EFFECTIVENESS OF BIOLOGICAL FIXATION OF DISTAL TIBIAL FRACTURES WITH LOCKING COMPRESSION PLATES IN ADULTS

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IN

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CERTIFICATE

This is to certify that this dissertation titled **"EFFECTIVENESS OF BIOLOGICAL FIXATION OF DISTAL TIBIAL FRACTURES WITH LOCKING COMPRESSION PLATES IN ADULTS"** is the bonafide original work of Dr.Vinoth.T in the partial fulfilment of the requirements for M.S Orthopaedics Examination of the TamilNadu Dr.M.G.R Medical Universityto be held in APRIL 2015.The period of study is from July 2012 to June 2014.

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DECLARATION

I, Dr.Vinoth.T , solemnly declare that this dissertation **"EFFECTIVENESS OF BIOLOGICAL FIXATION OF DISTAL TIBIAL FRACTURES WITH LOCKING COMPRESSION PLATES IN ADULTS"** is a bonafide work done by me at Government Thanjavur Medical College and Hospital between 2012 – 2014, under the guidance and supervision of Prof.Dr.M.Gulam Mohideen, M.S.Orth,D.Orth , Department of Orthopaedic Surgery.

This dissertation is submitted to the TamilNadu Dr.M.G.R Medical University towards partial fulfilment of regulation for the award of M.S Degree (Branch II) on Orthopaedic Surgery.

Place: Thanjavur (DR.VINOTH T)

Date:

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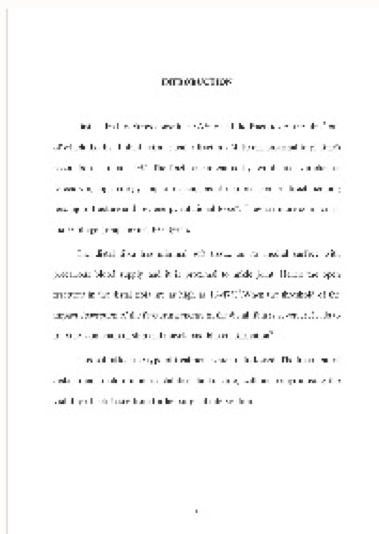
INTRODUCTION

EFFECTIVENESS OF BIOLOGICAL FIXATION OF DISTAL TIBIAL FRACTURES WITH LOCKING COMPRESSION PLATES IN ADULTS

INTRODUCTION

Distal tibial fractures constitute 5-7% of all the fractures of the tibia[1] out of which the distal tibial extra-articular fractures (4-10 cm proximal to plafond) accounts for around 15%[2]. The fractures are caused by two distinct varieties of forces via; high energy impact causing axial compression or direct bending leading to fracture and low energy rotational force[3]. They are more common in males of age group around 30-40years.

The distal tibia has minimal soft tissue on its medial surface with precarious blood supply and it is proximal to ankle joint. Hence the open fractures in the distal tibia are as high as 16-47%[2]. When the threshold of the impact absorption of the fracturing energy in the distal tibia is severe, it leads to fracture, contusion of skin and muscle and blisters formation[3].

ABSTRACT OF THE WORK

32 cases of adult distal tibial fractures were treated in an average period of five days with most injuries being from vehicular accidents. In spite of the bulky nature of the implant, we were able to pass the implant distal to proximally bridging the fracture under C-arm guidance. This process resulted in an acceptable reduction, though not anatomical.

Except for two cases who had wound dehiscence and infection, none others came for implant removal. Excellent to good results was seen in 76.6% of the study population. This study concludes that in distal tibial fractures taken for surgery early after anaesthetic assessment, minimally invasive plate osteosynthesis done biologically yields good results.

Keywords:

Distal tibial fractures, dia-metaphyseal, high velocity injury, soft tissue damage, minimally invasive plate osteosynthesis, pre contoured distal tibial medial locking plate, bulky implant, wound infection.

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INTRODUCTION

Distal tibial fractures constitute 5-7% of all the fractures of the tibia[1] out of which the distal tibial extra-articular fractures (4-10cm proximal to plafond) accounts for around 15%[2]. The fractures are caused by two distinct varieties of forces via; high energy impact causing axial compression or direct bending leading to fracture and low energy rotational force[3]. They are more common in males of age group around 30-40years.

The distal tibia has minimal soft tissue on its medial surface with precarious blood supply and it is proximal to ankle joint. Hence the open fractures in the distal tibia are as high as 16-47%[2] .When the threshold of the impact absorption of the fracturing energy in the distal tibia is severe; it leads to fracture, contusion of skin and muscle and blisters formation[3].

This will affect the type of treatment which is followed. The treatment of distal tibial fracture aims to stabilise the fracture, without compromising the viability of soft tissue from further surgical intervention.

The fracture involving distal tibia is usually accompanied by fracture of fibula[4]. Fixation of the associated fibular fracture with syndesmotic ankle injury is necessary for a surgically stabilised fracture involving extra-articular metaphyseal distal tibia[5].Surgeries were usually delayed until the appearance of wrinkle sign.

Various treatment available for management of distal tibial fractures are conservative treatment by cast application, external fixation by AO / Ilizarov ring application, hybrid external fixation, intramedullary interlocking nail, buttress plating, conventional plate osteosynthesis and minimally invasive plate osteosynthesis using locking plates.

Cast application, with prolonged limb immobilization, leads to knee and ankle stiffness. External fixation with frames is associated with infection at pin tracts leading to loosening of the pins, followed by malunion or non-union and later on osteomyelitis.

The broad medullary canal and marrow in the lower tibia leads to high rates of malunion and failure of the implant following intramedullary interlocking nailing[6].

Regular plate fixation strips the periosteum extensively which supplies outer one third of blood supply to cortex. This also causes skin break down, wound infection leading to delayed union and non-union, which latter needs additional secondary procedure like bone marrow injection and bone grafting[7].

To overcome all this complications, the recent decade has seen tremendous improvement in plating technology with the arrival of locking compression plate. This locking compression plate are precontoured to specific anatomical regions and can be applied through minimally invasive technique described as minimally invasive plate osteosynthesis(MIPO)[8].

In minimally invasive plate osteosynthesis, the plate is applied directly over the periosteum. This technique needs prior alignment by indirect closed reduction and it provides axial alignment at the fracture site without compression and provides stable fixation without disturbing biology of the fracture[9]. This thereby preserves much of the vascularity to fragments of the fracture with retaining the fracture haematoma, providing abundant growth factors like VEGF, PDGF, etc. for healing of the bone.

SURGICAL ANATOMY

The leg has three compartments the lateral, anterior and the posterior[10].

1) Lateral compartment:

The muscles of the lateral compartment are peroneus longus and peroneus brevis (shown in fig.1) which protect the fibula from injury except at the ankle where it is subcutaneous in nature. Thus the isolated fibular fractures by direct trauma are not uncommon in its lower part[4]. Between the peronei muscles and extensor digitorum longus, lies the superficial peroneal nerve. Hence it is rarely affected in fibular shaft fractures due to covering by soft tissues.

2)**Anterior compartment:**

The muscles in the anterior compartment of the leg are tibialis anterior, extensor hallucis longus, extensor digitorum longus and peroneus tertius(shown in fig.1). These muscles are enclosed in a relatively rigid compartment comprising of medially by osseous tibia, laterally by fibula, posteriorly by interosseous membrane and anteriorly by deep fascia. The neurovascular structures passes deep to the tendons close to the ankle.

Therefore fractures of distal tibia uniting with callus can mechanically restrict the movements of tendons from gliding.

The osseofacial rigid compartment when subjected to injury causes tissue edema, which results in increased pressure within the compartment resulting in compartment syndrome.

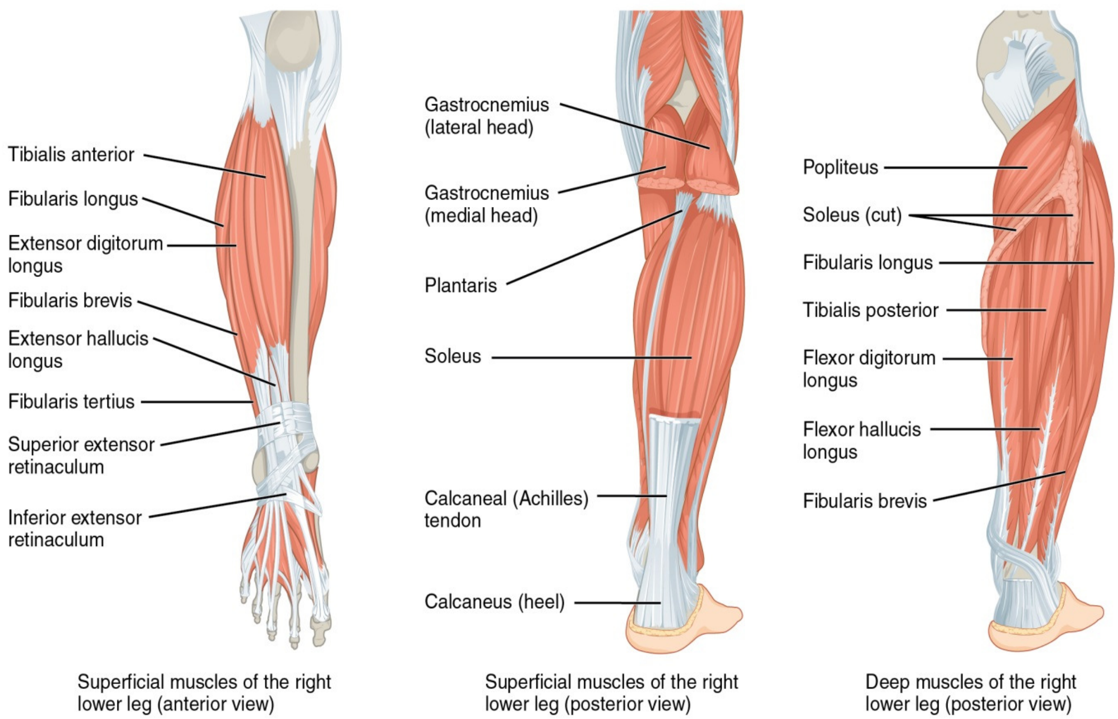


Fig 1: Muscles in various compartments of the leg

3)**Posterior compartment:**

The posterior compartment has the following muscles.

a) Gastrocnemius

b) Soleus

c) Tibialis posterior

d) Flexor hallucis longus and digitorum longus.

This compartment also has peroneal artery, posterior tibial artery and posterior tibial nerve.This neurovascular structures are enclosed by above muscles (shown in fig.1), which protect them from injury.Due to elastic nature of the posterior compartment muscles, it shows rarely damage during trauma.

Since the muscle insertion at the lower tibia is minimal, there is usually minimal displacement except proximal displacement of the fracture.

Blood supply of tibia

The medial surface of the tibia is subcutaneous in nature.The nutrient artery which supply tibia is a branch of posterior tibial artery and enters the posterolateral tibial cortex close to soleus origin. It gives rise to three ascending branches (shown in fig.2) which supply the endosteum.The periosteum has rich blood supply from the anterior tibial artery supplies the outer one third of cortex.[10]

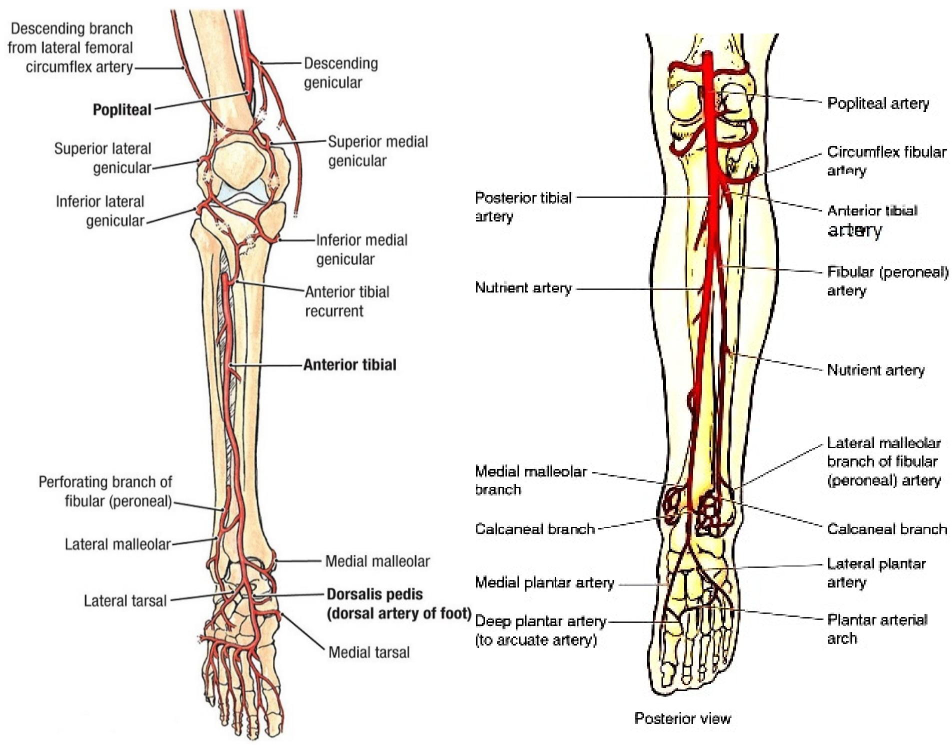


Fig 2: Blood supply of Tibia and Fibula anterior and posterior views

In addition the metaphyseal and epiphyseal vessels also provide vascularisation to tibia.[10]

Shaft of the tibia:

The tibia is considered as a cylindrical bone (shown in fig.3)which at its distal end articulates with talus.The shaft is made up of thick compact bone and the lower end is a cancellous structure[11].The lower third of the tibia is also circular or nearly quadrilateral with narrow marrow in its cross section (shown in figures.4 and 4a).

The medial surface of the tibia is rounded and felt subcutaneously whereas the posterior and lateral surface is covered by muscles.The lower third of the tibia is weak and hence majority of fractures occur here (shown in fig.5), and are open[2] due to its subcutaneous location. As we move from middle to distal tibia, the anteromedial surface is converted from convex to concave which favours placement of precontoured plates[12] using minimally invasive percutaneous techniques for distal tibial fractures.

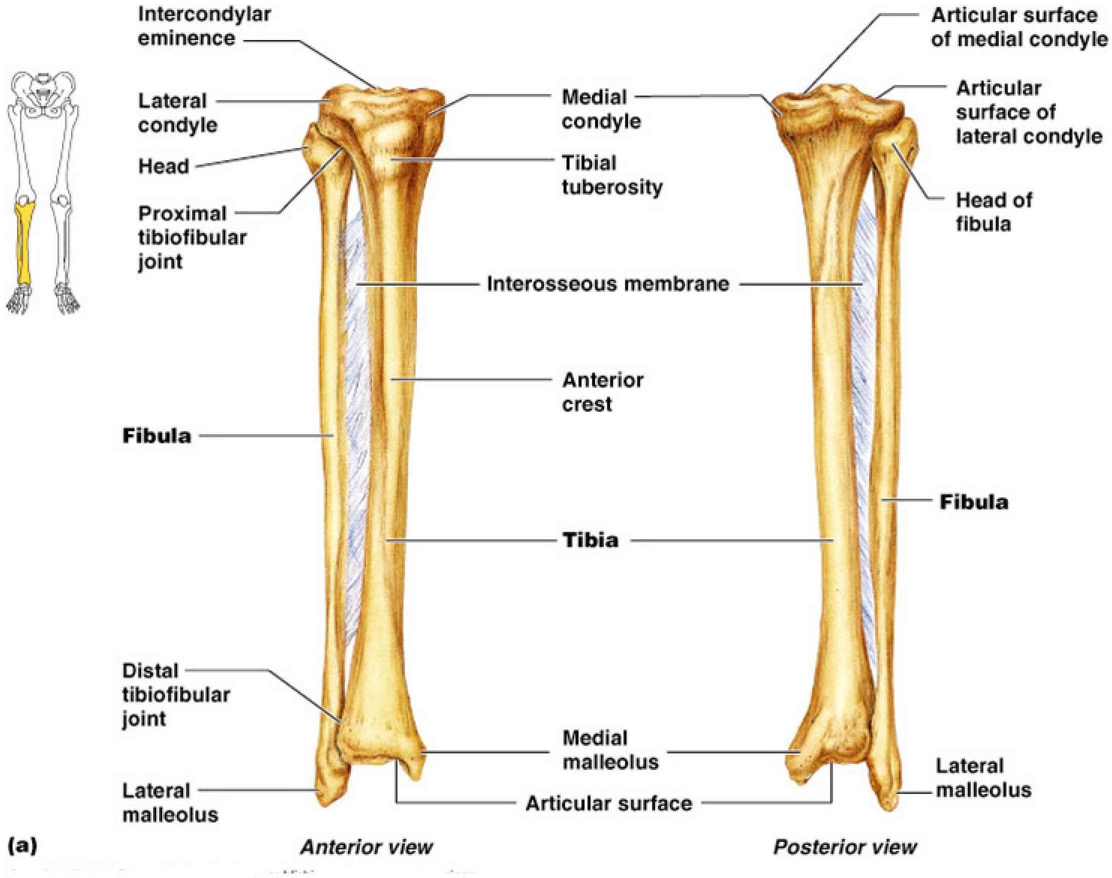
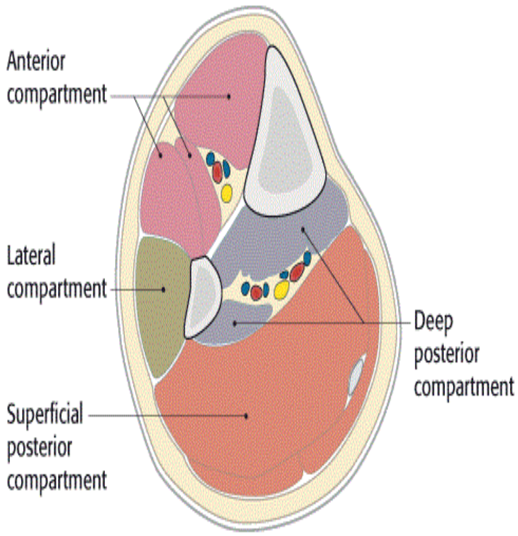


Fig 3: Bony anatomy of tibia and fibula – anterior and posterior view

The cylindrical tibial shaft is broadened proximally to form condyles and distally forms dome for talus articulation. The tibia and fibula are connected by interosseous membrane(shown in fig.3).



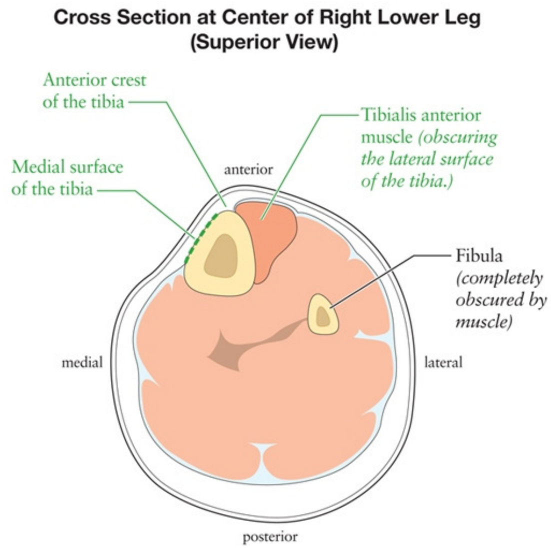


Fig 4: cross sectional view – mid leg Fig 4a: cross sectional view – distal leg

The tibia changes its shape from triangular in mid shaft to nearly circular marrow in distal end[11](shown in figures. 4 and 4 a).

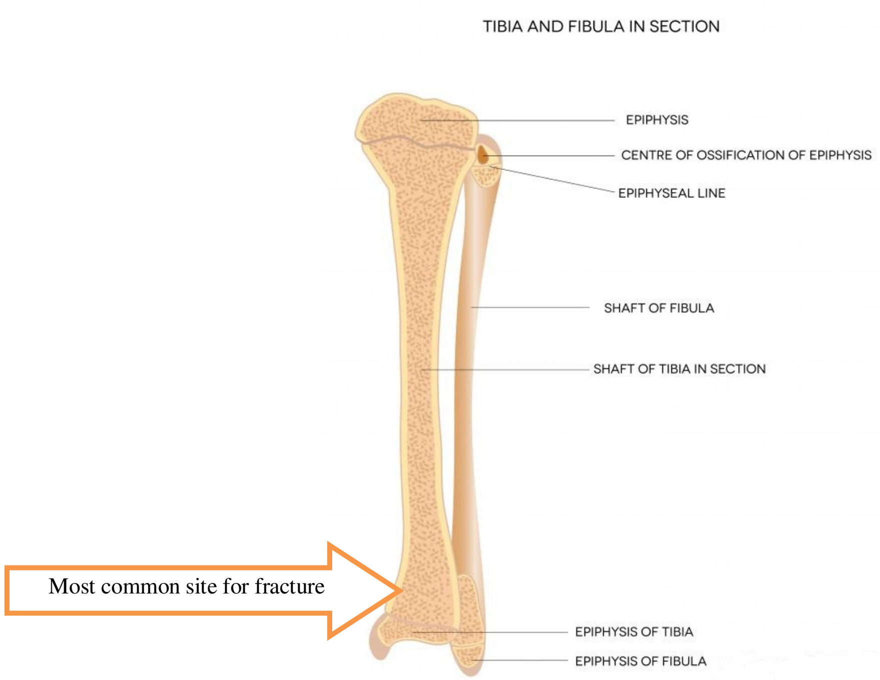


Fig: 5. Most common site of fracture – distal tibia

Interosseous membrane:

The interosseous membrane is made up of fibrous tissue, which connects and bridges the gap between tibia and fibula(shown in fig.3), except in proximal portion where there is space for passage of anterior tibial blood vessels(shown in fig.6). The function of interosseous membrane is to conduit the transmission of stress and share the load of fibula.when the interosseous membrane is completely removed, the load transfer by fibula is decreased by 30% and decreases the strain by fibula whileweight bearing by almost to zero[13]. Hence tibia will have maximum stress during weight bearing condition.

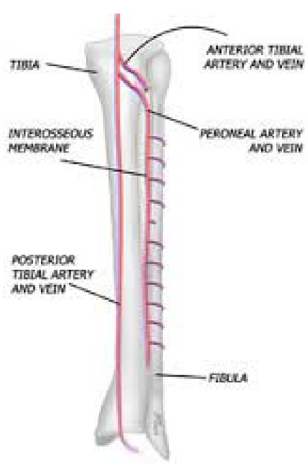
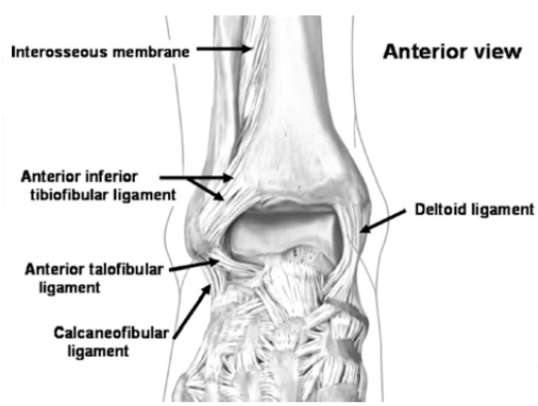


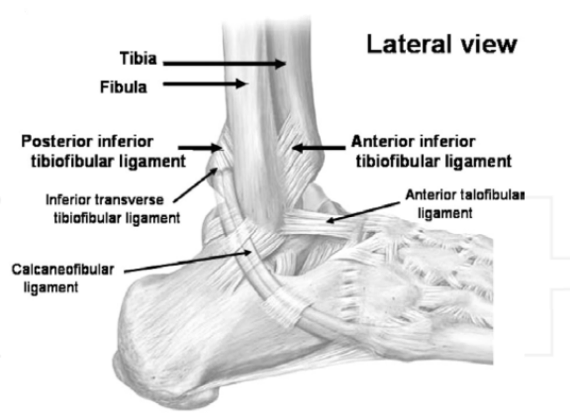
Fig 6: Shows piercing of interosseous membrane in its proximal part by anterior tibial vessels.

Biomechanics of distal tibia and fibula:

At some point of time, the distal tibia and fibula including the ankle joint experiences as high as six times increase in body weight stress. The syndesmotic ligament(shown in figures 7 and 8) at this time maintains the integrity of the distal tibia-fibular joint. It also prevents the displacement of fibula laterally. During full plantar flexion to dorsiflexion, there is a triplanar motion at the ankle joint. The fibula rotates externally up to two degrees and there is an increase in intermalleolar distance by 1mm[14].

If the syndesmotic ligaments and joint is disturbed, the rotational and gliding movements occurring at the ankle is altered and compressive stress at the tibia is increased.





Syndesmotic ligaments

Fig 7: Anterior view

Fig 8: Lateral view

MECHANISM OF INJURY

Injury in distal tibia is mainly due to axial loading[15]. As bone is a visco-elastic organ, the stress – strain curve shifts according to loading (shown in fig.9). Further the rapid axial loading absorbs energy and then when the bone fails releases much more energy. This released excess energy is put into the surrounding soft tissue. The exact position of ankle and the direction of impact give way for variety of fracture patterns and can involve the joint epiphysis or extend to metaphyseo- diaphyseal regions.

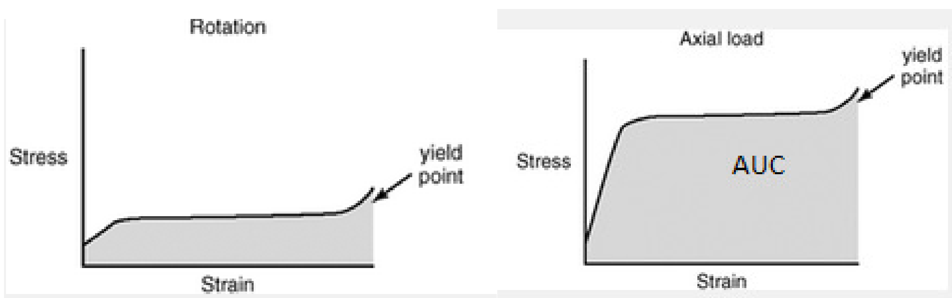


Fig 9: Stress – strain diagram for axial and rotational fractures.

Axial loading shifts the curve upwards and increases the area underneath the curve, implies that fracture releases much more energy and causes significant soft tissue injury.

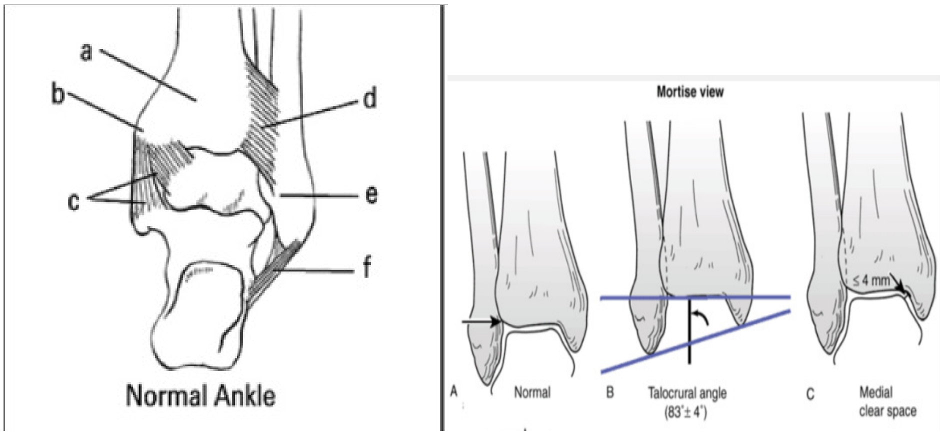


Fig 10: Normal ankle and ankle mortise view

a → lower tibia; b→ medial malleolus; c→deltoid ligament; d→interosseous ligament; e→lateral malleolus; f→ lateral ligament of ankle.

Direct injuries:

Direct injuries can be due to vehicular accidents (most common), injuries sustained during sports activity, direct blows and fall from height. The vehicular population in the recent years has increased by 200%, out of which two wheelers[15] accounts for 75%. At the time of accident due to flexed posture of the knee and subcutaneous nature of the tibia, it is more vulnerable to be hit by median of the road, foot rest or bumper of opposite vehicle or injury sustained from same vehicle while fall.

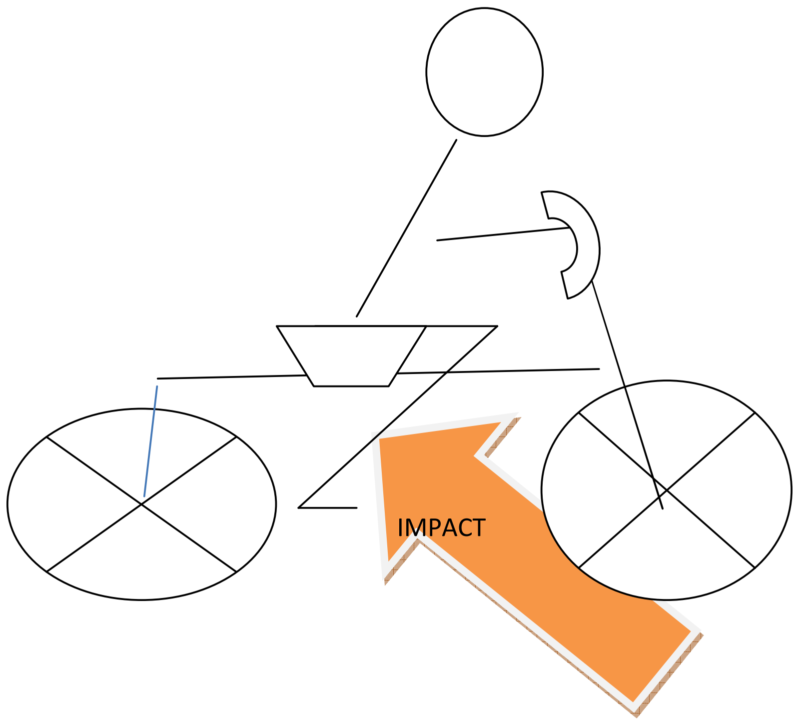


Fig: 11. Position of the leg during two wheeler driving and the direction of impact

The above schematic diagram((fig.11) shows the position of leg during two wheeler driving where it is subjected to high risk to injury by opposite vehicle or fall from same vehicle.

CLASSIFICATION

To reduce complications and to improve outcomes, the surgeon must exactly match the treatment techniques with different types of fracture and soft tissue injury. Once a fracture is put into a classification, the surgeon should know the treatment protocol, and plan management strategies to reduce complication and improve results. Various experienced surgeons from different parts of the world, from their outcome described the "personality of the fracture[16]

In the past surgeons classified the distal tibial fractures formally. Recently the soft tissue injury is also classified, but fracture classification used till recently had relatively poor observer reproducibility and reliability[17]. This caused inability of these systems to accurately predict the risks of poor results and complication. They have also presented different treatment methods, in different types of fracture.

Currently used formal classification:

1) Ruedi and Allgower's classification[18]
2) AO/OTA classification

1) **Ruedi and Allgower's classification:**

Based on the degree of articular comminution, Ruedi and Allgower classified distal tibial fracture into three types.

Type 1 – Non-displaced large fracture of the joint (shown in fig.12)

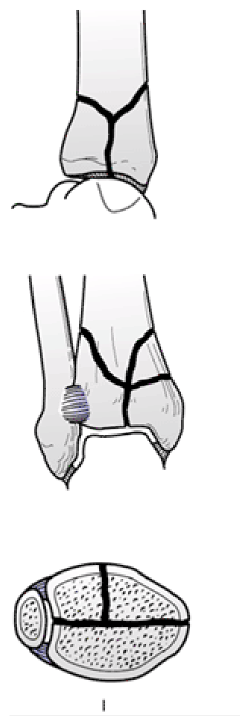


Fig 12: Ruedi and Allgower Type I

Type II – displaced but minimally comminuted fracture as shown in

Fig.13

Fig 13: Ruedi and Allgower Type II

This classification has prognostic significance because the results and complications were different for type I and type II fractures when compared with type III fracture.

Type III is highly comminuted and displaced fractures as shown in fig.14.

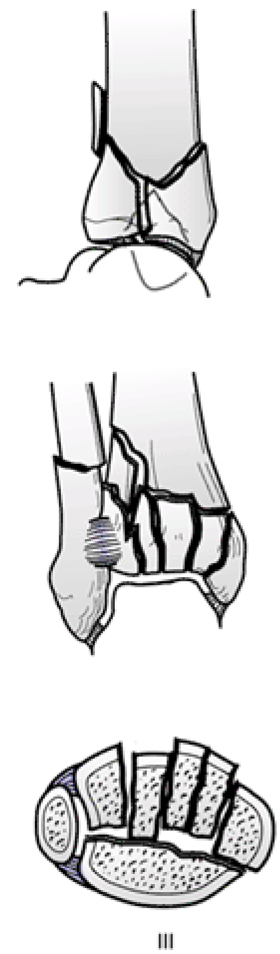


Fig14: Ruedi and Allgower Type III

Results for these three different types were not clearly made out, which leads to poor reliability by observer and hence this classification is replaced by AO/OTA classification system.

2) AO/OTA classification system:

AO/OTA classification is practically used to classify the fractures of distal tibia. In AO/OTA classification system, the fractures of distal tibia [AO-43] are categorised into three types.

Type A: Extra articular fracture: (shown in fig.15)

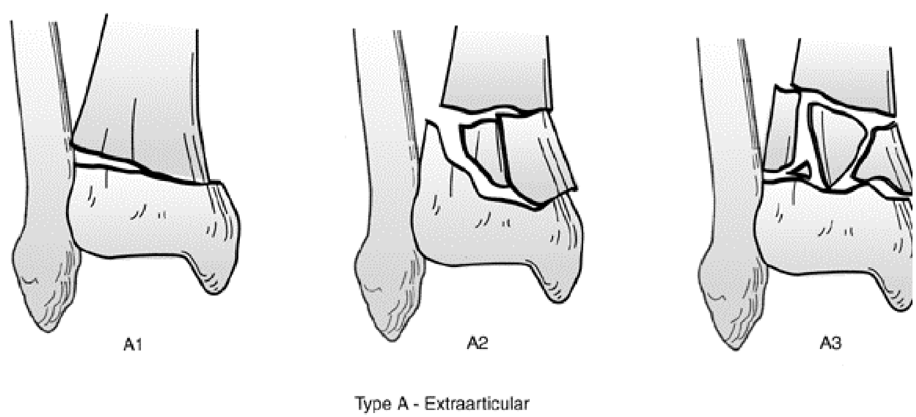


Fig 15: AO Type A Extra articular fracture

Type 43A1 -metaphyseal simple

Type 43A2 - metaphyseal wedge

Type 43A3 - metaphyseal complex

Type B: Partial articular fracture(shown in fig.16)

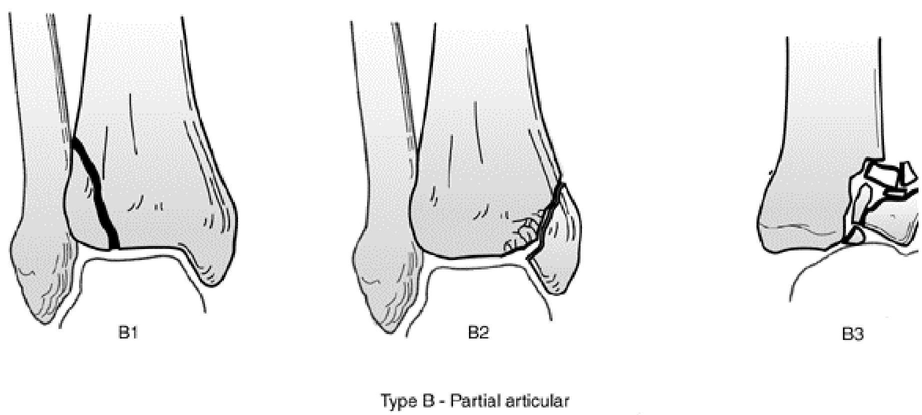


Fig 16: AO Type B – partial articular

Type 43B1 - Pure split

Type 43B2 - Split with depression

Type 43B3 - Multifragmentary depression.

Type C: Total articular fractures.(shown in fig.17)

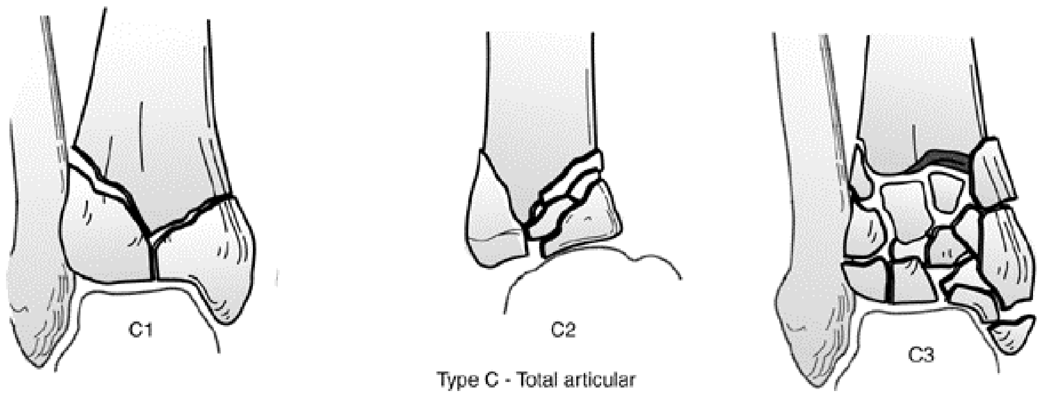


Fig 17: AO Type C – complete articular fracture.

Type 43C1 -Articular simple

Type 43C2 -Articular simple and metaphyseal multifragmentary

Type 43C3 - Articular multifragmentary

Based on the comminution, these three types (type A, B and C) are further divided into three groups and these groups in turn are further subdivided into three subgroups for each group, based on the nature of fracture like site of fracture line, direction of fracture line, metaphyseal impaction asymmetry and the extent and site of comminution. So there are twenty seven subgroups.

(3 types x 9 groups = 27 subgroups)

It is difficult to manage such a large subgroup. Type A fracture are uncommon and the fracture line is relatively proximal. Type B1 and B2 fractures are like rotational fracture. Type B3 are comminuted partial articular and type C1,C2 and C3are considered plafond fractures of tibia.

AO/OTA classification although gives direction of correct treatment plan and probable prognosis, poor observer reliability reduces the clinical use of this system. Only the major types A,B and C gives reliable prediction.

Another classification system used for classification of distal tibial fractures is one proposed by Robinson. (shown in fig.18).

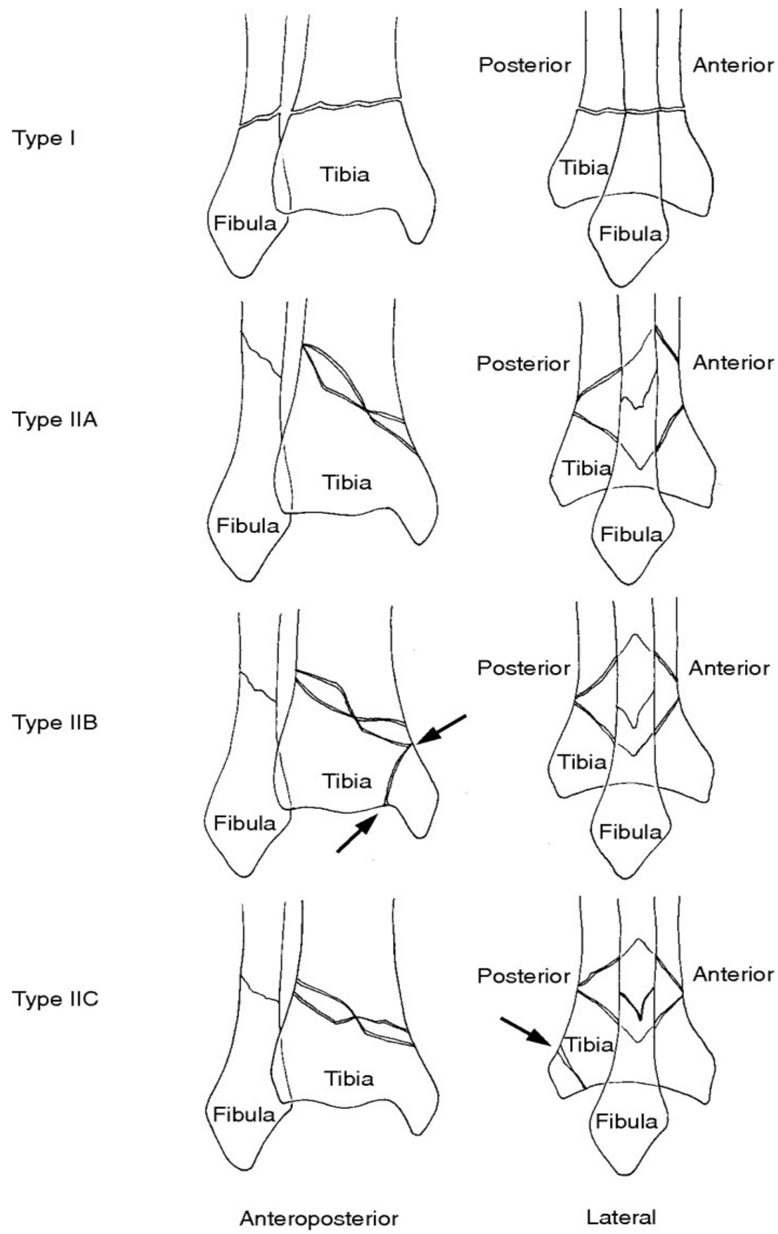


Fig: 18.Robinson classification of distal tibial fractures

We followed the AO/OTA classification because simple, reliable and it is useful for predicting the treatment method, and also complication and outcomes.

CLASSIFICATION OF SOFT TISSUE INJURIES

After studying 1025 open fractures in 1976, Gustilo and Anderson[19]described their grading system for treatment of fractures to give prognostic outcome.Later in 1984, this system was modified, taking into account the wound size, damage of soft tissue, stripping of periosteum and vascular injury.

GUSTILO - ANDERSON CLASSIFICATION OF OPEN FRACTURES

Type I: wound less than 1 cm and clean.

Type II: laceration greater than 1 cm without avulsion of skin or excessive damage to soft tissue

Type III A: extensive soft tissue laceration but with adequate coverage of bone by soft tissue or severely segmental fractures even with 1 cm wound.

Type III B: excessive stripping of periosteum with soft tissue loss and exposure of bone with severe contamination.

Type III C: open fracture with vascular injury, regardless of the wound size requiring intervention.

TSCHERNE CLASSIFICATION OF SOFT TISSUE INJURY

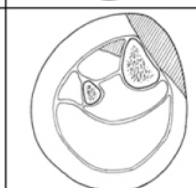
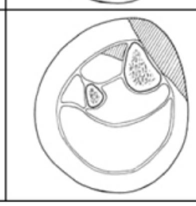
Grade 0	No soft tissue injury	0	
Grade 1	Superficial abrasion or contusion	1	
Grade 2	Localized deep contusion, abrasion or crushed skin associated with localized muscle damage	5	
Grade 3	Extensive soft tissue contusion or crushing, compartment syndrome, vascular injury and multifragmentary fracture pattern	3	

Fig 19: Tscherne classification of soft tissue injury

Gustilo and Andersen classification along with Tscherne classification of soft tissue injury (shown in fig.19) plays a vital role in management of distal tibial fractures. Good soft tissue condition is essential for carrying out minimally invasive technique.

REVIEW OF LITERATURE

HISTORICAL REVIEW

Fractures are identified and treated from Egyptian mummies even before 2700 years before the birth of Christ. The main method of fracture treatment by them was an external splintage using wood, clay, lime and egg white.

Treatment of fractures by external fixator was developed by Dr.Clayton Pak Hill of Denver and Dr.Albit Lambotte during late 18th century. This was later modified by Dr.Raowl Hoffman as Hoff man fixator and modified by Dr.Vidal and Dr.Adrey as Hoffman Vidal multiplanar frame system. This frame was too rigid to allow controlled collapse at the fracture site to allow union.

Fracture involving distal tibia is treated conservatively by plaster of paris. This leads to prolonged immobilization causing knee and ankle stiffness.

The principle of surgical treatment is to reconstruct the distal tibial articular surface and obtain adequate fibular length and. Stabilization of tibia with plate medially and bone grafting is also included.

Based on the above principle, a prospective study of 84 patients for nine years with open reduction and internal fixation with plate and screws, the author concluded that 90 % of patients return to pre injury functional level[18].

Another serious of study involving 26 patients with group A fractures with twisting injuries with minimal comminution and group B severe injuries including crush injuries based on fracture pattern shows that treatment with open reduction and internal fixation had excellent to good results in 65% of patients. 84 % of group A fractures had the best result implying that fracture pattern, type of reduction and length of immobilization are important. Immobilization for long time results in poor outcome. Hence the fixation should be stable to permit early mobilization[20].

In another series of retrospective study involving 42 patients treated with open reduction and internal fixation shows the importance of logical classification methods to describe the results of distal tibial fractures. The outcome of this study shows 80% success rate in Ruedi and Allgower type I and II fractures[21].

Another study involving large series of patients (145), in which 46% were injuries sustained due to high energy forces, 80 patients under went open reduction and rigid internal fixation, and others had closed reduction and casting (32), calcaneal pin traction and plaster of paris application (8), fixation of fibula and application of cast (3) and limited internal fixation and external fixation (5).

34 fractures in this series were equivalent to Ruedi and Allgower type III, in which excellent to good result was seen in 47% of patients only[22].

A case series reported 55 % infection and 36 % skin slough when the distal tibial fractures are inadequately and unstably fixed[23].A randomised prospective study of 38 patients, 18 patients in first group had open reduction and internal fixation and 20 patients in second group had external fixation for distal tibial fractures, showed no significant average clinical score difference between them.This shows that limited internal fixation along with external fixation was safer and equally effective[24].

In another series with 34 fractures involving distal tibia, the study concluded that outcome of surgical management mainly depends on 1) severity of initial trauma, 2) quality and stability of reduction, considering the soft tissue condition and comminution of fracture while treatment[25].

Fracture type	Excellent	Adequate	Poor
II	65.4%	11.5%	23.1%
III	20%	12.5%	37.5%

88.2% excellent to good result was obtained in a 30 patients study using open reduction and internal fixation with anatomical plates and screws, according to Oleurd and Mullander function ankle score[26].

In a study involving 20 patients with distal tibial fractures fixed with locking compression plates using minimally invasive plate osteosynthesis technique, 87.5 % of patients had excellent to good results. This method of treatment preserves the bone biology and reduces the soft tissue handling during surgery.Fractures classified by AO system was initially stabilized by external fixators followed by surgery later[27].

A series of study with 32 patients with a very small metaphyseal fracture fragment in distal tibia, treated with a poly-axial locking system which offers more fixation versatility, excellent to good result was obtained in 87.3 % using American Orthopaedic Foot and Ankle Society Score[28].

A series of 22 patients studied retrospectively, were the fracture are fixed with titanium locking compression plates using minimally invasive plate osteosynthesis, good biological fixation with good to excellent results using AOFAS score was obtained in 81% of patients[29].

RECENT REVIEWS:

A retrospective study of 80 patients with distal tibial fractures treated by Alexander A.Sitnik by minimally invasive percutaneous plate fixation, showed excellent results in 79% with patients returning to preinjury level .Delayed union,infection, non-union,and axial malalignment is seen in 21%. This method causes minimal soft tissue damage during surgery and preserves periosteum and provides biological union for fracture healing. If no union was seen radiologically by sixth month, it is termed as delayed union and no union by ninth month as non-union. The patients are examined for soft tissue condition, alignments and range of movement[30].

A randomised study involving 64 patients conducted by Im and Tae[31] in distal tibial metaphyseal fractures showed angulation of 2.8 degrees in patients with intramedullary nail compared to 0.9 degree with locking plates. Similar results are also seen in a study conducted by Vallier et al[9]involving 104 patients. Here intramedullary nailing group has unacceptable angulation of >4 degree[32].Guo et al conducted a randomised prospective study in eighty five distal tibial fractures, treated with minimally invasive plate osteosynthesis or intramedullary nail. This study shows no significant difference in function or alignment or pain statistically[33].

Based on these studies Chris Casstevens et al concluded that plate provides superior alignment and avoids knee pain as seen in nailing group. He also described extra articular fracture of distal tibia as no extension into the joint or simple, undisplaced articular extension. Soft tissue status along with fracture pattern should be considered while treating the patients[34].

Sixty two patients in a study with mean age of 44years conducted by Leung FK showed 88.7% excellent to good results based on Teens and Wiss ankle scoring system. Anatomical reduction with locking compression plate using minimally invasive plate osteosynthesis technique provides good union[35].

Ten patients retrospective study conducted by Jens Francois et al using indirect reduction technique and small incisions to insert the plate considerably decreases the soft tissue injury following surgical trauma[36]. Without much dissection and damage to surrounding soft tissue and periosteum, a stable fracture – bridging osteosynthesis can be achieved using minimally invasive plate osteosynthesis.

A prospective study of ten patients conducted by Shrestha D et al in distal tibial closed fracture using minimally invasive plate osteosynthesis with locking compression plate shows average union time of 18.5 weeks. Thus it is effective in achieving union and reducing complications[37].Skin irritation over malleolar surface is seen due to prominent implant in this study.

A prospective study by Mustafa Seyhan et al in sixty one patients, with percutaneous locking plate in thirty six patients and intramedullary nailing in twenty five patients, concluded non-union as no radiological signs of union for six months and mal union as angulation greater than five degree [38].

THE IMPLANT

The purpose of treating the fracture by surgical measures is to restore the function and bony anatomy. AO ASIF aimed at accurate reduction of the fracture with a stable fixation and preserving the vascularity to fracture fragments and also to provide early functional mobilization and prevent complications there by.

Excellent outcomes are obtained with the use of angular stable internal fixators for diaphyseo-metaphyseal fractures and also in osteoporotic fractures

A) **Anatomically contoured fixed angle locking compression plate**:

LC-DCP has hole spaces evenly with compression and neutral positions. Longitudinal screw angulation of 80° and transverse screw angulation of 14° is also provided (shown in fig.20).

Fig: 20. Distal medial tibial locking plate

The additional advantage is provided by the presence of combi holes, which permits the use of conventional cortical or cancellous screws or locking screw placements in same hole.

B) **Locking screws**:

Locking screws have threads in their head portion, which allows engagement of screw head in the threaded portion of the locking plate (shown in fig.21).Thereby it forms a stable screw-plate construct. The low thread profile in locking screw is not a disadvantage because the screw does not entirely depends on compression between bone and plate in providing stability.

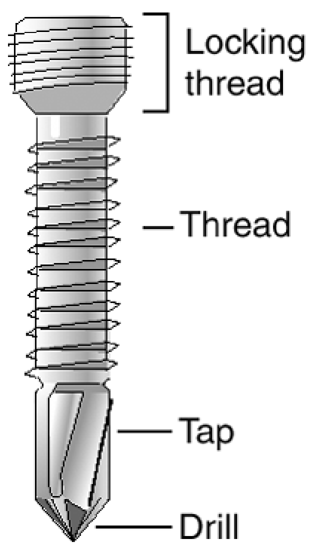


Fig : 21.Locking cortical screw

C) **Unicortical fixation**:

Unicortical screw fixation by locking screws transfer load and give stability at the near cortex by bone-plate interface and prevent plate pull-out.

Screw pull-out strength is more effectively utilized in locking plate and hence less implant failure.

Advantages of locking compression plates:

The aim of locking plate is to obtain anatomical reduction and absolute stability in articular fractures and to maintain length, alignment and rotation and relative stability and relative stability for biological fixation in extra-articular fracture.

A locking compression plate is useful in treatment of comminuted fractures by bridging them and providing relative stability.By use of combi holes (shown in fig.22), both the conventional compression plating and locking technology are brought together.

The locking compression plate is prevented from compressing against the periosteum, thereby protecting its blood supply to bone and provide biological environment for bone healing. Hence decrease the rate of infection, non-union and delayed union.

Stability of the fracture depends on the stiffness of the construct made by plate and locking screw as one stable construct. Poly-angle stable fixation in distal fractures favours stabilisation of many fracture fragments.

The plate-screw construct in locking compression plates provides better fixation in osteoporotic fractures than conventional plating. Fixed angle construct in locking compression plate increases the stiffness and stability.

Disadvantages:

Screw purchase in the bone cannot be determined as the head of the screw engages into the threaded plate.The fracture should be anatomically reduced before applying a locking plate.Locking compression plate if contoured alters the angulation of the holes and affects the screw fixation.

Indications of locking compression plating:

A) As conventional compression plate providing absolute stability in simple diaphyseal fractures, articular and metaphyseal fractures.
B) Locking compression plate by minimally invasive plate osteosynthesis technique provides relative stability in dia-metaphyseal comminuted fractures, open wedge osteotomies, secondary fractures after intramedullary nailing and periprosthetic fractures.

C) Locking compression plate in a combination of both methods (inter fragmentary compression and internal fixation) is used in articular fractures with comminution extending into diaphysis, segmental fractures with two different fracture pattern.

GENERAL PRINCIPLES:

Based on the experience gained with systems like PC-FIX and LISS, the evolution of locking compression plate has arrived.The development of locked internal fixator is based on deep understanding of bone biology especially its vascularity. It aims at fracture healing in natural course particularly osteoinduction principle. This is the principle of minimally invasive percutaneous osteosynthesis (MIPO).Indirect closed reduction, relative stability,biological healing and early mobilisation are the important principles of locking plate.

The screw head gets locked within the plate and hence the pressure exerted while applying the plate to bone is minimised without compromising periosteal vascularity.They are precontoured according to anatomical sites.

The combi holes – locking compression plate has versatility and can be used in fractures as conventional technique based on principle of compression, bridge plate based on principle of internal fixation or a combination of both.

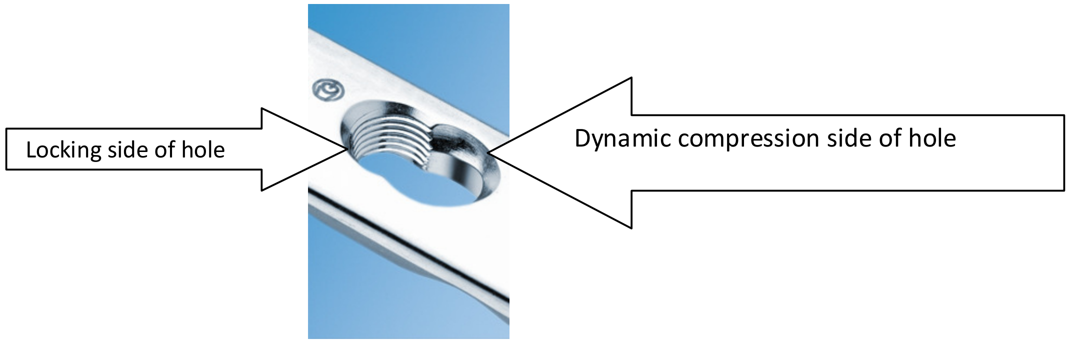


Fig: 21. Combi hole one hole for compression and locking options

Basic concepts of internal fixators:

The concept is formed by group of surgeons from Poland. Principles the polish surgeons used to design the implants are

1. Compression between the bone and plate should be avoided and the screws should be fixed to the plate.

2) Less numbers of screws should be used for a stable fixation to provide plate stability and interfragmentary compression.

The new locking compression plate concept is based on purely splinting the fractures.The screws here are similar to the pins in external fixators.

Angular stability provided by screw locking is the basic principle of internal fixator and not as friction between plate and bone as in conventional plates.In a dynamic compression plate, friction transfers load between bone and implant, whereas in locking compression plate the threaded heads of the screw acts as peg which splint the bone with plate.

Poor Contouring of the dynamic compression plate causes the fractures to malalign while tightening the screw. Precontoured locking compression plate thus made it ideal for minimally invasive plate osteosynthesis. Locking of the screws to plate favours unicortical screw fixation.

AIM OF THE STUDY

To evaluate the effectiveness of biological fixation of closed distal tibial fractures in adults treated with precontoured locking compression plates designed for the distal tibia.

MATERIALS AND METHODS

Cases of distal tibial fractures (closed and grade 1 open) with /without associated fractures involving other region who presented to Department of Orthopaedics, Thanjavur Medical College,Thanjavur,during the study period, who satisfy the inclusion criteria that are studied and medically fit for surgery.

STUDY DESIGN

Prospective study

SOURCE OF DATA

Patients who sustained closed and grade I open fractures of distal tibia and were treated by minimally invasive plate osteosynthesis using locking compression plate in the Department of Orthopaedics,Thanjavur Medical College,Thanjavur were taken as the study population.

Sample size

32 patients with closed and grade I open fractures of distal tibia and were treated by minimally invasive plate osteosynthesis using locking compression plate were selected for inclusion in the study.

Inclusion Criteria

1) Fresh distal tibial fractures closed and grade I open fractures.
2) Fractures of distal tibia unfavourable for interlocking nail
3) Complex fractures of lower third of tibia
4) Adult Patients willing to undergo surgery in both sexes

Exclusion Criteria

1) Fractures in skeletally immature age group
2) Significant contraindication to any anaesthesia
3) Patient unwilling for surgery
4) Grade II,III open fractures of distal tibia

The study was approved by the Institutional Ethical Committee (IEC) of Thanjavur Medical College, Thanjavur.

PROTOCOL

Management started as the patient was received in our trauma ward. This comprised primary assessment including airway, breathing, circulation and screening for spinal injury, alongside simultaneous management of shock and surveying for other system injuries. The injured lower limb is splinted in a Thomas's splint. Bed side imaging is done with X-rays. Blood investigations included blood sugar,urea, blood HBSAg, HIV 1 and HIV 2.

Thus the preoperative evaluation includes:

1. History
2. Clinical examination
3. Lab investigations
4. Radiological assessment

A detailed history was taken and proper systematic clinical examination was done to find out

1. Nature and violence of the trauma
2. Mechanism of injury and the duration since injury
3. Any significant past history or family history
4. Any associated injuries
5. General physical examination
6. Local examination- first to reveal swelling, deformity and blisters. Second any external injuries were assessed. Vascular status of the limb and any evidence of neurological deficit and compartment syndrome was carefully looked for and documented.
7. Abnormal mobility and crepitus were not purposely looked for as these are acute fractures.

The laboratory investigations include:

1. Complete blood count
2. Renal function tests and blood glucose levels
3. Urine analysis
4. HIV and HBsAg status
5. Chest X- ray
6. Electrocardiogram (ECG)

RADIOLOGICAL ASSESSMENT

A series of radiographs of the involved leg with ankle like antero-posterior view, mortise view and lateral view and X-ray of knee with leg antero-posterior and lateral views, X rays of the pelvis anteroposterior view to rule out other fractures were taken. Antero-posterior and lateral radiograph the uninjured limb were also obtained for comparison and templating purposes.

Assessment for anaesthesia is done by physician and anaesthetist. If the anaesthetist needed cardiac fitness was obtained. Most of the cases were operated within one week.

Further detailed data of the patients involved in the study was obtained by interviewing them and based on clinical examination findings. These data were recorded on a standard predesigned and pretested proforma.

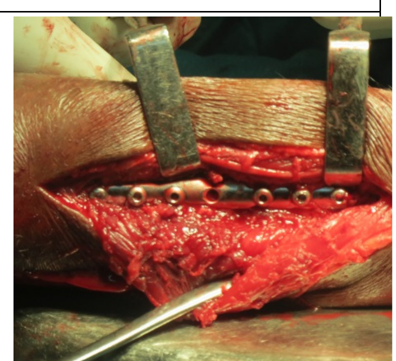
After sorting out the patients on the basis of the already defined inclusion and exclusion criteria, patients were selected for the study and were briefed about the nature of the study , the different surgical options available to them and a written informed consent in their own language was obtained.

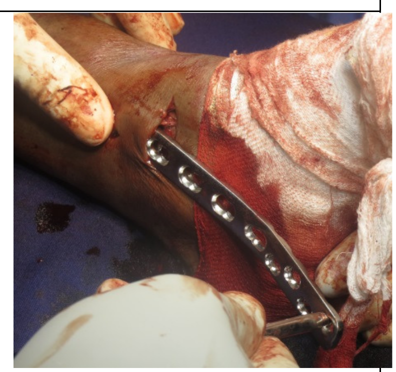
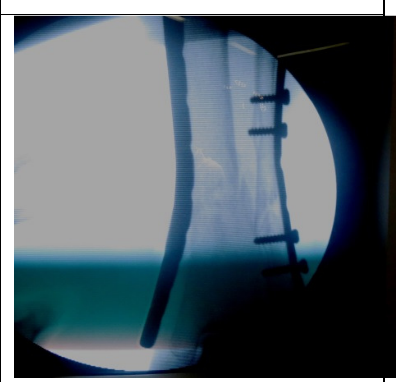
The step by step procedure is given below.

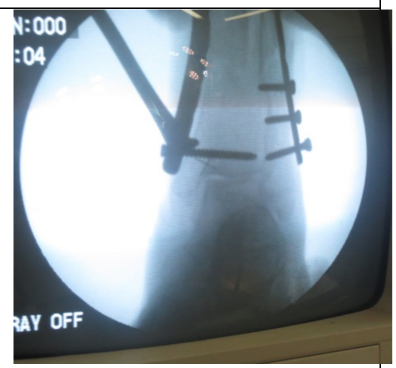
1. Spinal anaesthesia is given followed by prophylactic antibiotic.
2. Pneumatic tourniquet was applied and patient was put in supine position with sand bag under hip.

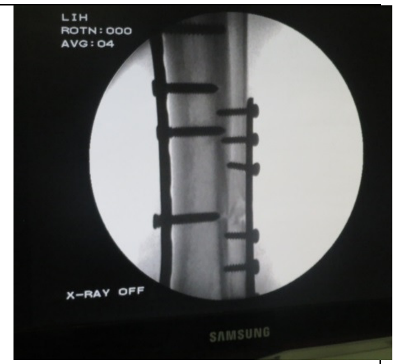
3. If the fracture is open, debridement done.
4. If associated fracture fibula present, it is first fixed by postero-lateral open approach using 1/3rd tubular plate.
5. The tibial fracture is reduced by closed manipulation without opening the fracture site and position verified under C-arm.
6. Then a small incision of 4cm size is made just below or over medial malleolus and extraperiosteal plane is made using long angled epi-periosteal elevator.
7. 4 mm distal medial tibial locking compression plate of adequate length is introduced from below upwards and verified under C-arm.
8. Distal locking done with a 4mm conventional cancellous screw.
9. Proximally close to the fracture 4.5 mm conventional cortical screw is used to bring the fracture close to the plate without plate offset proximally.
10. 5mm locking screws are fixed proximally.
11. Remaining screws distally is fixed with 4mm locking cancellous screws.
12. The conventional screws are now replaced by locking screws.
13. Position again verified under C-arm.
14. Tourniquet released.
15. Wound closed in layers.
16. Dressing done after checking distal pulses.

STEP BY STEP PROCEDURE WITH AVERAGE TIME

S.NO	STEPS	AVERAGE TIME TAKEN (IN MINUTES)	CLINICAL PICTURES
1.	Spinal anaesthesia is given followed by prophylactic antibiotic and pneumatic tourniquet applied and patient positioned	7	
2	Painting and draping and tourniquet inflated	7	
3.	The fibula, if fractured is exposed by postero-lateral approach and fixed with 1/3rd tubular plate.	15	

4.	Closed manipulation and reduction of tibial fracture done and verified under C- arm	5	
5.	A small incision is made just below medial malleolus and extra periosteal plane is made	5	
6.	Distal medial tibial locking plate with sleeve in distal part as a handle is passed in reduced position of the fracture.	3	
7.	Confirm that the plate has completely crossed the fracture segment and palpated in the proximal segment preventing offset.	2	

8.	Distal most hole is drilled with2.7mm drill bit and 4mm regular cancellous screw is fixed	3	
9.	Position of the distal screw is verified under C-arm	3	
10.	Small incision is made in the proximal fracture segment correcting plate offset. It is drilled with 3.2mm drill bit and passed with 4.5 mm regular cortical screw, to bring the bone close to the plate. Then remaining proximal and distal holes are filled with locking screws.	3	

11.	Position of plate and screw in proximal segment is verified with C-arm.	2	
12.	Entire plate with fracture in reduction visualised under C-arm filling desired number of screws. Regular screws are also replaced with locking screws.	10	
13.	Wound closure and final wound status. Draining tube if necessary is kept on fibular wound site.	5	
14.	Sterile compressive dressing done and tourniquet released.	2	

AVAILABILITY OF THE IMPLANT

We were equipped with the entire set of distal medial tibial locking compression plate(SSEPL®)with cancellous and cortical screw system (shown in fig.23)and also multiple K-wires and 4.5mm cortical screw system which are used for temporary fixations.1/3rd tubular plate sets for fibular fixation, if necessary (shown in fig.24). In all these cases, the distal tibia X-ray of the normal side is made mirror image and matched for assessing reconstruction (i.e.post-operative X-ray with the normal X-ray). All the implants were provided by the honourable CMCHIS scheme.

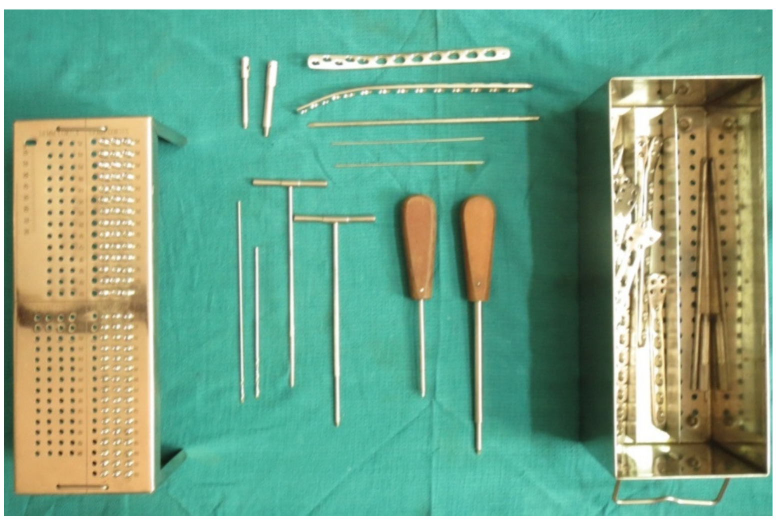


Fig:23. Distal medial tibia – locking compression plate set

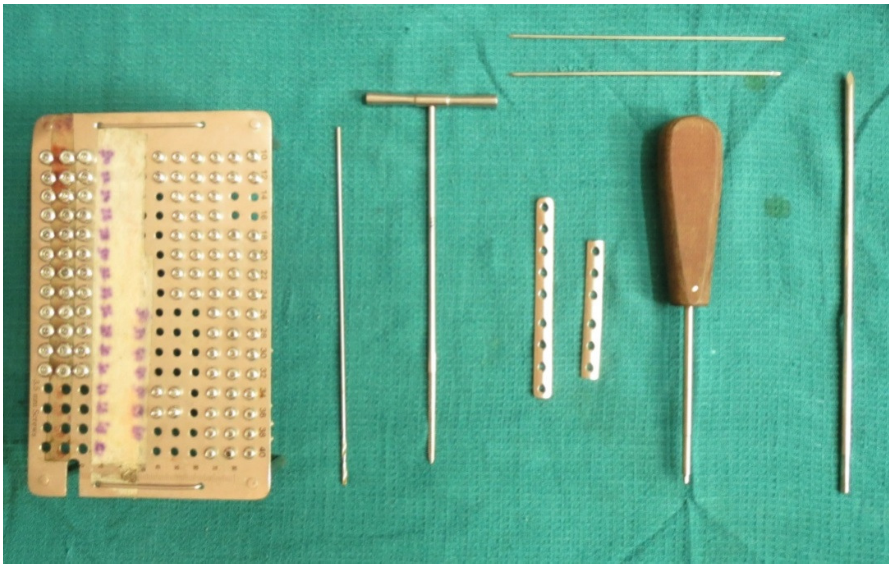


Fig:24. 1/3rd Tubular plate set and 4.5mm cortical screws.

After reducing the fracture, the correct size distal medial locking plate (shown in fig.25) is passed over the periostium. Now close to the fracture, conventional regular screws are applied, which brings the bone close to the plate and avoid much gaping and angulations. Later the regular screws can be replaced by locking screws. The length of the locking plate should be atleast two to three times the length of the fracture fragments. The adequate length can be confirmed under C-arm image intensifier.

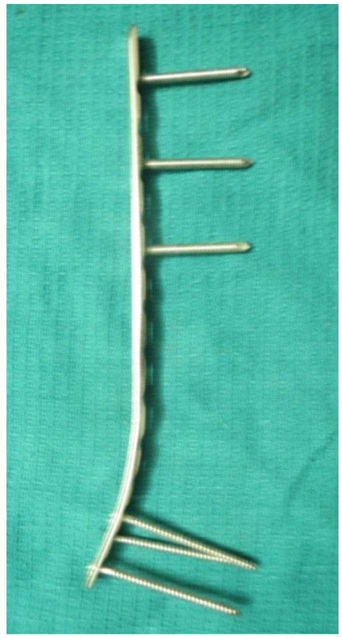


Fig: 25.Distal medial tibia locking compression plate with screws in position.

Fig: 26. Long angled epi-periosteal elevator used for creating extra-periosteal plane

For minimally invasive techniques which use small incision, the long angled epi-periosteal elevator shown in fig. 26 is much useful in creating an extra-periosteal plane, so that the implant can be passed without much difficulty and damage to soft tissues which are already compromised.

POST-OPERATIVE CARE AND REHABILITATION:

Postoperative care in the form of intravenous broad spectrum antibiotics and periodic change of dressing were done. Suction drain was removed at 48 hours. Proper postoperative care and rehabilitation is done to ensure the attainment of satisfactory range of motion, strength and function at the ankle joint.

Rehabilitation was ordered for each patients based on the fracture type or pattern and strength and quality of fixation. If the fracture was stable after fixation, gentle ankle mobilization was started on day 2. Static quadriceps exercises and hamstring strengthening exercises and knee mobilization were started simultaneously. Staples were removed at the 12^{th} postoperative day. Patients were strictly advised non weight bearing with crutches or walker support initially, if the fracture was stable. Weight bearing was allowed only after radiological evidence of union at the fracture site.

All patients were followed up regularly and evaluated for fracture healing, any change in alignment or screw breakage by assessing the patient clinically and radiologically at regular interval.

Clinical union was defined as a painless fracture site during full weight bearing. Radiologically union was defined as bridging trabeculation across the fracture site on three of the four cortices.

ORDER OF APPLICATION OF SCREW

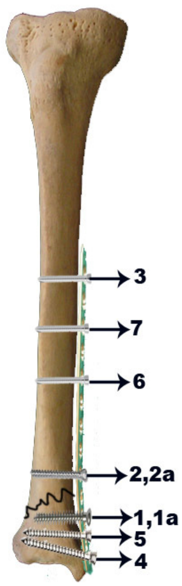


Figure 27.showing the order of screws.

Screws 1 and 2 are applied close to the fracture in conventional holes to bring the fracture ends close to the plate. Screw 3 is applied in the proximal hole of the plate in locking hole taking care of plate offset. Now screw 4 is applied in the distal hole i.e. locking cancellous screw taking care of joint articulations. Now screw 5 locking cancellous screw is applied followed by screw 6 and 7 locking cortical screws. Screw 1 and 2 are now replaced by respective locking screws 1a, 2a if necessary (as shown in fig.27).

ILLUSTRATED CASES

CASE 1

A 63 years old lady Mrs. A, with history of accidental slip and fall and sustained closed left distal tibial fracture with associated fibula fracture. The patient was initially stabilised with Thomas splint.

She underwent Total knee replacement, two months earlier in the same side knee for osteoarthritis.

Fig.28.Preoperative X ray(AP and lateral views)

The patient was taken up for surgery on the next day.

Under spinal anaesthesia with patient in supine position and tourniquet control with sand bag under left hip, the fibula was fixed through postero-lateral approach with $1/3^{rd}$ tubular plate (shown in fig.29).

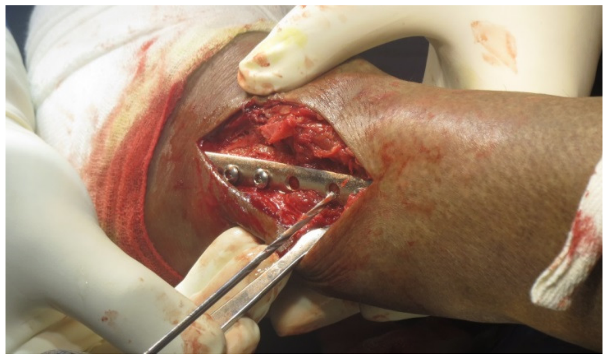


Fig: 29.Fibular fixation with $1/3^{rd}$ tubular plate.

The fracture tibia was then reduced under C-arm and fixed with distal medial tibia locking plate using minimally invasive technique.

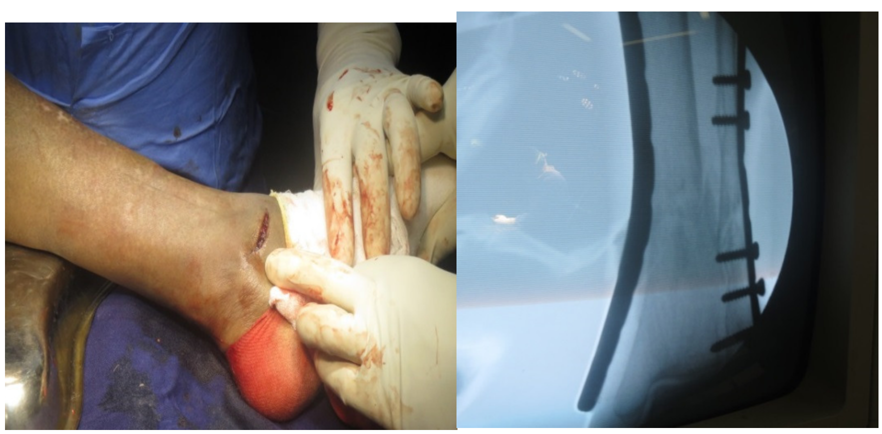


Fig:30.MIPPO incision and adequacy of implant length crossing fracture verified under C-arm.

A small curvilinear incision of size 4 cm is made just below the medial malleolus (shown in fig.30). An extra periosteal plane is made using long angled epi-periosteal elevator. The implant is introduced in the extra periosteal plane from distal to proximal and position verified under C-arm (shown in fig: 30). The implant should be atleast two to three times the length of fracture site for effective biological fixation.

Fig:31.Intra operative C-arm picture.

The intraoperative fracture reduction and plate fixation are verified under C-arm (shown in fig.31). There should be at least three screws in the distal part of the plate holding the fracture fragment. Articular surface must be taken care while applying distal most screw.

Fig:32.Sutured wound and immediate post-operative X-ray

The patient had minimal posterior angulation within the acceptable range (shown in fig.32). No plaster of Paris was applied, since the fixation was stable. Draining tube kept on fibular side was removed on 2nd day.The patient was sent home on 5thpost operative day and advised passive ankle and knee mobilisation. Knee mobilisation was also advised. Strict non weight bearing was advised. The suture was removed on 14thday.

Fig:33. 20 Weeks follow up radiograph

Postoperative range of movements

Fig: 34. Dorsiflexion

Fig:35.Plantar flexion

The patient has full range of ankle movements (shown in figures 34 and 35).

Fig:36.Post-surgical scar status

The wound was healed well. There was no implant prominence noted.

ILLUSTRATED CASES

CASES 2:

A 37 years gentleman Mr. B, with history of road traffic accident sustained closed fracture left distal tibia and associate fibula. He was stabilised in emergency room with Thomas splint.

Fig:37.Preoperative radiograph (AP and lateral views)

The patient had abrasion of size 2x1cm over the medial malleolar region. The patient was taken up for surgery after 1 week. Till then he was put on plaster of paris and immobilised. An oral antibiotic was also given.

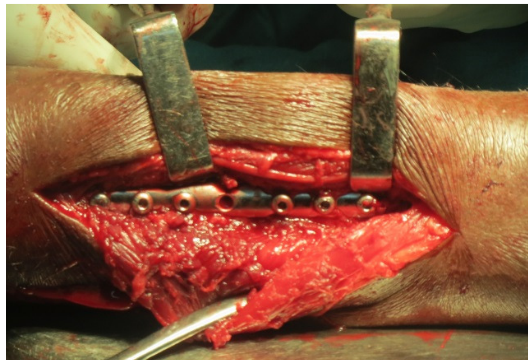


Fig:38. The fibular fracture was fixed with a1/3^{rd} tubular plate.

Under spinal anaesthesia, the associate fibular fracture is first exposed through posterolateral approach and fixed with 1/3^{rd} tubular plate (shown in fig.38).

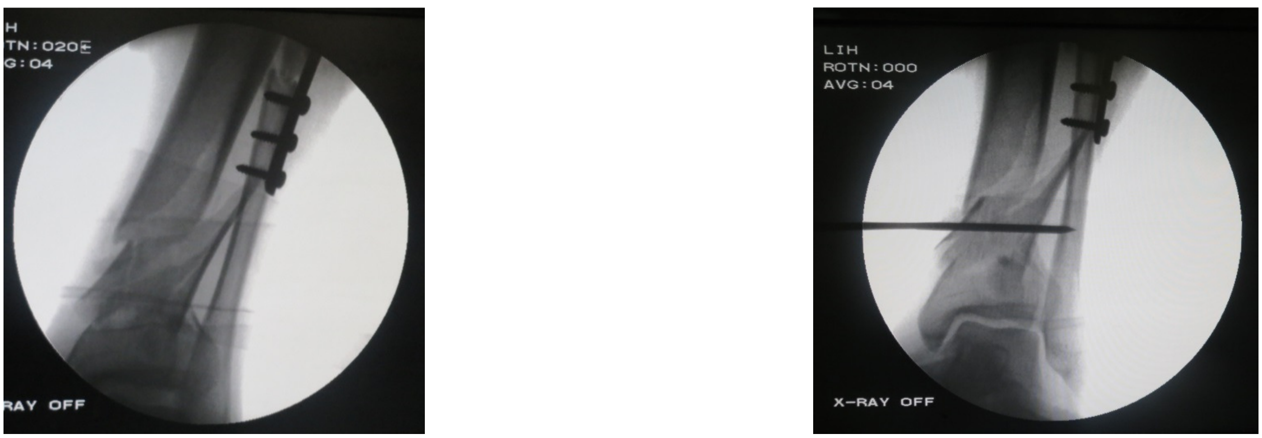


Fig: 39.Manipulation of the large displaced fragment using Steinmann pin as joystick

After fixing the fibula the tibial fracture fragments are found to be severely displaced. Since we planned for biological fixation and not to open the fracture site, we used a Steinmann pin as joy stick and manipulated the fracture and aligned it (shown in fig.39).

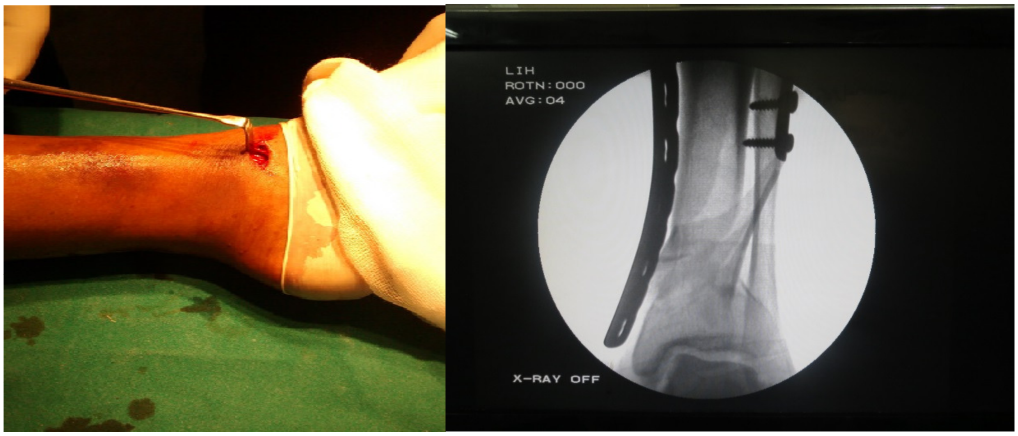


Fig:40. Showing incision below medial malleoli for MIPPO and C- arm picture of plating

The tibia was fixed with distal medial tibial locking plate using minimally invasive technique.

A curvilinear incision of size 4cm is made just below the medial malleolus and extraperiosteal plane is made and the plate is passed from below upwards (shown in fig.40). Care should be taken not to damage the neurovascular bundle. Adequate size of the implant is also confirmed by verifying under C-arm.

Fig: 41.Immediate post-operativeX ray

Since the distal fixation was done with only 2 screws, due to close proximity to fracture, the patient was put on above knee plaster of paris for 6 week and advised strict non weight bearing. Toe movements, hip movements and static quadriceps exercise were encouraged. Draining tube was removed on second day. Skin stapler was removed on second week and then the patient was discharged.

Fig:42.Wound status on second post operative day

The condition of the wound on first dressing was shown in fig.42. Draining tube kept on fibular side was also removed on day 2.

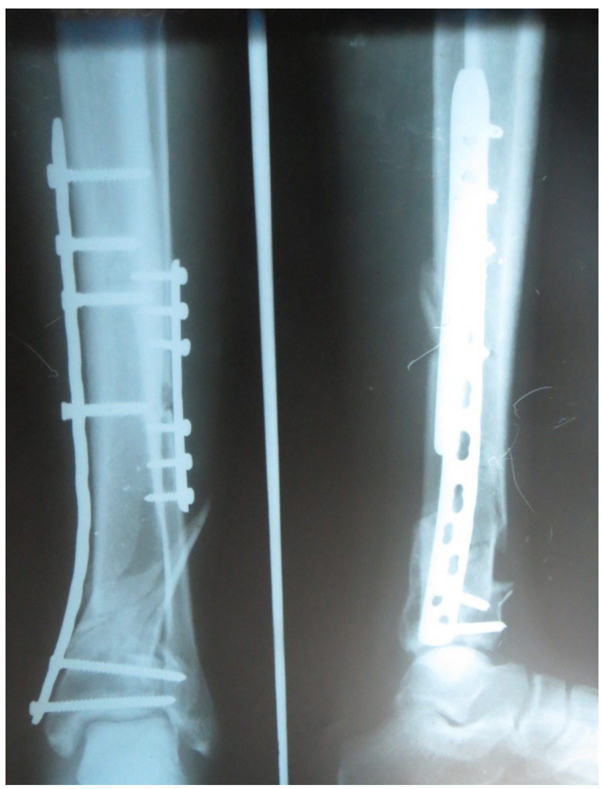


Fig:43.Post-operative x ray after 6 weeks.

The fracture is a complex type with multiple fragments.The patient was operated with biological fixation and hence individual fragments cannot be manipulated separately. The large fragment alone is manipulated using Steinmann pin. This X-ray in figure 43 show a spike of fragment projecting laterally. The patient was put on plaster of paris for eight weeks.

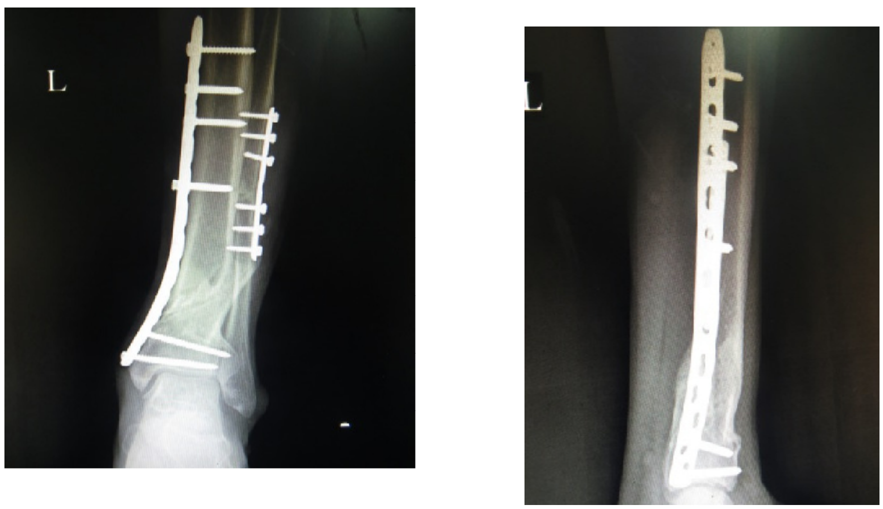


Fig:44.Six months post-operative X-ray

The serial X rays taken are shown in fig: 41, 43and 44.

The X ray in fig.44 showed sound union of the fracture.

Range of movements

Fig:45.Squatting position Fig:46. Squatting with heel off

The range of movements at the ankle joint was full. The patient was able to squat and raise his heel off the ground actively as shown in figures 45 and 46. The patient returns to his preinjury functional level.

Fig:47.Post-operative scar status.

The surgical scar is also healthy and there is no implant prominence.

ILLUSTRATED CASES

CASE 3:

A 45 Years old gentleman Mr. J, a known case of type II diabetes mellitus, with history of vehicular accident sustained closed left distal tibial fracture with lateral malleolus.

Fig:48. preoperative radiograph

Fig.48 shows the preoperative anteroposterior and lateral radiographs of left leg with ankle.

Initally he was put on plaster of paris. The patient was taken for surgery on the next day.The fibular fracture was fixed first with $1/3^{rd}$ tubular plate.The tibia was fixed with distal medial tibial locking compression plate using minimally invasive technique.

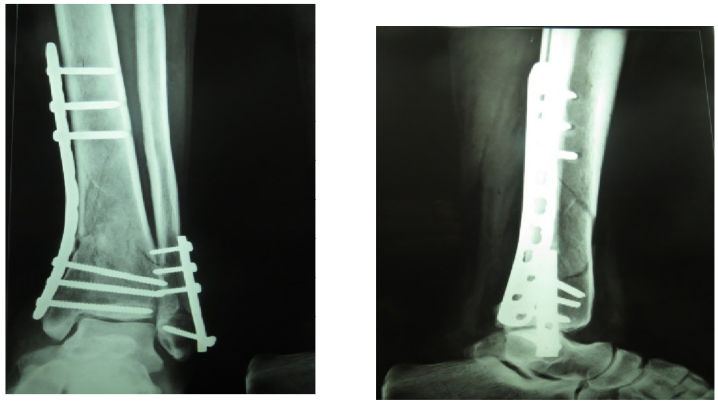


Fig: 49. Immediate post-operative radiograph

The ankle mobilization was started on 5th day as tolerable. The patient was discharged on seventh postoperative day. Suture was removed after 2 weeks. Non weight bearing ambulation was advised.

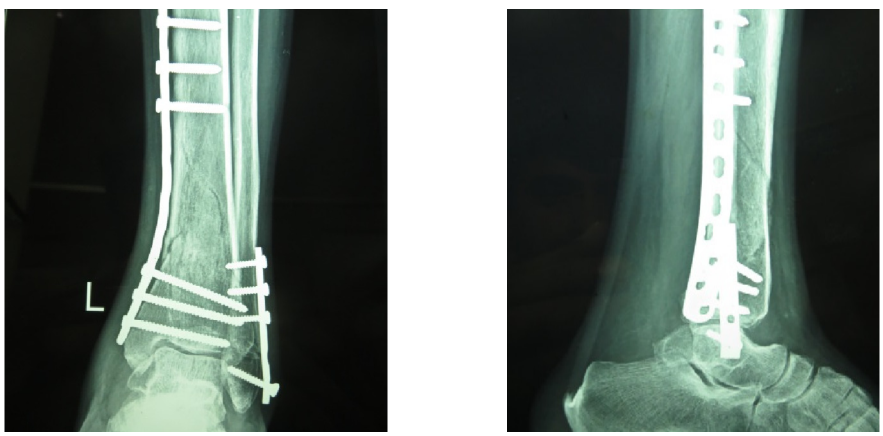


Fig:50. First month follow up X- ray.

Fig:51. 24 Weeks follow up X- ray

The serial radiographs were taken immediately following the surgery, first month and six months are shown in fig: 49, 50 and 51.

Follow up range of movements

Fig: 52a. Dorsiflexion

Fig: 52b.Plantar flexion

Fig:53.Post-operative scar

The patient has full range of movements at the ankle, as it is evident shown in figures 52a and 52b. He is able to raise his toe and heel off the ground. The surgical scar (shown in fig.53) was healthy and no implant prominence was noted.

ILLUSTRATED CASES

Case 4:

A 43 years old gentleman Mr. S, with history of road traffic accident and sustained Gustilo and Anderson grade I open right distal tibia fracture with closed distal fibular fracture.

Fig:54.Preoperative radiograph.

X ray right leg with ankle AP and lateral views on the day of trauma is shown in fig.54.

Since the patient had grade 1 open right distal tibia fracture, thorough wound debridement done on the day of trauma and the patient was put on calcaneal pin traction and intravenous antibiotics.

.

Fig: 55. Wound status before definite surgical procedure

The patient was taken for surgery 1 week after subsidence of the swelling. The wound was dry and healthy with no signs suggestive on infection (shown in fig.55).

Through minimally invasive plate osteosynthesis technique distal medial tibial locking plate was fixed, after fixing fibula with 1/3rd tubular plate using posterolateral open approach (fig.56).

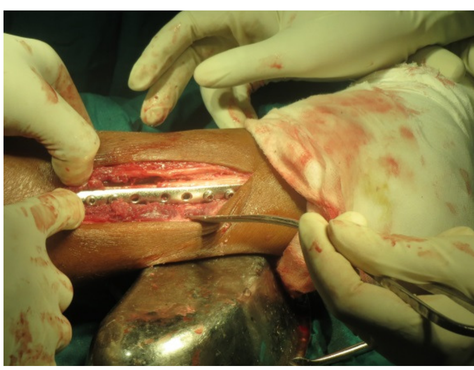


Fig: 56. Fixation of fibula Fig:57. Incision for MIPO

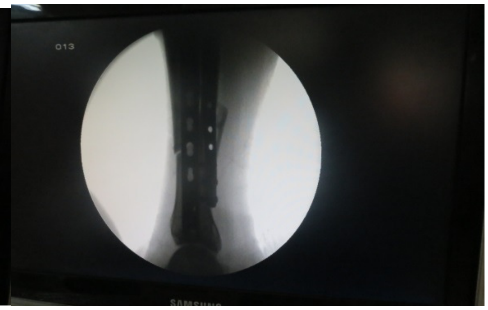


Fig: 58. Conventional screw fixation Fig: 59. Lateral view

The conventional screw application initially close to the fracture brings the segment of the bone close to the plate, preventing much gap between plate and bone and avoiding excess angulation (fig.58). It can be replaced with locking screw later.Anatomical reduction is must before the application of locking plate.

Fig: 60.Post-surgery sutured wound Fig:61.Immediatepost-operativeXray

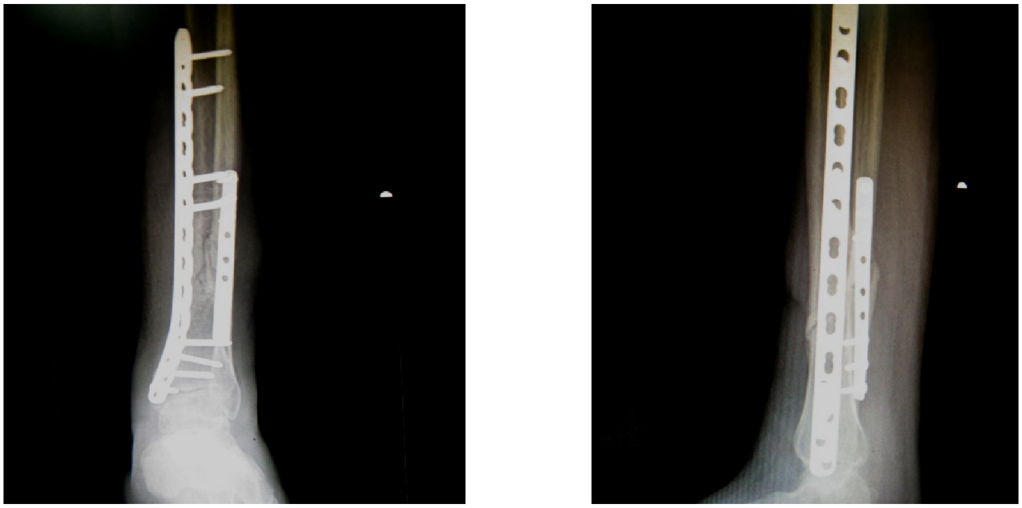


Fig: 62. 16 Weeks post-operative X-ray

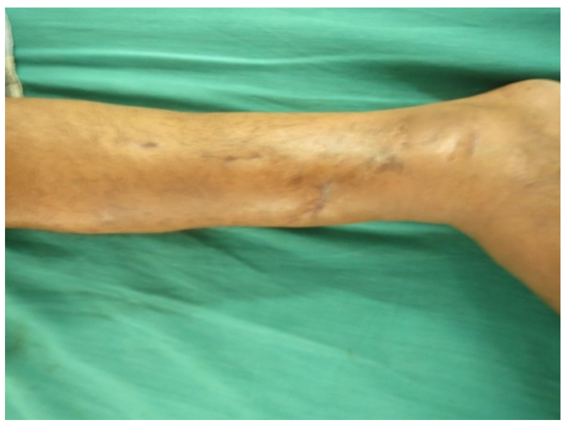


Fig: 63.Surgical scar after 16 weeks

Both the open wound and surgical wound healed uneventfully (fig: 63). Thorough debridement and intravenous antibiotics helps in controlling the infection in primary treatment. Minimally invasive plate osteosynthesis minimises the further soft tissue damage already compromised by trauma.

Post-operative range of movements

Fig:64a. Plantar flexion

Fig:64b. Dorsiflexion

The patient has full range of dorsiflexion and plantar flexion at the ankle shown in figures 64a and 64b.

RESULTS

Out of the total 32 cases, 30 cases were followed up for a period of 5 to 20 months with an average follow up period of 11.5 months.2 Cases were lost for follow-up. 30 cases were available for follow up and all cases were assessed using Karlsson and Peterson scoring system for ankle function. There were 14 excellent, 9 good, 3 average, 4 poor results. Radiological assessment is done for fracture union by taking X-rays in antero-posterior and lateral views at regular intervals. Radiological scoring, Template using the uninvolved leg with the operated leg especially valgus, varus, anterior and posterior angulation is done.Then the normal X-rays were compared with the operated side for assessing the accuracy of angulation.

The results of the study were statistically analysed and represented in pie chart and bar diagram as follows.

S. NO	NAME	AGE	SEX	SIDE	MOI	DOI	ASSOCIATE CO-MORB	AO TYPE	ASSO #	DOS	1ST FOLLOW UP	RESULT	UNITED IN	COMP
1	ANUS	63	F	L	ACC FAL	23.8.13	TKR DONE BEFORE 2MONTH IN LT KNEE	A1	# FIBULA LT	24.8.13	23.9.13	UNITED	18 WEEKS	NIL
2	JML	45	M	L	RTA	19.2.13	DM	B1	# FIBULA LT	20.2.13	22.3.13	UNITED	14 WEEKS	NIL
3	SWAM	49	M	L	RTA	14.2.13	-	A3	L IT & LT FIBULA #	21.2.13	20.3.13	MAL UNION	18 WEEKS	MALUNION
4	BALSUN	37	M	L	RTA	5.1.13	-	A3	# FIBULA LT	12.1.13	15.2.13	UNITED	16 WEEKS	NIL
5	MURUG	25	M	R	RTA	18.12.13	-	A1	# FIBULA RT, SCALP WOUND	25.12.13	27.1.14	NON UNION	-	NON UNION
6	RAMIY	65	M	R	FFH	28.12.13	HTN	A3	# FIBULA RT	2.1.14	6.2.14	UNITED	16 WEEKS	NIL
7	SAKTI	43	M	R	RTA	7.2.14	-	A3: GR I OPEN	# FIBULA RT	15.2.14	17.3.14	UNITED	14 WEEKS	NIL
8	MURU 2	55	M	L	RTA	4.3.13	DM	A2	# FIBULA LT;RAW AREA LT FOOT	25.3.13	28.4.13	UNITED	16 WEEKS	INFECTION
9	VAITHY	60	M	R	FFH	11.11.12	HTN	A2	# FIBULA RT	18.11.12	30.12.12	UNITED	18 WEEKS	ANKLE STIFFNESS
10	MEERA	51	F	R	ACC FAL	23.3.14	-	A1	# FIBULA RT	25.3.14	3.5.14	UNITED	18 WEEKS	NIL
11	AKBR	24	M	L	RTA	17.2.13	-	A3	# FIBULA LT	26.2.13	LOST FOLLOW UP	-	-	-

S.NO	NAME	AGE	SEX	SIDE	MOI	DOI	CO-MORB	AO TYPE	ASSO #	DOS	1ST FOLLOW UP	RESULT	UNITED IN	COMP
12	KUMD	53	F	R	ACC FAL	24.7.13	BA	A1	-	15.8.13	22.9.13	UNITED	16 WEEKS	NIL
13	SARAV	52	M	L	RTA	24.3.14	-	A3	# FIBULA LT	26.3.14	27.4.14	UNITED	14 WEELS	NIL
14	MOZV	27	M	R	RTA	9.1.14	-	A2	# FIBULA RT	18.1.14	23.2.14	NON UNION	14 WEEKS	NONUNIO N, INFECTED
15	MUKA	62	F	R	ACC FAL	19.12.13	-	A3	# FIBULA RT	24.12.13	30.1.14	DELAYED UNION	18 WEEKS	ANKLE STIFF
16	MARI	29	M	R	RTA	12.2.14	-	A2	R PUBIC RAMI #	18.2.14	19.3.14	DELAYED UNION	20 WEEKS	DELAYED UNION
17	MUNI	38	F	L	ACC FAL	22.3.14	DM	A1	-	29.3.14	2.5.14	MALUNIT ED	18 WEEKS	MALUNIT ED
18	RAJ	24	M	L	RTA	17.1.14	-	A2	# FIBULA LT	22.1.14	28.2.14	UNITED	16 WEEKS	NIL
19	NAND	36	M	R	RTA	7.2.14	-	A1	-	12.2.14	15.3.14	UNITED	16 WEEKS	SUP INFECTIO N
20	PANDI	43	M	R	RTA	6.11.13		A3	# FIBULA RT	15.11.13	22.12.13	UNITED	18 WEEKS	NIL
21	LAXMI	72	F	L	ACC FALL	2.8.13	DM,HTN	A3	-	12.8.13	24.9.13	UNION	2O WEEKS	NIL
22	GAYTR	26	F	R	RTA	27.1.14	-	A2	-	4.2.14	9.3.14	UNITED	18 WEEKS	NIL

S.NO	NAME	AGE	SEX	SIDE	MOI	DOI	CO-MORB	AO TYPE	ASSO #	DOS	1ST FOLLOW UP	RESULT	UNITED IN	COMP
23	NATRA	62	M	L	RTA	9.10.13	HTN	A3	# FIBULA LT	15.10.13	20.11.13	UNITED	20 WEEKS	ANKLE STIFF
24	SHEIK	57	M	R	RTA	7.5.14	PSYC ILL	A1	# FIBULA RT	10.5.14	15.6.14	UNITING	-	NIL
25	PARAM	30	M	L	RTA	27.2.14	-	A3	GR III OPEN L FEMUR	7.3.14	12.4.14	UNITED	16 WEEKS	NIL
26	MAHA	48	F	R	RTA	13.11.13	-	A2	# FIBULA RT	21.11.13	26.12.13	UNITED	16 WEEKS	NIL
27	KANN	34	M	L	RTA	6.2.14	-	A2	# FIBULA LT	14.2.14	19.3.14	UNITED	14 WEEKS	NIL
28	SAMPT	42	M	R	RTA	15.1.14	L PPRP	A1	-	19.1.14	23.2.14	DELAYED UNION	18 WEEKS	DELAYED UNION
29	PONNU	28	F	R	ACC FAL	22.5.14	-	A3	# FIBULA RT	28.5.14	30.6.14	UNITING	-	ANKLE STIFF
30	KASIA	65	F	R	RTA	18.2.14	HTN	A2	# FIBULA RT	26.2.14	LOST FOLLOW UP	-	-	-
31	NOORJ	36	F	L	RTA	3.1.14	-	A1	-	10.1.14	12.2.14	UNITED	16 WEEKS	NIL
32	RAMES	30	M	R	RTA	20.12.13	-	A3	# FIBULA RT	22.12.13	28.1.14	UNITED	16 WEEKS	NIL

TABLE 1.1

GENDER DISTRIBUTION

GENDER	NUMBER	PERCENTAGE
MALE	**21**	**65.6%**
FEMALE	**11**	**34.4 %**
TOTAL	**32**	**100%**

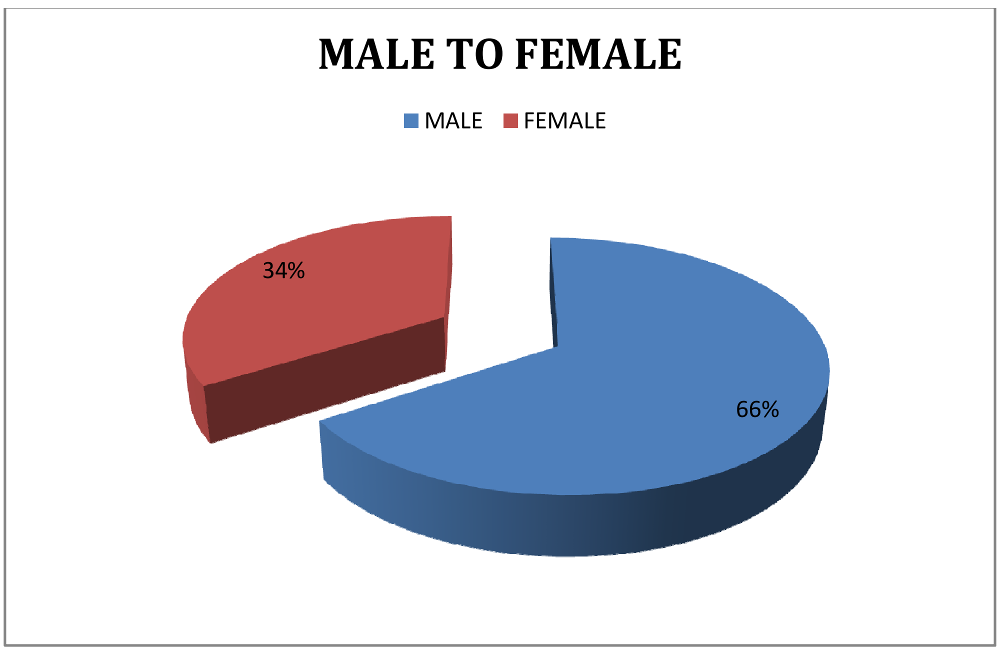


Fig: 65. Pie diagram of gender distribution

TABLE 1.2

AGE DISTRIBUTION

AGE	NUMBER	PERCENTAGE
18-30	**9**	**28.13%**
31-45	**8**	**25%**
46-60	**8**	**25%**
61-70	**6**	**18.75%**
>70	**1**	**3.12%**
TOTAL	**32**	**100 %**

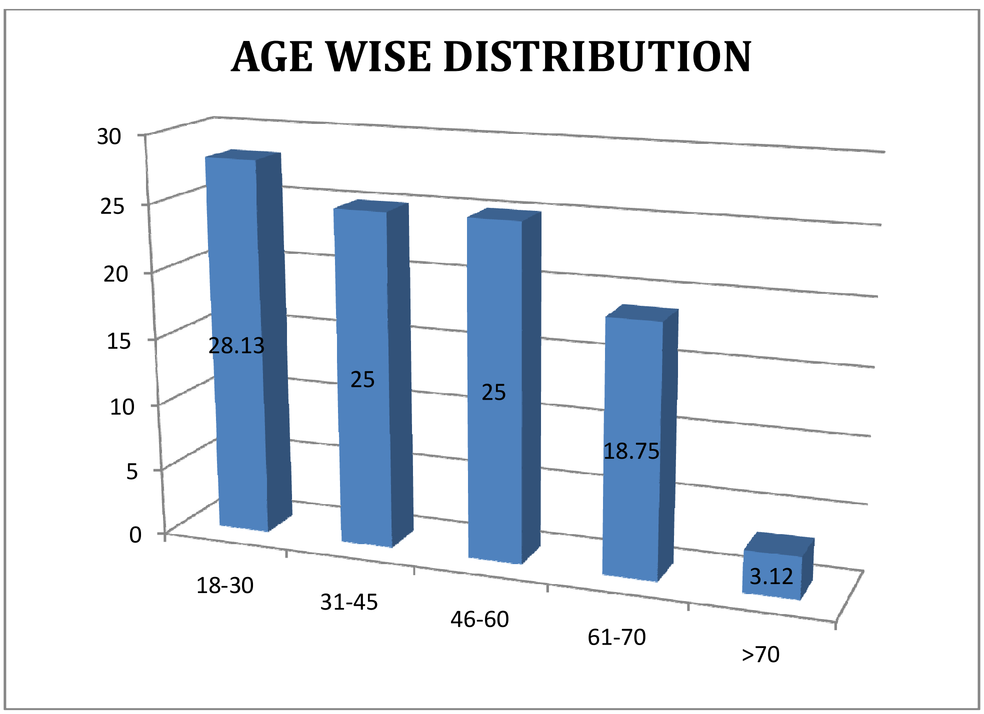


Fig: 66. Bar diagram of age distibution of distal tibial fractures.

TABLE 1.3

SIDE DISTRIBUTION

SIDE	NUMBER	PERCENTAGE
RIGHT	**18**	**56.25%**
LEFT	**14**	**43.75%**
TOTAL	**32**	**100 %**

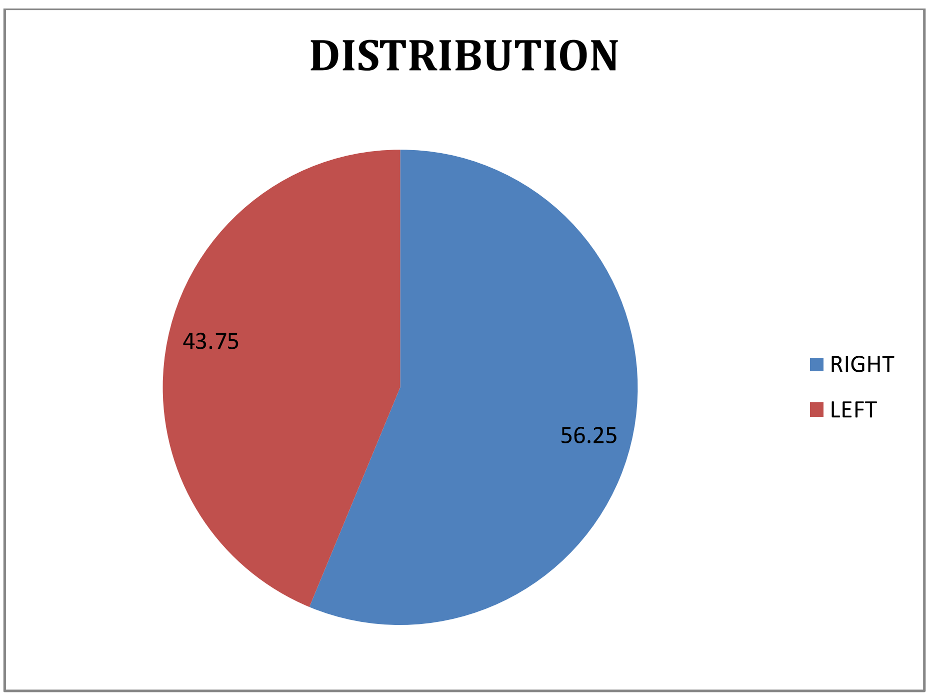


Fig: 67. Pie diagram of sex distribution.

TABLE 1.4

MECHANISM OF INJURY

MECHANISM	NUMBER	PERCENTAGE
RTA	**23**	**71.9%**
FFH	**2**	**6.25%**
ACCIDENTAL FALL	**7**	**21.86%**
TOTAL	**32**	**100%**

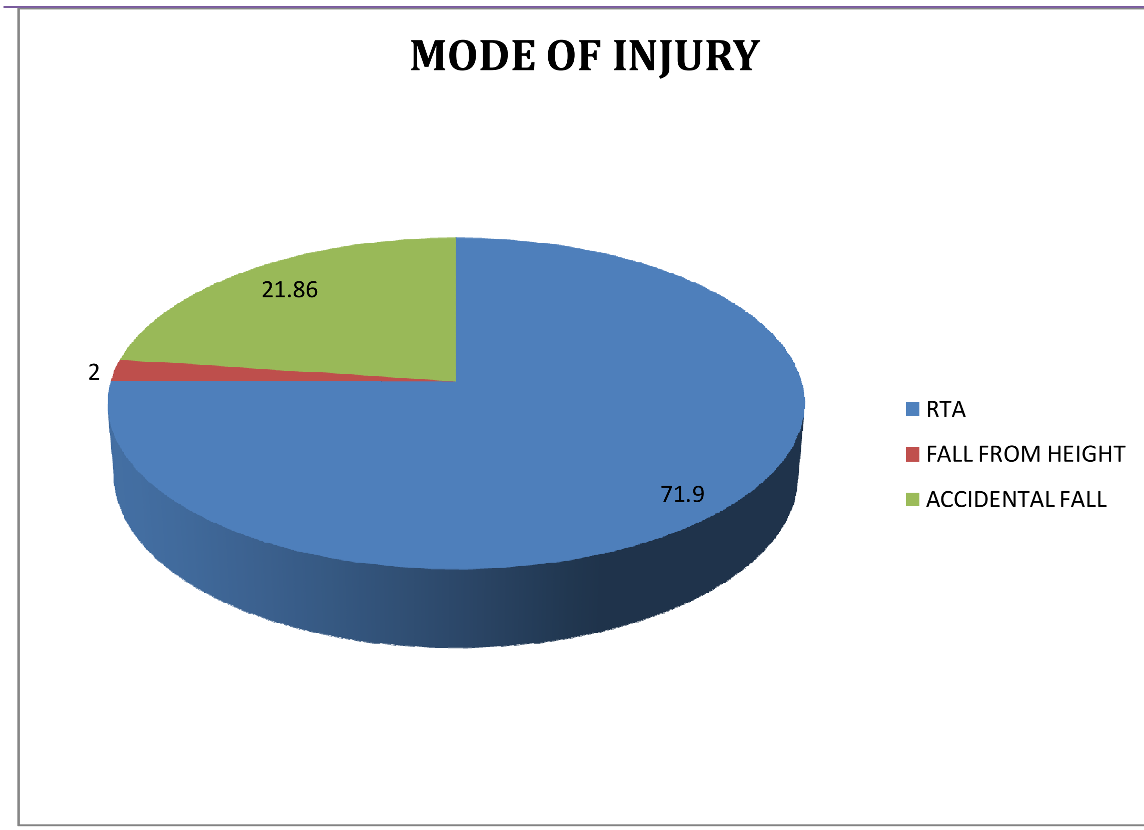


Fig: 68. Pie diagram of mode of injury.

TABLE 1.5 - FRACTURES PATTERN

PATTERN	NUMBER	PERCENTAGE
METAPHYSEAL SIMPLE (A1)	8	25%
METAPHYSEAL WEDGE(A2)	10	31.25%
METAPHYSEAL COMPLEX (A3)	13	40.62%
PARTIAL ARTICULAR UNDISPLACED (B1)	1	3.12%
Total	**32**	**100%**

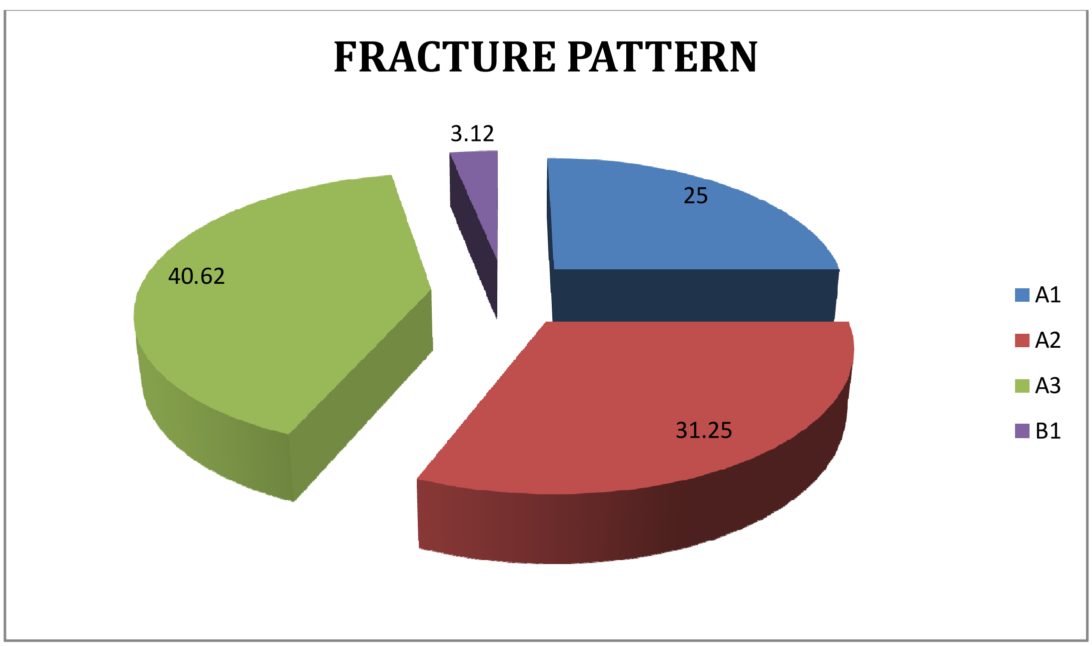


Fig: 69. Pie diagram of fracture pattern

TABLE 1.6

ANALYSIS OF OUTCOME BASED ON KARLSSON PETERSON SCORING SYSTEM FOR ANKLE FUNCTION

GRADING	NUMBER	PERCENTAGE
EXCELLENT	14	46.66%
GOOD	9	30.0%
FAIR	3	10.0%
FAILURE/POOR	4	13.33%

2 CASES LOST IN FOLLOW UP EXCLUDED

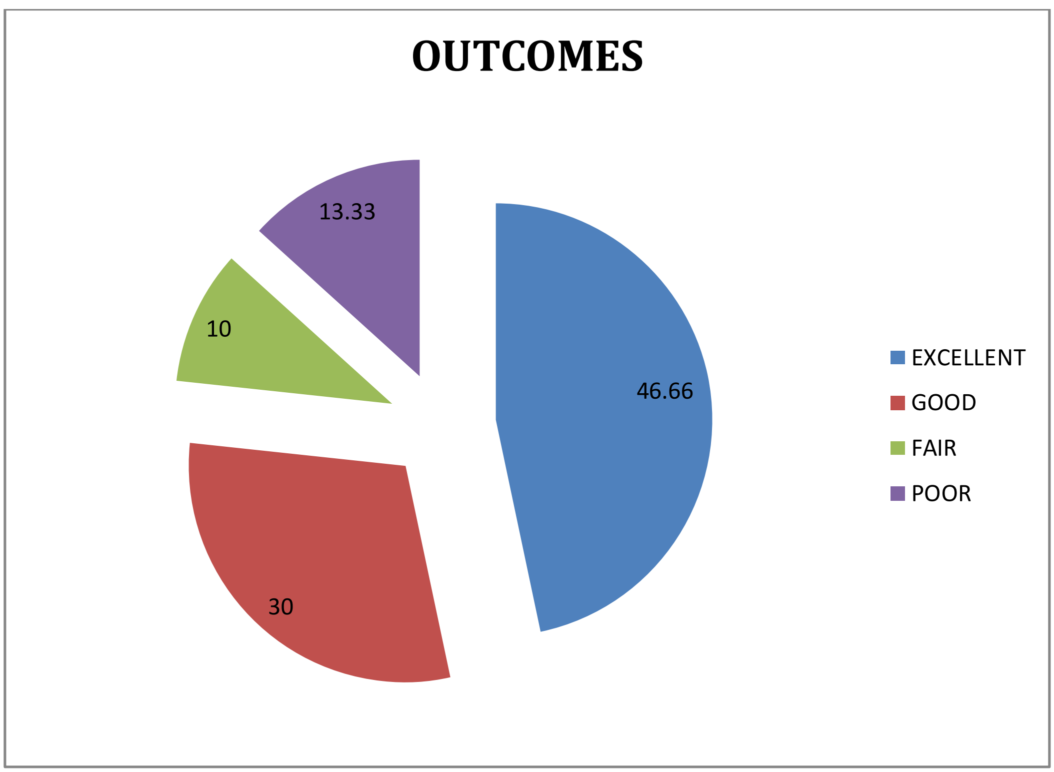


Fig: 70. Pie diagram of analysis of outcome.

TABLE 1.7

RADIOLOGICAL OUTCOME

GRADING	NUMBER	PERCENTAGE
EXCELLENT	11	36.6%
GOOD	12	40.0%
ACCEPTABLE	3	10.0%
POOR	4	13.3%

Excluding 2 cases lost follow up

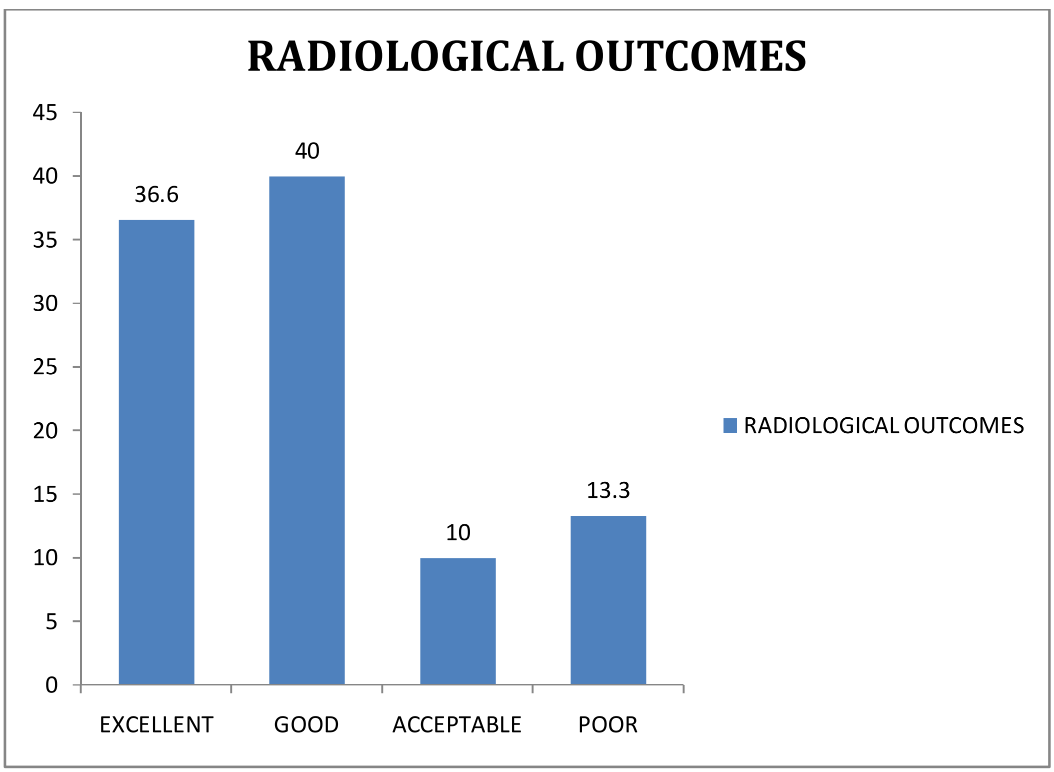


Fig: 71. Bar diagram of radiological outcome.

TABLE 1.8 – COMPLICATIONS*

COMPLICATION	NUMBER	PERCENTAGE
INFECTION	3	10.0%
ANKLE STIFFNESS	4	13.3%
NON UNION	2	6.66%
DELAYED UNION	3	10.0%
MALUNION	2	6.66%

*Excluding 2 cases lost follow up

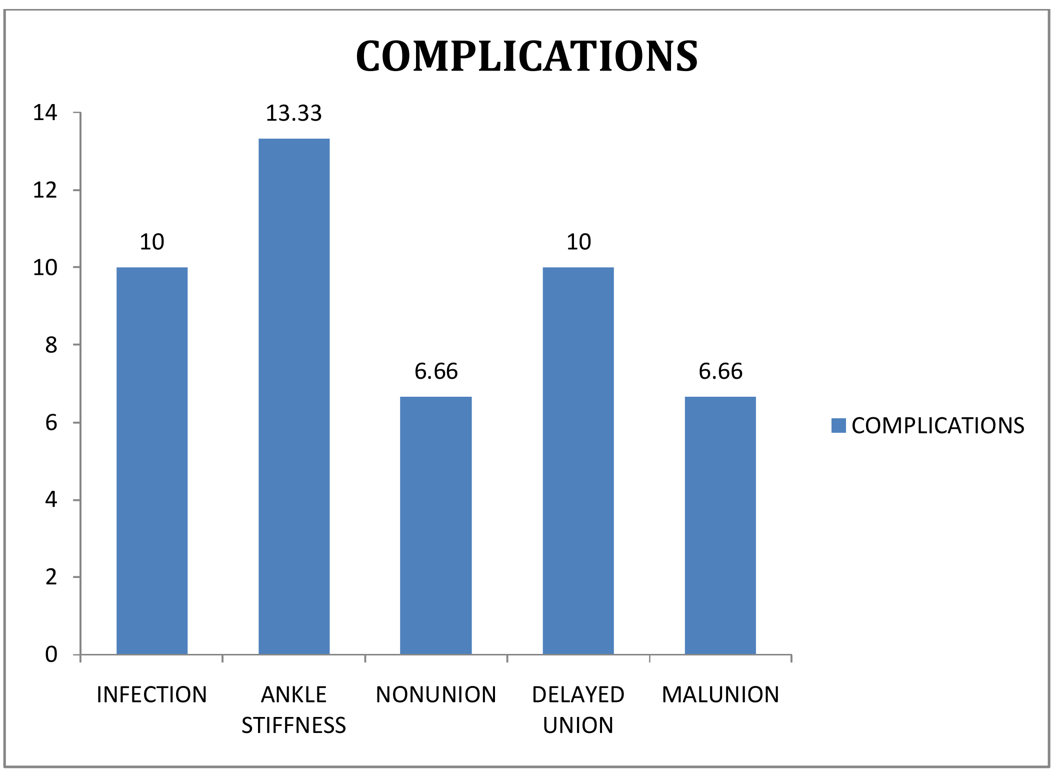


Fig: 72. Bar diagram of complications

COMPLICATIONS

There were few complications in our series.

1) Non-union,2) Malunion, 3) Delayed union 4) Infection and skin reaction and 5) Ankle stiffness.

1) **Non-union:**

   A 25 years gentleman, who is a college student sustained road traffic accident and sustained closed fracture both bone right leg lower third and lacerated wound in his scalp.

Fig:73.Preoperative X ray

The patient was taken up for surgery 1 week after the trauma, due to infection of the avulsion of scalp tissue. Till then he was put on above knee plaster of Paris.

Under spinal anaesthesia with sand bag under right hip, the fibula was fixed with Steinman pin in closed manner using C- arm guidance (fig.74).

The tibia was fixed by minimally invasive plate osteosynthesis using distal medial tibial locking compression plate.

Fig:74. Closed manipulation and fixationof fibula with steinmann pin.

Fig:75. Using sleeve in distal plate as guide plate is passed in extraperiosteal plane

A small incision is made over the medial malleolus and the plate is passed from below upwards (fig.75).

Fig:76. cortical screw fixation to bring bone close to plate

The plate with drill sleeve as a guide is passed through the minimal incision and position verified under C-arm. To bring the displaced distal fragment the 4.5mm cortical conventional screw is fixed and tightened.

Fig:77. wound before closure

Minimally invasive technique has the advantage of preventing extensive soft tissue damage due to surgical incission. Fig.77 shows the incisions used for plate application and screw placement.

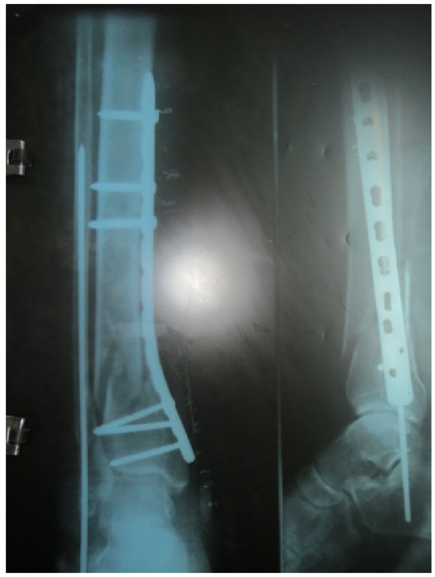


Fig: 78.Immediate postoperative radiograph

Fig: 79. Postoperative wound status.

Gentle ankle mobilisation was started on fifth day. Skin stapler was removed on second week. The postoperative wound healed uneventfully. Patient was advised non weight bearing ambulation with crutches.

Fig: 80. Radiograph taken after 12 weeks

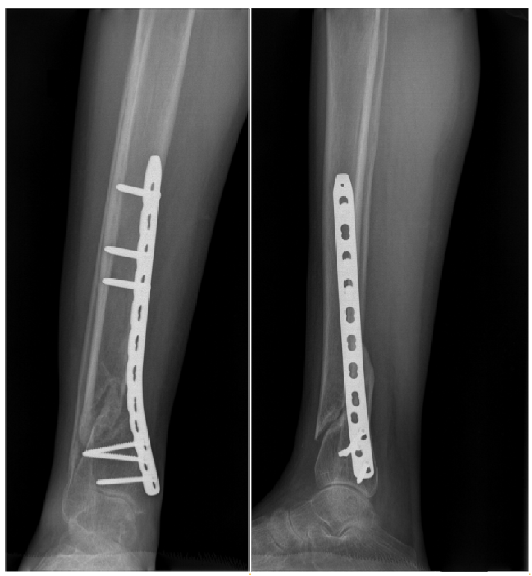


Fig: 81. Post-operative radiograph taken after 20 weeks

This radiograph in figures 80 and 81 shows that the fracture has not united. The patient is still under treatment for exposed calvarium under plastic surgery. Patient was not willing for any procedure related to augmentation of bone.

2) **Infection:**

2 cases had infection in our series**.**

First case was a 55 years old diabetic gentleman met with vehicular accident and sustained closed both bone distal third fracture on left side and raw area over the dorsum of left foot. He was stabilised with Thomas splint in trauma ward.

Fig: 82.Preoperative X- ray

The patient was taken up for surgery 3 weeks following trauma, due to poor glycemic control and problems in anaesthetic assessment. Till then the patient was put on above knee plaster of Paris immobilisation with window over dorsum of foot and regular dressing to the raw area.

Fig: 83. Preoperative raw area status   Fig:84.Immediate post-operative Xray

Fig:85. Condition of the wound after 1 month

The raw area was grafted in a separate sitting and the graft uptake was good. Post operatively his glycemic control was also good. But the screw sites got infected.

Fig: 86.X-ray taken after 12 weeks

The patient later underwent implant exit and was put on culture specific intravenous antibiotics and immobilised with plaster of Paris. The infection got settled in due course of time

Second case was a 36 years old gentleman sustained motor vehicle accident and sustained right isolated closed distal tibial fracture. The patient was operated on the next day with minimally invasive technique and distal tibial locking compression plate. The patient developed superficial infection at the proximal site which later settled with antibiotics.

Fig:87. Superficial infection at proximal site

Even though the plate appears little prominence in proximally, the patient does not worry much about it.

3) Residual angulation:

A 49 years old gentleman patient with history of vehicular accident and sustained closed both bone fracture left distal leg.

Fig:88.Post-operative X ray showing malunion

The concentration was on obtaining biological fixation. After plating the fracture fibula, it was difficult in reducing the antero-posterior angulation. The acceptable degree of antero-posterior angulation was 10 degree. But here it was above the acceptable (fig.88). Anatomical reduction is must before the application of locking plates.

DISCUSSION OF THE RESULTS

Of the 32 patients enrolled in this study, twenty one were males and the most common age group is 31 to 60 years. The most common cause is vehicular accident in young adults and accidental fall in old ages due to the osteoporotic nature of the bone.

There were eight patients with AO type A1 fractures, ten patients with AO type A2, thirteen patients with AO type A3 fractures and one patient with AO type B1 fracture. The partial articular undisplaced fracture can be considered as extra-articular fracture according to Chris Casstevens[34]. The mean duration between injury and surgery was five days. One patient had Gustilo Anderson grade I open fracture.

In this study, results of 30 patients with distal tibial fractures treated with biological fixation with distal medial tibial locking compression plates was analysed radiologically and functionally with Karlsson and Peterson scoring system for ankle function.86.6 % of patients has acceptable outcome and 13.4% patients has poor outcome. The implant we use is an angle stable construct and we employed minimally invasive percutaneous techniques for tibial plate insertion.

Twenty three patients have associated distal fibula fracture on the same side.Fixing associated fibular fractures first helps us to attain limb length. But it is difficult to control angulation. K –wire or Steinmann pin can be used to manipulate the fracture fragments without opening them. Preserving fracture haematoma is the most important principle of minimally invasive plate osteosynthesis. Anatomical reduction and relative stability helps in better callus formation and good healing.

Valgus and varus angulation of 5degrees and antero-posterior angulation of 10 degrees are accepted. The rigidity of implant allowed us for early mobilisation of the joint thus preventing stiffness.

One patient has associated intertrochanteric fracture on the same side treated with dynamic hip screw. Another patient has open distal femur on the same side which was treated by wound debridement and antibiotic cement and external fixation.

One patient developed deep seated infection which needs removal of the implant and debridement, intravenous antibiotics and application of plaster of Paris immobilisation, which later united. One patient developed superficial infection which settled with antibiotics. Above knee plaster of Paris was applied in one patient. Non-union was reported in two patients which warrant bone grafting, since the patients are not willing for the secondary procedure we cannot proceed further. Delayed union (no radiological signs of union beyond six months) is seen in three patients and non-union in two patients.

Ankle stiffness is seen in four patients out of whom three patients are above sixty years and poor adherence to post-operative protocol physiotherapy. All the patients were allowed to weight bear only after radiological signs of union and the functional score assessed were satisfactory.

Average interval between injury and surgery	Four – five days
Associated fibular fracture	Twenty three cases
Number of days for union	sixteen- twenty weeks
Average number of C-arm shots	Five
Average time of surgery including fibular fixation	Seventy minutes
Shortest time period of surgery	Forty minutes
longest time of surgery	One hour forty minutes
Blood transfusion	Nil
Implant removal due to infection	Two cases
Tourniquet usage	Almost all cases

Maintaining the length and rotation of the tibia is the main concern in the treatment of high velocity vertical fractures of the tibial plafond and lower tibia. There has been a lot of work throughout the world in managing this devasting injury. There may be associated con-commitent injury to the fibula. The energy transmitted to soft tissue manifesting as swelling, with the availability of implants which are thicker, so that while providing angular stability they also are notorious to produce tension in closure, wound dehiscence resulting in infection. The accuracy of the reduction is yet another problem in the biological fixations. The contours of the plate, the traction applied with one screw on only one side of the fracture are the main methods of reduction indirectly. Sometimes a threaded k – wire is passed into the fragments to rotate them into alignment.

The intention of doing a minimally invasive plate osteosynthesis is to reduce soft tissue damage while maintaining the vascularity of fracture fragments. However the fracture should be reduced to an acceptable limit before the locking plate is applied to prevent the non-union. An extensive approach in the name of anatomical reduction will reduce the vascularity and increase the chance of non-union and infection. So only this fracture is called as a challenging fracture. We tried to assess the effectiveness of the locking compression plate in distal tibial fracture in 21 males and 11 females.

Of the two non-unions in our series accounted for the poor result one patient was a diabetics and another patient is still in treatment under plastic surgery and currently not willing for any further treatment for augmenting bone healing. The size of the incision is another factor which decides the complication of the surgery. A very small incision in the name of cosmesis will cause injury to the neurovascular structures[39].

Problem of this system is less anatomic fracture reduction. However the fracture reduction is done as biologically and closed. The advantage is retaining soft tissue attachment in already compromised area. The bone is a viscoelastic structure that once the energy is spent on fracturing the component the extra energy is dissipated into surrounding soft tissue. This is the reason in high velocity injuries, these is severe soft tissue problems. Hence we have opted not to open the fracture site and also accept minimal angulation as in first case. The patient has full range of dorsiflexion and plantar flexion. Much distraction at the fracture site while fixing the implant leads to gap non union as seen in another case.

The implant used in this study was from a single manufacturer (SSEPL-DISTAL MEDIAL TIBIAL LOCKING PLATE). The plate was precontoured anatomically to match the distal medial tibia and therefore contouring is not necessary. The thickness of the implant is disadvantage as it makes the malleolar surface to appear prominent causing skin irritation.

We have not contoured any of the plates ourselves as these plates are having directions pointing away from the joint. We have not even put a single unicortical screws in any of our fixations as these screws are prone for failure. Our poor results are in our early cases, when we started using locking plate for these fractures. Once the implant becomes familiar the complication rates in our series become low. Intra operative c-arm guidance reduce faulty placement of the implants. The distal non parallel screw system offers good hold on the bone in the epiphyseo-metaphyseal region. We used monoaxial locking screws which are compatible with immediate partial weight bearing. On the other hand poly axial screws would be a better option for fragments, though they would not allow immediate weight bearing.

23 cases with associated fibular fractures, though tibia was fixed by closed method, the fibular fracture was fixed through posterolateral open approach with 1/3rd tubular plate. This fixation achieved length of the comminuted fragments.

In one patient with psychiatric illness the fracture united faster but stopped coming for follow up. In an associated open femur fracture, the femur fracture was treated by external fixation. None of our patients demand implant removal, except the infected cases.

The basic problem in the distal tibial region is obviously the lack of muscle cover. In this region if a high velocity fracture occurs, the resultant energy is spent directly on to the soft tissue and skin. This leads to fracture blister formation.

The next issue is to align the fragments in near anatomical position. An open technique of reduction of the fracture will appears to achieve this. In distal tibial fractures if one opens the poorly covered bone fragments for reduction, the fragments will get devitalized due to poor vascularity and subcutaneous in nature. Hence closed reduction is preferred.

Tibia is a strong tubular bone. An implant to hold such a bone even in Asian population should be strong enough. This is the reason for thick implant.

The locking option also increases the thickness of the implant, as the thread in the screw head need to align within the plate surface avoiding prominence.

The problem is to use a thick plate compulsorily in a closed fracture to avoid skin problems like dehiscence or difficult in primary closure of wound.

Having deliberated on the thickness of the plate so much, we need to consider implant removal if the patient feels such a subcutaneous implant warranting this. Though only one case came back to us after union due to changes in the skin like colour change. We have removed this plate in this patient. Another patient developed deep seated infection which needs implant removal. Remaining twenty eight patients which are followed till now did not have any specific skin irritation inspite of its subcutaneous location.

CONCLUSION

Distal tibial fractures pose a great challenge to an orthopaedic surgeon, since most of them are high velocity injury with cross soft tissue swelling. In the present study, the distal tibial biological locking plate technique achieved acceptable results both clinically and radiologically. As it reduces surgical trauma to soft tissue and retains vascularity of the fragments while providing rigidity of fracture fragments.

ANNEXURE-1

PROFORMA

1. NAME :
2. AGE :
3. SEX :
4. ADDRESS :
5. OCCUPATION :
6. DATE OF INJURY :
7. DATE OF ADMISSION :
8. DATE OF SURGERY :
9. DATE OF DISCHARGE ;
10. NATURE OF TRAUMA :
    - RTA
    - FALL FROM HEIGHT
    - ACCIDENTAL FALL
11. MECHANISM OF INJURY :
12. DURATION SINCE INJURY :
13. SIGNIFICANT PAST HISTORY :
14. SIGNIFICANT FAMILY HISTORY :

15.GENERAL PHYSICAL EXAMINATION:

- Pulse rate
- Blood pressure
- Spo2
- Respiratory rate
- Pallor Yes/No
- Cyanosis Yes/No
- Icterus Yes/No
- Lymphadenopathy Yes/No
- RS examination
- CVS examination
- Presence of associated injury: Yes/No If yes, specify

16.LOCAL EXAMINATION

17.RELEVANT INVESTIGATIONS

- X-rays of the involved leg with ankle anteroposterior and lateral and mortise view: Yes/ No
- Additional X- rays of associated injuries

  Yes/ No
- Routine blood investigations

  Yes/ No

- Renal profile

  Yes/ No

- HIV, HBs Ag

  Yes/ No

- Chest X - ray / ECG

  Yes/ No

18.DIAGNOSIS

19.TREATMENT

Yes/No

First Aid

a)Immobilisation of the limb

b)Thomas Splint /POP slab

c)Analgesics

Definitive treatment

a) Relevant investigations and medical fitness for surgery Yes/ No

b) Anaesthesia Spinal/General

c) MIPO with LCP Yes/No

d) Associate fracture fibula fixed : Yes/No

e) Antibiotic therapy –preoperative and postoperative :Yes/ No

f)Analgesics : Yes/ No

20. COMPLICATIONS :

Intraoperative:

a) Difficulty in reduction of fragmentsYes/ No

b) Excessive bleeding Yes/No

Postoperative:

a) Infection Yes/ No

b)Ankle stiffness Yes/ No

c) Non union Yes/ No

d) Hardware failure Yes/ No

e) Mal-union Yes/No

21. FOLLOW UP:

Date:

Serial number of Follow up;

Time since surgery:

Clinical Union:

Pain at fracture site Yes/No

Abnormal Mobility Yes/ No

Transmission of movements Yes/ No

Radiological union: Yes/ No

ANNEXURE II

KARLSSON AND PETERSON SCORING SYSTEM FOR ANKLE FUNCTION

The Karlsson and Peterson Scoring System for Ankle function

	Degree	Score
Pain	None	20
	During exercise	15
	Walking on uneven surface	10
	Walking on even surface	5
	Constant	0
Swelling	None	10
	After exercise	5
	Constant	0
Instability	None	25
	1-2 / year (during exercise)	20
	1-2 / month (during exercise)	15
	Walking on uneven ground	10
	Walking on uneven ground	5
	Constant (severe) using ankle support	0
Stiffness	None	5
	Moderate (morning, after exercise)	2
	Marked (constant, severe)	0
Stair climbing	No problems	10
	Impaired (instability)	5
	Impossible	0
Running	No problems	10
	Impaired	5
	Impossible	0
Work activities	Same as pre-injury	15
	Same work, less sports, normal leisure activities	10
	Lighter work, no sports, normal leisure activities	5
	Severe impaired work capacity, decreased leisure activities	0
Support	None	5
	Ankle support during exercise	2
	Ankle support during daily activities	0

- Karlsson J, Peterson L: Evaluation of ankle joint function: the use of a scoring scale. The Foot 1991, 1:15-19.

ANNEXURE III

ABBREVIATIONS

1. DMT-LCP: DISTAL MEDIAL TIBIAL LOCKING COMPRESSION PLATE
2. LCP: LOCKING COMPRESSION PLATE
3. LC-DCP: LIMITED CONTACT DYAMIC COMPRESSION PLATE
4. LISS: LESS INVASIVE STABILIZATION SYSTEM
5. PC-FIX: POINT CONTACT FIXATION
6. AO : **A**RBEITSGEMEINSCHAFT FÜR **O**STEOSYNTHESEFRAGEN
7. OTA: ORTHOPAEDIC TRAUMA ASSOCIATION
8. ASIF : ASSOCIATION FOR STUDY OF INTERNAL FIXATION
9. MIPO: MINIMALLY INVASIVE PLATE OSTEOSYNTHESIS
10. MIPPO: MINIMALLY INVASIVE PLATE PERIOSTEOSYNTHESIS
11. IEC: INSTITUTIONAL ETHICAL COMMITTEE
12. ROM: RANGE OF MOVEMENTS
13. AUC : AREA UNDER CURVE

14.RTA: ROAD TRAFFIC ACCIDENT

15.FFH: FALL FROM HEIGHT

16.PPRP: POST POLIO RESIDUAL PARALYSIS

17. AOFAS: AMERICAN ORTHOPAEDIC FOOT and ANKLE SCORE

18.DOI: DATE OF INJURY

19.DOS: DATE OF SURGERY

20.AP: ANTEROPOSTERIOR

21.P.O.P: PLASTER OF PARIS

22.E.C.G: ELECTROCARDIOGRAM

23.H.I.V: HUMAN IMMUNODEFICIENCY VIRUS

24.HBsAG: HEPATITIS – B SURFACE ANTIGEN

25.SSEPL: SHARMA SURGICAL ENGINEERING PRIVATE LIMITED

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