic[10,28].

2.5.2 ACUTE PHASE

(i) Prehospital and Emergency Room Care

At the accident scene the rescue workers must first direct their efforts at identifying life threatening conditions and be as complete as the patient`s status permits. The (ABCs) of initial management is addressed[10,43,58]. A- stands for airway, B-for bleeding, and C-for circulation profile[32]. Any attending personnel must assure that the patient has an adequate airway and cardiopulmonary function is enough to sustain life. Oro-airway should be cleared of debris, and whenever necessary intubation done. The open wounds are covered by sterile compression dressings to control haemorrhage,and a deformed limb is gently reduced, aligned, and splinted[10,43]. Tourniquet may be needed for a traumatic amputation or uncontrolled haemorrhage. Evidence of inadequate circulation **(shock)** requires immediate fluid administration, blood transfusion, and an immediate search of hidden life threatening source of haemorrhage in the abdomen, chest or elsewhere[58].

Dressings and splints are partially removed to inspect the wound and assess and muscular function of the extremity. All relevant adjacent joints should be thoroughly examined and the normal side is always compared to the abnormal side. A good quality anteroposterior (AP) and lateral x-rays of the fracture, including the joints above and below is the minimum examination necessary in any open fracture.

(ii) Tetanus Prophylaxis

Table 6: A guide to tetanus prophylaxis[10]

Abbreviations: **TT = Tetanus Toxoid,**
TIG = Tetanus Immunoglobulin

History of tetanus immunisation: (doses):	*Clean & minor wounds:*		*All other wounds:*	
	TT	TIG	TT	TIG
Uncertain or less than 2	YES	NO	YES	YES
Two	YES	NO	YES NO^{+++}	
Three or More	NO^{+}	NO	NO $^{++}$	NO

\+ **Yes if more than 10 years since last dose.**
++ **Yes if more than 5 years since last dose.**
+++ **Yes if wound more than 24 hours old.**

In every case, the patient`s immunity to tetanus is determined and either TT or TIG is administered according to the above schedule.[10] (Table 6). More frequent boosters are not needed and can even accentuate side effects.[224]

(iii) Antibiotic Administration

(a) Systemic Antibiotic

Are antibiotics in open fractures prophylaxis or therapeutic[4,43]? Purist would argue that in the acute wound, infection is not present and therefore antibiotic is not prophylactic or therapeutic for that matter. On the other hand, despite adequate debridement and irrigation some organisms remain and hence the role of host defence and antibiotics.[10,43] Therefore antibiotics in open fractures remained controversial until 1974, when Patzakis[178] proved their effectiveness in a prospective double blind trial. Other studies have since

confirmed the findings,[4,22,69,226] and this justified current routine use of antibiotics in open fracture in the first 3 to 5 days. On the other hand some workers prefer a single bolus or dose during induction of anaesthesia and continue the regime over the next 24 hours. When in the past staphylococcus aureus was a major player, today gram-negative organisms and mixed infections have become very prevalent thus imparting a change in the use of antibiotics[43] .

In grade I and II, cephalosporin is still preferred by most clinicians.[226] It is effective against most gram positive and negative organisms except pseudomonas. In grade III wounds an aminoglycoside (gentamicin or tobramicin) is added.[10] For fractures associated with a high contamination, vascular compromise, or severe soft tissue crush, penicillin G is added.[4]

General principles important in the use of antibiotics include;[43] (a) Parental administration of antibiotic as soon as possible, preferably during the emergency room care (b) choice of antibiotic that is bactericidal and active against gram negative and positive organisms.

(b) Local Antibiotic and Antiseptics

In an attempt to increase local concentration and retain prolonged action, numerous antibiotics have been incorporated in slow release carriers such as polymethylmethacrylate (PMMA)[77,218,220].However, because of the low concentration of antibiotic from PMMA in the local area, a swing to the use of collagen fibre impregnated antiseptics has gained much popularity[43].

One example is current use of taurolidin-polyvidon impregnated collagen which is reabsorbed in electrolytes solution. It has been found to be effective in infected arthroplasties, chronic osteomyelitis, and recently in high risk open fractures[107,14].Whereas beads have to be removed at intervals from 3 days to 2 weeks, collagen need not to be removed. In addition, secondary hematogenous infection of beads that were left permanently has been reported[10]

(iv) Surgical Intervention

While most clinicians agree on the priorities on life saving and stabilising measures, much controversy surrounds the issue of surgical intervention and focuses primarily on its timing[32].Most trauma centres advocate early, aggressive intervention for the management of acute musculoskeletal injuries. This concept has been termed orthopaedic resuscitation[35,130].Its benefit in patients with polytrauma scenario has been ernomous[32,33,130].

(v) Preparation for Surgical Debridement

In preoperative planning, the order in which multiple fractures will be treated, the teams necessary to treat them, are identified and made available[43].The optimal position of the patient on the operating table, and the need for the orthopaedic fracture table or fluoroscopy is determined[10,43].

In addition to eliminating the contaminating bacteria from the wound, it is critical to avoid further contamination by the hospital based organisms which

may prove to be even more virulent than those already in the wound[33,43,106]. For this reason debridement is carried out in a surgical suite and not in an emergency room. Only in the operating room are all splints and bandages removed. While maintaining gentle traction to prevent further injury to soft tissues the limb is elevated, and the operating team proceeds with the formal surgical preparation[43].A tourniquet is applied but is inflated only in case of massive bleeding.This approach prevents further ischaemia and makes it easier to assess soft tissue viability[10,32,43].

(vi) Irrigation and Debridement

The critical point in debridement is the meticulous removal of foreign materials, and all non viable and contaminated tissues.[27,43,105] The foreign bodies, especially organic if left in situ are very likely to incite an inflammatory response[43].Bullets and pellets are not easily sought out and removed from tissues[1,43,136].An exception of removing a bullet or particles occurs if they lie in the joint, pleural space, or in the subarachnoid space. Associated high energy injuries should be explored and redebridement carried out in the operating room within 48-72 hours and this can be repeated every 2-3-days until the wound is closed or covered[10,43].

In addition, such high energy lesions have a zone of soft tissue injury much larger than the fracture site itself[27,35,37,104,133].Exploration of the zone is vital as very often the broken bone is only the tip of the iceberg. Initial appreciation of such zones is crucial for the development of treatment

strategies for these lesions.[107.191] Radical, and repeated debridement of not only the fracture site but also the entire zone of injury, including obliteration of dead spaces is essential to promote cure. Afterwards fracture stabilisation and soft tissue coverage can continue much more safely.

While debridement per se is the essential component in open fracture surgery, there is a clear advantage of a properly carried out irrigation.[43,106] It was shown by Gustilo and associates[106],that in a series where less than 10 litres of normal saline were used, there was a high incidence of infection than in a series where more than 10 litres were used. However, whatever amount of fluid used, irrigation must be thorough and copious.[43] In a comparison study Museru[166] et. al. analysed the efficacy of Normal saline, distilled water, and boiled water as irrigating fluids in open fractures. The outcome was not affected by the type of the irrigating fluid. Since the volume of fluid is critical, it was concluded in this series that distilled and boiled water is quite a favourable alternative to otherwise scarce and expensive normal saline or ringer`s solution.

The advantages of irrigation include.[27,43]

(a) Flushing away blood clots, necrotic tissues, debris, clears the wound and facilitates debridement.

(b) Lavage restore normal colour of the tissue and assists determine viability,

(c) It reduces bacterial population. While irrigation by conventional methods like use of syringe that provide jet by a hand push are still common,

mechanical irrigators which pump fluid in a controlled manner are now available [102,144]. However, such irrigators may drive the debris or other foreign materials into deeper tissue planes and thus render debridement a difficult process.

(vii) Debridement

Debridement should be done in a systematic and logical manner from exterior of the wound toward its depth.[10,43] Considering the type of tissue,the debridement process is divide into four areas: Skin and subcutaneous tissue, fascia, muscles and tendons, and bone[26,35,181,214].

(a) Skin and Subcutaneous Tissue

The enlarging incision must; be extensile, enable effective debridement, avoid creating flaps especially distal ones, respect vascular territories, facilitate placement of implants, and wound closure.[26,43] Small puncture wounds or holes are excised in a manner that create an elliptical wound.[43] The elliptical wounds are easy to close , and can even be left open for a spontaneous closure leaving only a simple linear scar. Great efforts should be made as much as possible to preserve skin.[43,234] Subcutaneous fat has scanty blood supply and should be debrided.[43] The skin of amputated parts and cutaneous flaps can be used as donor sites for split thickness grafts.[27,43,234] Such grafts are used to cover skin defects where appropriate.

(b) Fascia

Any fascia that is nonviable, damaged, or contaminated is excised.[10] In addition,most authors now favour the practice of prophylactic fasciotomy and epimysiotomy in all open fractures secondary to high energy injury.[26,43,104] Limited fasciotomy is sufficient but often formal fasciotomy is required particularly in injuries associated with arterial repair.[83,84,172] In the leg all four compartments are released, and this is best done through one long incision over the lateral compartment.[43]

(c) Muscle

Necrotic muscle is the major and suitable media for bacterial growth, and posses a great danger for anaerobic infection.[74,106] All nonviable muscle must be removed although often this will require careful judgement. Judgement of the muscle viability is very challenging.[27,43] The parameters provided by Gregory[99], should be well addressed by the surgeon. These are the (Four C`s): **Colour, Consistence, Contractility, and Capacity to bleed.** According to Scully et als [202] consistence and capacity to bleed were the most significant, but from Chapman`s experience [43,46] contractility and consistence have been the most reliable because the other parameters are easily misinterpreted.
It should be remembered that the hypoxemia associated with a use of a tourniquet, shock, or injury to a major vessels may make the evaluation of these parameters a difficult exercise[43,58].

(d) Tendon

All tendons essential to function are preserved[10,43].Where coverage of tendons by some type of soft tissue is not be possible, preservation of peritenon is essential for tendon survival. Otherwise moist dressings should be applied on them until coverage can be obtained[43].If possible one should try to swing some muscle, subcutaneous tissue, or skin to cover the tendon without peritenon[46,98].

(e) Bone

The free ends of principal bone fragments must be delivered into the open wound[10].The medullary cavity is carefully examined and cleansed of all foreign material.The critical issue concerns the judgement of the bone viability[27,43].If judgement about muscle viability seems troublesome, then judgement about what is to be done with bone fragments is very perplexing[104,105,,132,214].All small devitalised pieces of cortical bone are removed, but cancellous bone is cleaned and retained as bone graft. Large bone fragments are retained if they are critical for stable reconstruction of the extremity. However, severely large contaminated fragments are discarded, and the defect later corrected by one of those reliable techniques of bone grafting or distraction osteogenesis[96,86,145,176], (see figure 7). Likewise, most of workers in open fracture surgery now advocate removal or resection of extensively large devascularised fragments for the very same reason given above. Moreover, a delayed union or non-union that may result is a far less challenging complication than an infected non-union[29,43].It is critical to

preserve any remaining periosteum,otherwise the bone must be covered by muscle, subcutaneous tissue, or skin to prevent desiccation and death of the bone[10,43].

Furthermore, when dealing with established bone infection, aggressive excision of dead bone, scar tissue, infected granulation tissue, as well as obliteration of the dead space is mandatory.[31,26,96,145,191] Historically, Orthopaedists have been reluctant to debride these lesions radically because of lack of reliable alternatives for bone and soft tissue reconstruction.[200] However with even the absence of newer plastic surgical techniques for wound management, still there is a clear advantage to radical debridement alone with subsequent bone grafting using the Papineau technique or by skin grafting of the newly developing granulation tissue[39,169].

(f) Joints

It is critical that the entire joint be explored and debrided through arthrotomy and sometimes arthroscopy[46]. A drain especially sunction type is left in situ not less than 24 hours.Beside removal of foreign bodies, osteochondral fractures are inspected for and noted[43].

(g) Vessels and Nerves

Major vessels and nerves in the zone of injury are commonly great obstacles to adequate debridement[27,43,177]. They should be carefully identified, mobilised, and separated from surrounding nonviable tissue. If transected,

major arteries and nerves must be repaired. The injury to these structures calls for first hand priority, since a loss of total blood supply to the limb for more than 8 hours will always result in amputation[33,107,214]. A very quick initial debridement and irrigation is done to remove the greatest contamination and then proceed with the repair. Repeat debridement is frequently done as stated above and external fixation is the preferred method of fracture immobilisation[10,8,44]. Hughes[84], and Hansen[111], have shown that non-operative immobilisation eg. traction may also work especially in a mass casualty situation.

2.5.3 AMPUTATION AND LIMB SALVAGE (REPLANTATION)

Amputation after severe limb injury is a critical decision[27,33]. Post-traumatic amputation can be divided into three different time periods:[27,33,43,105].

Immediate, Early, and Late amputation.

(i) Immediate Amputation:

This is done during the initial or primary treatment of the injured limb. There are several indications for immediate limb ablation[27,43,104,105,134].

1. When the limb is non viable. That means there is neuro-vascular injury that is irreparable or is accompanied by ischaemic time of more than 8 hours.

The following indications below from number 2 through 8 depend very much on the MESS system, (see table 4).

2. Loss of neurocontinuity to the leg in association with extensive soft tissue and bone damage. (Complete and irreparable transection of posterior tibial nerve itself is an indication for amputation)
3. Skin, muscle, and bone damage, that even with an intact neurovascular system is extensive enough to preclude the possibility of adequate limb function.
4. A coexisting severely debilitating medical disease and a severely injured limb where preservation of the limb is a threat to the patient.
5. In a limb where the severity of injury will demand multiple surgical procedures and a prolonged reconstruction time that is incompatible with the personal, psychosocial, and economic consequences to which the patient is not willing or able to withstand.
6. In a military situation where the severity of limb injury and salvage of life, transport of the injured victims, plus the need to direct attention to other severely injured patients justify amputation.
7. In a patient with severe multiple system injuries with a MESS of approximately 7 or more.(see table 4).
8. In cases of amputation, where the function does not justify salvage e.g. amputation of a single toe through zone two, the area of the proximal phalanx.

Lange and associates[134], published absolute and relative indications for immediate amputation which form a good guide line. Absolute indication is

item 1, and relative ones are items 2 through 8 in the list above. However, the decision to amputate or not is better based on the MESS system, (table 4).

(ii) Early Amputation

Early amputation is defined as any ablation done after the initial or primary treatment, and can be performed on the 1st postoperative day to 6 months later[36]. The most common indication is progression of tissue necrosis preventing functional limb salvage, following severe crush injury or failed vascular repair. The medical factors mentioned earlier play a role in early amputation, as only little may be known about the patient`s medical history[36,104].

(iii) Late Amputation

Late amputations are usually done 6 months after injury, and are performed after completion of wound closure or coverage[36]. Indications include[27,43],(a) failure of successful wound coverage with persistent infection resistant to debridement, and (b) persistent chronic osteomyelitis

2.5.4 FRACTURE STABILITY

2.5.4.1 Importance of Skeletal Stability

Immobilisation is crucial for the healing of soft tissues and bone[45,233]. From the stand point of view of the injured site, stabilisation of the fracture fragments[10,36,43] ;

a) Prevent further injury to the surrounding soft tissue sleeve and neurovascular structures.

(b) enable realignment of neurovascular structures that provide optimal circulation and improves venous and lymphatic return thus reducing soft tissue oedema.

(c) Facilitate revascularization of devitalised bone and soft tissue thus improving the tissue perfusion that in turn improves nutrition and local wound defence.

(d) Decrease pain and thus preventing the possible neurogenic shock.

On the other hand, stabilisation from the point of view of the whole patient[32,33,130];

(a) Permit muscle rehabilitation and joint motion.

(b) Enable early mobilisation.

(c) Facilitate pulmonary care.

(d) Prevent thromboembolic phenomena.

(e) Afford greater ease in nursing care and management of injuries elsewhere.

Stability can be achieved by traditional plaster casts, traction, external fixation, internal fixation with intramedullary nails, and kirschner wires, screws and plates or combinations of these. Whichever method is chosen it should meet certain criteria that include[10,35,46,164,18]:

1. It should not compromise further the injured soft tissue and bone.
2. It should provide free wound access for the inspection, redebridement, placement of local and distant flaps and bone graft.

3. It should maintain length of the bone.
4. It should produce good alignment of the bone fragments especially the joint surfaces.
5. It should be sufficiently stable and rigid to allow early joint motion and at least partial weight bearing.

All this must be achieved without undue risks and complications.

2.5.4.2 TYPES OF IMMOBILIZATION

(i) Splints, Casts, and Traction.

For many centuries, only non rigid methods including splints, casts, and traction, were used to stabilise open fractures[36,139,222].However, splints have the problem that their ability to control length and alignment is poor[35,36].

Casts or plaster of Paris have limitations because[36,43];

(a) access to the wound may be difficult,

(b) may increase the risk of contaminating the wound,

(c) they involve the circumferential hard material on a limb with potential for swelling and consequent development of compartment syndrome and

(d) they do not rigidly immobilise the fracture fragments hence high incidence of malunion, malrotation, shortening, and non-union.

On the other hand, casts are well desirable in[10,35,36,43] ;

(a) Type I and II open fractures especially in children,

(b) severe head injury with increased intracranial pressure,

(c) coagulopathies,

(d) life threatening conditions e.g. tear of aortic arch, and

(e) in multiply injured patients.

A full length longitudinal cut is made in the cast to produce univalved cast[43].Such a cast is superior to a bivalved one because it can be spread to accommodate the limb without loss of significant fracture reduction, and it provides more uniform decompression of the limb[36,43].Careful windowing in the cast over the wound may be sufficient for wound inspection and dressing. However making a bubble in the cast may be preferred.[43] A bubble is the circumscribed piece of plaster cast cut from the main plaster at the wound site and reinforced by more plaster. When fastened to the wound it offers a uniform compression thus preventing post window aedema.

The window or bubble must be 2.5 to 5 cm in diameter larger than the widest part of the wound[36,43].

Traction is a "classic" fracture treatment[10,36,43].Today it is only common in third world countries where immediate external fixation is not available. Skeletal traction may be carried out by inserting Steimann or Denham (threaded) pin through the calcaneum, tibial tubercle, or distal portion of the femur. Traction has a very significant place in complex tibial or femoral fractures in a situation where external fixator is not immediately available. Traction necessitates not only relative immobilisation of the whole patient but also requires prolonged hospitalisation[18,36,43].Other disadvantages are those listed above under the use of casts.

The advantages and beneficial effects of early functional weight bearing casts on the healing of fractures in the lower extremity have been demonstrated by Sarmiento,[196] Dehne,[65] Brown[24] and Urban,[10] hence the term (Sarmiento`s cast) This permits intermittent cyclic axial dynamization during loading similar to what takes place in treatment of fractures with the Ilizarov ring fixator.[89,145] Such total contact casts are normally delayed for up to 2 to 4 weeks.[43] The evolution from weight bearing casts to cast braces and prefabricated braces has been well described by Sarmiento[196].

(ii) External Fixation

(a) General aspect

Although the external fixator long appeared ideal[10,11,219], it is until two decades ago, when half pin frames were popularised by Fischer[85] and the AO group[164].Since then external fixation system has become the fracture stabilisation method of choice for the treatment of the most open fractures of the long bones especially the tibia[43,54,145,149,215].

External fixation device offers the following advantages[10,13,36,43]:

1. It is easily applied without placing foreign material into the wound.
2. It can be applied without additional soft tissue dissection and thus minimising infection.
3. It provides good rigidity and stability though there is certain shearing forces that may lead to instability .

4. It provides great versatility and flexibility because configuration and rigidity can be easily changed.
5. Joint motion and muscle rehabilitation is possible, and in certain instances even partial weight bearing.
6. Cardiopulmonary care is facilitated because the patient is mobile.(Low incidence of ARDS).
7. The delta (bimodal) construction enables sequential disassembly. That is the rigidity of the frame can be decreased during the course of the treatment thus allowing soft tissue healing , a first priority, and bone healing later.

- Regardless of the type of external fixation system used, the following precautions or points about application are important[8,36,43]:

(a) Bone necrosis is avoided by predrilling for the fixation pins using a water cooled, sharp, drill point of the appropriate size, and pins are inserted by hand. Necrosis cause loosening of the pins and finally infection.

(b) Loosening is more a problem in osteopenic and cancellous bones than in cortical bones.

(c) Pin drainage occurs in about 30% of all patients, but pin tract infections that require more than local care have become rare.

(d) Surgeon must be sure beyond doubts that there is no skin tension on the pin during and after the insertion.

Skin tension cause pressure necrosis of the soft tissues and this leads to pin tract infection.

(e) Tying down of musculotendinous units and injury to neurovascular structures must be avoided.

(f) The stability of the frame pin construction can be enhanced when;

(i) pins of larger diameter and shorter thread portion are used which purchase the far cortex only.

(ii)the minimum is two pins per bone fragment,

(iii)the first pin is located close to the fracture site and the second remote to the fracture site,

(iv)the working distance between the connecting bars or rings and the limb is made as minimum as possible,

(v) The single plane-half pin frame construction is further assembled to double plane, or two bars instead of one are used.

External fixators using **self taping** shwanz screws have a very high cost effective, and are very usefull in developing countries where resources are very limited. Predrilling with either mechanical or power drills is not required. The on going study with one of this type of fixator the tanzafix, at MOI (Muhimbili Orthopedic Institute) is one of a very good such example.

(b) Postoperative Management

The most effective method in post-operative care of EF is simple cleansing of the entire external fixation frame, pins sites, and skin daily with any commercial bathing soap to which the patient is not allergic[43].An effort should be made to remove all crusts and debris around the pin sites. The time

any persistent drainage is noted from the pin site, or discomfort is present, loosening of the pin must be suspected[36,43].Loose pin must always be removed, and if necessary replaced by new pin in another location. Sometimes the entire frame may need to be removed or replaced[8,43].

(c) Indications

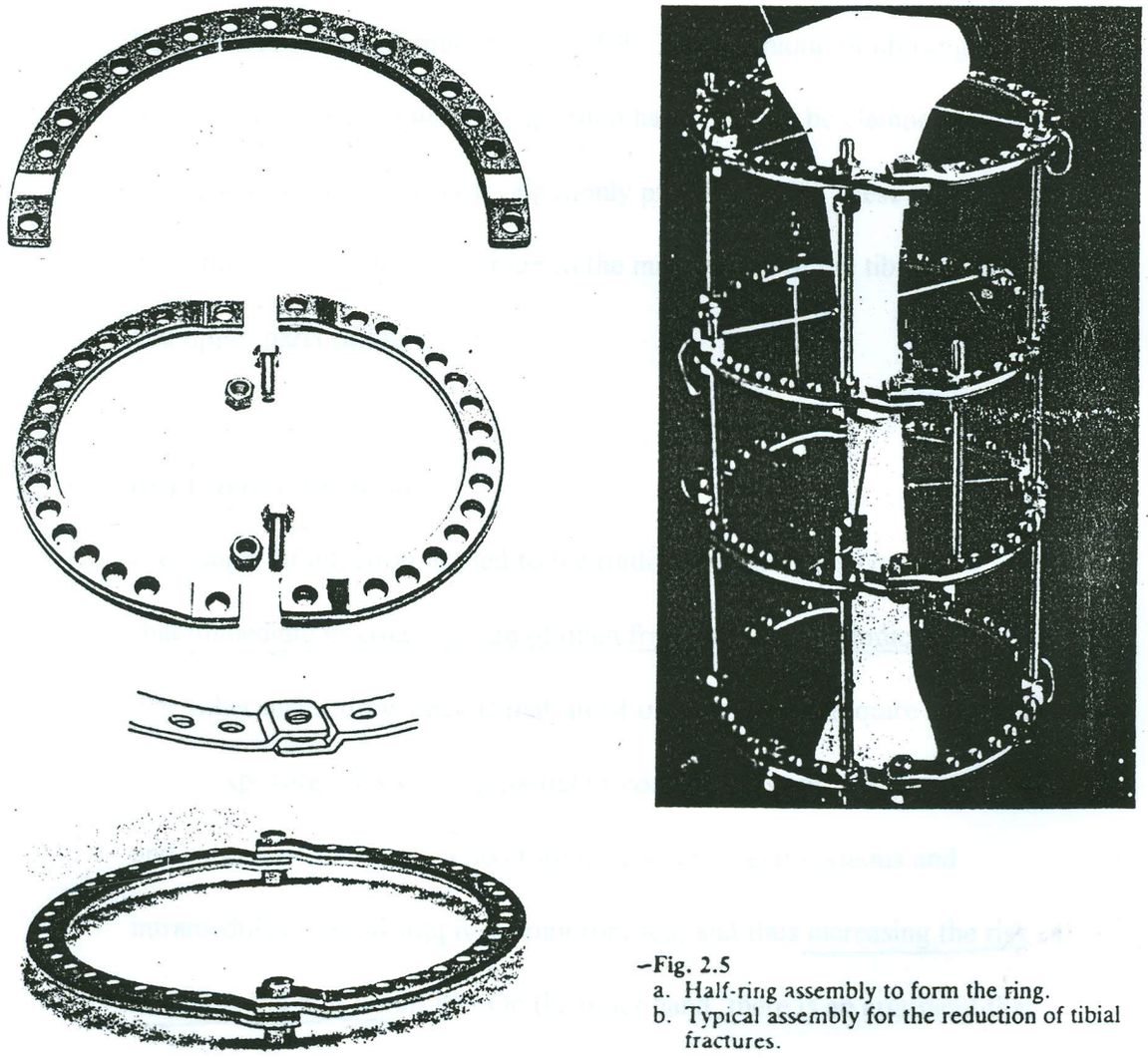
With regards to open wounds, external fixation is indicated in fractures associated with moderate to severe soft tissue injury[10,36,43].Nevertherless,external fixation is most strongly indicated in all grade III open fractures[10,105,107,214].

(d) Ilizarov Ring Fixator

This is an external fixation device using wires under tension and suspended from metal rings designed by Professor Gavriel Abranovic Ilizarov[43,145].The Ilizarov ring fixator gives the most optimal and unique biomechanical characteristics for fracture healing[89].It differs significantly from conventional unilateral or bilateral fixators in that, it maintains axial elasticity that permits cyclic axial dynamization which encourage fracture healing, remodelling and maintain bone mass[145].In addition, a four ring type Ilizarov using 1.8-2.0 mm olive wires under 100-130 kg of tension provide the most reliable shear control as opposed to conventional fixators[8,89].

Figure 3: The standard four ring configuration of Ilizarov fixator optimal for stabilisation of the most tibial fractures[145].

(a) (b)



–Fig. 2.5
a. Half-ring assembly to form the ring.
b. Typical assembly for the reduction of tibial fractures.

When the Ilizarov fixator is compared with a variety of the common uniplanar half pin fixators, the Ilizarov is significantly less stiff in lateral bending, and also comparable in anteroposterior bending and torsion, and even more significant is that, it is 75% less stiff in axial loading.[89,145]

While in Russia the device has been used for years in the management of acute trauma and soft tissue defects, most workers elsewhere in the world apply the technique in the treatment of both non-infected and infected pseudoarthrosis, bone defects, and deformity[43,175,176,206,207]. The technique of utilising partial or half rings to which large 5mm half pins may be clamped to substitute for transfixation wires is now commonly practised[178,204]. These are particularly helpful for anchorage to the mid aspects of the tibia, as well as mid and upper parts of the femur.

(iii) Internal Fixation

The danger of infection has led to the traditionally accepted opinion that immediate internal fixation of open fractures is contraindicated[3,9,10,23]. The other major draw back is that, most of the methods require additional soft tissue exposure, thus causing partial or complete loss of periosteum, cortical, and soft tissue coverage. Therefore the source of extraosseous and intramedullary blood supply is compromised, and thus increasing the risk of infection and non-union.[36,43] On the other hand, there is an argument that internal fixation provides excellent stabilisation of the injury zone, allows for early limb and patient mobilisation, facilitates fracture consolidation, lowers the incidence of ARDS in multiply injured patients, and prevents malunion and loss of length[36,93,130,164,205].

(a) Wires and Screws

Screw fixation is the most appropriate for the stabilisation of intraarticular or periarticular fractures where it is used alone, or in combination with a plate or external fixator.[10,43] Very often too, a combination of screws and wires is used for intra-articular fractures[39,228].

(b) Intramedullary Nailing

There are three types namely, the reamed nail, unreamed nail, and small flexible unreamed nail[36,43].While closed unreamed intramedullary nailing is safer for the soft tissue coverage, periosteal blood supply, and fracture hematoma, it is not clear yet wether they are not or less injurious to the intramedullary blood supply[10,141,153,174,205,217].At present, locked or unlocked, reamed or unreamed intramedullary nailing are the treatment of choice for open grade I, II, and possibly IIIA open tibial and femoral fractures[141,164,205,229].

(c) Plates

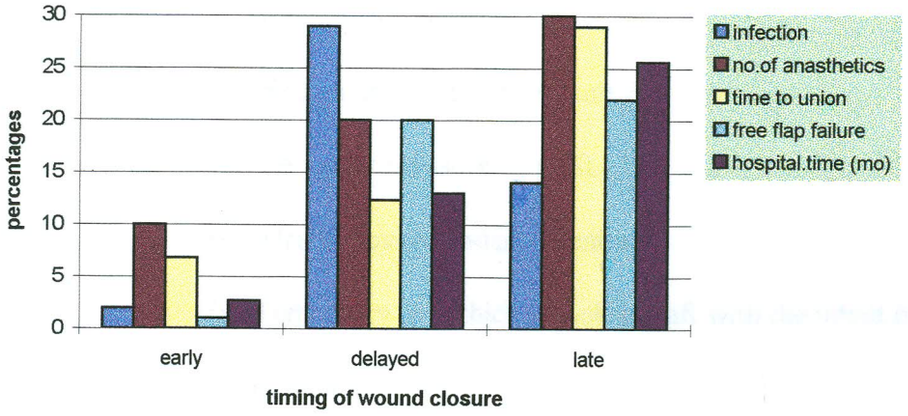
Plate fixation usually result in a good anatomic reduction and relatively rigid fracture fixation but requires soft tissue and periosteal stripping[10,36].This additional stripping, the presence of a large foreign body, and large cortical fragments of undeterminate viability in an already compromised soft tissue environment, makes plate fixation a unsuitable choice for the salvage of high energy leg injuries[68,101,106].In very distal or proximal fractures of long bones, eg. pilon tibial or tibial plateau fractures with intra-articular component, plate

and screw fixation may be indicated as a secondary means of stabilisation following primary minimal osteosynthesis with less invasive methods eg. screws or kirschner wires[7,36,43].

2.5.5 DEFINITIVE WOUND MANAGEMENT

When possible, open wounds should be covered within a week and before the wound is secondarily infected[10,188,191,234]. Timing and methods of coverage are carefully assessed when the injury is first seen[33,43,48,53]. There is great controversy with regard to the timing of wound closure. However, most treatment options are based on the nature and timing of surgical debridement. Godina and Liser[97],Gustilo[107],Byrd[38],Cierny[48],clearly revealed the advantage of radical debridement and early (within 72 hours) wound closure with vascularised tissue, (see figure 2). From such a protocol, the number of cases of nonunion and osteomyelitis decreased, the number of hospitalizations and of anasthetic sessions went down substantially, as well as the time for fracture healing. Each author noted the inflamatory sequelae of the wound as it remained open. However, recently Yaremchuk and coallegues showed surprisingly good results despite longer periods between initial injury and ultimate closure[23].

Figure 4 displays the advantages between early, delayed, and late wound closure.



The options or methods available for wound coverage are the following[43]:

2.5.5.1Primary Options for Definitive Wound Management

(i) Primary closure by suture.

(ii) Wound left open;

(a) gauze dressing,

(b) biological dressing eg. homograft, heterograft, or synthetic materials,

(c) non biologic dressing eg. vacuum sealing (coldex foli).

(iii) Relaxing incision and (primary closure)

(iv) Primary closure with autogenous skin graft or local rotation or soft tissue transfer microvascularised graft.

When the wound is left open, a series of secondary options must be considered as follows:

2.5.5.2 Secondary Options for Definitive Wound Management

(i) Delayed primary closure by suture.

(ii) Delayed primary closure by autogenous skin graft or local rotation or microvascularised flap.

(ii) Secondary closure by suture.

(iii) Secondary closure by graft.

(iv) Healing by secondary intention.

(v) Temporary split thickness skin graft with the intent of subsequent excision and

closure by suture or graft.

(i) Primary Closure

Primary closure by suture is rarely done in open fractures if ever indicated[43,62]. Only type I open wounds should be treated in this way. The biggest risk of primary closure is gas gangrene[74,106].Whenever there is doubt the wound should be left open[10,234].

(ii) Leaving Wound Open

(a) Gauze dressing: For major soft tissue wounds that are to be left open after debridement, a gauze dressing inserted to a point just beneath the fascia is sufficient[43].The dressing should just keep the fascia and skin edges separated. Wounds are not packed because this brings about obtructive effect and thus preventing drainage[43,234].Loosely placed dressings conduct the

exudate or transudate by capillary action to the surface[43].Normally drains are not indicated when wounds are left open[4].

(b) Biologic dressing: Homologous human skin, heterologous porcine skin, (commercially made) and synthetic dressisng may suffice to cover a wound that has been left open[30,43].They seem to be a deterrent to infection, and evidence exist that underlying infection may be controlled. Such graft need to be changed frequently because host granulation tissue may invade them and incite chronic inflamation that may delay epithelialisation, even if removed before clinical evidence of take up[43,234].

(c) Non biologic dressing: Vacuum sealing is a new technique of wound treatment[86,87,88].The wound is covered with a polyvinyl acrylate foam (PVA) eg. coldex foli to which drainage tubes are inserted. The foam (coldex) and part of the surrounding skin are covered by a transparent polyurathane dressing impermeable to air and bacteria. The drainage tubes are anchored by piercing through the skin or alternatively can be attached to the skin by use of glue material[88].They are then connected to a vacuum device in form of vacuum bottles. This result into a high pressure contact zone at the foam-wound interface. Such effect not only enhance continued cleaning of the wound, but also accelarate formation of granulation tissue and hence rapid wound healing[86,88].

(iii) Relaxing Incision

Underlying swelling may prevent closure without tension in the wound[43]. When it is important to obtain full thickness coverage over other structures, closure can often be effected with a relaxing incision[43,234]. The incision is placed at a distance sufficient enough to avoid a threat to the blood supply of the intervening skin. It must also be long enough, and normally require skin grafting later on.

(iv) Delayed Primary Closure

As long as closure is achieved between 5th and 7th day, wound strength at 14 days is comparable to that closed on the first day, hence the term "delayed primary closure"[43]. This is feasible for most of grade I, II, and IIIA wounds[10,43]. Retraction of the wound edges is prevented after each debridement with retention sutures under gentle traction[43].

(v) Secondary Closure

This is closure of the wound after one week when granulation tissue has been formed[10,43,105,214,234]. Recently, in most instances delayed 1° closure has replaced 2° closure[43,234].

(vi) Healing by Secondary Intention

Wound with soft tissue loss, can be left open and wait for granulation tissue to form after debridement and fracture immobilisation[10,43]. This was the standard regimen during the world war I[54]. The rate of infection was unacceptably high,

about 80%[54,213],and the granulation tissue which is later skin grafted, still face the disadvantages of split thickness skin graft listed below.

The following options may be carried out as primary or as secondary options as well[10,43]:

(i) Skin Graft

This is defined as those grafts that occupy less than the whole depth of the dermis[191].They are subgrouped into **thin split thickness skin graft** smaller than 0.016 in, **thick split thickness skin graft,** and **full thickness graft**[191,234].The thigh skin is by far commonly used. It measures approximately 0.5 in (1.25 cm) thick.[8,202] The former two have the following advantages[191,234];

(a) they are easily acquired,

(b) they have increased success rate,

(c) large amount can be taken to cover big wounds, and

(d) re-epithelialization of donor site is possible.

The disadvantages include;

(a) the need to have sophisticated instrumentation to harvest the skin. (Brown or Padgett dermatome),

(b) donor site scarring, and variable contraction of the graft on the recipient bed.

Full thickness skin grafts involve the entire dermal and epidermal structures.[191] Advantages of these include;

(a) greater durability,

(b) ability to maintain their original texture,

(c) they minimally shrink or contract,

(d) better color match and,

(e) donor site morbidity can be decreased by closure with single line scar. A major disadvantage is that only small amount of skin can be transferred. A skin graft is totally dependent for its survival on the vascularity of the recipient bed[10,43,234].Such grafts are ideal for coverage of defects overlying viable tissue such as muscle and often granulation tissue[10,43].Their prospect for survival is limited on tissues with poor blood supply such as periosteum, fascia, and joint capsule. In addition split thickness skin grafts will not take on tendons without paratenon, or bones without periosteum[10,94,115,234].Generally, skin grafts measuring 0.25-0.40 mm (0.010-0.016 in.), and run through a 1 to 1 1/2 mesher, have demonstrated better drainage and greater survival[43,208,234].

(ii) Temporary Split Thickness Skin Graft

Such grafts can be used as a tempory measure to cover wounds with high bacterial count or highly contaminated[10].The mesher is wide spread, preferably through 1 to 3 or more dimensions in order to improve drainage[10,43].The resulting graft may serve as a permanent one but the subsequent scar is not durable, and a future operation cannot be performed through such weak areas[26,43,94,132].

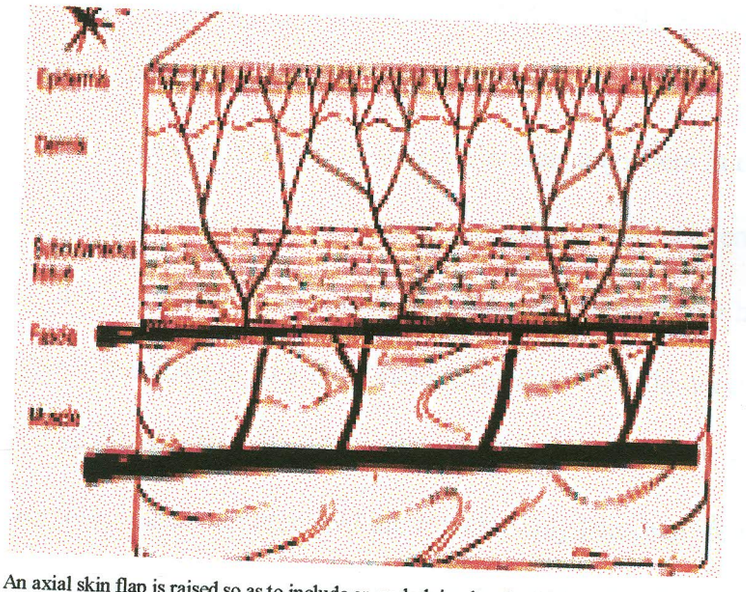
(iii) Flaps

These are transferable blocks of soft tissue that maintain viability through their own native circulation[10,43,234].On the basis of their vascular anatomy, flaps can be considered as: (a) Random and (b) Axial types[149,158,191,200].

(a) Random flaps: Skin and subcutanous tissue are parts of the graft[158].The blood supply of these grafts is highly compromised because the vertically oriented perforators from the underlying muscle or fascia are transected[35,234], (see figure1). The safety and survival of a random flap demands that the dimensions of its length and width be similar, that is 1:1 ratio, except in areas of rich blood supply such as face and scalp[234].These constraints have made such flaps fall out of practice today[191,234].

(b) Axial flaps: There are three types of axial flaps[10,43,158,234].Cutaneous, muscle or musculocutaneous, and fasciocutaneous This may be local rotation, distant or free tissue transfer flaps, (figure 5).

Figure 5 shows an axial skin flap.



An axial skin flap is raised so as to include an underlying longitudinally oriented vessel lying in the subcutaneous tissue.

(i) Local rotation flaps. These may be either cutaneous, muscle, or myocutaneous[43,234] (figure 5). The cutaneous type is associated with a very high failure rate, except for a groin flap[2]. The main reason being the same as for random flaps above. Muscle rotation flaps provide coverage of a small to medium size defects in the proximal and middle thirds of the tibia[10,158,191,234]. Muscle component covered with split thickness skin graft is preferred because is less bulky than the myocutaneous flaps[43,107,200].

(ii) Free Tissue Transfer. Conceptually, the axially supplied vascularised muscle and musculocutaneous flaps, type I and V according to Mathes and Nahai, (table 2 and figure 5) are potential not only for rotation but also for free tissue transfer[34,43,149,151,152,158,191,200,234].Free tissue transfer has the following advantages[10,15,32,43,46,107,191,200,234].

1. It can deal with defect of almost any size, anywhere in the body.
2. It is associated with increase of perfusion in the recipient bed.
3. It is associated with a short hospital stay and therefore high cost effective.

Another source of free flaps include omentum but this need laparatomy [30,43,200]. Groin flap though axially supplied, has relatively a short pedicle of narrow vessel diameter, making it technically less than ideal.[2] It is mainly confined to microsurgical reconstruction of hand and foot[2,234].

Cross leg flaps. These flaps have a number of constraints[204,234] .It is associated with lengthy periods of hospitalisation, prolonged immobilisation which make joint motion and muscle mobilisation impossible, predisposition to DVT, poor compliance[43] .However, they are worth considering in extremities with only a single major blood vessel, and as a salvage procedure following a failed free flap[43].

2.5.6 ELEVATION OF THE LIMB

The question of controlling post-debridement edema by simple elevation of a limb is a critical matter[10,43].The persistent or increased swelling may prevent

delayed 1° clossure. On the other hand, tension in the suture line may increase and lead to marginal wound necrosis. Other disadvantages include increased risk of infection, compartment syndrome, and loss of reduction of fracture[104,132]. A limb should be elevated in a manner that is comfortable for the patient, and ensure continued elevation at a level above the heart[4]. The previous argument that such elevation should not exceed 10 cm above the level of the heart hardly serves any advantage. The greater this level is, the better the limb drainage.

2.5.6 MANAGEMENT OF BONE LOSS

Most open diaphyseal fractures carry a non-union rate of 20% to 60% or more, when there is partial or complete bone loss[10,191]. Limb functions can be significantly improved and healing times reduced, if early prophylactic bone grafting is carried out rather than waiting six months to make a formal diagnosis of a non-union or pseudoarhrosis[17,29,59,86,176]. The tibial grade 1 and 2 injuries, are best observed for 2 to 3 months, then a bone graft is applied to those fractures that show minimal or no callus. Conversely, more severe grade 3 lesions should be bone grafted at the time of wound closure or when stable soft tissue coverage without discharge is achieved[29,90,96,104,214].

Appropriate preoperative planning that includes timing of the procedure, the surgical approach, and the bone grafting is essential[29]. It is possible to treat the majority of high energy tibial injuries with posterolateral or anteromedial approach[17,29,43]. In most cases cancellous graft from posterior

superior iliac crest is adequate, otherwise graft from anterior superior iliac crest should suffice when bone defect is not large.Non vascularised fibula graft or pedicle constitute a favourable option too. Another well practically developed, and now widely accepted is **Callus Distraction** by bone transport using Ilizarov ring fixator. Such ring system has proved to be a useful salvage procedure in most difficult tibial fractures, (see figure 6). For more proximally located fractures, posteromedial or anterolateral approach is used to avoid injury to the anterior tibial artery[29,43].The graft placement is planned at least 2.5 cm above and below the fracture level.Graft malposition and inadequate grafting is avoided by careful radiological preoperative assessment[29,32].and intraoperative imaging.

(i) Cancellous and Cortical Grafts

Generally speaking, the better vascularised the bed, the more likely the graft will bridge the gap[43].Autogenous cancellous grafts are used for short defects (less than 6 cm), and have shown a high success rate than cortical grafts[10,29,39,107,191]. It is less susceptible to infection and incoporation is faster[17,29].·This is frequently harvested from posterior or anterior iliac crest with the patient in lateral or prone position in case of posterior approach[29].

A direct cancellous grafting of infected fractures with a health layer of granulation tissue (Papineau technique) is an option when soft tissue coverage is absent[169]. While Papineau grafts are excellent for large metaphyseal defects in long bones as tibia, posterolateral grafting approach avoiding the area of

anterior soft tissue loss or infection is superior to Papineau grafts in diaphyseal areas[61,90,179].

(ii) VASCULARISED BONE GRAFTS (VBG)

The osteogenic potential, vascularity, and strength of these grafts is thought to be greater than conventional bone grafts[10,43,83,191].Lengthy defects are generally treated by this method.

(a) Pedicle Graft (PG) -Ipsilateral Fibular Transfer and Tibiofibular Synostosis

In the severely injured or single vessel extremity, pedicle graft that is similar to ipsilateral fibular transfer and tibiofibular synostosis may be a safe method for limb salvage[10,29,61,96]. This can be achieved either in a single or two stage procedure. Often, additional cancellous grafting is required[43].The blood supply of such pedicle grafts is maintained either through attached muscle tissue or an arteriovenous pedicle[61,191].

(b) Free Vascularised Bone Graft (FVBG)

Large segment of bones can be transferred (up to 30 cm of fibula) and revascularised by microvascular anastomosis[43].

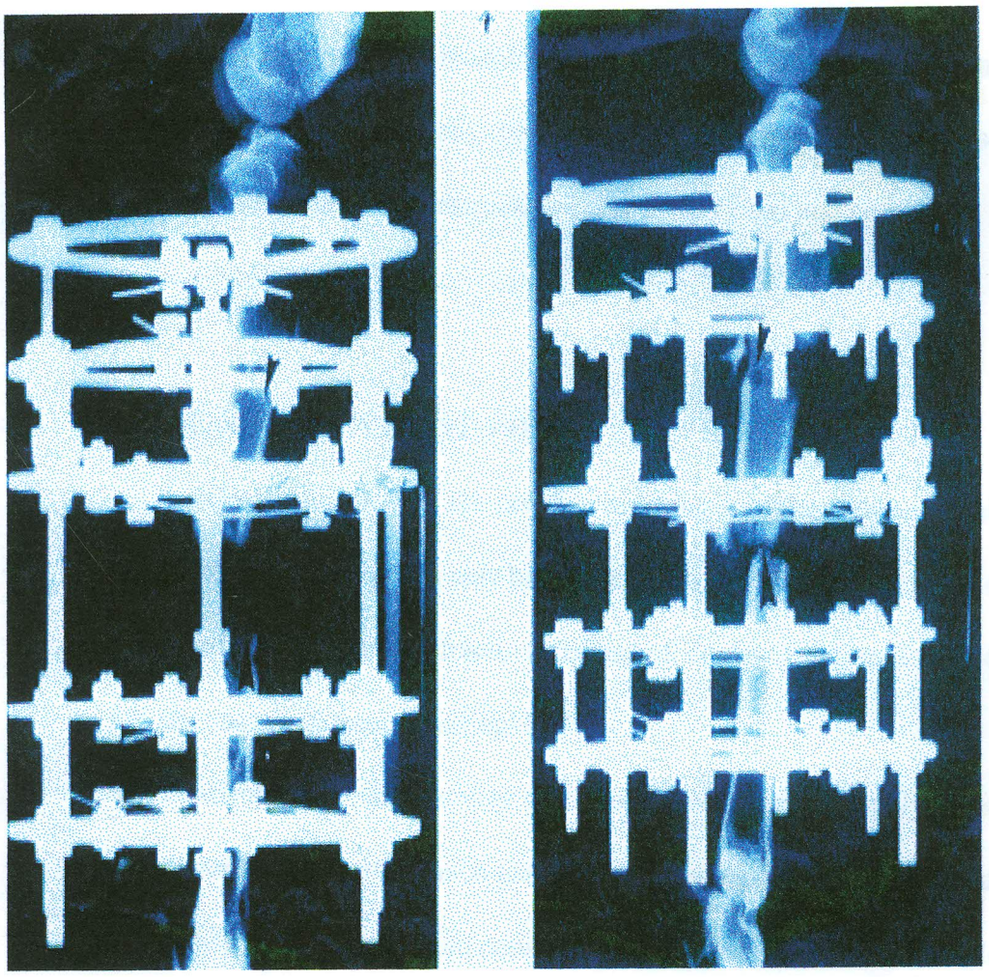
Free fibula bone graft. These has been used extensively for reconstruction of segmental diaphyseal tibial defects.[95,191,227]. Secondary cancellous grafting is needed, and reported union rates range from 62% to 89%[10,43,46].

Free iliac bone graft. For tibial reconstruction, vascularised iliac bone graft may be harvested on the deep circumflex and superficial circumflex iliac arteries[43,191,227].The reported success rate ranges from 87.5% to 90%, but about 30% of patients may require additional bone graft as well[10,29].

(c) Ilizarov Technique

Ilizarov technique of reconstruction of segmental tibial defects by distraction osteogenesis or **"bone transport"** is now widely accepted and used[145,169,206,207] (figure 7). Ilizarov method is highly efficient, versatile, and has shown a significant high cost-effective[43,145,215]. However, the use of transfixation pins, size and bulkness of the fixator, and patient discomfort are still among the important parameters to be taken into consideration especially in patient counselling[85].The combination of half pin (shwanz screws), olive wires and half rings, have significantly improved soft tissue handling and it may be a solution to most of the above problems[178,206,207].

Figure 7 shows bone transport by Ilizarov technique. Note callus distraction at the arrow site.



(d) Conservative treatment

Shortening of up to 3 cm may be accepted or produced to avoid reconstruction of a defect, and this be compensated by a shoe

lift[10,43,191].The main disadvantage being the renewal of the shoes as they wear out.

Furthermore, when considering different options for either bone or soft tissue reconstruction, modifying factors such as infection, scars, poor local vascularity, and radiation must be accounted for[43,191].In combined bone and soft tissue loss as it is usually the case, staged reconstruction as opposed to immediate combined reconstruction is the widely used and acceptable method[10,43,46,191].

2.5.7 RECONSTRUCTIVE PHASE

During this period, the possible resulting complications are dealt with accordingly[28].Readmission may be necessary to construct a segmental defect, bone grafting a non-union fracture, release of contractures, perform skin or full thickness soft tissue grafting[10,32,43].

Most patient with open fractures of the lower extremity have polytrauma, and **"Postoperative Care"** of such patients is a great demand[35,43].Resuscitation and early management should consist maintainance of adequate hemoglobin and blood oxygen tension to ensure oxygenation of peripheral tissues. Iron (ferrous sulphate) and blood transfussion when indicated shoud be instituted[10,28].Nutritional demands are extremely increased and special diet is very often necessary[43,87].

2.5.8 REHABILITATIVE PHASE

As mention above, the phases are separated for simplicity but in practical sense they are carried out simultaneously[10,191].As soon as the patient recovers from the initial acute phase should be made aware of the effects such injuries may carry with respect to his or her physical well being, social and economic circumstances, recreational and occupational aspirations[10,18,28,32]. Family and friends should be incorporated to help set the goals for each stage of the rehabilitation process. After stabilization of the fracture, the patient is enrolled on gradual and graded physiotherapy, eg. he or she is helped to get onto upright position, move to a chair, stand and walk on walkers, then crutches and soforth[10,28].Following discharge from the hospital, the patient is planned in a regular and well monitored out-patient follow up program[10,28,32].If medical,social, and occupational goals are pursued simultaneously and uninterruptedly, many patients are able to go back to their former employment or engage into a new task before the injuries are completely healed[10,28,32].The function and level of activity regained by the patient have been elaborated by Tegner. and Norbert[214]. Table 7 below shows the grading system for the perfomance of patients on occupation basis.

Table7 Tegner activity scale.

STAGE	ACTIVITY LEVEL	NATURE OF WORK
STAGE 5	**heavy labour**	**construction, forestry**
STAGE 4	**moderately heavy labour**	**track driving, heavy domestic work**
STAGE 3	**light labour**	**nursing etc,**
STAGE 2	**light labur**	**mailing etc.**
STAGE 1	**sedentary work**	**secretary office**
STAGE 0	**sick leave or disability**	**confined home**

PART TWO

THE PRESENT STUDY

3 OBJECTIVES

(i) Main Objective

To study and analyse the quality of various operative management of open fractures of the lower extremity.

(ii) Specific Objectives

1. To study the new vacuum sealing technique, and determine its efficacy in the control of infection in open fractures.
2. To analyse different operative options in patients presenting with open fractures in particular the role of external fixation system with emphasis on ilizarov ring fixator in such injuries.

3. To study the complications of open fractures and analyse the optimal solution.
4. To determine the correlation between the fracture classification, and treatment methods.
5. To evaluate the outcome of treatment in terms of the level of patient`s activity.
6. To study the healing times and determine the time interval between injury and re-intergration of patient into the previous job or a new endeuvour.

4. METHODOLOGY

(i). Patients and Methods

The surgical department of the University of Ulm Germany including the traumatology unit has a computer data base from which information on admitted, operated, discharged, follow up, and readmitted patients can be readily and easily retrieved. Beside rendering services to patients it is also a University teaching hospital,which is provided with all basic and high technical Orthopaedic Armamentarium. That gives the hospital staff a wide range of treatment options for patients.

A total of 116 consecutive patients admitted and operated for open fractures between January 1994 and April 1996 were enrolled in this study. 56 patients were studied retrospectively and 60 prospectively. The latter took place between May 1995 to April 1996. On discharge patients were given an appointment to either a polyclinic in the same hospital or to their family

doctors and rehabilitation centres. It was possible to organize and contact any patient or the house doctor through the telephone call and obtain any relevant information as necessary according to the formulated standard questionnaire, (see appendix page 126).

(ii) Questionnaire

A questionaire that consisted mainly of three parts was developed. (See appendix page 126).

(a) Preoperative data including personal particulars, clinical and radiological evaluation. Fractures were classified according to Gustilo and Co-Workers.[104] (See table 3)

(b) Intraoperative data consisting evaluation of the type of operation, the implant used, antibiotics and its duration, and the type of wound coverage.

(c) Postoperatively, assessment of complications, reoperation, and fracture healing was carried out. Outcome of treatment and rehabilitation was assessed basing on pain as a factor that limited mobility of the patient on different activity.

4:3 Data Analysis

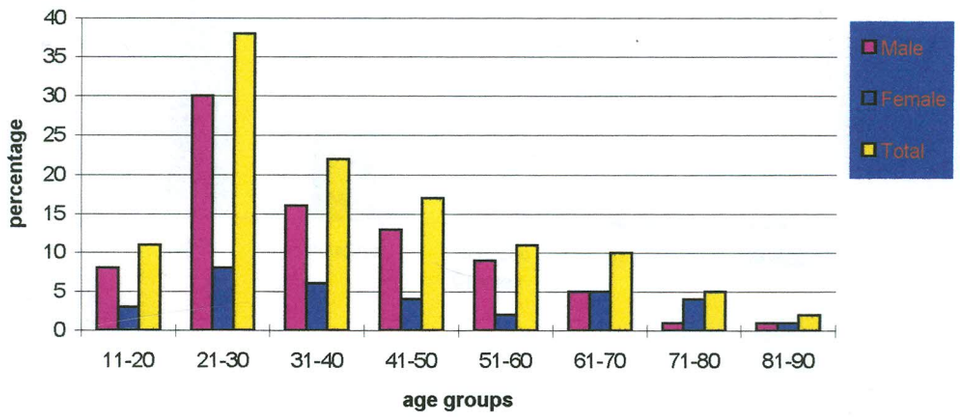
A series of selected clinical variables were determined and subjected to analysis. Data was then analysed by a calculator and computer to find out the association between variables and the outcome.

5 RESULTS

5:1 Age and Sex Distribution

Figure 8 shows the age and sex distribution of 116 patients. There were 83 males and 33 females with a ratio of 2.5:1 Their age ranged between 11 and 83 years with a mean of 36. The mean age of the wounded males was 34.3 whereas that of females was 47.0 Peak incidence was noted in the 21-30 years age group, and another small peak in the 31-40 years age group. Despite the male preponderance almost in all age groups, a definitely declining incidence in males was noted with advancing age,whereas the incidence in females was apparently increasing.

Figure 8 shows distribution of patients by age and sex



5:2 Causes of injury

Figure 9 illustrates the causes of injury in the order of frequency. Road Traffic Accident (RTA) was the commonest cause of injury accouting for 87 (75%) Both motor-vehicle and motor-cycle caused the severest form of injury. Motor vehicle alone caused 53 (45.7%) of injuries whereas motor-cycle accounted

for 29 (25.0%), (Figure 10). Furthermore, among these victims of RTA were quite few pedestrians 3 (1.9%),and bicyclists 2 (1.2%).Industrial injuries occured in 18 (15.5%), domestic in 9 (7.8%), missiles and sports in 1 (1%) each. Among the victims of industrial accidents,fall from height contributed the majority of injuries 13 (11.2%) resulting particularly from construction.

Figure 9. Frequency of various causes of injury in patients with open fracture

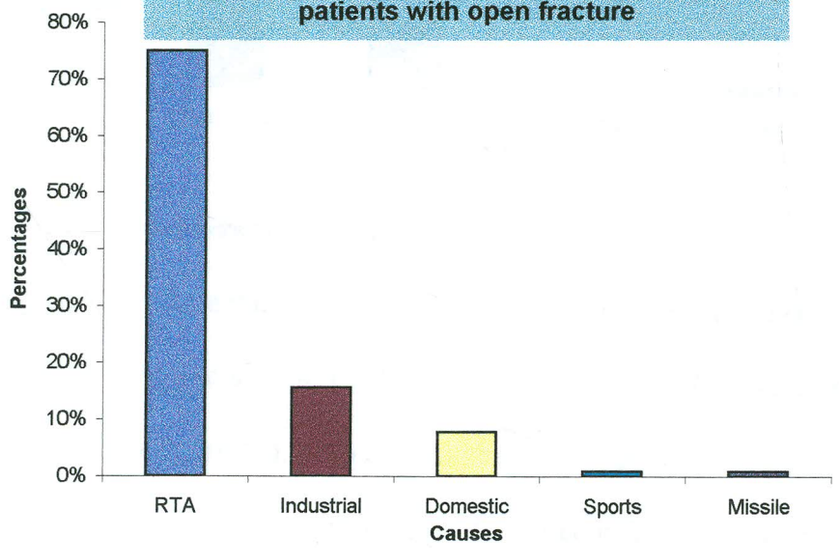
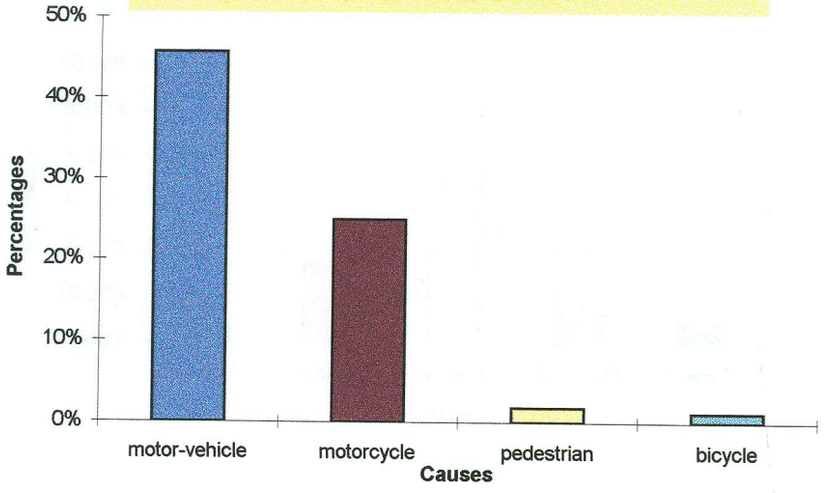


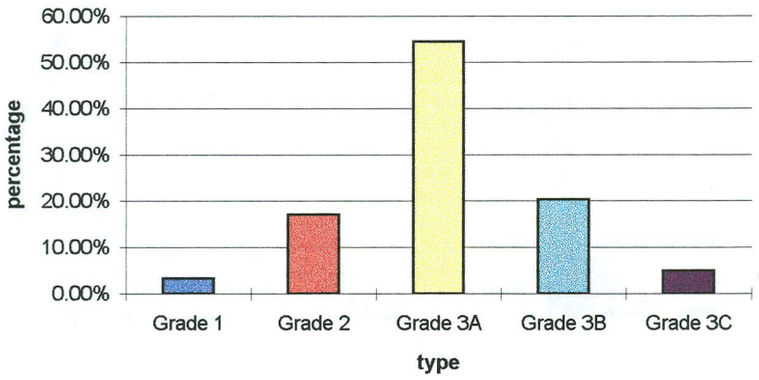
Figure 10. Frequency of various causes of RTA in patients with open fracture



5:3 Grade of Injury

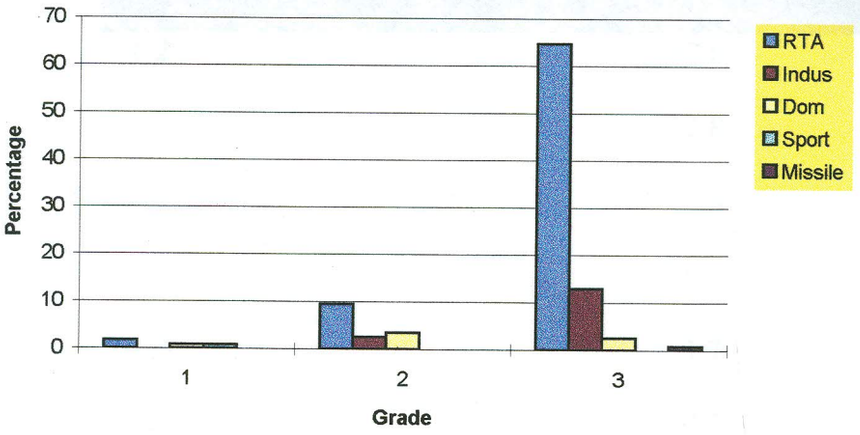
All fractures were classified according to the modified Gustilo and Co-workers 1984. Of the 123 fractures, 98 (79.7%) were grade 3 lesions. (Figure 11). Among these grade 3A were 67 (54.5%), grade 3B 25 (20.3%) grade 3C 6 (4.9%), grade 2 occured in 21 (17.1%) and grade 1 in 4 (3.3%).

Figure 11. Frequency of the grade of injury in patients with open fracture



While majority of grade 3 injuries 75 (64.7%) (i.e. all subgroups A,B,and C) (Figure 12) were caused by RTA, only 13 (11.2%) of grade 1 and 2 resulted from the similar cause. 15 (9.0%) of type 3 injuries were due to industrial causes. Injuries occuring as a result of domestic, sports, and missile accidents were quite few.

Figure 12. Frequency of the grade of injury in relation to the cause.



5:4 Timing of Operation

The time lapse between injury and operation ranged from 1 to 8 hours (Table 8). 67 (57.8%) were operated within 2 hours of injury, 38 (32.8%) between 3 and 4 hours, and 9 (7.8%) between 5 and 6 hours. It follows that the majority of patients 114 (98.3%) were operated within 6 hours of injury,(the golden time). Therefore only 2 patients had operation after 6 hours, one at 7 hours and the other one at 8 hours.

Table 8.Percentage distribution of the wounded on the basis of time between injury and operation.

lapse time	*%*
1-2	57.8
3-4	32.8
5-6	7.8
7-8	0.9
9-10	1.7
11-8	0.9
Total	100.0

5:5 Site of Fracture

Table 9.Percentage distribution of type of bones involved

BONE	*N*	*%*
tibia	76	46.3
femur	28	17.1
talus	8	4.9
calcaneum	7	4.3
patella	12	7.3
medial malleolae	13	7.9
lateral malleolae and fibula	18	11.0
navicula	2	1.2
metatarsals	2	1.2
pelvis	1	1.6
TOTAL	164	100

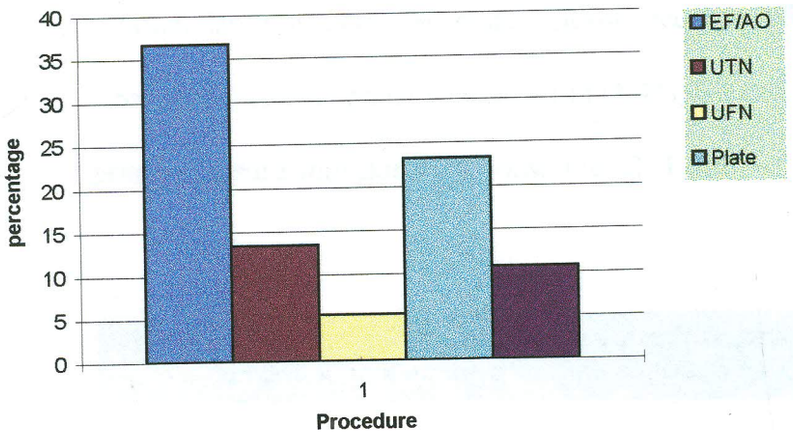
A total of 164 bones were involved (Table 9). Tibia was the most common involved bone in 76 (46.3%). Femoral fracture accounted for 21 (17.1%), fibula and lateral malleolae 18 (11%), patella 8 (7.3%), medial malleolae 13 (8%), talus 8 (4.9%), calcaneum 7 (4.3%), navicula and metatarsals 2 (1.2%) each, and acetabulum 1 (0.6%).

In consideration to the fracture level of the tibia, out of 76 tibial injuries, fracture of distal 1/3 were 36 (46.2%), of middle 1/3 were 23 (29.5%), and of proximal 1/3 were 19 (24.4%).The average healing time of the severe fractures of distal 1/3 of the tibia was 11 months with a range of 4 - 26 months. That of middle 1/3 was 10 months with a range of 3-36 months, and of proximal 1/3 was 9 months with a range of 2-24 months.

5.6 Fracture Stabilization

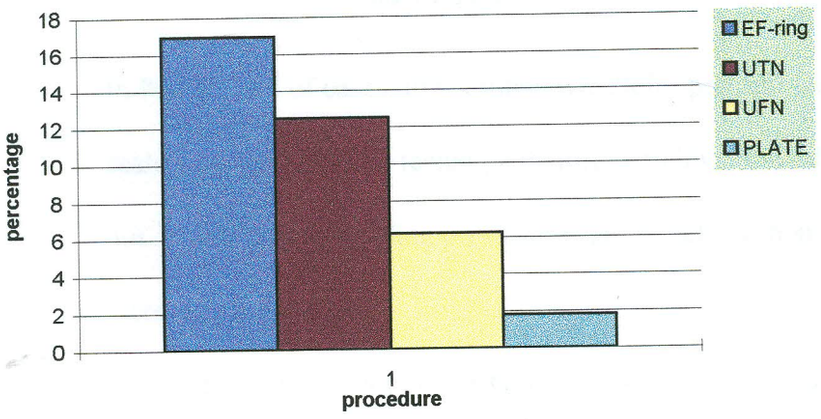
Figure 13 categorizes primary bone operation and type of implant. 40 (36.7%) of the patients underwent external fixation (EF), as a primary temporary measure before switching to internal fixation (IF) as a definitive treatment. However,while external fixation accounted for 10 (10.1%)as a primary definitive treatment, internal fixation accounted for 59 (54.1%) as a primary definitive measure. Of the fractures treated by internal fixation as a primary treatment 26 (23.2%) were fixed by means of plate, 15 (13.4%) by unreamed tibial nail (UTN), 6 (5.4%) by unreamed femoral nail (UFN), and in 8 (10.7%) screws and wires were used.

Figure 13. Percentage distribution to display various types of primary bone operation.



Ilizarov Ring Fixator,was carried out as a secondary procedure in 18 (17.0%), (UTN) in 14 (8.5%), (UFN) 7 (6.25%), and plating in 2 (1.8 %), (figure 14).

Figure 14. Percentage distribution to show secondary bone operations)

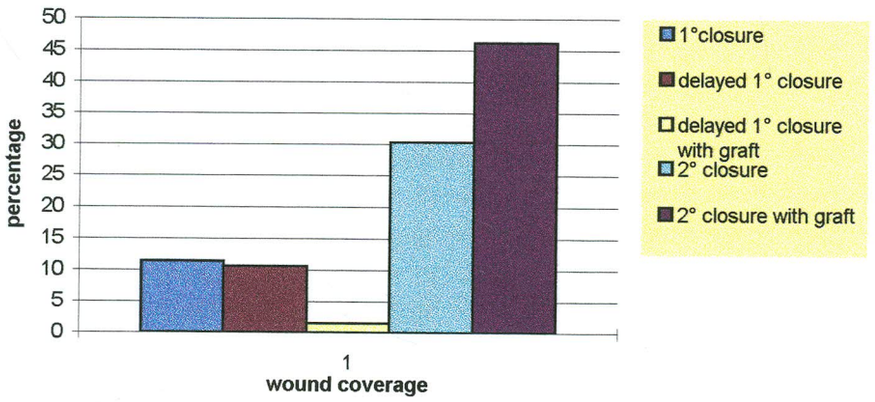


5.7 Soft Tissue Stabilization (wound coverage)

Figure 15(a) illustrates distribution of patients by type of wound coverage. A total of 132 soft tissue coverage procedures were carried out. Of these,45

(34.1%) were split thickness skin grafts, 7 (5.3%) lattisimus dorsi microvascular grafts, 5 (3.8%) and 4 (3.0%) radial and gastrocnemius rotation flap respectively, secondary closure accounted for 40 (30.3), primary closure and delayed primary closure 14 (11.4%) for each one, and delayed primary closure with skin graft constituted 2 (1.5%).

Figure15(a). Percentage distribution to categorize patients according to the type of wound coverage



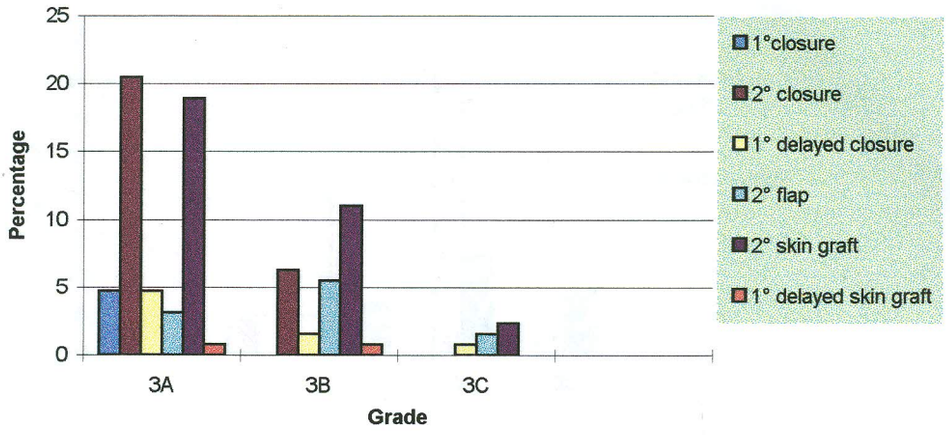
In 84 (72.5%) of cases, the wounds were left open and treated by vacuum sealing (a coldex plate) technique before definitive wound closure was carried out. 1 to 8 vacuum sealing procedures per patient with an average of 3.1 were carried out.

In consideration to the type of wound closure and grade of fracture the majority of type 3 injuries were eventually treated by secondary closure with either secondary skin graft or suture (figure 15(b). Type 3A lesions included 26 (20.5 %) wounds closed by secondary suture, 24 (18.9%) wounds

closed by secondary skin graft, 6 (4.7%) primary closure and delayed primary closure for each one.

14 of the type 3B injuries were closed by secondary split thickness skin graft, 8 by secondary closure, 7 by soft tissue microvascular transfer and 2 by delayed primary closure and delayed primary skin graft respectively. 3 of grade 3C injuries were closed by secondary skin graft, 2 by soft tissue trasfer, and only 1 was closed by delayed primary closure.

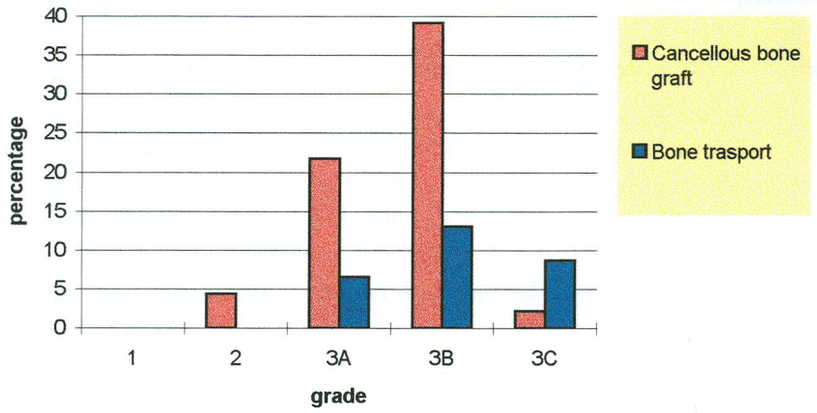
Figure 15(a). Percentage distribution to categorize the type of wound closure in relation to grade 3 injury



5:8 Bone Graft and Type of Fracture

A total of 46 bone graft procedures among 114 (40.4%) fractures were carried out.These were 33 (29.0%) cancellous bone grafts (CBG).Of these, majority were caried out for grade 3B 18 (39.1%), (Figure 16), 10 (21.7%) for grade 3A, and 3 (6.5%) for grade 3C, only 2 (4.3%) for grade 2, and none for grade 1. Bone transport was performed most for grade 3B lesions 6 (13.1%), 4 (8.7%) for grade 3C, and 3 (6.5%) for grade 3A.. There was no callus distraction done for grade 1 or 2 injuries.

Figure 16. Percentage distribution to categorize patients according to bone graft and grade of fracture



Bone defects of greater than 3 cm as a result of injury or resection were treated by callus distraction i.e.by bone transport. In this case resection was due to infection, infected or noninfectedpseudoathrosis or severe comminution usually associated with extensive soft tissue stripping. Otherwise, conventional cancellous bone graft (CBG) was carried out in bone defects less than 3 cm. and in uncomplicated nonunion. In some fractures, CBG was performed as a prophlactic measure with the anticipation that nonunion or delayed union is a possibility in severe lesions with extensive soft tissue and bone loss.

5:9 Amputation

Out of 116 injured limbs, only 9 (7.8%) amputations were carried out. Of these 2 were performed as immediate amputation, 6 as delayed amputation, and 1 as a late amputation. All 2 immediate amputations were type 3C

fractures. Type 3B and C accounted for the majority of amputations 4 each. There was only 1 amputation in type 3A and none in type 1 and 2.

15 (13.0%) of the wounded had impending compartment syndrome, and all underwent fasciotomy and epimysiotomy. Only 2 patients had a fully developed compartment syndrome. 6 (5.2%) with grade 3C underwent vascular surgery and 2 of them had delayed amputation (48 hours after injury) due to progressive ischemia and necrosis.

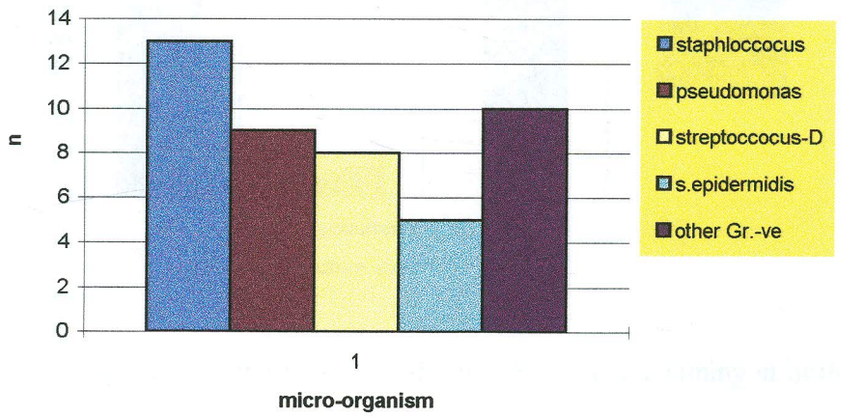
5:10 Antibiotics and Bacteriology

Cefuroxime, a cephalosporin group of antibiotic was administered as a prophylaxis (single bolus) to all patients admitted with open fractures.This was done during anaesthetic induction. Antibiotic was continued for a minimum of 5 days in those patients with type 3 lesions. Preoperative as well as intraoperative cultures were taken in all patients regardless of the presence or absence of infection. The change or adjustment of antibiotic was guided by the sensitivity pattern. Of all 25 infected wounds, 19 yielded bacterial growth in which 16 yielded mixed growth and 6 had no growth (figure 17). Of those that revealed growth, 13 revealed Staphlococcus aureus, 8 Streptococcus group D, 9 Pseudomonas aureginosa, 5 Staphlococcus epidermidis, and 10 different gram negative bacilli. Most micro-organisms were sensitive to erythromycin, gentamycin, cotmoxazole, and ciprofloxacillin, whereas most were resistance to penicillin, amoxycillin augmented clavulinic acid, ofloxacin,

and oxacillin. Cefazolin, cefuroxime and other cephalosporins in the first generation were fully or moderately sensitive.

In consideration to the type of fracture, type 1 were not infected, type 2 revealed bacterial growth in 3 cases (gram positive in 2 cases and gram negative in 1), type 3A in 10 cases (gram positive in 6 cases and gram negative in 4), type 3B in 6 cases (gram positive in 5 cases and gram negative in 1). The microbiologic status of grade 3C was unknown on account of missing of data in the computer.

Figure 17. Frequency to show type of micro-organism in patients with open fracture



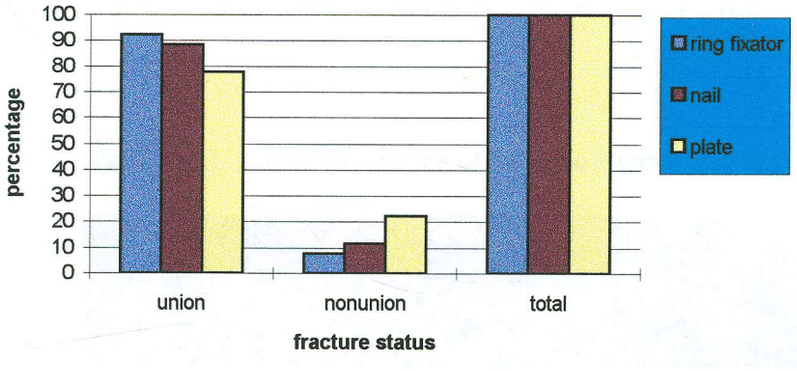
5:11 Outcome

Out of 105 fractures evaluated during the first eight months of injury, union had occurred in 70 (66.7%), nonunion in 15 (14.3%), and delayed union in

20 (19.5%). The mean healing time in severe tibial fractures was 10.31 months,and 7.84 months in femoral fractures.

When fracture healing and type of implant was taken into account, union occurred in 24 out of 26 (92.3%) for fractures treated by means of Ilizarov ring Fixator,in 38 out of 43 (88.4%) for fractures treated with unreamed interlocking intramedullary nail, and in 28 out of 36 (77.78) for fractures treated by plate and screws (Figure 18).

Figure 18. Percentage distribution to categorize fracture healing according to type of implant.



Vacuum sealing was carried out in 84 patients, aiming at both treating and preventing infection. In the majority of cases either infection did not occur or subsided early without further sequelae. In the prospective group, vacuum sealing technique was done routinely. In this study group, the healing time and hospital stay as mentioned above were shortened, a finding partly attributable to the use of vacuum sealing, and of course thorough debridement. It should be noted that pin tract infection was common than reported here, but

depending on severity, most of these were diagnosed and treated on outpatient basis.

5:12 COMPLICATIONS

Figure 20 categorizes patients according to complications. 32 patients out of 114 had infection, table (9a and b). Of these 32 patients, 22 were referred, whereas 10 were newly admitted patients. Therefore the overrall acute infection rate among the newly admitted patients was 10 (8.6%) with 3 (2.6%) proceeding to chronic osteomylitis. Among the referred patients, overrall infection rate was 19.0% with chronic infection (osteomyelitis) rate of 8 (6.90%), table 9 (a) and 9 (b).

Table 9(a). shows incidence of infection among newly admitted patients

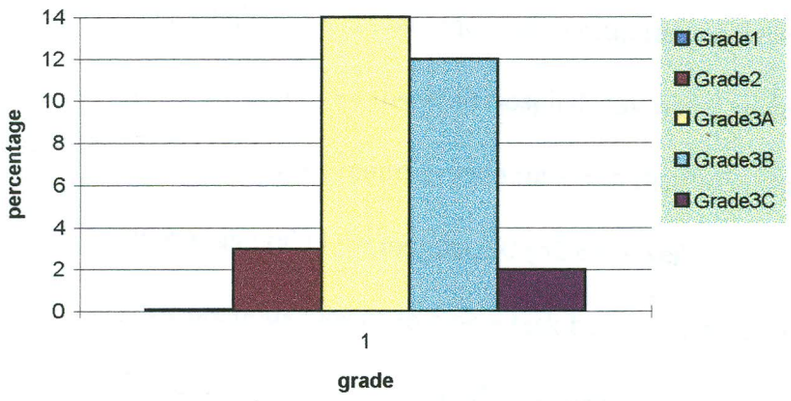
Newly admitted patients					
Overall		Acute		Chronic	
n	***%***	n	%	n	%
10	***8.62***	7	6.03	3	2.59

Table 9(b) shows incidence of infection among referred patients

Referred patients					
Overall		Acute		Chronic	
n	**%**	n	%	n	%
22	**9.0**	14	2.	8	6.9

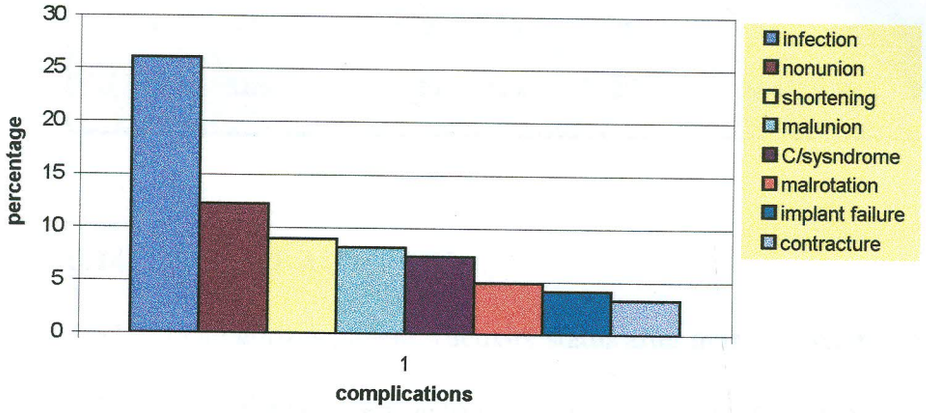
When the type of fracture was taken into consideration, the majority of infections occured in high energy injuries, i.e type 3 (A,B,and C) accounting for 28 (24.6%) in total,and 4 (3.5%) in type 2, and none in type 1 (figure 19).

Figure 19. Percentage distribution to classify infection according to grade of fracture



Other common and important complications, (figure 20) were nonunion seen in 15 (13.2%), shortening in 11 (9.5%), malunion in 10 (8.6%), malrotation in 6 (5.17%), contracture of the knee and ankle joint 4 (3.45%) for each one.

Figure 20. Percentage distribution to categorize patients according to complications



5:13 SOCIOECONOMIC ASPECT

The healing time among the study group ranged from 2 to 39 months with a mean of 10.75 months, their hospital stay was 2 to 164 days, with a mean of 50 days, and the reintergration time into their jobs was 2.5 to 28 months with an average of 11.16 months. 60 (52.6%) were able to reintergrate into their previous jobs or to a new task before the first anniversary of their injury, 26 (22.8%) were able to do that between one and two years (table10). Re-intergration status of 28 (24.6%) of patients was undetermined.

The mean number of reoperations in this series was 5.1 with a range from 1 to 20. Of these, the mean number of vacuum sealing procedures and redebridement were 3.13 and 2.72 with a range from 1 to 15 and 1 to 13 respectively.

Table 10 displays occupation status of the patients

OCCUPATIONAL STATUS							
Previous job		New job		Undetermined		Total	
n	**%**	n	%	n	%	n	%
60	**52.6**	26	22.8	28	24.6	114	100

5:14 LEVEL OF ACTIVITY

Table 11 categorizes patient`s activity status after musculoskeletal trauma. 60 (52.6%) of patients were able to return to their previous job whereas 26 (22.8%) re-engaged into much lighter tasks and 28 (24.6%) were not yet reintergrated. When functional aspect in terms of mobility and pain were taken into consideration, (table 11) 54 (47.4%) of patients had no pain at all,whereas 9 (7.9%) had pain on walking, 15 (13.2%) on light labor, 19 (16.7%) on heavy labor,and none had pain at rest. 17 (14.9%) couldn`t be assessed. In order to reach final assessment and according to modified "**Tegner Scale**" of activity level, (table 7) that group with no pain was accorded **EXCELLENT** (47.4%), **GOOD** (16.7%) with pain on heavy labor **FAIR** (11.4%) with pain on light labor, and **POOR** (7.9%), with pain on walking, and at rest.

Table 11 shows activity level in relation to pain

(n=114)

GRADE OF PAIN	*ASSESSMENT*	*N*	*%*
No pain	EXCELLENT	54	47.4
Pain on heavy labour	GOOD	19	16.7
Pain on light labour	FAIR	15	13.2
Pain on walking	POOR	9	8.0
Pain at rest	POOR	0	0.0
Not assessed	---	17	14.9

5:15 MULTIPLY INJURED PATIENTS (ASSOCIATED INJURIES)

Table 12 categorizes the wounded on the basis of polytrauma. There were a total of 201 associated injuries. Of these 128 (63.7%) were fractures whereas 73 (36.3%) were soft tissue injuries. Closed fractures that involved long bones of the lower and upper extremities accounted for the majority of them 72 (56.3%), followed by fractures of short bones of the lower and upper extremity 29 (22.7%), spine fractures 13 (10.2%), ribs and sternum fractures 8 (6.3%), pelvic fractures 6 (4.7%).

Table 12 shows the frequency of the wounded according to the associated fractures and soft tissue injuries

FRACTURES		SOFT TISSUE INJURY		TOTAL	
n	%	n	%	n	%
128	63.7	73	36.3	201	100

6 DISCUSSION

6:1 AGE AND SEX

The male:female **(M:F)** ratio of 2.5:1, mean age of 36.0 years, peak age incidence in the 3rd and 4th decade in this study are similar to those reported by Museru et al [167], as well as Behren and associates[10]. The ratio of 1.8:1 and the mean of 32.5 years found by Chapman[43] in his series is comparatively slightly low. Although the male preponderance in this series and other series is difficult to explain, some authors have attributed that to the higher tendecy of males going out and engage into much risk activities[39,167]. Even more important is the observation of a similar finding of higher incidence among the young male population suggesting that, most probably age, alcohol, and drugs have a significant influence to the occurance of these injuries[10]. It was noted that in this series, the male preponderance begins well in the 2nd decade, goes up steadly, and then starts comming down gradually at 6th decade and becomes the least at 9th decade.

6:2 CAUSE OF INJURY

The high rank position of Road Traffic Accident (RTA) as a major cause of injury in this series 75% is not uncommon. Dellinger[68]in his series had RTA accounting for 64% of all injuries, whereas Museru et al [167], reported an incidence of 55.7% and contrary to other studies they reported high

incidence in females. In this study motor vehicle accidents were leading 45.7% as compared to motorcycle accidents 25%. This is in contrary to Dellinger who reported an incidence of 28% in motorcycle accidents as compared to 24% in motor vehicle injuries[10].

Bicycle and pedestrian accidents with figures as low as 1.2% and 1.8% respectively in this study are clearly in contrary with those found in other studies. Museru et al [167] noted an incidence of 38.8% in pedestrians and 6.2% in bicyclists. However, Dellinger [68] found an incidence of 1.2% among pedestrians struck by car. Industrial accidents occupied a second place just ahead of domestic accidents. In this study, Domestic injuries were less severe as compared to the industrial ones. The majority of patients in the latter group either fell from great heights or crushed by mashines, whereas in the former group most missed a step and fell down during domestic activities. It is also very curious that missile and sport accidents came last in the list, one case each. Museru [167] reported slightly higher figure of 4.8% in sports, and 18.1% for the assaults. Dellinger[68] reported as low incidence as 2%, but in general in places of big cities with a big number of underprevileged and unemployment people and where life styles revolve around violence, such incidence has been quite high[10,167]. Such findings makes the road RTA accidents a big challenge , and at the same time places violence or assault in a very critical position, which trauma and orthopedic surgeons cannot simply ignore.

6:3 GRADE OF INJURY

The finding of higher incidence of high energy injury in this series 79.7% (n=98) is not coincidental. Hansen[107] and Browner[10], found a similar incidence and explained this as a function of a modern technology. While about a century ago low or moderate energy injuries dominated, today more young people are driving, most under the influence of alcohol or recreational drugs[10] .This in addition to the state of our highways, and high powered fast moving vehicles and motorcycles contribute significantly to these extremely devastating injuries.Usually, severe grade 3 injuries are associated with high operation rate, prolonged union and hospitalisation times, not mentioning higher amputation rate.

6:4 TIMING OF THE OPERATION

In this series 98.3% of the patients were timely operated in the first 6 hours of injury,and even more than half 58.8% in the first 2 hours of injury. The importance of early intervention has been emphasized by previous authors. Burges[33], Gustilo[107], observed a higher complication rate in operations performed late as opposed to those carried out as early as 6 hours after injury. Timing itself is probably not the only key factor but also the degree of soft tissue destruction, bone loss, and the level of contamination are other factors determining the outcome[43]. In this study severe type 3 injuries were associated with a high complication rate, despite the fact that operation were performed early. Furthermore, the fact that only 2 patients were operated after 6 hours is a clear credit to the structure of the health and surgical delivery care system

observed by the author, that permited early patient transport and immediate surgical intervention.

6:5 SITE OF FRACTURE

The fact that tibia was the most fractured bone in this series with an incidence of 76 (46.3%), is well consistent with other results elsewhere[43,106]. It`s anatomic features in terms of location and muscle coverage constitute the major reason for it`s higher predilection[34,43]. All orthopaedist would agree that a grave mistake was made in the design of the human tibia[43]. First, the largely subcutaneous anterior border and medial surface leaves the shaft of tibia to trauma[34]. This lack of coverage presents problems to trauma surgeon with respect to both soft tissue coverage and reconstruction of this relatively unprotected bony surface. Second, a triangular cross sectional anatomy of its anterior diaphyseal shaft portion, is primarily a thick cortical bone surrounding a relatively empty marrow cavity[34]. This can lead to several complications with respect to hardware placement including such simple ones as traction pins. Thermal necrosis during pin placement is common and this exposes the bone to a high incidence of pin tract infection and sequestrum formation unless pin holes are drilled across the marrow cavity to provide a good purchase[10,34,43].

In addition, in this study tibia presented the most difficult therapeutic problems. Until today, the management of severe open fractures of the tibia remains one of the most challenging problem facing the orthopaedic surgeon[230] In this series, 36 (46.2%) of the tibia were fractured at distal one third. The proximal one third was involved least. Again anatomic characteristics plays a major part here. Distal third of the tibia, according to Behren was the most involved part in his series[10]. When fracture healing was taken into consideration in relationship to the level of fractures of the tibia, the middle one third revealed the most prolonged healing time of 10.5 months almost similar to distal one third with a range of 3-36 months. Of course this is not a mere coincidence because the key issue in relation to fracture healing is the bone vascularity. The blood supply of the tibia is that, the nutrient artery enters the middle third and may be damaged by fractures especially segmental ones[192]. In such a situation the only remaining alternative is the bone to depend on it`s soft tissue envelope for blood supply, and stripping of the soft tissue owing to trauma or surgical exposure renders the bone avascular and make the outcome even worse. The key factor in distal one third fractures is blood supply as well, and indeed the soft tissue envelope. The region has no muscle coverage and this leaves tibia to be a subcutaneous bone, hence highly predisposed to high infection and nonunion rates[10,33,43].

6:6 STABILIZATION OF THE FRACTURE

The fact that in this study, the majority of patients underwent primary temporary treatment by unilateral external fixation and subsequently changed into different types of internal fixation (IF) as a secondary definitive means, is well consistent with most of the protocols in different centres dealing with open fracture surgery [10,32,43,200]. External fixation as a part of primary fracture care, is especially aimed at avoiding complications particularly in severe type 3 open fractures[105]. External fixators are best indicated for most grade 3A, B, and C fractures whereas unreamed interlocking nails are the treatment of choice for grade 1, 2, and 3A[141,164]. The use of unilateral EF especially (AO) exhibited high degree of flexibility including ability of a surgeon to carry out either skin graft, flap rotation or transfer. This was associated with high union rate, low infection rate, and ealy restoration of function. Ilizarov fixator was associated with the similar favourable outcome, but it doen`t permit easy and free soft tissue transfers. Old literature indicates that immediate internal fixation carries an infection and nonunion rate of 18% and 33% respectively [43,91] whereas, external immobilisation has only 9% and 3% respectively. However, during the same period Lottes et al.[142,143] reported excellent results with a 7% infection rate and no nonunion.

Furthermore, studies in 1980s, have shown remarkably good results[43,111,181]. The average infection rate was 8.9% with a long term osteomyelitis rate of only 0.8% and without nonunions. However, the majority of grade 3 fractures required bone grafts to achieve union, and few

amputations were carried out following failure of limb salvage. It is evident that still severe grade 3 open fracture of the tibia remains a problem[43]. In addition, Gustilo and Chapman warned that there is little room for misjudgement or error, because the consequences are usually more severe than the complications of external immobilization. Then the main policy is that of discrimination and precise indications, impeccable irrigation and debridement, excellent technical execution of IF, meticulous postoperative care, adequate patient compliance, well surgically equipped orthopedic centre, before any attempt at IF of open fractures is considered.

6:7 SOFT TISSUE COVERAGE

Secondary closure with either sutures or grafts were the most frequently performed procedures for wound closure 30.3% and 46.2% respectively.The latter was carried out either as a split thickness skin graft, rotation flap, or free microvascular soft tissue flap. The preponderance of skin graft and secondary closure in this series, clearly indicates their simplicity, versatility, as well as effectiveness. The role of reconstruction of soft tissue envelope has been well argued by previous authors. Godina[97] in his series had better results in those wounds closed early,that means intervention within 72 hours of injury. Behren[10] in his series had less complications including low infection rate in those wounds closed early. There is little discussion that, fractured bone heals most rapidly when it is covered early with infection free pliable vascular tissues[37,38,43]. Godina et al.[97] in their excellent work

demonstrated short healing times, short hospital stay, few number of operations and therefore few number of anasthesia in patients who underwent early wound closure preferrably in the first 72 hours.

Chapman[43] mentioned primary wound closure just to condemn it. 7 out of 8 wounds in which he carried out primary closure became infected. Russel[193] in his series, had 8 nonunions out of 9 cases following primary closure. Fortunately, the primary wound closure carried out in this study 11.4% was unremarkable. Most probably this is attributed to the extensive use of vacuum sealing. However, primary wound closure should be avoided especially in the treatment of open tibial fractures. Delayed primary closure is the most accepted and recommended method of wound closure[98]. Cierny[48], and Russel[188] in their extensive report, found better wound strength, low complication rate, and high success rate in their series, after delayed primary closure. Unfortunately, only 10.6% of the patients in this series underwent such procedure. Partly because most of the injuries were grade 3 wounds.

6:8 BONE GRAFT

All bone graft procedures carried out in this study were either cancellous bone graft or callus distraction by Ilizarov ring fixator. Most of this grafts were done in grade 3 injuries for nonunion and delayed union. Where nonunion was anticipated (as in grade 3B and C) early bone graft was carried out at least in the first 6 weeks of injury. The major controversy that surrounds this subject is the timing of grafting and the correlation with the

type of fracture. Behren[14], and Blick[17], in their series postponed grafting up to the time of wound closure.This is done most favourably during the time of delayed wound closure, or when stable soft tissue coverage is established. In case of a complex fracture pattern and high risk injuries e.g. type 3B, and C, grafting is usually done at 6-8 weeks[43] Exception is type 1 and 2 intra-articular fractures where cancellous bone graft is necessary to fill defects to obtain a desirable anatomical reduction[14]. In this study the majority of grafts (most grade 3 fractures) were performed as early as 4 to 8 weeks after initial trauma. The great defects due to bone loss or resection, underwent callus traction by use of Ilizarov ring fixator as immediate as infection free wound was established. The union rate of 24 (92.3%) with this method in this study group is encouraging and places the ring fixator a salvage procedure in complex and difficult fracture pattern. However 6 patients needed conventional cancellous graft at the docking site to achieve final union.

6:9 AMPUTATION

The low amputation rate of 7% in this series is impressive.One and half century ago,amputation rate ranged between 25% to 75%[10]. In this series it was possible to salvage most of the complex grade 3 injuries which could otherwise be amputated just 3 decades ago. The key factors that made all this possible was avoidance of infection through aggressive serial debridement, copious irrigation,extensive use of vacuum sealing technique (coldex plate) to cover wounds before final wound closure, early restoration of soft tissue

envelope by grafting and even more important is the meticulous use of EF and especially ring fixation for callus distraction to fill the big bone defects. Gustilo[107] (1976-79), found a much higher amputation rate of 18.3% in his series among patients with grade 3 injuries. Small [207] who followed his patients for 15 years found an amputation rate of 18 (11%). However, the etiology of the grade 3 injury has a pronounced effect on the complication rate unfortunately including high amputation rate.

6:10 OUTCOME

6:10:1 Bone Healing. The low non-union rate in this study group 13.8% is very encouraging. Gustilo[107], (1979) found a slightly high nonunion rate of 20% in his series. However, Russel [188] reported a slightly low rate of 10% whereas, March[148] reported even much lower nonunion rate of 5.0%. In this study group, the mean union time for tibial fractures was 10.3 months and 7.9 months for femoral fractures. Severe open fractures of the lower extremity particularly the tibial ones are reckoned of high therapeutic challenge[43]. In this series, the majority of severe type 3 fractures united at a reasonable time within 8 months. Sander[196], in his series reported a mean healing time of 9 months in type 3 fractures.

Nevertheless, most open diaphyseal fractures carry a nonunion rate of 20 to 60% or even more when there is partial or full bone loss[10]. Early bone grafting, and early axial dynamization have been shown to contribute

considerably in the healing of such fractures[13,14,148]. The mean number of vacuum sealing performed among the study group was 3.2 with a range of 1 to 15, and the accompanying redebridement ranged between 1 to 14 with a mean of2.7. This systematic way of treating not only the fracture but also the soft tissues made it possible to avoid complications namely infection and nonunion. This may have accounted for the reasonably good outcome in this study group. The healing time and hospital stay were comparable to those of previous authors[14,15,148,191].

In addition, nonunion rate for Ilizarov ring fixation of 7.69%, was better than that for unreamed intramedullary nail 11.6% and plate osteosythesis 22.2%. Nonunion for Ilizarov ring was mainly due to patient`s compliance who demanded premature removal of the fixator. As mentioned before, this shows that ring fixation can serve as a salvage procedure in open fracture surgery of the lower extremity. Turker[222] in a retrospective study, reported union of all fractures treated by ring fixation in a duration ranging from 8 to 47 weeks without bone grafting. None contracted chronic infection except pin tract infection and fracture of wires.

6:10:2 Complications The acute infection rate of 8.6% and chronic infection rate of 2.6% among the newly admitted patients in this study are similar to those rates reported elsewhere. However, the incidence among the referred group in this study was 19.0% for acute infections and 6.9% for chronic infection (osteomyelitis). Gustilo[106,107], reported an incidence ranging from

2.1% to 9.4% in all types of open fractures, with 2.0% going to chronic infection. Hope[122], found slightly higher figures in acute infection 11.0%. Mhina et. al unpublished, noted even much higher incidence of 18%. In this study group, when individual grades were taken into consideration, there was no infection in grade 1, an incidence of 2.5% in grade 2, 5.8% for newly admitted patients with grade 3, and 16.7% for referred patients with grade 3 as well. This may coincide well with the fact that almost all patients referred had severe grade 3 fractures. In 1972, Gustilo[106], et.al reported no infection in grade 1, an incidence of 3.8% in grade 2, and 9% in grade 3, with an overrall infection rate of 3.2%. In later series, by the same authors the infection rate in type 1 fractures was unchanged, in type 2 was 1.8%, and in type 3 was 18.4%, with an overrall infection rate of 8.9%. Gustilo and associates, attributed this increase in incidence to an increase of severe type 3 fractures in their practice.

Vacuum sealing procedures were performed routinely to all patients with open fractures in this study. It`s contribution in preventing infection is just enormous and the low infection rate reported among the study group is a pretty good evidence. Fleischman,[86,88] had all his 15 patients healed uneventfuly. However,the nonunion rate of 13.2%, in this study is relatively high compared to those of previous authors. Gallinaro[91] and associates, found an incidence of 11% in their series. Hope[122] and associates found even a much lower incidence of 7.5%. On the other hand , a delayed union rate of 17.3% in the study group is almost similar to that reported by Hope[122] of 16%. Implant

failure in this study group was seen in 4.4% Chapman and associates [43,45] reported an incidence of 3.8% in their series.They argued that the patient`s compliance, technical capability of the surgeon, and indication criteria, as the most important factors influencing this type of complication. The only single case of avascular necrosis of the talus in this study is surprisingly low. Both high and low figures have been reported by previous workers, and Hawkin who reported relatively low figures concluded that the incidence of avascular necrosis of the talus is pressumably low than previousy thought[42,118].

6:11 BACTERIOLOGY

The preponderance of Staphlococcus aureus (a gram positive organism) as opposed to gram negative rods regardless of grade of the fracture in this study is not consistent with those of other workers. Dellinger[68] and associates noted Staphlococcus aureus in 43% and facultative gram negative rods in 14% of grade 1, 2, and 3A fractures. The same authors found mixed organisms from most of the grade 3B, and 3C fractures in which staphlococcus aureus represented only 7% and aerobic or facultative gram negative rods accounted for 67%.

Gram negative organisms, Staphlococcus aureus, Streptococcus group D and mixed infection were the major player involved in this series.The latter was the most common. Ubiquitous use of cephalosporins, high prevalence of nosocomial infective organisms, and severely traumatized limb have been

already argued as the most probable cause of high prevalence of gram negative organisms[43].

The majority of the Staphlococcus aureus and gram negative rods among the study group responded very well to erythromycin, gentamycin, bactirim, ciprofloxacin and mezlocillin. Cephalosporins, (including cefazolin, cefuroxime etc.) Oxacillin, ofloxacin, ampicillin responded fairly good, whereas response from most of the micro-organism to penicillin and augmentin was very poor.

Optimal antibiotic choice depends on the severity of the soft tissue injury, the contaminating agent, and the local nosocomial flora[4,10]. The first generation of cephalosporins is normaly preferred for grade 1,and 2 fractures[10]. It is effective against most gram positive and many gram negative bacteria except Pseudomonas. In grade 3 fractures an aminoglycoside (gentamycin or tobramycin) is added[43,173]. Penicillin is added for fractures associated with a farm enviroment, vascular compromise or extensive soft tissue crush.

6:12 SOCIOECONOMIC ASPECT

The fact that more than half of the patients 58.8% in the study group healed before the first anniversary of their injury is very encouraging. Likewise the duration of hospital stay was short, and number of operation and work days lost were few. Bonderrant[18] and associates, reported slightly higher figure of 61% in his series,. Tscherne and associates[214], found slightly higher

figures for the duration of hospital stay 16.5 weeks, little number of operations 4.5, and slightly big number of work days lost 47.9 weeks. When amputation was taken into consideration, the average number of operations and duration of hospital stay diminished 2.5, and 8.5 weeks, respectively. The healing times in the last category is usually shorter[43].

6:13 LEVEL OF ACTIVITY

The return of 52.7% of the wounded to their previous jobs and 22.7% to the new tasks means quite a great achievement. Unfortunately, not all authors on this subject report on aspect of patient`s activity, most likely due to lack of a uniform criteria for the evaluation. However, previous authors have reported even less than a quarter re-engaging into their old job, and most of them due to partial incapacity have to take and accept much lighter new tasks[10,93]. Pain as a limiting factor on daily activities has been used as a rating parameter[171]. **Excellent** activity level was accorded to those with no pain on any activity, **Good** for pain on heavy labor, **Fair** for pain on light labor, and **Poor** for pain on walking and at rest. About three quarters of the wounded in this study group, had excellent and good results. Norbert[171], rated the activity level of the injured in his series as stated in Tegner`s activity scale (Table 7) . He evaluated the level before and after the accident. He found less than one quarter of the patients had Tegner grade 5 after injury. However, in general more than 95% of the injured in his series either went back to their jobs but most took over new tasks. (These included patients with activity level 3, 2,

and 1). Although Tegner rating system of the injured is reasonably satisfactory, still there is a need to modify it or develop a more uniform criteria for the sake of evaluation and comparison.

6:14 ASSOCIATED INJURIES (POLYTRAUMA)

Closed fractures of the lower limbs and upper limbs predominated the picture whereas, injuries named craniaocerebral, thoracic, and abdominal trauma were the most common in this study group. The majority of accidents took place as a result of high energy forces, e.g. motor vehicle and industrial trauma. While the first priority is directed to the life threatening conditions such as hemothorax, the treatment of musculoskeletal injuries is given the second priority. Such early stabilisation of long bones, in other words early aggressive approach; minimises internal bleeding, facilitate pulmonary toilet, lessens blood transfusion requiments of the injured, forestalls the continued surge of marrow products into the blood, lessens the incidence of sepsis and improves patients physiological profile including pulmonary, neuroendocrine, and nutrition.

7. CONCLUSION

Routine use of vacuum sealing and use of the external fixation system particularly Ilizarov ring system formed the basis for the favourable results obtained in this study.. Vacuum sealing also known as coldex foli, enables cleaning of the wound continually with subsequent formation of early granulation tissue that can be grafted. That provide early soft tissue stability free of infection.The single most important issue is whether these measures are smoothly applicable at Muhimbili Orthopaedic Institute (MOI).

The cost of one coldex foli is 7 US$ when imported and it is even much cheaper when locally produced in the country. The components of the material are available though that may need some degree of improvisation. The method of application is simple and versatile. There is no doubt that high infection rate in our set up justify the cost.

The role of external fixator in fracture stability and hence infection control cannot be over emphasised. External fixators including Ilizarov rings is available at the centre except for the Olive wires that need regular replacement. There is little discussion now about the high cost effectiveness of external fixators, and the important manoeuvre now is to work out logistics to ensure prompt availability of the fixators to the surgeon during the primary emergency surgery of open fractures particularly for those associated with high energy trauma.

There is little to discuss on the important role of serial debridement and copious irrigation in open fracture surgery. That accounted too for the favourable outcome in this study. Failure to perform serial debridement after initial surgery, has been associated with unpredictably higher morbidity and amputation rate.The present theatre constraints at Muhimbili Medical Centre (MMC) does not allow a regular revision or serial debridement due to few operating days and sessions. It is expected that when a new and modern Orthopaedic theatre at Muhimbili Orthopaedic Institute is complete the problem may become solved. In addition, uninterrupted availability of irrigation fluid is among the important pillor in open fracture surgery. Therefore, the substitution of the scarce and rarely available normal saline or ringer`s solution with distilled or boiled water needs to be reinstalled. Previous experience and study in this centre revealed that distilled water or boiled when used as an irrigation fluid is as effective as the normal saline or the ringer`s solution.

The use of prophylactic antibiotics cannot simply be dismissed. When antibiotic resistance to commonly encountered micro-organisms is steadily growing, however from the results of the previous study at Muhimbili medical centre, either cloxacillin or erythromycin can be used as an effective and cheap prophylactic agent which majority of our regular patients can afford.

It is also a fact that, early bone grafting in severe injuries is associated with short healing times, short hospital stay, and early functional

restoration. However, that is possible in the absence of infection. Cancellous bone graft for small defects, non vascularised fibula graft, pedicle fibula graft, and bone transport for large defects have worked quite favourably, and these are measures readily applicable at Muhimbili Orthopaedic Institute.

The issue surrounding the timing of surgery is quite a critical matter, and needs to be comprehensively addressed. It has been revealed that, the interval between injury and surgery in our patients is alarmingly high. More than three quarters of these victims undergo initial surgery more than 8 hours after injury. The answer to the problem is complicated and almost beyond the capability of the surgeon or any clinician because it really needs improvement in the general social infra-structure including transportation, telecommunication, health care delivery system, and aggressive policy makers with appropriate vision. However, Orthopaedicians should tackle and address the statistical and epidemiological aspect of the problem.

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