Management of Compound Tibial Fractures

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To Study Functional Outcomes of Monorail Fixator as a Primary Mode of Fixation in Compound Tibia Fracture as Classified by Gusttilo-Anderson Type 2 and Type 3a, 3b (30 Cases)

In memory of my Grandfather

S. Bachan Singh Sandhu

1908-1988

PREFACE

Not all books include a preface, as you can combine the information the preface covers into the Introduction. However, some authors like to separate it. This is written by the author of the book, and appears before the Introduction. The preface usually deals with the background to the book. The reason for it being written. It can also include what it doesn't include as well!

DECLARATION

I declare that the thesis entitled "To Study Functional Outcomes of Monorail Fixator as a Primary Mode of Fixation in Compound Tibia Fracture as Classified by Gusttilo-Anderson Type 2 and Type 3a,3b (30 Cases)" has been prepared under the guidance of Dr. Kanwarjit Singh Sandhu, Professor and Head, Department of Orthopaedics, Government Medical College, Patiala. No part of this thesis has formed the basis for the award of any degree previously.

ACKNOWLEDGEMENTS

As the thesis sees the light of the day, I find myself at a loss of words to express my thankfulness to the almighty, for without his gracious blessings; this work would not have been conceived, much less completed.

It gives me immense pleasure to thank my revered and esteemed teacher and supervisor **Dr. Kanwarjit Singh Sandhu,** Professor and head, Department of Orthopaedics, Government Medical College, Patiala for his keen personal interest, able guidance and overall supervision in carrying out this work and guiding me in every step during the process. I am indebted to him for the unremitting encouragement, kind patronage and never-ending willingness to help. I hope to strive hard to achieve the ideas he has shown me.

I am highly grateful to my co-supervisor **Dr. Ashok Kumar**, Associate Professor and Head, Department of Microbiology, Government Medical College, Patiala, who provided a constant source of invaluable guidance and inspiration and steered my way throughout the study.

I also owe my thanks to all the patients without their cooperation this work would not have been possible.

I am thankful to **Nanak Documentation,** Patiala for their constant help in transforming this vision into its rock solid shape.

Above all, I am grateful to God, the Almighty, who sustains this beautiful world grace nobody can ever succeed.

Dr. Kuldip Singh Sandhu
Dr Kanwarjit Singh Sandhu

CONTENTS

ABBREVIATIONS

AI: Associated Injuries

BBL: Both Bone Leg

C/L: Contralateral

CRP: C Reactive Protein

DF: Dorsiflexion

DM: Diabeties Mellitus

E: Extension

ESR: Erythrocyte sedimentation rate

F: Flexion

FWB: Full Weight Bearing

GA C/F: Gustillo-Anderson classification

HBV: Hepatitis B virus

HCV: Hepatitis C virus

HTN: Hypertension

I/L: Ipsilateral

IEF: Illizarov External Fixator

LRS: Limb Reconstruction System

Lt: Left

Min: Minutes

No.: Number

PF: Plantar flexion

Rt: Right

SD: Standard Deviation

Wk: Weeks

ABSTRACT

The purpose of this book was to guide the budding/fellow orthopaedic surgeons to deal with compound fractures. This book explains the outcome of monorail fixator (Limb Reconstruction System) as primary and definitive mode of fixation of compound fractures of tibia, which have high rates of infection and non-union resulting in poor functional outcome. This provides treatment guidelines for prevention of infection, soft tissue coverage and fracture stabilization with simultaneous mobilization of nearby joints; thereby enabling early return to function.

We have conducted a study on patients having compound tibial fractures as classified by GUSTTILO-ANDERSON in type 2 and 3A, 3B, cases. During follow up, patients were assessed for various complications and statistical analysis was performed using software SPSS 25.0. Benefits of monorail fixator (LRS) has been mentioned in this book as excellent to good results in 90 percent of cases with minimum surgery time of 52.17 minutes. Full weight bearing (with fixator) was seen in 5.37 days. Fracture union occurred at 31.8 weeks with minimum complications

INTRODUCTION

The tibia is one of two bones that comprise the leg. As most of the weight is transmitted through tibia, it is significantly larger and stronger than its counter bone, fibula. The tibia forms the knee joint proximally with the femur and forms the ankle joint distally with the fibula and talus. The tibia runs medial to the fibula from just below the knee joint to the ankle joint and is connected to each other by the interosseous membrane.[1]

The proximal end of the tibia consists of a medial and lateral condyle, which combine to form the inferior compartment of the knee joint. Between the two condyles lies the intercondylar area, which is where the anterior collateral ligament, posterior collateral ligament, and menisci are attached.[1]

The shaft of the tibia is triangular in cross-section with three borders and three surfaces. The anterior border divides the medial and lateral surface, the medial border divides the medial and posterior surface, and the interosseous border divides the lateral and posterior surface. While the medial surface is mostly subcutaneous, the lateral surface abuts the anterior compartment of the leg, and the posterior surface abuts the posterior compartment.[1]

Fractures of long bones constitute the majority of emergency operating room procedures in most trauma centres. Of these long bone injuries, tibial fractures are the most common. The National Centre for Health Statistics (NCHS) reports an annual incidence of 492,000 fractures of the tibia and fibula per year in the United States. Patients with tibial fractures remain in hospital for a total of 569,000 hospital days and incur 825,000 physician visits per year in the United States.[2,3,4]

Tibial fractures are prone to complications. The lack of a circumferential soft tissue envelope around the bone makes the bone ends more likely fail to unite (non-union). Approximately 50,000 North Americans suffer from these non-union complications each year. Other complications include infection, malunion, malalignment etc that sometimes necessitate additional operations. Management strategies to best minimize these frequent complications and resulting re-operations have been proved controversial.[2,3,4]

While deciding the treatment strategy, the treating surgeon must consider the patient's condition, the mechanism of injury, and the fracture type. Although some of the most impressive injury patterns are from highenergy mechanisms, more commonly, patients present with an open fracture from a simple low-energy mechanism such as a fall. Each fracture could conceivably be treated quite differently, ranging from external fixation and delayed closure or fixation to immediate irrigation, debridement, and primary closure. The status of the soft tissues surrounding the fracture site is of paramount importance in this decision-making process, which usually influences the initial management.[5]

Complications are also more in open fractures which may lead to non-union of these bones. Fracture of the shaft of long bone should not be considered a nonunion until at least,[6,7,8,9] months post injury. Non-union are more common when the fractures are open, infected, segmental, comminuted, insecurely fixed, immobilized for an insufficient time. They are also common if treated by ill-advised open reduction, distracted either by traction or by plates, screws and irradiated bones. Two types of non-union has been described in literature, Hypervascular non-union in which ends of the fragments are capable of biological reaction and avascular or atrophic non-union in which ends are inert and incapable of biological reaction.[6]

There are several procedures of surgery depending upon the type of fractures such as plating, nailing, bone grafting, external fixation, ring fixation etc.[3]

Every method has got its own merits and demerits. One of the most reliable techniques is application of ring fixators e.g. Illizarov but it has some disadvantages followed by dissatisfaction with patients. It causes various complications such as persistent pain, discomfort and heaviness. It has been seen in several studies, that the Limb reconstruction surgery (LRS) through Monorail system is superior to ring fixator.[5] Monorail system has more advantage for patients and for surgeon as well due to its light weight and uniplanar application. This mono rail device is cost effective and it's easier for the patient to move which promotes healing.[3]

Moreover, the anatomical and mechanical axis of the tibia is parallel to each other as a result it does not cause displacement of the bone. It also provides axial compression which promotes union and the patient can start walking even though undergoing treatment.

Monorail system is an external fixator which provides an easy access without excessive vascular injury to the soft tissues and to the bone. It causes minimal anatomical loss or displacement, and minimal complications considering the knee joint and ankle joint both.[3]

Surgical Anatomy

Surgical Anatomy of Leg[1]

The leg has 3-compartments:

1. Anterior compartment
2. Lateral compartment
3. Posterior compartment – This compartment is subdivided in-

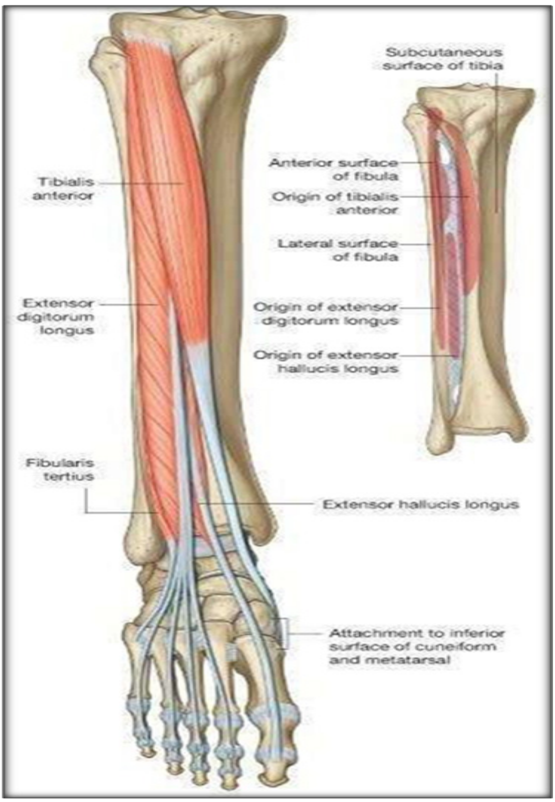
a. Superficial posterior compartment
b. Deep posterior compartment

Anterior Compartment:

- The muscles of the anterior compartment of the leg are extensor hallucis longus, extensor digitorum longus, tibialis anterior, and peroneus tertius.

- The primary function of anterior compartment is dorsiflexion of ankle and foot. Inversion of foot caused by tibialis anterior, extension of hallux by extensor hallucis longus and extensor digitorum longus perform extension of toes.

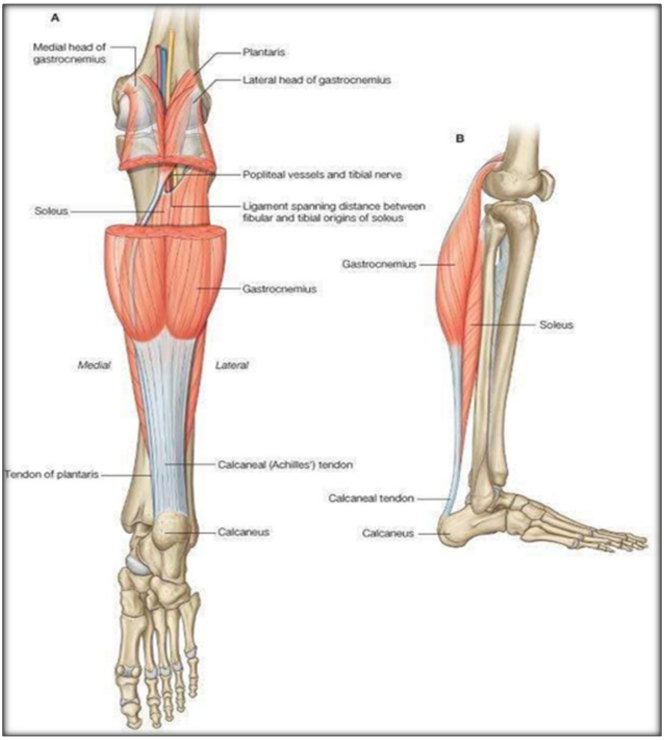
The muscles in the anterior compartment are enclosed with fascial covering, which makes the anterior compartment more at risk for compartment syndrome. Tendons of extensor digitorum longus, tibialis anterior, and extensor hallucis longus are close to the distal end of tibia. These muscles may get injured and incorporated by the callus formation during fracture healing



Muscles of Leg-Anterior view

Lateral Compartment

The muscles in this compartment are the peroneus brevis and longus. Their function is eversion of foot. The peroneus longus everts and plantar flexes the foot. Compartment syndromes are much less common in lateral compartment as compared to the anterior compartment.



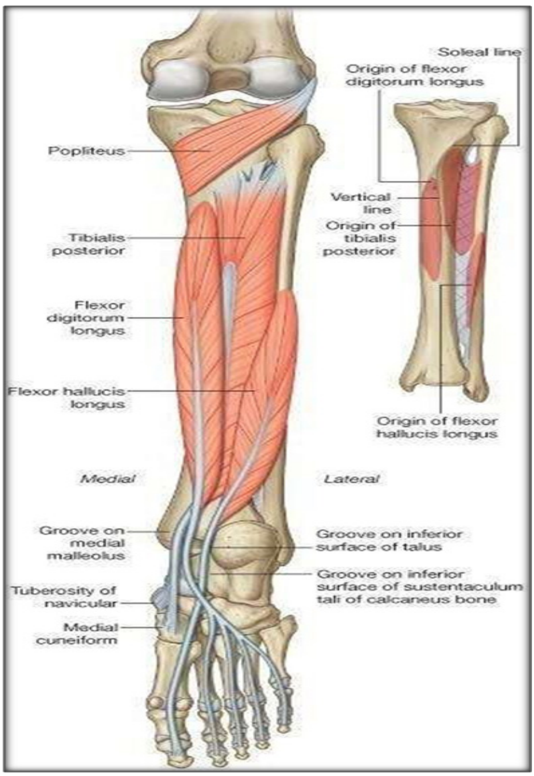
Muscles of Leg – Posterior View 1

Superficial Posterior Compartment

- The muscles of Superficial posterior compartment are gastrocnemius, soleus and plantaris.
- The Gastrocnemius muscles crossing both knee and ankle are primarily responsible for the flexion of the knee and ankle joints.

- Gastrocnemius tendon joins soleus tendon in distal third of the leg to form triceps surae or Achilles tendon.
- Plantaris has no anatomical significance, but may serve as a source of tendon graft.
- Deep Posterior Compartment
- This compartment contains flexor digitorum longus, flexor hallucis longus, tibialis posterior and popliteus.
- The function of these muscles are plantar flexion and inversion of foot.

Popliteus muscle is an internal rotator of tibia, leg flexor, and knee flexion initiator.



Muscles of Leg – Posterior View 2

Structure and Function

The tibia is the second largest bone in the body. One of the main actions of this bone is weight transmission. The majority of the weight load.[7] It also serves as the origin or insertion site for 11 muscles; these allow for extension and flexion at the knee joint and dorsiflexion and plantar-flexion at the ankle joint.

Tibial Osteology

The Proximal Tibia:

- Lateral condyle - lateral proximal part of the tibia that articulates with the femur.
- Medial condyle - medial proximal part of the tibia that articulates with the femur.
- Lateral tibial plateau - the superior articular surface of the lateral condyle.
- Medial tibial plateau - the superior articular surface of the medial condyle.

Intercondylar area:

- Anterior area: located anteriorly between the medial and lateral condyle. The attachment point of the anterior cruciate ligament.
- Posterior area: located posteriorly between the medial and lateral condyle. The attachment point of the posterior cruciate ligament.
- Intercondylar eminence (tibial spine): located between the articular facets and consists of a medial and lateral tubercle. The depression posterior to the intercondylar eminence serves as attachments for the cruciate ligaments and menisci.

The Tibial Shaft:

The shaft of the tibia is prism-shaped and has 3 surfaces (lateral, medial/anterior, and posterior) and 3 borders (anterior, medial, and interosseous).

- Anterior border: divides the medial and lateral surface.
- Medial border: divides the medial and posterior surface.
- Interosseous border: divides the lateral and posterior surface.
- Medial/anterior surface: palpable down the lower leg, commonly referred to as the shin. It contains the tibial tuberosity.
- Tibial tuberosity: bony projection of the anterior tibia where the patellar ligament inserts.
- Lateral surface: presents the border where the interosseous membrane is attached which connects the tibia and fibula.
- Posterior surface: presents the soleal line.
- Soleal line: an oblique line located on the posterior surface of the tibia and serves as the origin for the soleus, flexor digitorum longus, and tibialis posterior muscles.

The bone serves as the site of origin or insertion point of many muscles including tibialis anterior, extensor digitorum longus, soleus, tibialis posterior, flexor digitorum longus, sartorius, gracilis, quadriceps femoris, semimembranosus, semitendinosus, and popliteus muscles.[8]

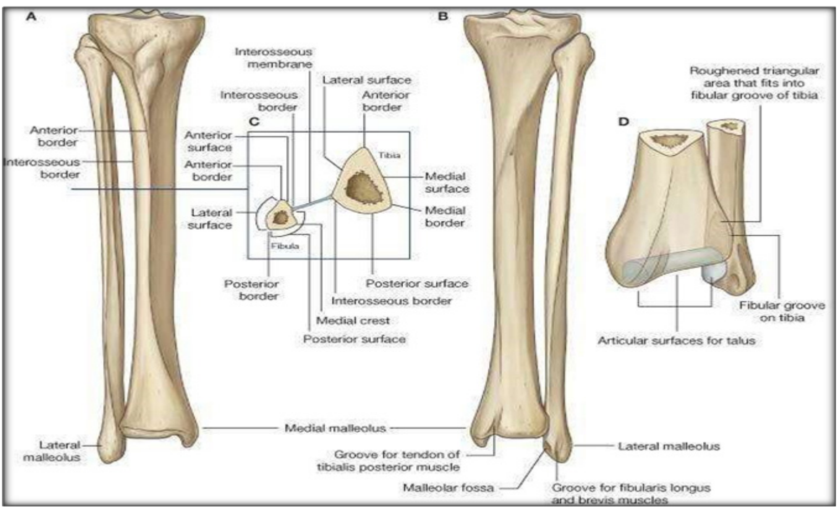
The Distal Tibia:

The distal end of tibia is box shape.[9] There are five surfaces that make up the distal tibia.

- The inferior surface provides a smooth articulation with the talus.
- The anterior surface is covered by extensor tendons

and provides an area for the capsular attachment of the ankle joint.

- The posterior surface has a groove for the tibialis posterior muscle.
- The lateral surface has a fibular notch which gives attachment for the interosseous membrane.
- The medial surface is a large bony prominence that makes up the medial malleolus.
- Medial malleolus: distal projection of the tibia which articulates with the talus
- Groove for the tendon of tibialis posterior is located on the posterior aspect of the medial malleolus.
- Fibular notch: location of the tibiofibular joint



Bones of the Leg – Tibia and Fibula

Embryology

The tibia has three ossification centres: one for the diaphysis and one for each epiphysis. It begins in the shaft at around the seventh week in utero. The proximal ossification centre starts at birth and closes at the age of 16-17 in females and the age of 18 in males.[10] The distal ossification centre starts at first year of age and closes at the age of 15 in females and the age of 17 in males.

Blood Supply and Lymphatics

The nutrient artery and periosteal vessels supply the blood to the tibia. The nutrient artery arises from the posterior tibial artery and enters the bone posteriorly distal to the soleal line. The periosteal vessels stem from the Anterior tibial artery.[11]

Nerves

The nerves that supply the tibia are all branches of the main nerves that supply adjacent compartments.[12] In the posterior compartment of the leg, the tibial nerve gives off branches that supply the posterior aspect of the tibia, and in the anterior compartment of the leg, the deep peroneal nerve gives off branches that supply the anterior aspect of the tibia

Muscles

Muscles Originating from the Tibia,

- Tibialis anterior originates from the upper two-thirds of the lateral tibia.
- Extensor digitorum longus originates from the lateral condyle of the tibia.
- Soleus and flexor digitorum longus originate from the posterior aspect of the tibia on the soleal line.

Muscles Inserting on the Tibia,

- Tensor fasciae latae inserts on the lateral tubercle of the tibia which is known as the Gerdy's tubercle.
- Quadriceps femoris inserts on the base, lateral and medial borders of the patella which continues as the ligamentum patellae and gets attached to the lower part of the tibial tuberosity.
- Sartorius, gracilis, and semitendinosus insert medially

on the upper part of the tibia as the hockey stick insertion which are called as the guy rope muscles.

- Horizontal head of semimembranosus muscle inserts on the medial condyle.
- Popliteus inserts on the soleal line of the posterior tibia.

Mechanism Of Injuries[13,14]

The tibial shaft fracture is caused by a significant amount of force. To appreciate the bone fractures in certain patterns, one must understand that bone is weakest in tension and strongest in compression. Therefore, when a force creates tensile stresses in a particular region of a loaded bone, failure will occur first in that region. A transverse fracture created in a long bone subjected to pure bending. As because the upper convex surfaces undergoes the greatest elongation, it is subjected to maximum tensile stresses and failure (indicated by a crack) initiates there. The crack then progresses transversely through the material. The layer just below the outer layer became subjected to high tensile force, until they get cracked as well. In this manner, the crack progresses through the bone transversely until it fails.

The concave surface is subjected to compression because of that the crack does not initiate there. The fracture line or crack that occurs when a bone is subjected to torsion or axial twisting resulting into a spiral fracture.

A rectangular area present on the surface of a long bone is loaded in torsion. The rectangle distorts when the bone get twisted with one diagonal of the rectangle elongating and the other shortening alongside the direction of the twist. A crack will form perpendicular to the diagonal that is elongating and it progresses around the perimeter of the bone results in a spiral fracture. The region with the smallest diameter usually has the greatest distortion as it allows the largest amount of twists. This explains why torsional fractures of the tibia often occur in the narrow distal third of the shaft.

A compressive load results in failure of cortical bone by shear, indicated by slippage along the diagonal because bone is weaker in shear than in compression (The stresses 45^0 to the compressive force within the material are shear stresses). In such case, compression causes the surface of the bone at 45^0 to the applied load to slide along an oblique surface.

At very high loads such as during impact fractures, crushing or comminution of bone also occurs, especially at the weaker metaphyseal ends of a long bone. The trabecular bone at the metaphyseal ends is weaker in compression than the diaphyseal cortical bone is in shear. Because of this it is unlikely that shearing failure will occur in the diaphysis due to pure compressive forces.

The butterfly fracture result from combined bending and compression. Bending load causes the fracture to start failing in tension producing a transverse crack. But as the crack progresses and remaining intact bone weakens, it starts to fail in compression causing an oblique (shear) fracture line. As the ends of the failing bone are driven together, the third fragment and the butterfly may result as because the oblique fragment splits off.

The production of a butterfly fragment probably depends on the timing and magnitude of the two basic applied loads, compression and bending.[13]

There are five principal causes of tibial diaphyseal fracture. These are falls, sports injuries, direct blows or assaults, motor vehicle accidents and gunshot injuries. Falls may be subdivided into simple falls. The simple falls are those in which the patient falls from his or her height, falls from down stairs or slopes and falls from a height.

Motor vehicle injuries usually affect motor cyclists, pedestrians or automobile occupants. The gunshot injuries may vary according to the type of the gun that has been used. Other causes of tibial diaphyseal fractures include land mines or other explosions. But these types of injuries are uncommon.

The tibial fracture with simple fracture pattern tends to result from simple falls, fall down stairs, sports injuries and direct blow to the tibia. However, falls from a height and motor vehicle accidents are associated with a much higher incidence of Gustilo-Anderson type 3A, B and C fractures, which are more difficult to treat.[14]

Classification of Tibial Fractures

There are so many literatures on the classification of the compound tibia fractures. Several attempts have been made by the authors in the past.

Ellis classified fractures into three basic groups.[15]

1. Mild

A mild fracture is a fracture with a minor degree of comminution or a minor open wound by low energy trauma and due to helical injury mechanism.

2. Moderate

It is the total displacement or angulation of fragments with a small degree of comminution or a minor open wound by moderate energy trauma and due to oblique oriented forces.

3. Severe

Here is the complete displacement of the fracture fragments with more than two fragments with major degrees of comminution or a major open wound with high energy trauma.

Fracture description:

While describing the X-ray, the fracture is classified according to the anatomical location of the fracture as in proximal, middle or distal third.

The nature of fracture radiologically: Transverse, oblique or spiral, comminuted and segmental. Angulation is measured in both anteroposterior and lateral view. The angulation is measured in the direction of the apex of the fractured fragments. Thus, it is anterior or posterior angulation and in anteroposterior view, the angulation is varus and valgus.

In addition shortening, overlapping and distraction to be noted. Rotation is difficult to judge on the X-rays and must be measured clinically.

Gustilo open fracture classification system[16,17]

Gustilo type	Definition	Example fracture patterns
I	Open fracture, clean wound, wound <1 cm in length	Simple transverse or short oblique fractures
II	Open fracture, wound > 1 cm in length without extensive soft-tissue damage, flaps, avulsions	Simple transverse or short oblique fractures
III	Open fracture with extensive soft-tissue laceration, damage, or loss or an open segmental fracture. This type also includes open fractures caused by farm injuries, fractures requiring vascular repair, or fractures that have been open for 8 h prior to treatment	High energy fracture pattern with significant involvement of surrounding tissues
IIIA	Type III fracture with adequate periosteal coverage of the fracture bone despite the extensive soft-tissue laceration or damage	Gunshot injuries or segmental fractures
IIIB	Type III fracture with extensive soft-tissue loss and periosteal stripping and bone damage. Usually associated with massive contamination. Will often need further softtissue coverage procedure (i.e. free or rotational flap)	Above patterns but usually very contaminated

IIIC	Type III fracture associated with an arterial injury requiring repair, irrespective of degree of soft-tissue injury.	Above patterns but with vascular injury needing repair

As classified by Gustilo-Anderson, 1976,[4]
Type-I fracture: Open fracture with clean wound < 1cm long.
Type-II fracture: Open fracture with laceration > 1cm long without extensive soft tissue damage.
Type-III fracture: Open segmental fracture, open fracture with extensive soft tissue damage.
As classified by Gustilo & Mendoza- 1984 further subdivision of grade-III. Grade- III a: high energy regardless of wound size, adequate soft tissue.
Grade- III b: Extensive soft tissue with periosteal stripping and bone exposure, major wound contamination, bone loss.

Gustilo-Anderson's Classification System for Open Fractures[17]

Type	Wound	Level of contamination	Soft tissue injury	Bony injury
I	< 1 cm long	Clean	Minimal	Minimal comminution
II	> 1 cm long	Moderate	Moderate, some muscle damage	Moderate comminution
IIIa	> 10 cm long	High	Severe with crushing	Includes segmental comminuted fractures. Soft tissue coverage of bone possible.
IIIb	> 10 cm	High	Extensive soft tissue injury with periosteal striping	Bone exposed, soft tissue reconstruction required

IIIc	Regardless of size	High	Extensive soft tissue injury with vascular injury	Vascular and soft tissue reconstruction / repair required.

Segmental fractures, farmyard injuries, fractures occurring in a highly contaminated environment, shotgun wounds or high velocity gunshot wounds automatically result in the classification as a Type III open fracture.

This classification system has prognostic significance.

Byrd Classification[18]

Believing in the fact that the vascular status to be the most important character, Byrd classified as:

Type I Low energy forces causing a spiral or oblique fracture pattern, skin laceration less than 2 cm and relatively clean wound.

Type IIModerate energy force causing comminuted or displaced fracture pattern with skin laceration more than 2 cm with moderate adjacent skin and muscle contusion but without devitalized soft tissue.

Type IIIHigh energy forces causing a significantly displaced fracture pattern with a severe comminution / segmental fracture or bone defect with the extensive associated skin loss and devitalized tissue.

Type IVFracture pattern as in Type III but with extreme energy forces as in high velocity gunshot.A history of crush injury or degloving injury and associated vascular injury requiring repair.

MONORAILFIXATOR (Limb Reconstructive System)

Limb Reconstructive System (LRS) is a modular unilateral frame consisting of Shanz pins, rail rods and sliding clamps. It is simple, effective, adjustable, light weight and offers rigid stabilization of fracture fragments along with the access to wound dressing. The management of open fractures with the LRS fixator allows immediate functional stabilization of fractures, weight bearing and axial fracture site movement promoting an early callus formation and fracture union. It can induce and enhance fracture healing by compression and distraction osteogenesis as well as bone transport can also be done easily in cases of bone loss.[19]

Advantages:[5]

It interferes with the soft tissue minimally.

- It causes less damage to the blood supply of bone.
- Fixation is adjustable without surgery.
- Stabilisation in open fractures.
- Technically less demanding.

REVIEW of LITERATURE

Raschke MJ et al in 1992,[20]reported the new fixation method and the primary clinical experience. Four patients who previously sustained Grades II-IIIb open tibial fractures had an average bony defect of 9 cm. Two patients had previous bony infections. All patients had serial debridement and myocutaneous flaps were required in three patients. An unreamed IM nail was inserted, and the transport device was applied. After an osteotomy, segmental transport was carried out until docking was attained. The external fixator was removed after interlocking of the transported segment. The mean duration of external fixation was 17.9 days/cm and the mean period until roentgenographic consolidation of the distraction and non-union site was 41.2 days/cm. There were two pin-tract infections but no IM infections. One nail broke after osseous consolidation of the regenerate at the distal interlocking site and required exchange.

Yongu WT et al in 2009,[21] have conducted a study on bone gap management using linear rail system. They have selected the femur bone fracture patients for the study. They have found the linear rail system as a simpler, less challenging and cosmetically accepted procedure.

Wani N et al in 2011,[22]assessed the results of patients with Gustilo types II, IIIA and IIIB open tibial fractures managed early with the Ilizarov external fixator (IEF). Sixty patients (51 males, nine females; age range 20–62 years; mean age 32.8 years) with type II (11 patients), type IIIA (13) and type IIIB (36) tibial diaphyseal fractures underwent emergency debridement and minimal bone fixation (with external fixator), followed by definite fixation with the IEF after three to five days. Average duration of the hospital stay was 8.6 days. All fractures united with an average union time of 21.1 weeks (standard deviation [SD] 3.18) in type II, 21.7 weeks (SD 3.57) in IIIA and 24. 9 weeks (SD 5.14) in IIIB fractures. The difference between union time in type II and IIIA was not significant ($p > 0.05$), but that between IIIA (and also type II) and IIIB was significant ($p < 0.05$). The healing index in patients who underwent lengthening was 1.5 months/cm. The wounds in 27 patients were managed by delayed primary closure, in 19 patients with second intent (all IIIB), in 11 patients with skin grafting (mostly type IIIB fractures) and in three patients with musculocutaneous flaps. The most common complications of the procedure were pin tract infection and pain at the fracture site. Most of the patients were able to achieve good knee and ankle range of motion. Early application of the Ilizarov fixator constitutes an excellent management of open tibial fractures, especially types II, IIIA and IIIB, due to good functional and radiological results.

Lakhani A et al in 2014,[23] assessed the outcome of rail fixator system in reconstructing bone gap. 20 patients (17 males and 3 females with mean age 30.5 years) who suffered bone loss due to open fracture and chronic osteomyelitis leading to infected gap non-union. Ten patients suffered an open fracture (Gustilo type II and type III) and 10 patients suffered bone gap following excision of necrotic bone after infected nonunion. There were 19 cases of tibia and one case of humerus. All patients were treated with debridement and stabilization of fracture with a rail fixator. Further treatment involved reconstructing bone defect by corticotomy at an appropriate level and distraction by rail fixator. They achieved union in all cases. The average bone gap reconstructed was 7.72 cm (range 3.5-15.5 cm) in 9 months (range 6-14 months). Normal range of motion in nearby joint was achieved in 80% cases. They had excellent to good limb function in 85% of cases as per the association for the study and application of the method of ilizarov scoring system [ASAMI] score. All patients well tolerated rail fixator with good functional results and gap reconstruction. Easy application of rail fixator and comfortable distraction procedure suggest rail fixator a good alternative for gap reconstruction of limbs.

Ajmera A et al in 2015,[24]evaluated the outcome of the limb reconstruction system (LRS) in the treatment of open fractures of tibial diaphysis with bone loss as a definitive mode of treatment to achieve union, as well as limb lengthening, simultaneously. Thirty open fractures of tibial diaphysis with bone loss of at least 4 cm or more with a mean age 32.5 years were treated by using the LRS after debridement. Mean followup period was 15 months. The mean bone loss was 5.5 cm (range 4-9 cm). The mean duration of bone transport was 13 weeks (range 8-30 weeks) with a mean time for LRS in place was 44 weeks (range 24-51 weeks). The mean implant index was 56.4 days/cm. Mean union time was 52 weeks (range 31-60 weeks) with mean union index of 74.5 days/cm. Bony results as per the ASAMI scoring were excellent in 76% (19/25), good in 12% (3/25) and fair in 4% (1/25) with union in all except 2 patients, which showed poor results (8%) with only 2 patients having leg length discrepancy more than 2.5 cm. Functional results were excellent in 84% (21/25), good in 8% (2/25), fair in 8% (2/25). Pin tract infection was seen in 5 cases, out of which 4 being superficial, which healed to dressings and antibiotics. One patient had a deep infection which required frame removal. Limb reconstruction system proved to be an effective modality of treatment in cases of open fractures of the tibia with bone loss as definite modality of treatment for damage control as well as for achieving union and lengthening, simultaneously, with the advantage of early union with attainment of limb length, simple surgical technique, minimal invasive, high patient compliance, easy wound management, lesser hospitalization and the lower rate of complications like infection, deformity or shortening.

Pal P C et al in 2015,[25]have conducted a study on 32 cases of selected compound fracture of tibia. There were 26 males and 6 females and the average age was 40 years. Patients were randomly divided into two groups (n=16 for each): one underwent Ilizarov fixation and the other received LRS fixation. Cases were followed up for 3-24 months, 6 months on average. Functional and radiological outcomes were assessed using the Association for the Study and Application of Methods of Ilizarov (ASAMI) criteria for both rail and ring fixator. Radiological outcome was found excellent in 68.75%, good in 18.75% and fair in 12.50% of cases treated by rail fixators whereas it was excellent in 56.25%, good in 18.75%, fair in 12.50% and poor in 12.50% of cases treated by ring fixators. Functional result was satisfactory in 75.00% of cases treated by rail fixator and 68.75% of cases treated by ring fixators whereas the corresponding rate of unsatisfactory was 25.00% vs. 31.25%.

Rohilla R et al in 2016,[26]compared the radiological and functional outcomes of ring and rail fixators in patients with an infected gap (> 3 cm) non-union of the tibia. 70 patients were treated for a posttraumatic osseocutaneous defect of the tibia measuring at least 3 cm. These were randomised into two groups of 35 patients using the lottery method. Group I patients were treated with a ring fixator and group II patients with a rail fixator. The mean age was 33.2 years (18 to 64) in group I and 29.3 years (18 to 65) in group II. The mean bone gap was 5.84 cm in group I and 5.78 cm in group II. The mean follow-up was 33.8 months in group I and 32.6 months in group II. Bone and functional results were assessed using the classification of the Association for the Study and Application of the Method of Ilizarov (ASAMI). Functional results were also assessed at six months using the short musculoskeletal functional assessment (SMFA) score. The result was excellent, good, fair and poor in 21, 12, 0 and 2 in group I; and 14, 15, 3, and 3 in group II, respectively. The functional results were excellent, good, fair, and poor and failure in 16, 17, 1, 0 and 1 in group I; and 22, 10, 0, 3 and 0 in group II, respectively. Both fixator systems achieved comparable rates of union and functional outcomes. The rate of deep pin-tract infection was significantly higher in the rail fixator group but patients found it more comfortable. They recommend the use of a ring fixator in patients with a bone gap of more than 6 cm. Patients with a bone gap up to 6 cm can be managed with either a ring or rail fixator.

Tekin AÇ et al in 2016,[27]evaluated functional and radiological results following treatment with the single-plane external fixator limb reconstruction system (LRS) for open tibial diaphyseal fractures resulting from high-energy trauma. 50 tibias from 49 patients (males: 32, females: 17) were classified as type 3 according to the Gustilo-Anderson open fracture classification, and definitive treatment was applied with the LRS. The patients ranged in age from 20 to 36 years. Time to union, time of external fixator usage, complications and functional results according to the Johner-Wruhs criteria were recorded. The mean follow-up period was 23 ± 12 months (range: 1144). Of the 50 tibias, full union was achieved with the LRS in 48 (96%). No shortness or deformity was observed in any patient. Knee and ankle range of movement were measured as full in all patients at the final follow-up examination after removal of the LRS. The mean time to union was 20.4 ± 4 weeks (range: 16-24). The mean time of external fixator use was 20 weeks (range: 16-24 weeks). For the definitive treatment of open tibia diaphyseal fractures, the LRS was an optimal and safe choice that offered single-stage surgery.

Patil MY et al in 2016,[28]determined the efficacy of Limb Reconstruction System for treatment of compound tibia fractures. A prospective study was carried out where 54 cases out of 412 compound tibia fractures having Modified Gustilo Anderson Type IIIA and IIIB with a mean age of 42±5 years were treated using LRS over a period of 26 months. Bony and functional assessment was done by Association for the Study and Application of the Methods of Illizarov (ASAMI) criteria. Among 54 patients, bony results as per ASAMI score were excellent in 36, good in 14, fair in 2 and poor in 2 patients. Functional results were excellent in 43, good in 7, fair in 4 patients. The average fracture union time was 8 months. Post-surgery patient satisfaction was excellent since fixation allowed weight bearing immediately. Average hospital stay was 7 days and financial burden was reduced by 40% as compared to multi staged surgery. The average time of return to work was 20 days. LRS is an easy, simple and definitive surgical procedure that allows immediate full weight bearing walking. It reduces hospital stay, is cost effective with excellent patient compliance and can also be used for bone lengthening/transportation

Dabkana TM et al in 2016,[29]assessed the effectiveness bone transport/distraction technique using the Linear Rail System for the treatment of segmental bone loss following trauma. There were 10 patients involve in study,8 males and 2 females, age between 22 and 48 years. All patients with segmental bone loss of more than 4 cm following RTA were included in the study. All our ten patients achieved adequate defect correction of up to 80% to 100%. H.S. Pitkar LRS System when used properly is good for management of segmental bone loss following trauma.

Patil NVP et al in 2016,[30]compared the outcome of the unreamed intramedullary nailing and limb reconstruction system (LRS, Orthofix) in the treatment of type IIIA Gustilo-Anderson open fractures of tibial diaphysis. 80 cases were treated with orthofix were labelled as group A and 80 cases treated with unreamed intramedullary nailing were labelled as group B. Average time of union in group A was an average 35 weeks (30-40 weeks) in 64 cases (80%) with 16 cases (20%) of non-union which were subsequently treated with bone grafting and showed union at an average 40 weeks (38-44 weeks). Group B showed average time of union at an average 29 weeks (2438 weeks) in 66 cases (82.5%) with 10 cases(12.5 %) of infective non-union at which subsequently treated with external fixator and showed union at average 36 weeks (34-38 weeks). 4 cases which showed delayed union were dynamised and bone grafted and showed union at an average 32 weeks. Intramedullary nailing can be used in the management of type IIIA fractures as it allows early union and primary closure with the avoidance of secondary procedures with the risk of higher rate of deep infection.

Nath RG et al in 2017,[31]evaluated outcome of the open tibial fractures treated with Orthofix. The study was prospective study involving 30 patients with open Tibial fractures. The patients were treated with wound debridement and stabilisation with Orthofix and followed up. Then the patients were followed up to evaluate clinically, functionally by Lower Extremity Functional Score (LEFS) and radiologically by Radiographic union scale in Tibial fractures (RUST). All the 30 patients included in our study had achieved bone union (100%). One patient (3.33%) had delayed union and required bone grafting and fibulectomy. The mean follow up period is 32.6 weeks. The average period taken for fracture union is 24.4 weeks. The mean LEFS score for the 30 patients at the end of follow up is 88.75%. The mean RUST score at the end of follow up is 2.6. Orthofix serves as external fixator and definitive fixation device as it allows dynamization. Hence Orthofix is a very good device in Open tibial fracture management if proper rehabilitation measures and proper timing of dynamization is followed.

Pangavane S et al in 2017,[32]conducted a study on 20 compound tibia and femur fractures treated by the limb reconstruction system (LRS). 10 cases of compound tibia IIIa and 10 cases 0f IIIb were included in study. Status of wound was classified by Gustilo -Anderson open wound criteria, comorbidies were noted additional procedure if any were noted. Radiological union was defined as minimum of 3 cortical continuity in views of X-Ray. Time duration was recorded in which knee Range of motion was assessed by 'hand goniometry during treatment. Average age of patient was 37.9 years, fracture tibia showed total 100% union. Average time for tibial union was 10.2 month. Average time for tibial LRS in situ was 10.6 month. 6 patients required corticotomy with lengthening Average lengthening was 2.5 cm in 7 no cases (1.5-5 cm range). Average knee ROM are 100 degree of flexion (range90130). Complication noted were pin tract infection, Delayed or Non-union, multiple surgeries, patient's co-operation.

Mahajan NP et al in 2017,[33]evaluated the outcome of limb reconstruction system in 20 patients for management of compound tibia diaphyseal fracture. The mean time of partial weight bearing was 3.5±2.97 weeks, full weight bearing was 8.55± 4.14 weeks and bone union time was 20.22±5.22 weeks. The pin tract infection was found in 5 (25%) cases. Delayed union was observed 06 (30%) cases. Shortening of more than 2 cm were recorded in 3 (15%) patients. Joint (knee or ankle) stiffness was observed in 6 (30%) cases. Loosening of pin was observed in 3 (15%) cases. Chronic osteomyelitis was observed in 3 (15%) cases. Secondary procedures were done in 11 (55%) cases. Bone marrow aspiration was done in 5 (25%) cases, iliac bone grafting in 5 (25%) cases. LRS is found to be wonderful tool in management of compound tibia fractures as primary and definitive mode because of its safety, versatile nature, patient friendly and cost effectiveness.

Mangukiya HT et al in 2018,[34]did a prospective study comprising 40 patients with compound tibia diaphyseal fracture managed with AO monolateral external fixator (Group 1) (n = 20) and Limb reconstruction system (Group 2) (n = 20) as primary and definitive tool. In their study bony outcome by ASAMI score shows 6 (30%) patients had Excellent, 5 (25%) patients had Good and 9 (45%) had Poor bony outcome from Group I. In group II, 12 (60%) patients had Excellent, 4 (20%) patients had Good, 2 (10%) patients had Fair, and 2 (10%) had Poor bony outcome. The functional outcome by ASAMI score shows 3 (15%) patients had Excellent, 8 (40%) patients had Good, 5 (25%) patients had Fair, 3 (15%) had Poor bony outcome from Group I. In group II, 9 (45%) patients had Excellent, 7 (35%) patients had Good, 2 (10%) patients had Fair, and 2 (10%) had Poor functional outcome. Limb reconstruction system (LRS) offers several advantage over AO monolateral external fixator such as ease of application, versatility, stronger fixation, less fixator related complications, early weight bearing and early bony union for management of compound tibia diaphyseal fracture as primary and definitive tool.

Sandhu KS et al in 2018,[35]compared the role of Ilizarov (group1) and Rail fixator devices (group 2) in their study of 15 patients each under both groups. 15 patients of non-union long bones in each group from 21 to 60 years with mean age of 37.6 year in group A and 40.5 years in group B. 90% of the patients were male. Most of the patients had non-union of tibia and further the middle one third was more commonly involved in either group. Nine out of 15 patients in both the groups had infected type of non-union. Average shortening was 2.9 cm in group A and 2.86 cm in group B. Maximum number of patients had undergone about two previous surgeries. 12 patients underwent acute docking or compression in group A compared to 13 in group B. Three and two patients underwent compression – distraction for treatment of non-union in group A & B respectively. Patients were followed up at 6, 12 and 24 week intervals. Union was seen in 13 cases in group A and 14 cases in group B. The duration for union was average 8.8 months and 8.1 months in respective groups. Normal range of motion in nearby joint was achieved in 80% cases. They had excellent to good limb function in 80% of the cases in Group A and 86% of cases in group B as per ASAMI scoring system. Bone results were more or less similar in both the groups. Functional results were a bit better in rail fixator group.

Anand VK et al in 2018,[36] assessed the union rates, infection control and complications associated with LRS. 42 patients with complex nonunion of long bones managed with application of rail fixators were enrolled. Fixation was performed using a monolateral external fixator. Patients were followed up regularly in OPD every two weeks for the first two months and thereafter every month till docking of the fracture fragments was achieved. Majority of the patients had an external fixator or infected implant at the time of presentation. No special investigations were required in our study except for frequent X-Rays and pus culture and sensitivity. Corticotomy was done in almost half (55%) of the patients. Two patients required additional bone grafting and one patient required freshening of bone ends as secondary procedures. Another secondary procedure adopted was PRPP injection in 1 patient at the docking site to achieve union but it ultimately failed to unite. Out of 42 patients, 22 patients are while remaining 18 patients are still undergoing treatment and one patient lost to follow up. Mean treatment duration was 7.9 months ranging from 4 months to 14 months. Complex nonunion can be managed satisfactorily with rail fixators.

Singh AK et al in 2019,[37] studied the Functional outcome of performing distraction osteogenesis in cases of infected non-union of tibia treated with Ilizarov and Limb Reconstruction System. The study was done with 27 patients of infected gap nonunions of the tibia. After implant removal, if required radical resection of necrotic tissue and fractures were stabilised with Ilizarov or mono-lateral fixator depending on non-union site. Corticotomy was either done proximally or distally. Patients were followed up at monthly intervals for a minimum of 6 months. The ASAMI-Bone healing score was excellent or good in 86% patients and Functional score was excellent or good in 89% of patients. The commonest problems were of pin tract infection, wire loosening and angulation of the transported segment. Elderly age, persistent infection, sensory loss in the foot, the stiffness of the knee, and above all the patient's reluctance to go any further given the protracted treatment besides, systemic disorders such as diabetes are all pointers for considering amputation as an alternative.

Singh P et al in 2020,[38]analysed the efficacy, functional and radiological outcome of Limb Reconstruction System (LRS) in management of open fractures of tibia with or without bone loss as a primary and definitive tool. They treated 20 patients with compound injuries of tibia with Limb Reconstruction System (LRS) as a primary and definitive tool. 15 males & 05 females were included. Average follow up period was 36.45±4.7 weeks ranging from 06 – 18 months. There was sound bony union in all of the cases with resolution of infection. The mean time of full weight bearing was 10.45±2.25 weeks and bone union time was 23.26±6.33 weeks. ASAMI score (Association for the Study and Application of the Method of Ilizarov) for bony outcome was Excellent in 13 (65%) patients, good in 5 (25%) patients, fair in 1 (5%) patient and Poor in 1 (5%) patient. ASAMI score for functional outcome was Excellent in 14 (70%) patients, Good in 4 (20%) patients, fair in 1 (5%) patient and Poor in 1 (5%) patient. Rail external fixator was sufficient enough for wound healing & bony union. Limb Reconstruction System (LRS) offers an alternative option to treat compound fractures of tibia because of simplicity of application, its good fracture stability, adjustable geometry, light weight, affordable cost, and patient friendly and can induce/enhance fracture healing by compression and distraction osteogenesis.

AIMSAND OBJECTIVES

To study the functional outcome of the patients treated with the primary fixation using monorail system in open fracture of tibia by-

1. To assess stability of monorail fixator and total time taken in fracture union.

2. To assess range of motion in operated patient.

3. To assess full weight bearing on follow up.

4. To assess compliance of the patient.

5. To assess pin track infection and post-operative surgical site infection by taking swab for culture and antibiotic sensitivity.

MATERIAL AND METHODs

At Rajindra Hospital and Govt. Medical College, Patiala after taking the permission from the ethical committee 30 cases of compound fractures of tibia were selected, treated and followed up in between the time period of November 2018 and October 2020 under the department of Orthopedics.

Inclusion criteria

1. Compound fractures of tibia
2. Extra-articular fractures tibia
3. Ages between 18 years to 60 years
4. Type 2 and 3 (A and B) open fracture classified by Gustilo-Anderson
5. Skeletally mature patients

Exclusion criteria:

1. Skeletally immature patients.
2. Ages less than 18 years and more than 60 years.
3. Type 1 and Type 3C Compound fractures classified by Gustilo-Anderson

Materials

1. Radiolucent operating table

2. C-Arm machine

3. General instruments and LRS[39,40]

This instrumentation has got four models.

1. Long model – 500 mm
2. Standard model – 400 mm
3. Short model – 200 mm
4. Pediatric – 100-150 mm

We are using standard and short model. It has got:

1. Railing: made up of hard carbon, the function of this is to equalize the lever of the bone.
2. Connecting clamps which are three in numbers, each clamp has got 8 mm 3 threaded bolts, two in the front and one in the back of clamps which is connected to railing.

3. Compression and distraction unit.
4. Schanz pins 6 mm long threaded depending upon diameter of the bone.
5. Allen key.
6. Spanner 14 mm.
7. T-clamp: It can be attached to either end of rail. It is not a movable one, has got its own Templet.
8. Dyna ring is locked to the rail with the silicon cushion facing the clamp, which has been unlocked for dynamization and it permits only limited dynamization of fragment to safeguard the collapse of fragments. So, it allows earlier conversion from a rigid to dynamic mode and corresponding reduction in the neutralization period.
9. Fracture reduction forceps.
10. Power drill with bits.
11. T handles.

Methodology

Primary management-

When Patients were presented at emergency department of Rajindra hospital-

- Thorough examination was done to rule out any other systemic injury like head injury, cardiorespiratory and abdominal status.
- Patients with hypovolemic shock were treated with IV fluids like plasma expanders, dextrose, normal saline, ringer lactate solution.
- Immediate intravenous antibiotics and intramuscular tetanus toxoid, tetanus immunoglobulins were given.

Once the patient became hemodynamically stable, clinical evaluation and primary wound debridement was done under local anaesthesia with 5-6 litre of normal saline, betadine and hydrogen peroxide were used to clean the wound. The patient was given splintage of the limb, anti-inflammatory drugs and analgesics according to the needs.

- Detailed history was recorded as per the proforma attached, after that patient shifted to radiology department for X-rays.

Pre-operative preparation:

- Wounds were graded according to Gustilo-Anderson's classification as Type 1, 2, 3A, 3B and 3C based on the size of wound, degree of soft tissue injury, and level of contamination, degree of bone injury and presence or absence of neurovascular injury.
- Pre-operative counselling of the patients and his relatives regarding the method of treatment and prognosis was done and consent was taken.
- Complete preoperative radiographic assessment was done and preoperative surgery plan was prepared. Local preparation of part was done by shaving and painting with 10% betadine.
- Appropriate intravenous antibiotics were given immediately before operation or during operation and were continued following operation.

In our series, we have excluded type 1 fracture as they were treated with primary intramedullary interlocking nailing and type 3C compound fracture as they needed vascular surgeons.

Postoperative Management:

- Static quadriceps exercises & toe movements, as tolerated were started from the 1st postoperative day.
- Ankle and knee mobilization was started from 2nd postoperative day.
- Intra-venous antibiotics were given for 5-8 days followed by a course of oral antibiotics for 5-7 days.
- Analgesics were given as per need.

Protected full weight bearing was allowed once the pain was tolerable usually at postoperative day 5th.

- Regular antiseptic dressing of open wound with appropriate sterilized technique was done in postoperative wards.

- After 2-3 weeks, once the wound is clean and covered with healthy granulation tissue plastic surgeon opinion was taken and treated accordingly.
- Suture removal was done on 11th postoperative day.
- The fracture union status in all the treated cases with monorail fixator on follow up were evaluated on the basis of radiological union scale in tibial fracture score (RUST).
- After which the fixator is removed and patient's limb were immobilized with PTB cast for another 3-4 week.

Radiographic union scale in tibial fracture (RUST),[41]

Score per cortex	Callus	Fracture Line
1	Absent	Visible
2	Present	Visible
3	Present	Invisible

Follow up

- The final functional outcome was evaluated using the modified 'Johner and Wruhs' criteria with modification' to favour life style needs for an Indian patient.
- Patients were followed up periodically at 4 weeks, 8 weeks, 12 weeks, 6 months, 9 months and may be in between if required. The complaints were noted, clinical and radiological analysis had been done.

Assessment of the patients were done, for pain, deformity, shortening, range of motion of knee, ankle, and radiological union have been evaluated.

- Pain was noted as none, occasional, moderate and severe.
- Deformity was noted as none, anteversion-recurvatum, varus-valgus and rotation deformity in degrees.
- Shortening was noted in the form of measurement

and was noted in cm or was noted as nil if absent.

- Range of motion of knee, ankle and subtalar joints was noted in percentage. 100% being normal, more than 80% for knee, more than 75% for ankle and more than 50% for subtalar joint was considered as good.
- Radiological assessment is done on the basis of whether there is callus, or union or if fracture is consolidated.
- Radiological union is noted as consolidated for excellent and good results. Union for fair results and not consolidated for poor results.
- Angular alignment (varus-valgus, anterior and posterior angulation) was assessed radiologically. Varus-valgus was determined by measuring the angle between the line drawn perpendicular to bisecting the tibial plateau and proximal medullary canal with the line bisecting the distal medullary canal and tibial plafond.
- Anteroposterior alignment was determined by measuring the angle between the lines parallel to the proximal fragment and distal fragment on lateral radiographs.
- Rotations were assessed clinically.
- Malunion was considered when varus-valgus angulation was more than 5^o, anterior-posterior was more than 10^o, internal and external rotations of more than 10^o and shortening of more than 10 mm.

Gait was assessed whether normal or associated with a limp.

- In this study fracture, union was considered when patient was weight bearing without pain, fracture site was not tender on palpation, radiograph showed osseous union in antero-posterior and lateral views after removal of fixator.

Modified Johner and Wruh's criteria,[42]

Excellent – no non-union, no infections, no deformity, no shortening, no pain, full range of ankle and knee movements, no neurological deficit and normal gait

Good - no non-union, mild infections, mild deformity, <10mm shortening, occasional pain, range of ankle (>75%) and knee (>80%) movements, no neurological deficit and normal gait.
Fair - no non-union, moderate infections, moderate deformity, shortening 10 to 20mm, moderate pain, range of ankle (>50%) and knee movements (>75%), no neurological deficit and mild limp.
Poor- non-union, deep infections, significant deformity, >20mm shortening, severe pain, range of ankle (<50%) and knee (<75%) movements, neurological deficit and significant limp.

Surgical technique

- Position the patient - The patient was positioned supine with both lower limb in extension on a radiolucent table.
- The C Arm image intensifier on same side of fractured limb and screen was in front of operating surgeon.
- The pneumatic tourniquet was applied above knee position.
- Reduce the fracture- A fracture reduction was performed under supervision or image intensifier guidance according to the wound condition. The reduction was temporarily fixed with reduction forceps.

Application of LRS

After preparation of the part, three Schanz pins were introduced in to proximal fragment of fractured tibia anteromedially. This instrumentation has to be applied only at compressive force side, that is medially or anteromedially to nullify the compressive force of the muscles which are present at posterolaterally which is the side of tensile force.

The insertion of Schanz pins should be done in the following manner:

These three pins were fixed to proximal clamp of LRS. We had to take the measurements of the distal fragment for application of Schanz pins depending upon the length of distal fragment. If distal fragment was two-thirds of tibia, 2 clamps and 6 Schanz pins were used. For one-third, 1 clamp and 3 Schanz pins were used.

a) Assemble the triple trocar and penetrate soft tissue (through a stab incision) down to the bone surface.
b) Remove the trocar and drill through both cortices using a long 4.5 mm drill bit.
c) Remove the drill sleeve.

d) Insert the depth gauge probe through the probe sleeve hooking the far cortex.
e) Loosen the locking pin, advance the knurled disk to the top of the drill sleeve and tighten the locking pin.
f) Remove the probe. Place the threaded tip of the Schanz pin into the Schanz pin recess of the knurled disk.

g) Advance the universal chuck over the non-threaded end of the Schanz pin until the tip of the probe touches the end of the universal chuck. Tighten the universal chuck onto the Schanz pin in this position.
h) Insert the Schanz pin until the universal chuck nearly touches the top of the drill sleeve, the Schanz pin is now fully inserted into far cortex.
i) Remove the drill sleeve and attach the adjustable clamp.

j) To give more stability to distal fragment as it is mobile, after the application this has to be fixed with nuts situated at posterior aspect of railing with the help of spanner.
k) The compression distraction unit has to be fixed in between distal clamp of proximal segment and distal first clamp of distal fragment.
l) The fixator was placed in neutralization mode in case of comminuted and butterfly fragment fractures. Compression mode in case of transverse, oblique and segmental fracture as to narrow fracture gap and improve stability.
m) Application of fixator should be in such a way that

it should be away from the site of wound. If a soft tissue coverage procedure is required later on, then railing application should be such as to leave enough area for the soft tissue procedure intended.

Soft tissue procedure:

Relaxing skin incisions were placed around the pin tracts to avoid skin compression, bone was covered with overlying muscles, skin approximated with stay sutures. The foot and ankle were manipulated at the end of the procedure to ensure absence of musculotendinous tethering by half pins.

Statistical Analysis

All data were entered in Excel 2010 and statistical analysis was performed using the statistical software SPSS 25.0.Quantitative data were expressed as mean values (with standard deviations) and categorical data were expressed as frequency (with percentages)

OBSERVATION AND RESULT

In the Rajindra hospital and Govt. Medical College, Patiala the present study was undertaken for assessing the functional outcomes of monorail fixator as a primary mode of fixation in compound tibia fracture type 2 and type 3A,3B as classified by Gustilo-Anderson. The 30 cases of compound tibia fracture were selected and followed up between November 2018 to October 2020 under the department of Orthopaedics. Both the males and females patients who had presented with compound tibia fracture at emergency department were selected between this period. The present study of surgical treatment of compound tibia fracture with monorail system revealed the following.

1. Age incident
2. Sex incident
3. Mode of injury
4. Type of fracture / classification
5. Side of fracture
6. Associated injury (AI)
7. comorbidity
8. Duration of surgery
9. Secondary procedure done
10. Time of full weight bearing post-operative
11. Time of fracture union
12. Complication
13. Modified Johner and Wruh's criteria parameters

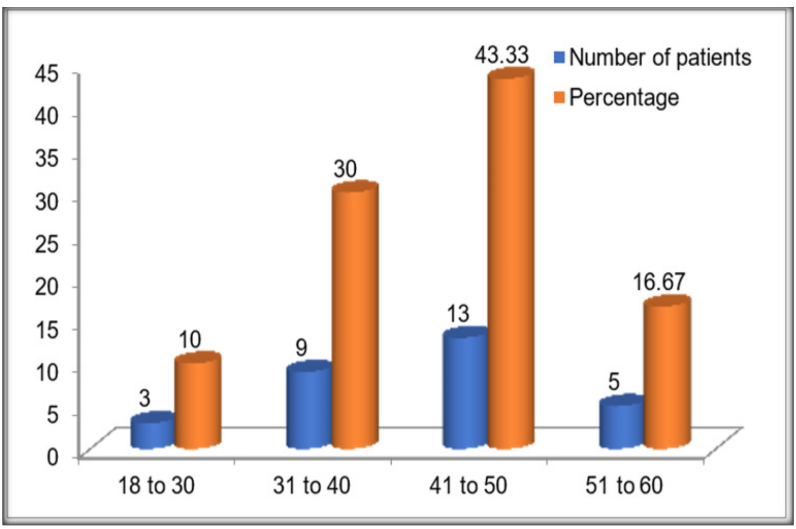
α. Nonunion
β. Post-operative neurovascular injury
χ. Pain
δ. Infection
ε. Knee and ankle range of motion
ϕ. Gait
γ. Result

<u>Following results were obtained:</u>

Age Incidence

Table 1: Age-wise distribution of patients

Age group (years)	Number of patients	Percentage
18 to 30	3	10
31 to 40	9	30
41 to 50	13	43.33
51 to 60	5	16.67
Total	30	100
Mean ± SD	42 ± 10.09	



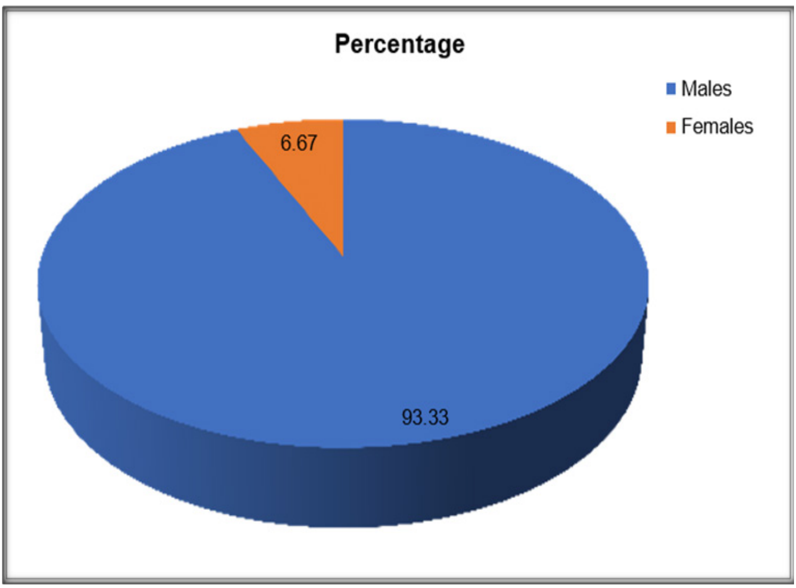
Graph 1: Age-wise distribution of patients

In our study we include patients aged between 18 and 60 years and the maximum numbers of patients (43.33 percent) belonged to the age group of 41 to 50 years while 16.67 percent of the patients belonged to the age group of 51 to 60 years. 30 percent of the patients belonged to the age group of 30 to 40 years. The youngest being at age 21 and the oldest being 58 year of age. Mean age of the patients was 42 years.

Sex Incidence

Table 2: Sex-wise distribution of patients

Sex	Number of patients	Percentage
Males	28	93.33
Females	2	6.67
Total	30	100



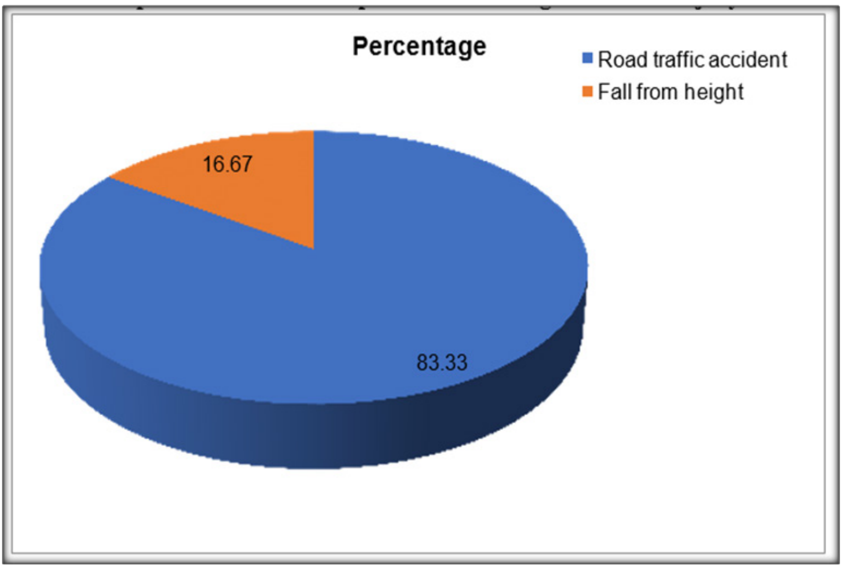
Graph 2: Sex-wise distribution of patients

In our study, there was male dominance. The 93.33 percent of the patients were males while the remaining 6.67 percent were females.

Mode of Injury

Table 3: Distribution of patients according to mode of injury

Mode of injury	Number of patients	Percentage
Road traffic accident	25	83.33
Fall from height	5	16.67
Total	30	100



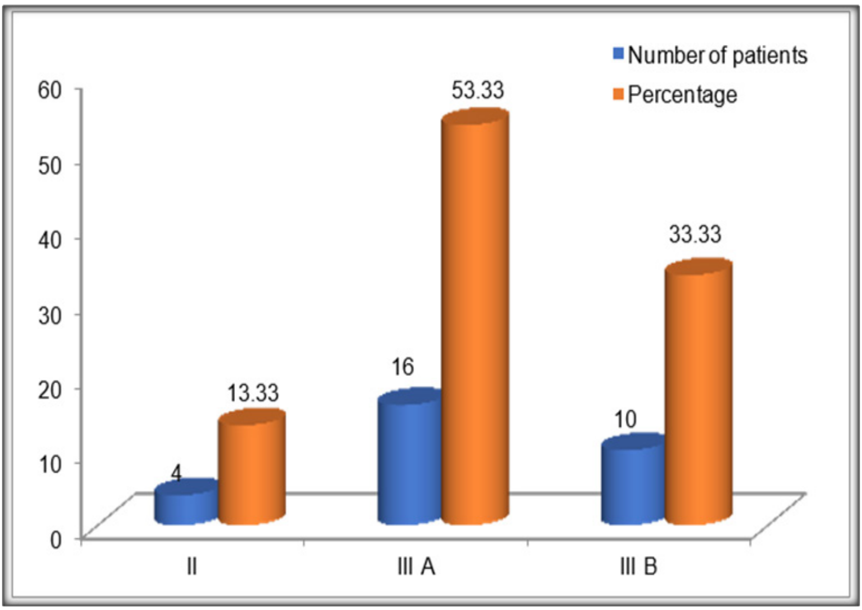
Graph 3: Distribution of patients according to mode of injury

In our study, most common cause was road traffic accident in 83.33 percent of the patients while it was fall from height in 16.67 percent of the patients.

Types of Fracture Classification

Table 4: Distribution of patients according to type of fracture (Gustilo-Anderson classification)

Type of fractures (Gustilo-Anderson classification)	Number of patients	Percentage
II	4	13.33
III A	16	53.33
III B	10	33.33
Total	30	100



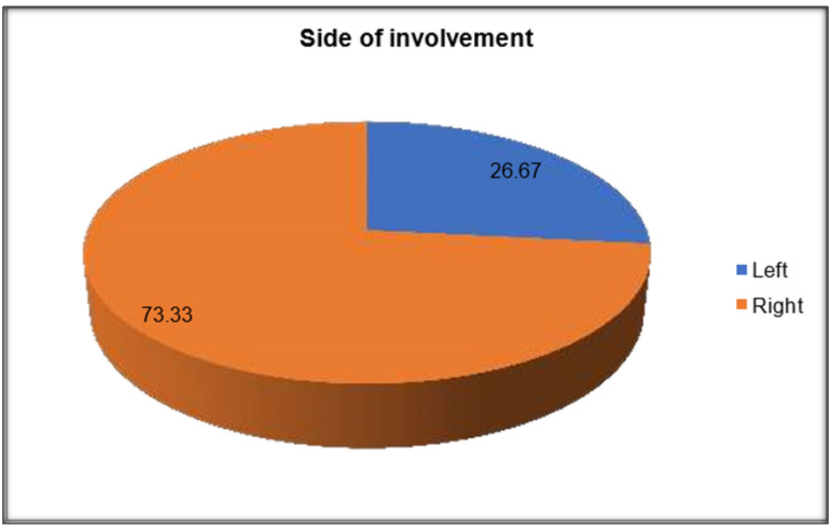
Graph 4: Distribution of patients according to type of fracture (Gustilo-Anderson classification)

According to Gustilo-Anderson classification we included in our study from type II to type III B, in our study 53.33 percent of the patients were belonging to type III A while 33.33 percent of the patients were of type III B. 13.33 percent of the patients were of type II.

Side of Injury

Table 5: Distribution of patients according to side of involvement

Side of involvement	Number of patients	Percentage
Left	8	26.67
Right	22	73.33
Total	30	100



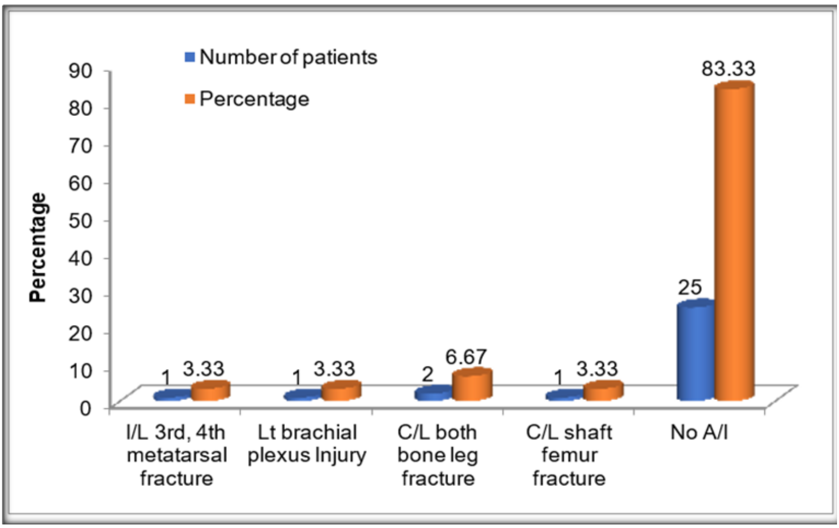
Graph 5: Distribution of patients according to side of involvement

In our study Right side involvement occurred in 73.33 percent of the patients while left side involvement occurred in 26.67 percent of the patients.

Associated Injury

Table 6: Associated Injury

Associated Injury	Number of patients	Percentage
I/L 3rd, 4th metatarsal fracture	1	3.33
Lt brachial plexus Injury	1	3.33
C/L both bone leg fracture	2	6.67
C/L shaft femur fracture	1	3.33
No A/I	25	83.33
Total	30	100



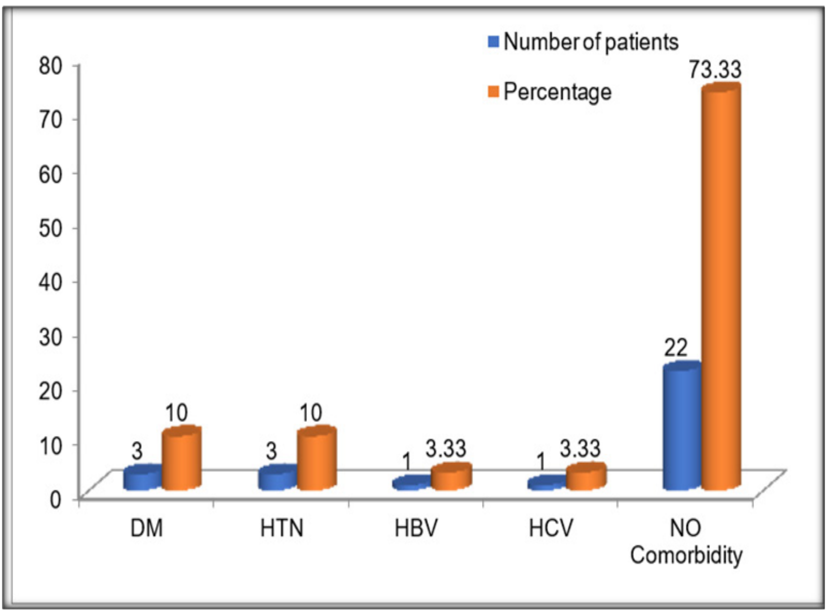
Graph 6: Associated Injury

In our study 6.67 percent of patients had C/L both bone leg injury, 3.33 percent patient come with Lt side brachial plexus injury while one patient (3.33 percent) presented with C/L shaft femur fracture. 83.33 percent patient had no associated injury.

Comorbidity

Table 7: Comorbidity

Comorbidity	Number of patients	Percentage
DM	3	10
HTN	3	10
HBV	1	3.33
HCV	1	3.33
NO Comorbidity	22	73.33
Total	30	100



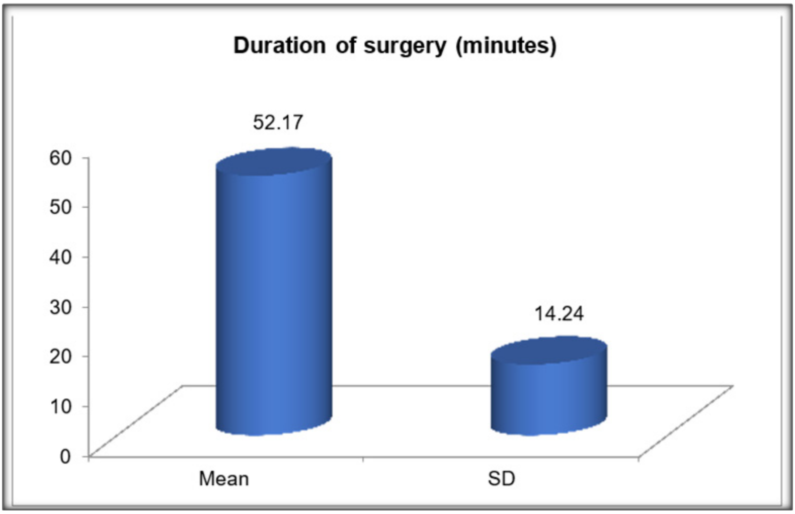
Graph 7: Comorbidity

In our study 10 percent of patients had Diabetes and Hypertension each while 3.33 percent patients presented with hepatitis B and hepatitis C infection each.

Duration of Surgery

Table 8: Duration of surgery

Parameter	Mean	SD
Duration of surgery (minutes)	52.17	14.24



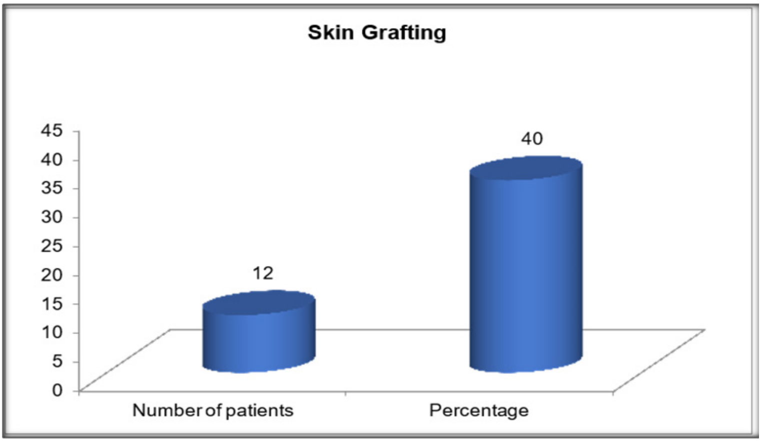
Graph 8: Duration of surgery

The Mean duration of surgery was 52.17 minutes.

Secondary Procedure

Table 9: Secondary procedure done

Secondary procedure done	Number of patients	Percentage
Skin Grafting	12	40
Total	30	100



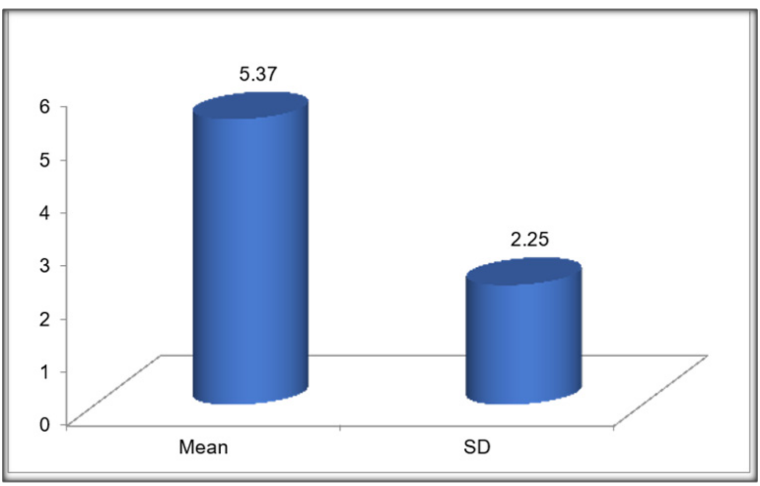
Graph 9: Secondary procedure done

In our study, Secondary procedures (Skin Grafting) were done in 40 percent of the patients.

Time of Full Weight Bearing Post-Operative

Table 10: Time of full weight bearing post-operative

Parameter	Mean	SD
Time of full weight bearing (days)	5.37	2.25



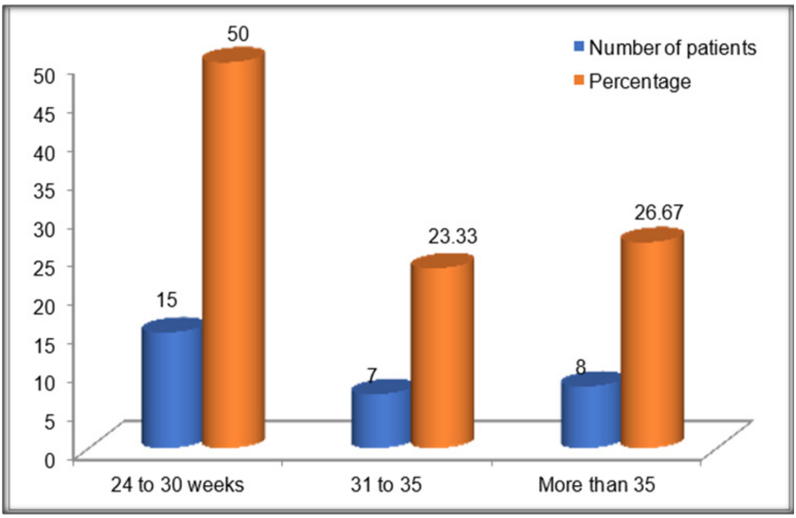
Graph 10: Time of full weight bearing post-operative

The mean time of full weight bearing post-operative was 5.37 days.

Time of Fracture Union

Table 11: Time of fracture union

Time of fracture union (weeks)	Number of patients	Percentage
24 to 30 weeks	15	50
31 to 35	7	23.33
More than 35	8	26.67
Mean ± SD	31.8 ± 5.8	8



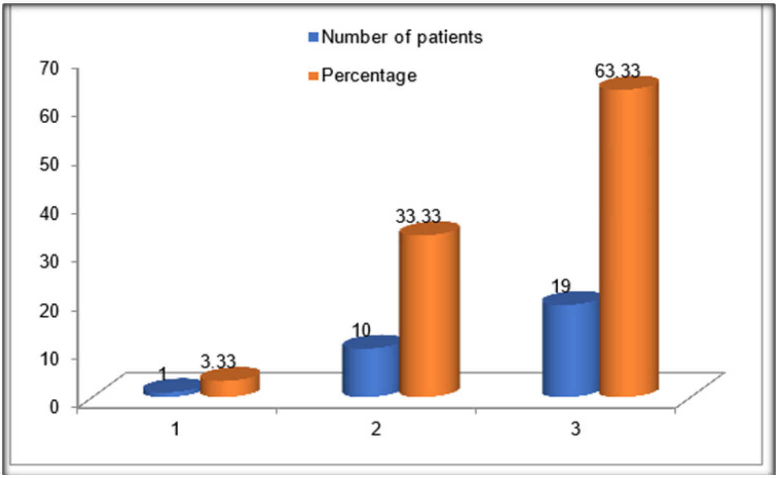
Graph 11: Time of fracture union

In our study, the 50 percent of the patients, time of fracture union was 24 weeks to 30 weeks, while in 23.33 percent of the patients; time to fracture union was 31 to 35 weeks. Mean time of fracture union was 31.8 weeks.

Rust Score

Table 12: RUST score (Radiographic Union Scale in Tibia)

RUST score	Number of patients	Percentage
1	1	3.33
2	10	33.33
3	19	63.33



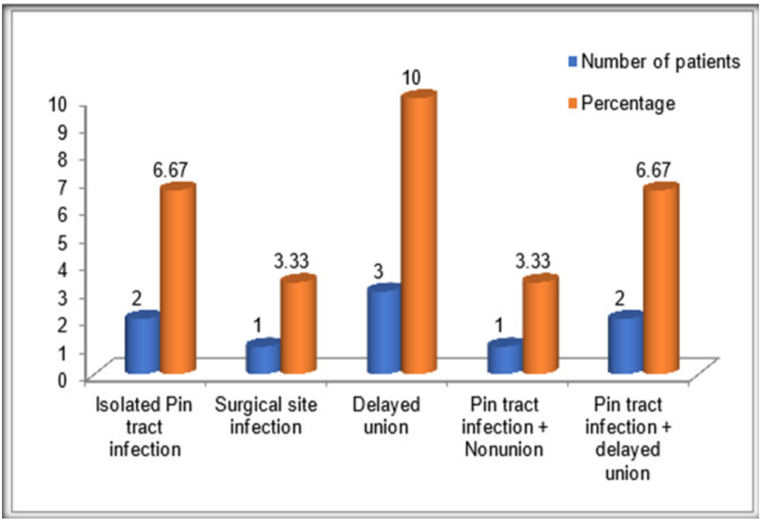
Graph 12: RUST score

In our study 33.33 percent of patients presented with RUST score 2 and 3.33 percent patient presented with RUST Score 1 while remaining 63.33 percent with RUST score 3.

Complication

Table 13: Complications

Complications	Number of patients	Percentage
Isolated Pin tract infection	2	6.67
Surgical site infection	1	3.33
Delayed union	3	10
Pin tract infection + Nonunion	1	3.33
Pin tract infection + delayed union	2	6.67



Graph 13: Complications

In our study Overall complications were seen in 9 patients. Two patient showed pin tract infection, one patient showed surgical site infection, one patient showed presence of pin tract infection along with nonunion. Two patients showed delayed union associated with pin tract infection the remaining 3 patients shows Delayed union only.

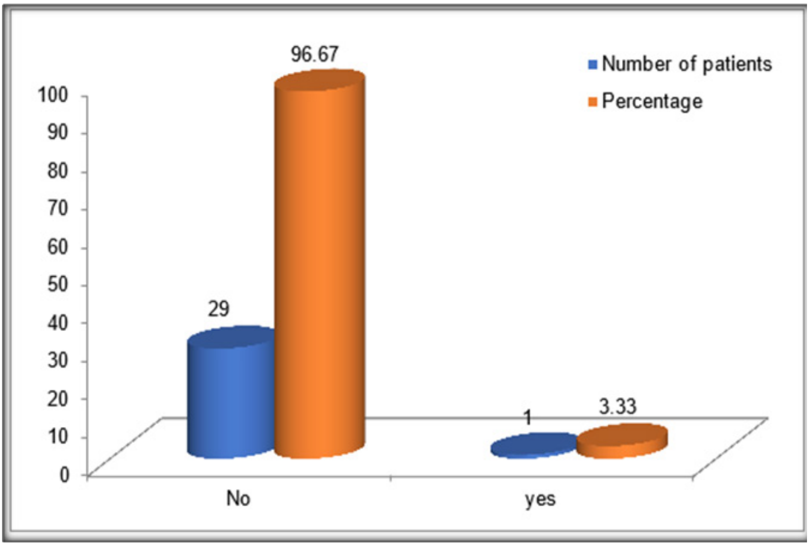
Modified Johner and Wruh's Criteria Parameters

A. Nonunion

Table 14: Nonunion

Nonunion	Number of patients	Percentage
No	29	96.67
yes	1	3.33

Total	30	100



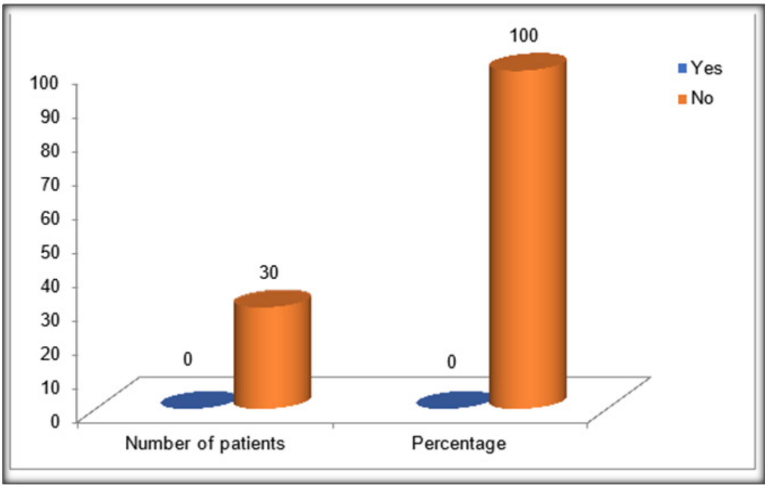
Graph 14: Nonunion

Among 30 cases, majority (96.67%) of the cases united within, whereas 3.33% cases landed into non- union.

B. Postoperatively Neurovascular Injury

Table 15: NVI - Postop

NVI - Postop	Number of patients	Percentage
Yes	0	0
No	30	100
Total	30	100



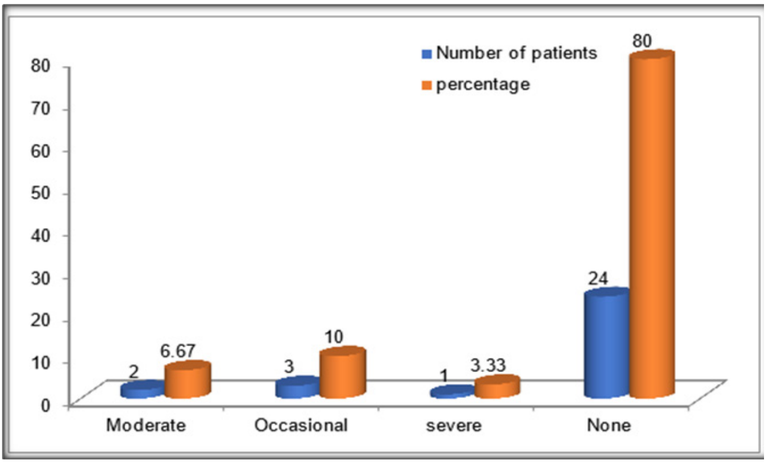
Graph 15: NVI - Postop

In our study neurovascular status after the placement of rail fixator was studied. Among 30 cases no neurovascular injuries seen post operatively.

C. Pain

Table 16: Pain

Pain	Number of patients	Percentage
Moderate	2	6.67
Occasional	3	10
severe	1	3.33
None	24	80
Total	30	100



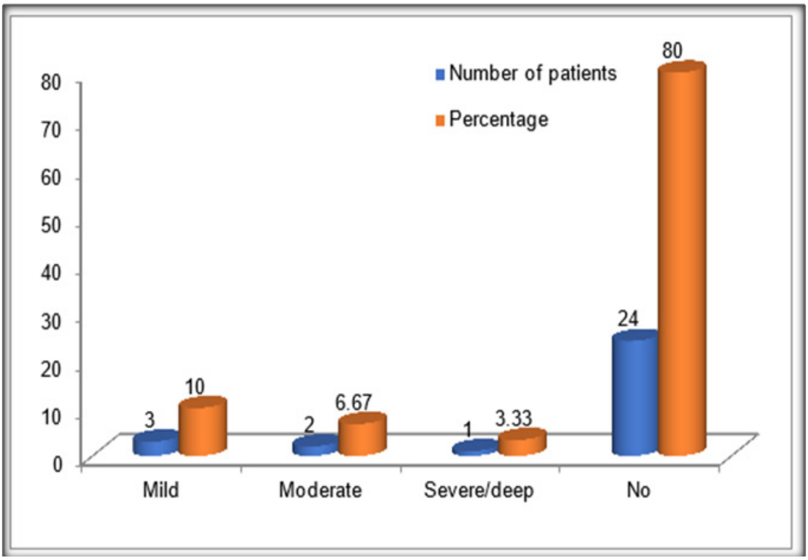
Graph 16: Pain

Among 30 cases, 6.67% cases were having moderate pain and 10% cases were having occasional pain where as 80% cases were fully recovered with no residual pain. One patient (3.33%) having severe type of pain. The functional assessment of pain was noted on the final follow up at time of fixator removal.

D. Infection

Table 17: Infection

Infection	Number of patients	Percentage
Mild	3	10
Moderate	2	6.67
Severe/deep	1	3.33
No	24	80
Total	30	100



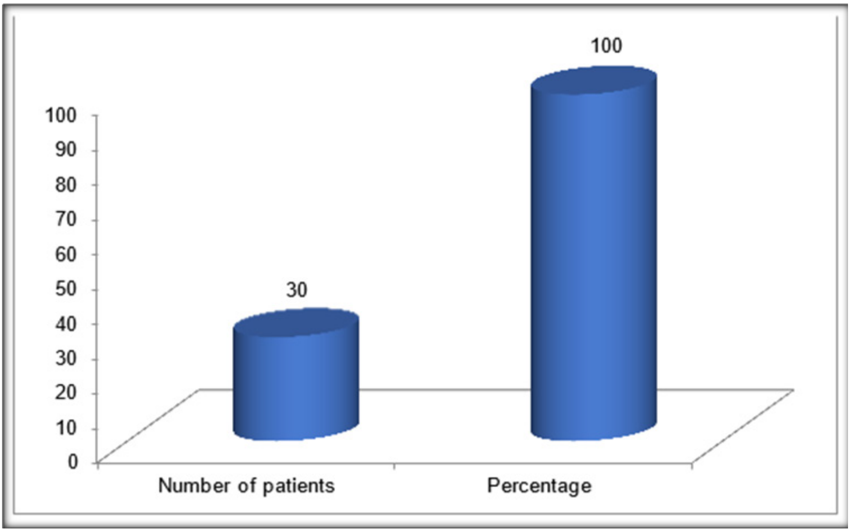
Graph 17: Infection

In our study among 30 patient's 10 percent of patients were presented with mild pin tract infection while 6.67 percent of patients came back with moderate infection on follow up. 3.33 percent of patients was presented with severe deep bone infection.

E. Knee and Ankle Range of Motion

Table 18: Knee range of motion

Knee range of motion	Number of patients	Percentage
Full range	30	100
Total	30	100



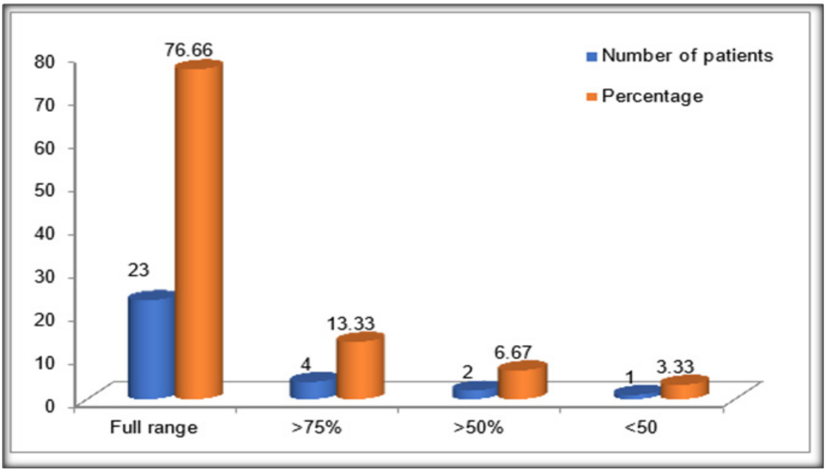
Graph 18: Knee range of motion

Full range of motion was present in 100 percent of the patients.

F. Ankle Range of Motion

Table 19: Ankle range of motion

Ankle range of motion	Number of patients	Percentage
Full range	23	76.66
>75%	4	13.33
>50%	2	6.67
<50	1	3.33
Total	30	100



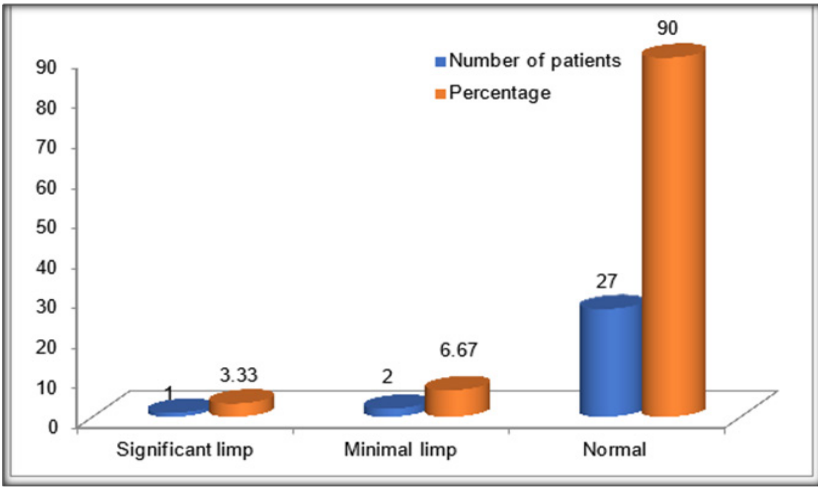
Graph 19: Ankle range of motion

Full range of motion at ankle joint was present in 76.66 percent of the patients while more than 75% present in 10 percentages of patients. 6.67 percent of the patients shows >50% range of motion at ankle and 3.33 percent patients shows <50%.

G. Gait

Table 20: Gait

Gait	Number of patients	Percentage
Significant limp	1	3.33
Minimal limp	2	6.67
Normal	27	90
Total	30	100



Graph 20: Gait

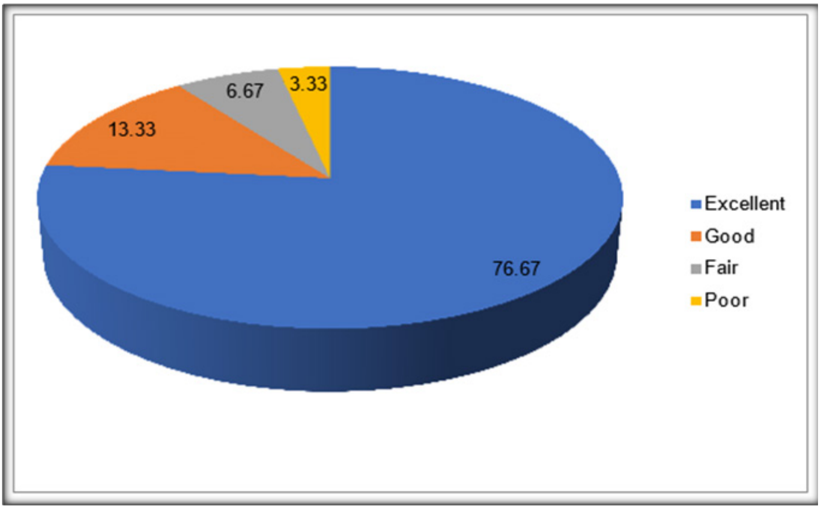
In our study among 30 cases, 3.33% cases were having significant limping gait and 6.67% cases were having minimal limping gait where as 90% cases were fully normal gait. The functional assessment of pain was noted on the final follow up at time of fixator removal.

H. RESULT

Table 21: Outcome according to Modified Johner and Wruh's criteria

Outcome according to Modified Johner and Wruh's criteria	Number of patients	Percentage
Excellent	23	76.67
Good	4	13.33
Fair	2	6.67

Poor	1	3.33
Total	30	100



Graph 21: Outcome according to Modified Johner and Wruh's criteria

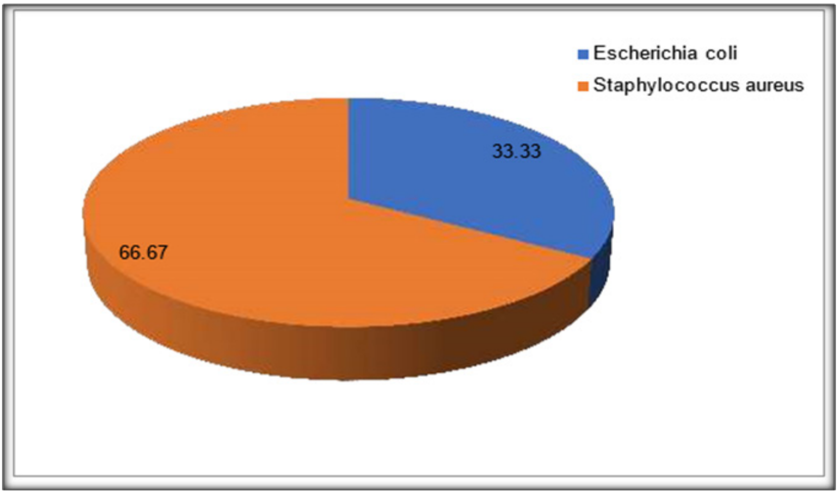
According to Modified Johner and Wruh's criteria, excellent results were seen in 76.67 percent of the patients while good results were seen in 13.33 percent of the patients. 6.67 percent of the patients showed fair results while 3.33 percent of patients show poor results.

Microbiological Profile

Table 22: Microbiological profile

Microbiological profile	Number of patients	Percentage
Escherichia coli	2	33.33
Staphylococcus aureus	4	66.67

Total	6	100



Graph 22: Microbiological profile

Microbiological culture and sensitivity testing was sent in 6 patients in whom complications were seen. Among these 6 patients, Escherichia coli were seen in 2 patient (33.33 percent) while staphylococcus aureus was seen in 4 patients (66.67 percent).

Antibiotic Sensitive Pattern

Table 23: Antibiotic sensitive pattern

Microbiological profile	Escherichia coli (n=2)		Staphylococcus aureus (n=4)	
	Sensitive	Resistant	Sensitive	Resistant
Amikacin	+		++	
Gentamicin	+			-
Ciprofloxacin		-		--
Ceftriaxone	+		++	
Cotrimoxazole	+			

Clindamycin			+	
Erythromycin				--
Vancomycin			++	
Ampicillin		-	++	

Antibiotic sensitivity of E. coli was seen for Amikacin, Gentamicin, Ceftriaxone, and Cotrimoxazole. Antibiotic resistance of E. coli was seen for Ciprofloxacin, Ampicillin. Antibiotic sensitivity of Staphylococcus aureus was seen for Amikacin, Clindamycin, Vancomycin, Ampicillin and Ceftriaxone while resistance was seen for Erythromycin, Gentamicin and ciprofloxacin.

CASE-1

Preoperetive xray

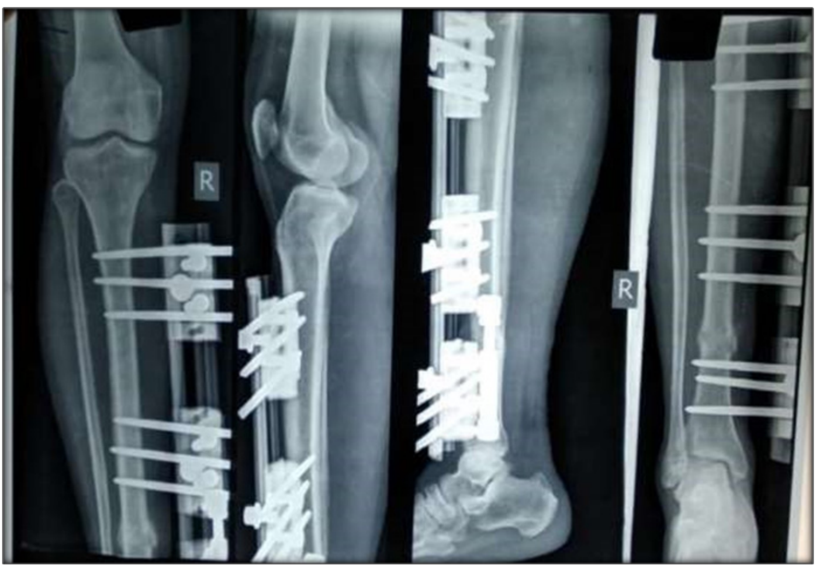
Intra-operative picture

Postoperetive xray

Postoperetive full weight bearing (FWB) picture

Follow up range of motion at knee and ankle

Follow up xray

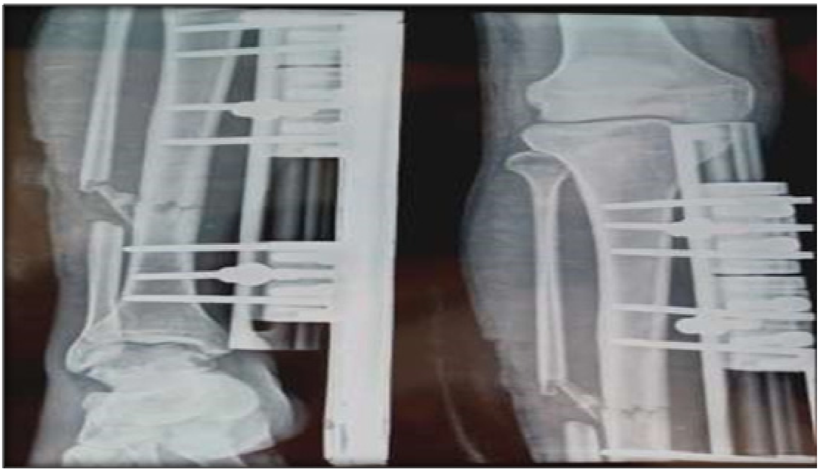


Case 2

Preoperative x-ray

Intraoperative picture

Postoperative x-ray



Postoperative FWB

Range of motion at knee and ankle on follow up

Patellar tendon bearing cast (PTB cast)

Follow-up x-ray

Case-3

Preoperative X-ray

Dr.

Postoperative X-ray

Postoperative FWB picture

Range of motion at knee and ankle on follow up

Follow-up Xray

DISCUSSION

Incidence of fractures of long bones is increasing day by day due to increased road traffic accidents and other domestic accidents. The shaft of the tibia is one of the most common sites of an open fracture as one third of its surface is subcutaneous. Open fractures of the tibia are associated with massive soft tissue injury and bone loss with high rates of infection and nonunion resulting in poor treatment outcome. The treatment goals include prevention of infection, soft tissue coverage and fracture stabilization leading to union with simultaneous mobilisation of nearby joints enabling early return to function. The specific method of skeletal fixation and soft tissue management in open fractures continues to be a topic of debate in orthopaedic traumatology with the treatment options ranging from external fixators, Ilizarov fixators, nailing, plating, tibial synostosis, free or vascularized bone grafting along with allografts or bone substitutes, all having their own set of complications. Treatment protocol of compound fractures involves thorough initial debridement and external fixation followed by closure of the wound either by flap rotation or skin grafting. Then intramedullary interlocking nailing or plating with or without bone grafting is done as a secondary procedure.

The disadvantages of this technique are higher incidence of infection than closed fractures treated with intramedullary nailing alone; need for several operative procedures, longer period of hospitalization and increased economic burden to the already poor patients. Stabilization of compound fractures of tibia by external fixators promotes soft tissue healing, preserves the bone vascularity, accessibility to wound and causes less blood loss. Traditionally complex nonunions and open fractures are managed by the Ilizarov ring fixators but it is heavy and complicated to manage, both for the surgeon and the patient. Limb Reconstructive System (LRS) is a modular unilateral frame consisting of Shanz pins, rail rods and sliding clamps. It is simple, effective, adjustable, light weight and offers rigid stabilization of fracture fragments along with access to wound dressing. The management of open fractures with the LRS fixator allows immediate functional stabilization of fractures, weight bearing and axial fracture site movement promoting an early callus response and fracture union.

Hence; the present study was undertaken in the Rajindra Hospital and Govt. Medical College, Patiala for assessing the functional outcomes of monorail fixator as a primary mode of fixation in compound tibia fracture type 2 and type 3A,3B as classified by Gustillo-Anderson. The 30 cases of compound tibia fracture were selected and followed up.

Age Incidence

In our study we include patients aged between 18 and 60 years and the maximum numbers of patients were 43.33 percent belonged to the age group of 41 to 50 years while 16.67 percent of the patients belonged to the age group of 51 to 60 years. 30 percent of the patients belonged to the age group of 31 to 40 years. The youngest being at age 21 and the oldest being 58 year of age. Mean age of the patients was 42 years. Our results were in concordance with the results obtained by previous authors who also reported similar findings. In a study conducted by Singh P et al, mean age of the patients was 35.5 years.

Mean age of the patients in the studies conducted by Kale AB et al and Thakur et al was 35.6 years and 38 years. In other studies, conducted by Mahajan NP et al, Pangavane P et al and Patil NVP et al, mean age of the patients was 37.85 years, 37.9 years and 44 years respectively.

Study	Mean age (years)
Singh P et al	35.5
Kale AB et al	35.6
Thakur et al	38
Mahajan NP et al	37.85
Pangavane et al	37.9
Patil NVP et al	44
Present study	42

Sex Incidence

In our study, there were male dominance which may suggest higher level of activities and mobility among male population. The 93.33 percent of the patients were males while the remaining 6.67 percent were females. Our results were in concordance with the results obtained by previous authors who also reported male preponderance in their respective studies. In the studies conducted by Mahajan N et al, Kale AB et al and Thakur et al, 65%, 93.33 % and 83.5% of the patients were males respectively.

Study	Males (%)
Singh P et al	75
Kale AB et al	93.33
Patil NVP	70
Mahajan et al	65
Thakur et al	83.5
Present study	93.33

Mode of Injury

In our study, most common cause was road traffic accident in 83.33 percent of the patients while it was fall from height in 16.67 percent of the patients. These fractures are usually related to high energy trauma associated with road traffic accident. Our results were in concordance with the results obtained by previous authors who also reported that road traffic accidents were the major etiologic factors in their respective studies. In the studies conducted by Singh P et al, Kale AB et al and Mahajan NP et al, road traffic accidents were etiologic factors in 80%, 100% and 65% of the cases respectively.

In the study conducted by Antich-Adrover P et al, road traffic accident was the major cause of injury in 81.9% of patients where as in Thakur et al series, 87.3% of patients with open fractures were caused by road traffic accidents.

Study	Road traffic accident (%)	Others (%)
Singh P et al	80	20
Kale AB et al	100	0
Mahajan NP et al	65	35
Present study	83.33	16.67

Types of Fracture Classification

According to Gustilo-Anderson classification we included in our study from type II to type III B. In our study 53.33 percent of the patients were belonging to type III A while 33.33 percent of the patients were of type III B. 13.33 percent of the patients were of type II.

In the study conducted by Singh P et al, 7 (35%) had Grade II fracture, 8 (40%) had Grade III A fracture and 3 (15%) had Grade III B fracture. Mahajan NP et al, in another study reported that according to Gustilo Anderson classification, 5 (25%) cases were of grade I, 3(15%) cases were of grade II, 5 (25%) cases of were grade IIIA and 7 (35%) cases were of grade IIIB. In another study conducted by Granhed et al, 45%

of the patients were of the type 3b and rest 55% patients were belonging to type 3c Gustilo- Anderson group.

Type of fractures (Gustilo-Anderson classification)	Singh P et al	Kale AB et al	Present study
II (% of patients)	35	50	13.33
III A (% of patients)	40	10	53.33
III B (% of patients)	15	33.33	33.33

Side of Injury

In our study Right side involvement occurred in 73.33 percent of the patients while left side involvement occurred in 26.67 percent of the patients. Similar results were reported in the study conducted by Singh P et al who observed involvement of right side in majority of the cases.

Study	Right side (%)	Left side (%)
Singh P et al	60	40
Present study	73.33	26.67

Duration of Surgery

The Mean duration of surgery was 52.17 minutes. In our study the minimum and maximus duration of surgery was 35 minutes and 90 minutes respectively. The maximum duration of surgery was due to a comminuted fracture in which achieving proper reduction was difficult. Our results were in concordance with the results obtained by previous studies who also reported similar findings. In a study conducted by Singh P et al, in 16 (80%) cases operation time was 45 minutes while in the rest 4 (20%) cases duration of surgery was about 1 hour due to difficulty in achieving proper reduction and placement of implant. In a study conducted by Akhtar A et al, mean duration of surgery was 60 minutes.

Study	Mean duration surgery (minutes)
Akhtar A et al	60
Present study	52.17

Secondary Procedure

In our study, Secondary procedures (Skin Grafting) were done in 40 percent of the patients. All the grafting procedures were carried out in patients with Gustilo-Anderson classification 3A and 3B.

- Regular dressing of these open wound with appropriate antibiotics administration was done in postoperative wards.
- After 2-3 weeks, once the wound is clean and covered with healthy granulation tissue plastic surgeon opinion was taken and treated accordingly.
- In our series 12 patients needed skin grafting and rest heal without any plastic surgery interventions. Out of 12 patients who underwent skin grafting in all 12 cases graft took up well and they were discharged later after the wound had healed up.

In a study conducted by Singh P et al, Adequate soft tissue coverage was done with split skin grafts for 2 (10 percent) and local flaps for 1 patient (5 percent) after 3-4 weeks and took up well.

Study	Secondary procedures (%)
Singh P et al	15
Kale AB et al	46.67
Present study	40

Time of Full Weight Bearing Post-Operative

In our study the mean time of full weight bearing post-operative was 5.37 days. The maximus time taken for full weight bearing was 15 days in the patient with ipsilateral 3rd and 4th metatarsal bone fracture. One patient with

contralateral shaft femur fracture and two patients with contralateral shaft tibia fracture managed with intramedullary nailing postoperative 4th day of rail fixation. These patients take more time to full weight bear postoperatively.
Variable results have been reported in this context in the past literature.
In the study conducted by Singh P et al, mean time to full weight bearing was 10.45 days. Kale AB et al reported the mean time to full weight bearing to be 6.3 days.

Study	Time of full weight bearing (days)
Singh P et al	10.45
Kale AB et al	6.3
Present study	5.37

Time of Fracture Union

In our study, the 50 percent of the patients, time of fracture union was 24 weeks to 30 weeks, while in 23.33 percent of the patients; time takes to fracture union was 31 to 35 weeks. Mean time of fracture union was 31.8 weeks. Patient with comorbidities like DM, HBV, HCV Infection were taken more time to fracture union. Our results were in concordance with the results obtained by previous authors who also reported similar findings in their respective studies. Mean time of fracture union in the studies conducted by Singh P et al and Ajmera A et al was 23.26 weeks and 52 weeks respectively.
In the studies conducted by Patil NVP et al and Pangavane P et al, mean time of fracture union was reported to be 35 weeks and 41 weeks respectively. Mahajan et al reported the mean time of fracture union to be 20.22 weeks. Thakur et al, Chandraprakash et al reported mean bony union time to be 20 weeks and 22 weeks respectively.

Study	Time of fracture union (weeks)

Singh P et al	23.26
Ajmera A et al	52
Patil NVP	35
Pangavane P et al	41
Present study	31.8

RUST score (Radiographic Union Scale in Tibia)

In our study 33.33 percent of patients presented with RUST score 2 and 63.33 percent with RUST score 3. One patient (3.33 percent) had RUST Score 1 after three consecutive follow-up Xrays. This patient treated with removal of fixator, debridement, sequestrectromy and fracture refixation with Ring fixator and bone grafting.

All the patients with RUST score 2 advised protected weights bearing with patellar tendon bearing cast for 3 weeks post fixator removal.

Complication

In our study Overall complications were seen in 9 patients. Most of the patients showed complication had comorbidities like DM, HBV and HCV infection. Three patients (10%) showed isolated delayed union of fracture, two patient (6.67%) showed isolated pin tract infection, one patient (3.33%) had surgical site infection, one patient (3.33%) developed pin tract infection along with nonunion and remaining two patients (6.67%) showed presence of pin tract infection along with delayed union. In the patient with surgical site infection, debridement was done with broad spectrum IV antibiotics administered. Once the infection was subsided skin grafting was done. Pin tract infection was treated with IV antibiotics according to culture and sensitivity. Two patients showed presence of pin tract infection along with delayed union required pin removal because of pin loosening and was treated by replacement of new schanz pin over nearby slot in connecting clamp. One patient showed presence of deep pin tract infection along with nonunion required removal of fixator, debridement, sequestrectromy and fracture refixation with Ring fixator and bone grafting.

	Studies	**Complications (%)**
Sing P et al (2020)	Pin tract infection	20
	Delayed union	10
	Pin loosening	15
Kale AB et al (2017)	Pin tract infection	26.67
	Malunion	3.33
	Nonunion	3.33
Present study	Isolated pin tract infection	6.67
	Isolated delayed union	10
	Surgical site infection	3.33
	Pin tract infection +Non union	3.33
	Pin tract infection + Delayed union	6.67

In the study conducted by Singh P et al, pin tract infection was found in 04 (20%) cases which healed by pin tract dressing. Delayed union was observed 02 (10%) cases. Joint (knee or ankle) stiffness was observed in 03 (15%) cases. Loosening of pin was observed in 03 (15%) cases. Shortening and chronic osteomyelitis were not observed in any of the cases. One of the patients of type III B fracture ended up with infected nonunion. This patient was treated by debridement, sequestrectromy and refixation with LRS fixator. Corticotomy and bone transport was done to replace the excised portion of the bone.

Ajmera A et al, in another study reported that pin tract infection was seen in 5 cases, out of which 4 being superficial, which healed to dressings and antibiotics. One patient had a deep infection which required frame removal.

In the past studies, the most common complication, in accordance with previous studies, was pin tract infection which was seen in 8 (28%) of our patients, 5 (16%) had limb shortening, which healed on suitable parenteral antibiotics after culture and sensitivity (Robert Rozbruch S et al, Sen C et al, Mekhail AO et al).

Outcome according to Modified Johner and Wruh's criteria

According to Modified Johner and Wruh's criteria,excellent results were seen in 76.67 percent of the patients that means there was no non-union, no infections, no deformity, no shortening, no pain, full range of ankle and knee movements, no neurological deficit and normal gait. while in 13.33 percent of the patients shows no non-union, mild infections, occasional pain, range of ankle (>75%) and knee (>80%)movements, no neurological deficit and normal gait that means good outcome. 6.67 percent of the patients showed fair results in the form of no non-union, moderate infections, moderate pain, range of ankle (>50%)and knee movements (>75%), no neurological deficit and mild limp while 3.33 percents shows poor outcome by non-union, deep infections, severe pain, range of ankle movement (<50%) and significant limp.

Our results were in concordance with previous authors who also reported similar findings. In a study conducted by Ajmera A et al, Functional results were excellent in 84% (21/25), good in 8% (2/25) and fair in 8% (2/25). Excellent results were seen in 79.63 percent of the patients in the study conducted by Patil MY et al while good results were seen in 12.96 percent of the patients.

In a study done by Vijay et al on management of open tibial fractures with LRS rail external fixators, overall, 90% of the fractures united well: excellent to good results were seen in 72%, fair in 18% and poor in 10% of cases based on the modified Anderson and Hutchin's criteria. Lakhani et al used rail fixator system in reconstructing bone gap and reported that union was achieved in all the cases.

Studied		Percentage
Patil MY et al	Excellent	79.63
	Good	12.96
	Fair	7.41
	Poor	
Singh P et al (2020) [Functional outcome]	Excellent	70
	Good	20
	Fair	5
	Poor	5
Lakhani A et al	Excellent to good	85
	Poor	10
Pal CP et al	Excellent	68.75
	Good	18.75
	Fair	12.50

Kale AB et al (Modified Anderson and Hutchinson's criteria)	Good	78
	Moderate	18
	Poor	4
Akhtar A et al (Modified Johner and Wruh's criteria)	Excellent	43.33
	Good	33.33
	Fair	16.67
	Poor	6.67
Present study (Modified Johner and Wruh's criteria)	Excellent	76.67
	Good	13.33
	Fair	6.67
	Poor	3.33

Microbiological profile & Antibiotic sensitivity pattern

Microbiological culture and sensitivity testing was sent in 6 patients in whom complications of infection were seen. Among these 6 patients, Escherichia coli were seen in 2patients (33.33 percent) while staphylococcus aureus was seen in 4 patients (80 percent). Antibiotic sensitivity of E. coli was seen for Amikacin, Gentamicin, Ceftriaxone, and Cotrimoxazole. Antibiotic resistance of E. coli was seen for Ciprofloxacin, Ampicillin. Antibiotic sensitivity of Staphylococcus aureus was seen for Amikacin, Clindamycin,

Vancomycin, Ampicillin and Ceftriaxone while resistance was seen for Erythromycin, Gentamicin and ciprofloxacin

According to Yokoyama K, treatment of grade IIIB and IIIC with intramedullary nailing was risky as it leads to deep infection and nonunion in 20.3% cases. Therefore, external fixators are preferred modality because they are easy to use and allow soft tissue treatment. But the problems associated are prolonged immobilization and need for revision surgery for definitive fixation at a later stage. Therefore, LRS, which is different from the simple external fixators in allowing full weight bearing immediate postoperatively like an intramedullary fixation was used. LRS fixation technique also has an added advantage of salvaging the limb and preventing amputation. On other side, it has its own complications like pin loosening and pin tract infection.

Summary

The present was conducted to evaluate the functional outcome of monorail fixator as a primary mode of fixation in compound tibia fracture as classified Gustilo-Anderson type 2 and 3A, 3B wound in 30 cases presented in the Department of Orthopaedics, Rajindra Hospital and Govt. Medical College, Patiala.

Following results were obtained which summaries here-

- Open fractures are slightly predominating in the age group between 31-50 years of age (73.33%). Mean age of the patients was 42 years.
- Open fracture of tibia is common among males (93.33%).
- In our study, most common cause was road traffic accident in 83.33 percent patients.
- Most of the fractures were Gustilo Anderson type III (86.66%) and rest were type II (13.33%).
- Right side involvement (73.33%) is more than left side (26.67%) of the tibia.
- 16.67 % of the patients presented with associated injuries with primary compound tibia fracture.
- 26.67% of the patients suffered with comorbities.
- The mean duration for monorail fixation was 52.17 minutes.

- Secondary procedures like skin grafting were done in 40% of the patients.
- Full weight bearing with fixator was allowed 5.37 days of mean duration.
- Among 30 patients 10 percent of patients showrd isolated delayed union, 3.33 percent surgical site infection, 6.67 percent pin tract infection with delayed union while 3.33 percent of patients showed Nonunion associate with deep pin tract infection and 6.67 percent patients developed isolated pin tract infection as a complication.
- The mean time taken to unite the fracture was 31.8 weeks.
- Excellent result were seen in 76.67 percent of patients while 13.33 percent showed good result and 6.67 percent patients had fair result while 3.33 percent of patients showed poor outcome according to Modified Johner and Wruh's criteria
- Among these 6 patients of infection, Escherichia coli were seen in 2 patient (33.33 percent) while staphylococcus aureus was seen in 4 patients (66.67 percent) in pus culture.
- Antibiotic sensitivity of E. coli was seen for Amikacin, Gentamicin, Ceftriaxone, and Cotrimoxazole. Antibiotic resistance of E. coli was seen for Ciprofloxacin and ampicillin. Antibiotic sensitivity of

Staphylococcus aureus was seen for Amikacin, Vancomycin, Clindamycin, Ampicillin and Ceftriaxone while complete resistance was seen for Erythromycin and ciprofloxacin and gentamycin.

CONCLUSION

In the light of above obtained interpretation we have come under conclusion that-

- Our result in open fracture of tibia Gustilo-Anderson Type 2 and type 3 injury demonstrated the benefits of primary fixation with monorail fixator.
- Patients were satisfied on early full weight bearing post-operatively over a stable construct.
- Complications are minimal with good range of movements at knee and ankle.
- Soft tissue procedures like skin grafting can be easily accomplished with external fixator in position.

But as this study involved small number of patients (n=30), so its results can't be projected to the general population, for which a trial involving large number of cases is required.

Limitations

- Long term follow up in terms of restoration of pre injury ambulatory status, mortality may not be possible.
- In the limited time duration of the study period, only a small number of patients could be studied.
- Ethnicity of result found in this study cannot be stated to be absolutely correct as sample size (30 cases) was very small. However, if sample size of study is significantly larger than a carry home message can be given.

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