Dissertation on

EVALUATION ON THE OUTCOME OF MANAGEMENT OF INFECTED NON UNION AND GAP NON UNION FRACTURE OF LONG BONES BY ILIZAROV METHOD

Submitted to

THE TAMILNADU DR. M.G.R. MEDICAL UNIVERSITY
CHENNAI – 600032

In partial fulfilment of the Regulations
for the Award of the Degree of

M.S. DEGREE - BRANCH - II
ORTHOPAEDIC SURGERY

DEPARTMENT OF ORTHOPAEDICS
STANLEY MEDICAL COLLEGE AND GOVERNMENT STANLEY HOSPITAL
CHENNAI-TAMILNADU

APRIL 2017

CERTIFICATE

This is to certify that this dissertation in **" EVALUATION ON THE OUTCOME OF MANAGEMENT OF INFECTED NONUNION AND GAP NONUNION FRACTURE OF LONG BONES BY ILIZAROV METHOD "** is a bonafide work done **by Dr. P. BALASUBRAMANIYAN** under my guidance during the period August 2015 to July 2016 . This has been submitted in partial fulfilment of the award of **M.S.** Degree in **Orthopaedic surgery (Branch –II)** by The Tamil Nadu Dr. M.G.R. Medical University, Chennai.

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DECLARATION

I, **Dr.P.BALASUBRAMANIYAN,** solemnly declare that the dissertation titled **" EVALUATION ON THE OUTCOME OF MANAGEMENT OF INFECTED NONUNION AND GAP NONUNION FRACTURE OF LONG BONES BY ILIZAROV METHOD "** was done by me at The Department of Orthopaedics, Stanley medical college & Hospital, Chennai -1 during the period August 2015 to July 2016, under the guidance of my unit chief **Prof.R.SELVARAJ M.S. (Ortho) , D.Ortho, DNB, MNAMS.**

The dissertion is submitted in partial fulfillment of requirement for the award of M.S. Degree (Branch –II) IN Orthopaedic Surgery to **THE TAMILNADU Dr. MGR MEDICAL UNIVERSITY.**

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ACKNOWLEDGEMENT

I would like express my deepest gratitude to **Prof.Dr.ISAAC CHRISTIAN MOSES, M.D., F.I.C.P., F.A.C.P.** DEAN, Stanley Medical college & Hospital, for providing me an opportunity to conduct this study.

I would like to express my sincere thanks to **Prof.Dr. PONNAMBALA NAMASIVAYAM, M.D, D.A, DNB**, Dean in charge , Stanley Medical College & Hospital ,for providing me an opportunity to conduct this study.

I would like to express my sincere gratitude and reverence to my unit chief and guide, **Prof.Dr.R.SELVARAJ,M.S.(Ortho),D.Ortho,DNB, MNAMS. Professor and Head of the Department**, Department of Orthopaedics, Stanley Medical college, Chennai -1, whose blessings, support and guidance helped me to complete this study.

I would like to express my sincere thanks and gratitude to **Prof.Dr.T.THOLGAPIAN, M.S. (Ortho), Professor of Orthopaedics,** Department of Orthopaedics, Stanley medical college for his support and guidance enabled me to bring out this dissertation.

I would like to express my sincere thanks and gratitude to **Prof.Dr.S.VEERAKUMAR, M.S.(Ortho), Professor of Orthopaedics,** Department of Orthopaedics , Stanley Medical College, for his support and valuable suggestions, enabled me to bring out this dissertation.

I would express my deepest gratitude to **Prof.Dr.K.MOHANKUMAR, M.S.(Ortho), Professor of Orthopaedics,** Stanley Medical College for his support and valuable suggestions to bring out this dissertation.

I would like to express my sincere thanks and gratitude to **Prof.Dr.M. ANTONY VIMAL RAJ, M.S.(Ortho), Professor of Orthopaedics,** Department of Orthopaedics, Stanley Medical College for his valuable suggestions to bring out this dissertation .

I would like express my sincere thanks to **Prof. Dr.C.ASHOKAN, M.S. (Ortho), Professor of Orthopaedics** , Department of Orthopaedics, Stanley Medical College for his valuable advice and timely suggestions helps me to bringout this dissertation.

I would like to express my sincere thanks to **Prof.Dr.S.SENTHILKUMAR, M.S.(Ortho), D. Ortho., Former Professor of Orthopaedics**, Department of Orthopaedics, Stanley Medical College for his valuable suggestions to bringout this dissertation.

I sincerely thank Dr.S.Karuppasamy, Dr.R.Prabhar Singh, Dr.S.Makesh Ram, Dr.M.Karthikeyan, Dr.P.Vinod Rajkumar, Dr.R.Agni Raj, Dr.R.Ramaraj, Dr.V.Prabhu, Dr.H.Vardhaman Dhariwal, Dr.P.Balakrishnan, Assistant professors, Department of Orthopaedics, Stanley Medical College for their valuable suggestions and unrelenting support during this study.

I am grateful to all my postgraduate colleagues for their help during this study.

Last but not least my sincere thanks to all my patients , without whom this study would not have been possible.

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File size:	494.27K
Page count:	123
Word count:	11,104
Character count:	60,601
Submission date:	02-Oct-2016 03:02AM
Submission ID:	712411349

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INTRODUCTION

Infected non-union is one of the greatest problems in orthopaedic surgeries. The incidence of infected non-union and gap non-union of fractures of long bone is increasing in India due to road traffic accidents. Moreover infected non-union and gap non-union of fracture of long bones is not a single problem, it is associated with multiple problems like long standing infection associated with organism resistant to most of commonly used antibiotics, bone loss due to extensive debridement or primary bone loss at the site of injury, soft tissue loss.

Subcutaneous bones like tibia are susceptible to open fractures wound infection, non-union, deformities, shortening and other problems. Duration of treatment and the cost of treatment of infected non-union and gap non-union causes a huge burden to the patient as well as to the treating institution. There are various treatment modalities available for treatment of infected non-union and gap non-union of fracture of long bones. Treatment modalities like wound debridement and external fixation with AO external fixator, antibiotic coated nailing, limb reconstruction system, Ilizarov ring fixation etc, but each method has its own merits and demerits.

Ilizarov ring fixation is a versatile technique in treatment of infected non union and gap non-union of fracture of long bones. Infected non-union of long bone fractures are associated with problems like deformities, shortening, limb length discrepancies, rotational deformities soft tissue defects etc. Ilizarov ring fixation address all these problems simultaneously. Distraction osteogenesis is a novel technique by which new bones can be created in the bone defects, limb lengthening to compensate shortening, rotational deformities can be corrected, soft tissue loss can be dealt with progressive histiogenesis. Unlike conventional AO external fixator which provides uniplanar stability, Ilizarov ring fixator provides three dimensional stability and patient can bear weight in the immediate post operative period , ambulation and joint mobilisation.

Gap non-union of fracture long bones due to various causes like primary bone loss in open fractures, debridement of sequestrum in infected wound, segmental bone loss due to resection of bone tumor. Ilizarov fixation achieves union in these fractures by corticotomy and bone transport.

AIMS AND OBJECTIVES

To evaluate the outcome on the management of infected non-union and gap non-union fractures of long bones by Ilizarov method.

REVIEW OF LITERATURE

The first result of elongation of the extremity was published by ***codvilla***[3] in the year 1905.

Dr. Lambotte [5]of France was the first to use the technique of distraction osteogenesis and transfixation.

Many types of external fixators and various techniques are described to address the infected non-union and bony defects but the most commonly used and well known system is the one developed at the Kurgan institute (**KINEKOT) by *Gavrill Abramoviah Ilizarov*** in 1951[5].

Ilizarov observed the formation of new bone radiologically in one of his patient who accidently distracted the ring which was actually compressed. Following this observation he started his work in animal models and confirmed the formation of new bone after low energy osteotomy called as corticotomy and distraction after a period of latency.

Prof .Ilizarov had three important contributions :

1. Distraction osteogenesis,

2. Corticotomy,

3. Ilizarov ring fixator system

Prof. Ilizarov had to treat a large number of wounded soldiers in second world war and the condition in which he worked was very primitive and he lacked many necessary medicines and instruments, so he was called as "**Magician of Kurgan**[6]"

Early in 1960s Ilizarov reported his first successful limb lengthening of lower extremity upto 10 inches.

In the early 1980's Orthopaedic surgeons like SARMIENTO and MAC EWAN were the first to report the work of Prof .Ilizarov.

The method was widely applicable that the Association for the Study and the Application of the Methods of Ilizarov(ASAMI) was established in 1982 in Italy.

The indication of Ilizarov ring fixator has extended in the treatment of fractures and their complications like Chronic

Osteomyelitis, Infected Nonunion, Gap Nonunion, Limb length discrepancies, Deformity corrections and Joint contractures.

Initially the ring fixator system which was made with steel progressively evolved after it came to be known in western countries. **Catagni** and **Cattaneo** developed a special fixator system with Italian arches of 90° and 120° for management of proximal humerus and femur fractures.

Subsequently **Green**[5] introduced use of" Rancho cubes" with half pins which improves the patient compliance and decreases the risk of infection and inflammation.

At Rancho Los Amigos Medical Centre, Stuart Green and colleagues applied the first circular transfixation wire external fixator in 1986.Since then they gradually modified the technique now they are using Titanium half pins[6,16].

This decision of using half pins for proximal and distal mounting in most of long bones is based on the observation that good regenerate bone forms in the distraction gap when half pins were used for elongation provided the surgeon follows the Ilizarov principles of

marrow and periosteal preservation during corticotomy, stability, latency period and high frequency distraction.

They avoid creating a cantilever system by inserting the half pins in different directions and in different planes.

The other system which were developed similar to Ilizarov system are,

1. The Kalnbernz apparatus-developed at LNIITO institute of Riga

2. Volkov Oganesian system-developed at Moscow by Central Institute of Traumatology and Orthopaedics

3. Fischer system-developed in Minnesota State University in Minneapolis

4. Dyanamic Axial Fixator often referred to as Orthofix was introduced by De Bestani in 1979.

SURGICAL ANATOMY

Tibia is the second largest[23] bone in the body, bears the entire body weight on standing .The fibula is a slender bone and it does not bear weight but it provides attachment to the interosseous membrane binds with tibia providing additional space for attachments of muscle, tendons and through the syndesmosis in the lower end provides stability to the ankle joint.

The anterior border of tibia is the most prominent one and its medial surface is subcutaneous throughout its entire length making it susceptible t o open fracture. The interosseous border is sharp and it provides attachment to the interosseous membrane. The nutrient foramen is present on the posterior surface immediately distal to the soleal line.

The leg is divided into anterior, posterior and lateral compartments. The muscles of the same compartment shares the common neurovascular supply.

ANTERIOR COMPARTMENT

Otherwise called extensor compartment and it is located anterior to interosseous membrane.

The muscles of anterior compartment are

Tibialis anterior

Extensor digitorum longus

Extensor hallucis longus

Peroneous teritus

These muscles are bounded medially by tibia, laterally by fibula, posteriorly by interosseous membrane and anteriorly by the fascia.

Nerve of anterior compartment: Deep peroneal nerve.

LATERAL COMPARTMENT

The lateral compartment is the smallest compartment bounded by the lateral surface of fibula, anterior and posterior intermuscular septae and deep fascia of the leg.

The muscles of lateral compartment are

Peroneous longus

Peroneous brevis

Nerve of lateral compartment: Superficial peroneal nerve

POSTERIOR COMPARTMENT

Divided into superficial and deep posterior compartment

SUPERFICIAL POSTERIOR COMPARTMENT

The muscles of superficial compartment are

Gastronemius

Soleus

Plantaris

Helps in plantar flexion of foot.

Serves as a source for flap cover in soft tissue defects.

Site for compartment syndrome

DEEP POSTERIOR COMPARTMENT

The muscles of deep posterior compartment are

Tibialis posterior

Flexor digitorum longus

Flexor hallucis longus

BLOOD SUPPLY OF TIBIA

The blood supply of tibia is derived from afferent vascular system and consist of

1. Principal nutrient artery:

   Arises from posterior tibial artery and enters the posterolateral cortex of the bone, divides into three ascending and one descending artery which supplies the endosteal surface.

2. Periosteal blood supply:

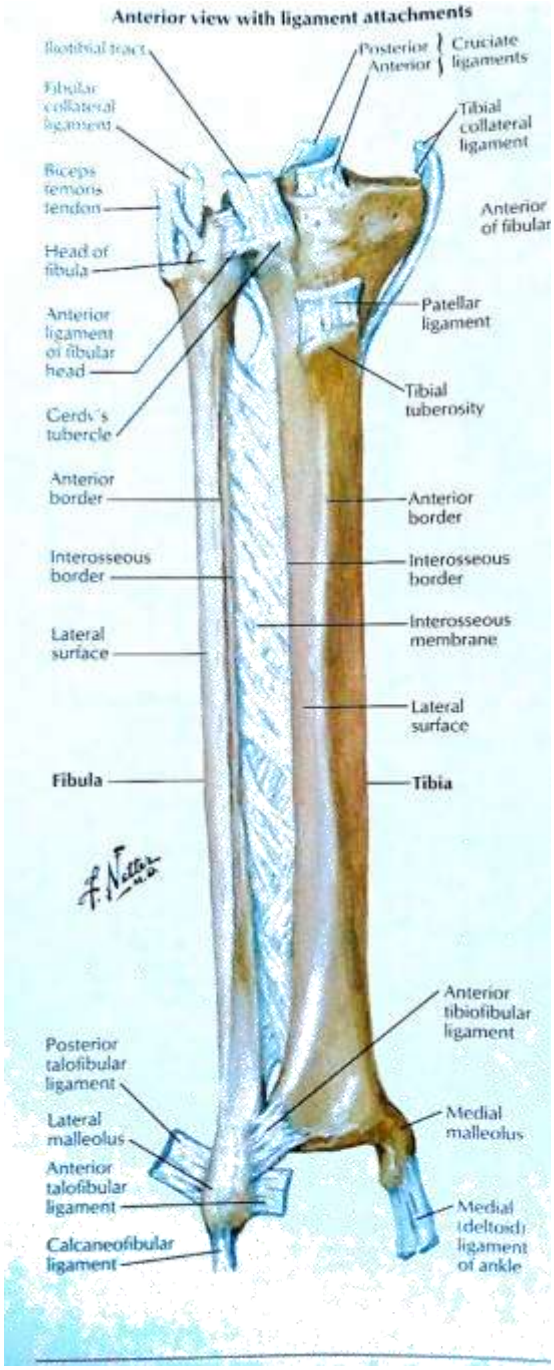
   From the branches of anterior tibial artery, periosteal artery enters the diaphyseal cortex along the fascial attachments.

3. Metaphyseal artery supply each metaphysis and anastomose with the medullary arteries.

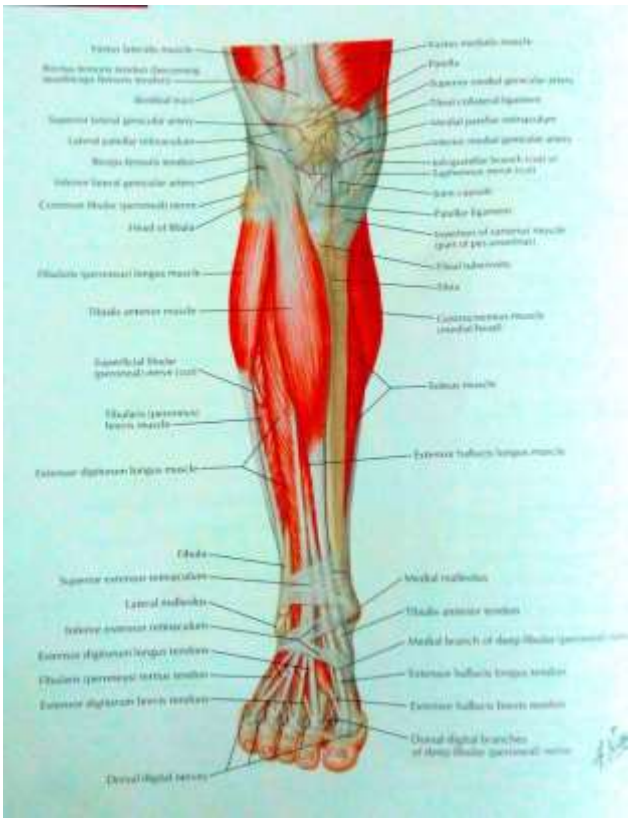
4. Epiphyseal arteries

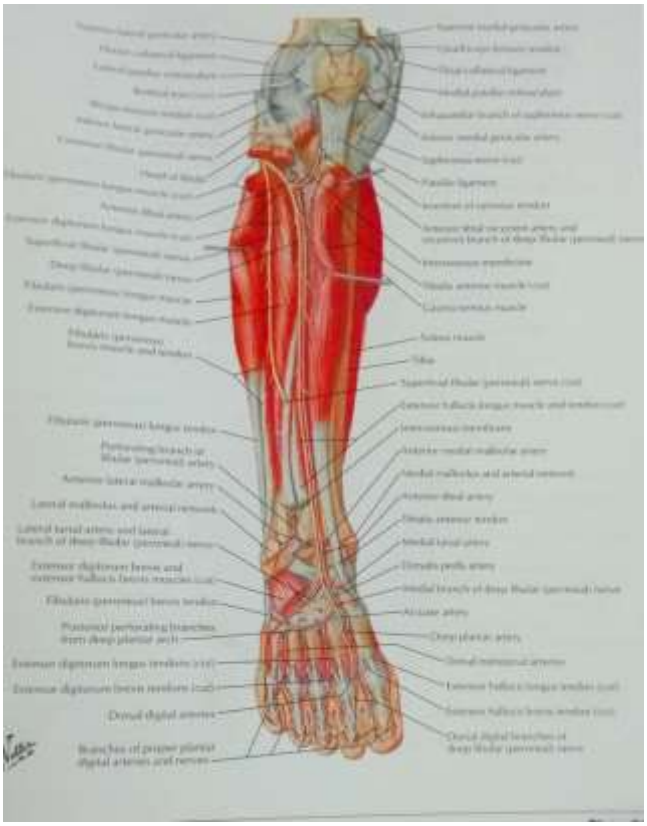
   The anterior tibial artery is vulnerable to injury after its division from the popliteal artery when it passes through the hiatus in the interosseous membrane. The lower third of tibia is prone for infection and non union because of the precarious blood supply and lack of muscular attachments in this region.

OSTEOLOGY OF TIBIA AND FIBULA

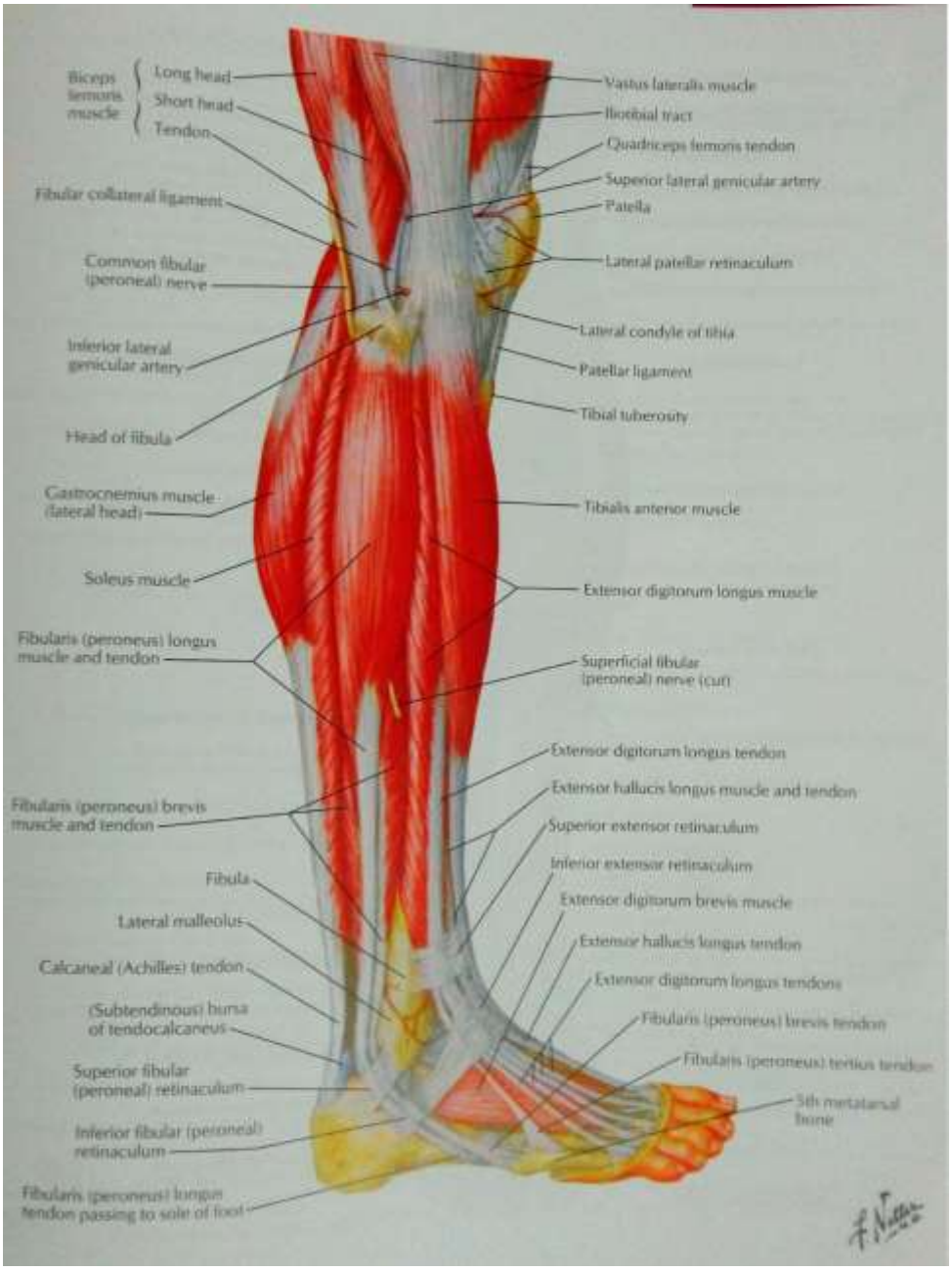


ANTERIOR COMPARTMENT OF LEG

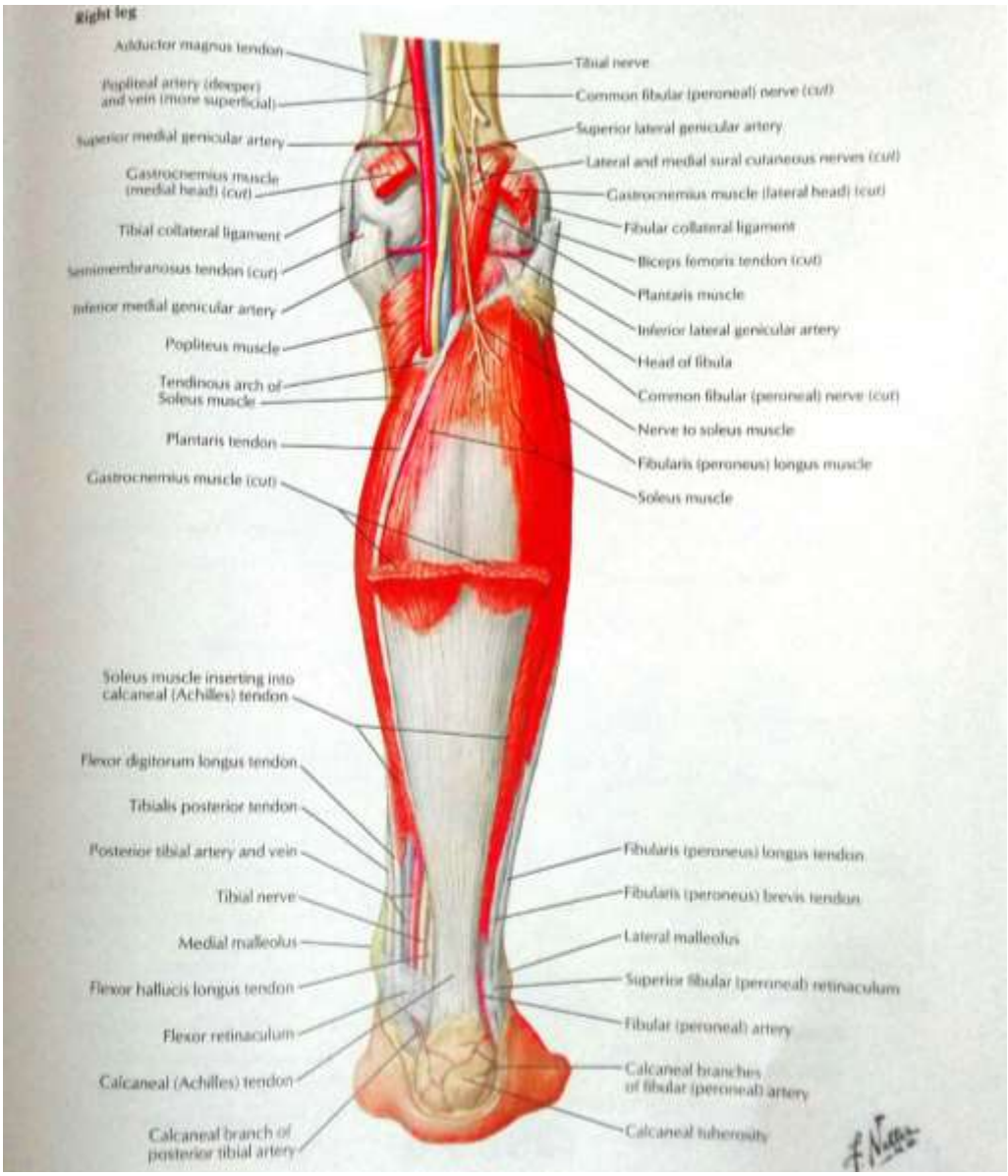




LATERAL COMPARTMENT OF LEG



POSTERIOR COMPARTMENT OF LEG



NON UNION OF FRACTURES OF LONG BONES

NON UNION

Non union of fracture of long bones is a state in which all the healing processes comes to a halt as judged by clinical and radiological evidence, beyond the stipulated period of healing for a particular bone due to mechanical or biological failure with a gap being filled with fibrous or fibro cartilaginous tissues usually requiring change in treatment.

FDA definition of Non union

Non union as “established when a minimum of 9 months as elapsed since injury and the fracture shows no visible progressive signs of healing for 3 months”.

This criterion cannot be applied to every fracture. Eg: Non union Fracture Neck of Femur.

CAUSES OF NON UNION

I. Mechanical failure **II. Biological failure**

1. Open Fractures

2. Infection

3. Unstable fixation

4. Loss of Bone segment

5. Segmental fractures

6. Intact fellow bone

7. Distraction by either traction, plate screws

8. Treatment by ill advised open reduction

9. Soft tissue injury in open or closed fractures

10. Precarious blood supply of bones

11. General condition of the patient-poor nutrition, smoking, radiation therapy, steroid therapy

CLASSIFICATION OF NON UNION

Judet and Judet , Muller, Weber and Cech[8,11] classified Non union based on viability of bone ends

1. Hypertrophic Non union
2. Atrophic non union

Hypertrophic Non union further classified into

1. Elephant foot Non union
2. Horse hoof Non union
3. Oligotrophic non union

Atrophic Non union further classified into

1. Torsion wedge Non union
2. Comminuted Non union
3. Defect Non union
4. Atrophic Non union

PALEY'S MODIFICATION OF ILIZAROV CLASSIFICATION

Based on bone loss, Fracture mobility, Deformity, Shortening

Type A- Non union with bone loss less than 1 cm

A-1 – Lax Non union

A-2 – Stiff Non union

A-2.1- Stiff Non union without deformity

A-2.2 – Stiff Non union with deformity

Type B- Non union with bone loss more than 1 cm

B-1 – Non union with bone defect without shortening

B-2 –Non union with shortening but no bone defect

B-3 – Non union with shortening and bone defect

Type C-Non union associated with infection

INFECTED NON UNION

Infected Non union is one of the greatest problems in Orthopaedics. Its incidence is increasing in recent years due to Road Traffic Accidents. Treatment of infected non union becomes extremely difficult because two major problems to be solved simultaneously : 1. Non union ,2. Infection

PROBLEMS ASSOCIATED WITH LONGSTANDING INFECTED NON UNION

1. Scarring and Cicatrization of soft tissues due to multiple surgeries.
2. Presence of sinus tract leading to fracture site indicating presence of sequestrum
3. Chronic Osteomyelitis of bones
4. Limitation of joint movements
5. Infection with mixed drug resistant organisms
6. Limb length discrepancy due to bone loss at initial injury or removal of sequestrum
7. Complex deformities

INFECTED NON UNION OF TIBIA

High energy trauma usually leads to open fractures with soft tissue damage due to subcutaneous nature of tibia and further complicated by infection leading to Non union. Segmental bone loss may be due to initial injury, secondary to wound debridement or produced by post traumatic osteomyelitis (**Ellis H, Bauer**)[24,25]

Conventional methods of treating infected non union of tibia includes AO External fixation, Sequestrectomy and massive cancellous bone grafting (**Green SA, Meyers**).[26]

These methods are associated with limitations including quantity of graft availability, Donor site morbidity, Persistence of infections, Extensive bone grafts and deformity

Distraction Osteogenesis – the new concept of bone transport introduced by Ilizarov is used in treatment of infected non union is based on creation of an environment conducive to bone formation with preservation of blood supply, osteogenic elements, and stable fracture fixation coupled with distraction at appropriate rate and rhythm.

CLASSIFICATION OF INFECTED NONUNION

The infected clinical non union is defined as that state of fracture healing when, after the duration of time of about 4 to 6 months has elapsed , there no evidence of fracture will heal – *ROMAN GRISILO*

Umiarov's classification of infected nonunion

Four types - based on viability of bone ends, presence of bone and soft tissue defect, limb shortening.

Type I – normotrophic without shortening

Type II – hypertrophic with shortening.

Type III – atrophic with shortening

Type IV – atrophic with bone and sof ttissue defect,as a result of open fractures,complicated by infection and bone loss.

Rosen et al classified infected non-union into two broad categories:

1. Infected nondraining non-union .

    A. Quiescent (nondraining for atleast 3 months)

    B.Active (nondraining but with abscess)

2. Infected draining non-union .

KULKARNI'S CLASSIFICATION OF INFECTED NONUNION[6]

Depending upon the severity of infection, apposition of fragments, presence or absence of deformity.

Type 1: fragment in apposition with mild infection and with or without implant, stable implant insitu with mild infection.

Type 2: fragment in apposition with severe infection with a large or small wound.

Type 3: severe infection with gap or deformity or shortening or combination.

Type 3 A: Defect with full circumferential cortex.

Type 3 B: Defect with more than one third of cortex is present.

Type 3C: With deformity.

Type 3 Is treated by Ilizarov ring fixation.

GENERAL PRINCIPLES OF TREATMENT OF INFECTED NONUNION [6]

- Eradication of infected tissue by radical debridement.
- Achievement of vascular or viable environment around and at fracture site.
- Fracture stability.
- Adequate soft tissue coverage.
- Early and massive bone grafting.
- Early mobilisation.
- Correction of deformity and limb length discrepancy.

There are various methods available for treatment of infected non-union like radical debridement followed by insertion of antibiotic coated nails , posterolaterolateral bone grafting, Ilizarov ring fixation.

Ilizarov external fixation achieves union, correction of deformity, eradicates infection, re-establishes bone defect simultaneously maintain the joint mobility and early weight bearing. Although the results are good, this method is technically demanding and requires thorough

training and experience. Stiffness of non-union depends upon the type of tissue interposition. Stiff non-union have loose connective tissue interposition in between the fragments and distraction of this fibrous tissue leads to new bone formation .

TREATMENT PROTOCOL FOR INFECTED NONUNION OF TIBIA

Based on the classification and therapeutic principles developed by Umairov at The Central Institute Of Traumatology and Orthopaedics of Moscow.[7,8]

S.NO.	TYPES	TREATMENT
1.	Normotropic non-union with shortening	Debridement monofocal osteosynthesis (compression – distraction)
2.	Hypertrophic non-union with shortening	Debridement, monofocal osteosynthesis (distraction)
3.	Atrophic non-union with shortening	Debridement ,bifocal osteosynthesis (Compression-distraction)
4.	Nonunion associated with bone and soft tissue loss	Debridement,bone resection without soft tissue coverage, bone transport.

DISTRACTION OSTEOGENESIS

When the fracture callus is slowly distracted new bone is slowly formed in the gap. This procedure is called distraction osteogenesis. It is based on the "Tension- stress principle" proposed by GA Ilizarov[6,14].

TENSION STRESS PRINCIPLE

Slow steady traction of tissues caused them to become metabolically activated, resulting in a increase in the proliferative and biosynthetic function

The essence of this technique is the gradual distraction fracture callus after low energy corticotomy of long bones with careful preparation of soft tissues envelopes the bone and under stable mechanical condition

Corticotomy is a low energy osteotomy which is performed using an osteotome to cut only the cortical surface thus preserving the medullary canal and periosteal blood supply.

Following corticotomy, initial healing response is allowed to bridge the cut bone surfaces before distraction is started .This period is called latency period.

The rate and rhythm of distraction is critical in formation of new bones. The optimum distraction rate 1 mm/day divided by 4 times-with a rate of 0.25 mm every six hours

During the first week of distraction central zone of avascular fibrous tissue bridges the 6-7 mm corticotomy gap and is known as **fibrous interzone** composed of loosely interspersed collagen bundles and spindle cells but no osteoblast .

During the second week of distraction clusters of osteoblast appears on each side of fibrous interzone adjacent to vascular channels which fuse to form osteoid like matrix. As these primary bony spicules enlarge by circumferential apposition of collagen and osteoid, osteoblastic cells become enveloped with matrix. Later in the second week, **primary mineralisation front** is formed.

During the third week, thin walled sinusoids surround each microcolumn of new bone this is called **microcolumn formation .**

The mode of bone formation in distraction osteogenesis is primarily membranous ossification. The regional blood supply is the most important factor in distraction osteogenesis. Various study shows

that blood flow increases to seven times in the initial four weeks and then remains elevated three times for the next three months.

FACTORS AFFECTING THE QUALITYOF REGENERATE

1. Rate and the rhythm
2. Stability of fixation.
3. Vascularity of the segment
4. Displacement of fragments or comminution.
5. Soft tissue covering of the bone.
6. The distribution of forces on the bone circumference.

Quantative CT scan has been useful in detecting the mineralisation of the osteogenic area, which occurs in predictable area.The average density of the affected extremity is compared with the normal extremity. During Distraction, fibrous inter zone shows 25-35% and primary mineralisation front shows 40-50% and microcolumn shows 60- 70%.

If the new bone formation is not demonstrated by plain X rays and quantative CT scan, then triphasic bone scan can be useful. In triphasic bone scan , both sides of the distraction appears hot.

Radiological appearance of regenerate

1. Central radiolucent zone.

2. A zone of increased bone density.

3. A zone of increased density.

Defined columns of new bone usually appear radiologically in 6 to 8 weeks of distraction. If the regenerate maintains the constant diameter , then normal development , if it is of varying diameter then it is poor quality of regenerate.

ILIZAROV RING FIXATOR SYSTEM

The Ilizarov device is a circular fixator[15]. The principal component is a ring with a flat surface with multiple holes connected to each other by means of threaded rods with nuts and fixed to the bones by K wires which are adequately tensioned to provide stability.

The entire Ilizarov apparatus contains half rings of various sizes diameter with multiple holes. The diameter of the holes are slightly larger (2mm) than the diameter of the rod and bolts making alignment and introduction flexible.

The half rings are available in various diameter from 80mm to 240mm .Each half ring has 18 to 28 holes depending on its diameter. It is important that the surface is even when the two half rings are joined with bolts and nuts.

Specially designed rings like five - eigth rings and Omega rings are available. They are used in special situations. Five –eigth rings are used near joints to facilitate joint movements. Five –eigth rings have additional advantage of providing space for insertion of more wires. Five – eigth rings are used in case of open fractures where it facilitates wound management.

In original Ilizarov system is composed of semicircular arches of large diameter with two rows of holes with side walls used for fixation of fractures of femur. Later in 1980‘s Cattagni and Cattaneo introduced a new component for use in proximal femur fractures i.e, 90 ° and 120° arches. This newer components facilitates insertion of half pins instead of wires which decreases the risk of neurovascular injuries

The main connector in Ilizarov system is the 6mm threaded rods of various length. The threaded rods have high strength characteristics for axial loading, acts as guides in distraction and compression. All the rods share the same pitch of about 1 mm. This is important as the full turn of the nut corresponds to a change of about 1mm. Threaded rods serves not only as the primary ring connectors but also as ring direction guides in the crucial distraction and compression motion. To assure equality of distance when affixing connecting rods, a practical tip is to count the holes of rings and divide by four. Biomechanically four rod construct is superior to three rod construct.

Specially designed rods like slotted cannulated rods, telescopic rods with partially threaded shaft are also available. Telescopic rods are used to connect rods and rings. Telescopic rod with a partially threaded shaft is an aluminium alloy cylindrical tube with one end fastened to a

ring with bolts and a partially threaded shaft protruding from cylinder attached to next ring in the frame.

Graduated telescopic rods have two major features: the inside of the cylinder is fully threaded, and it has a square head that is adjustable by hands, permitting easier and simpler adjustment for both surgeon and patient. Graduated telescopic rods makes easier for surgeons to control the rate and rhythm of compression and distraction.

In many clinical situations, Ilizarov fixator requires reinforcement on either temporary or permanent basis. In case of multiple level fractures, multiple level osteotomies, and bone lengthening, such reinforcement is achieved with the use of connection plates. These connection plates are 5 mm thick, 14mm wide and have 7 mm diameter perforated holes. Connection plates are of various types viz; short, long connection plates, connection plates with threaded end, twisted connection plates, curved connection plates etc.

Fastening is achieved with the help of bolts and nuts .No screws and screw drivers are used in Ilizarov system. The bolts are available in 10mm, 16mm,30 mm length with a pitch of 1mm. Nut are used to stabilise the connecting rods, tighten the wire fixation bolts.

The threaded rods can be reinforced and lengthened by using threaded sockets and bushings. Threaded sockets can be 20mm or 40mm long. They are hexagonal, with diameter exactly corresponding to that 10 mm nut, makes it convenient to adjust with standard wrenches. Both ends are threaded to the bolts or threaded rods. Bushing is a short 12mm cylinder with smooth unthreaded aperture (7mm) running through it. It is wider than a threaded rods, which makes it easier to place on rods. To stabilise the bushing while it is on the rod, nuts must be fastened on both ends above and below.

The posts, supports, half hinges are the auxillary parts of the fixator system and they facilitates a variety of frame constructions. The wire fixation bolts are used to fasten the K wires to the rings.

The main advantage of these auxillary parts are they can be placed in any location, turned to 360° and placed in any desired position. The male post has a 13 mm long standard threaded leg protruding from the butt end. The leg serves as a connection to other components. The female post has no protruding rod, but a 10mm deep threaded hole at the butt end. This hole serves to connect bolts or rods .The posts are available as 30mm with two holes, 40 mm with three holes, 50 mm with four holes.

The half hinges have a supporting base with two flat surfaces matching with wrenches. They differ from post in that the flange has only one hole and is only 4mm thick. The male hinge has a standard threaded leg protruding from the base. This leg connects it to other components. The female half hinge has no leg, but a threaded hole at its base. This hole connects it to a bolts. Both types of half hinges have flanges at one side of base. Connected to each other and fixed by bolts-nuts system, two half hinges form a low profile hinge.

The Ilizarov system contains two specially designed nuts used to fasten the Kwires to the flat surface of the rings. Both the cannulated and slotted wire fixation bolts has a head with special shape 14 mm x10 mm oval, with two flat surfaces for wrenches. The length is equal to the width of the ring.

Because both type of bolts have equal stability to fix the wires, 1.5 mm wire is more securely fixed with cannulated bolts and 1.8 mm wires are secured with slotted wire fixation bolts. For optimal tightening, 5 mm bolts are used.

Washers are used to fill the space between the ring and the wires. The 1.5 mm thick,12 mm diameter washer is equal to the diameter of the nut and the bolts.

The main proximal frame supporting ring is stationary and always located at the base of the frame. It bears the entire weight of the construction. In a femoral frame it is replaced by Italian arches. The stabilising frame supporting ring always located distally. It can be stationary ,movable, depending on the frame.

The pusher -puller ring is a movable ring used for application of compression and distraction forces. It is located distal to the fracture-osteotomy non-union site.

The reference ring is used as reference for the supporting ring or distraction –compression rings. It can be stationary, movable, depending on the location.

The choice of ring inclination will determines the direction of forces applied to the ring. In most instances, the inclination of the ring is such that it is perpendicular to the axis of the bone. To position the ring, the must take into account the surrounding muscles and the subcutaneous fat, the ring is not positioned to the exact geometric centre but to the centre of the anatomical axis of the bone. Scars and subcutaneous tissue may misguide the placement of the ring. During limb lengthening, tension on the muscle may deviate the distracted segment. This should be taken into account to prevent deformity.

The muscles of lateral compartment muscles will deviate the fragment laterally and posterior compartment muscles will deviate the segment posteriorly results in valgus and antecurvatum deformity. To avoid this, the proximal ring is inclined 5° recurvatum to bring the correct position of the distracted leg.

ILIZAROV SYSTEM

BIOMECHANICS OF ILIZAROV RING FIXATOR

Biomechanics of Ilizarov ring fixator has been extensively studied, clinically, experimentaly by Ilizarov, Flamingo, Paley, and many others[6,14].

The Ilizarov ring fixator system is composed of smooth thin K wires of size 1.5mm and 1.8 mm which is connected to the circular ring fixator and is adequately tensioned. Half pins can also be used in hybrid types of Ilizarov fixator. The ideal external fixator have stability of fragments in alignment and at the same time allows micromotion by elasticity. They are elastic type of fixator and allows axial micromotion which are conducive to bone healing and regenerate..

Forces acting in the circular fixator are in plane. It is a multilevel, multiplanar fixator. Its circumferential rings distribute stress evenly across the fracture site and osteotomy site. So, three dimensional corrections is possible. Axial distraction, compression, angular deformity and translational corrections are all possible using gradual distraction technique.

Ilizarov fixator is less stiff in axial loading than any other frames. It maintains its same stiffness at various loads and this unique behaviour is attributable to increasing wire tension under loading.

Ilizarov fixator allows early weight bearing and is useful in osteoporotic bones. Ilizarov fixator can work in septic condition and helps in correction of deformity, limb length discrepancy due to aseptic pseudoarthrosis or following removal of stable implant.

There are some disadvantages like transfixation of soft tissues, bulky implant, neuro vascular injury, time consuming to assemble and steep learning curve and poor patient compliance.

BIOMECHANICS OF THE WIRE[2,6]

The tensioned wires are considered nonlinear, self stiffening pins. When thin wire is tensed ,it achieves rigidity equal to half pins. BAGNOLI argues that one should not exceed 50% of the yield strength of the wire to be on the safer side and to minimise breakage and stretching. Now a days tensioning is done using dyanomometer

Maximum limits are 90 kg for 1.5 mm wires and 130 kg for 1.8 mm wires. Tension of the soft tissues also determines how much tension is applied to the wire.

Multiplanar positioning of wires on each side of the ring and introduction of wires increases the stability of assembly.

Stability of fixator increases with increase in number of wires .Bending and axial stiffness is directly proportional to the number of wires. The use of olive wire increases the stability by minimising the translation of the bones.

Dor paley puts forth the working hypothesis :

1. Cyclic axial loading is beneficial to fracture healing.

2. Translational shear at the fracture site is deleterious to fracture healing.

Increase in wire diameter increases with wire tension, decreased ring diameter increases the stability of the apparatus to axial load. The optimum diameter of the wire is 1.5mm for children and 1.8mm for adults with large bones to optimise this stiffness property while maintain sufficient strength and stiffness increases as the square of the diameter of the wire.

BIOMECHANICS OF THE RINGS

Stability of assembly depends on number of rings size, position of rings. Stability increases with increase as the number of rings in the frame increases. Reduction of 2 cm of ring radius resulted in rise of axial stiffness of 77% under 100 N load and 86% under 500 N load. Increase in radius also decreases axial stiffness and bending stiffness.

Ilizarov recommends a 2cm of minimum distance between ring and the skin to allow for the swelling and pin site care.

Carbon fibre rings fibre rings are stronger, lighter, more expensive and radiolucent.

Kummer suggest the following principles to maintain the fixation stability;

1. Use smallest rings as possible.
2. Minimise the unsupported segment with rings, use more or large ring connectors or an intermediate free rings.
3. Use olive wires for control of fragments or free ends particularly in compression.
4. Use large wires or greater number per ring to increase maximum stiffness .

5. Reuse of ring fixation bolts is not recommended because of possible failure of these components due to yielding during tightening.

6. Wire crossing angle should be atleast 60 degree.

According to Calhoun, in many internal and external fixation systems, bone compression accounts for part of fracture healing .Bone compression is an important factor for fracture and non-union healing. Without bone contact many fracture fixation system cannot be used or devices may fail. High level of bone compression may promote early healing, early weight bearing and healing of non-union.

Compression stiffness can be increased by increasing the number of wires, compressing the rings together and by adding the olive rings. Olive wires have found to be two to five times more stiffer in oblique fracture model than smooth wires for compression and distraction stiffness.

BIOMECHANICS OF THE HINGES

Ilizarov fixator system is used to treat the deformity. This is achieved with the help of hinges. The positioning, orientation, number of hinges plays an important role in correction of deformity.

The advantages of hinges are:

1. They constrain motion in specific plane or planes.
2. They provide a specific fulcrum for calculation and correction of angulation and displacement.
3. They provide biological adaptation of tissdues to the new desired position.

Few important steps to be followed while applying the hinges as follows:

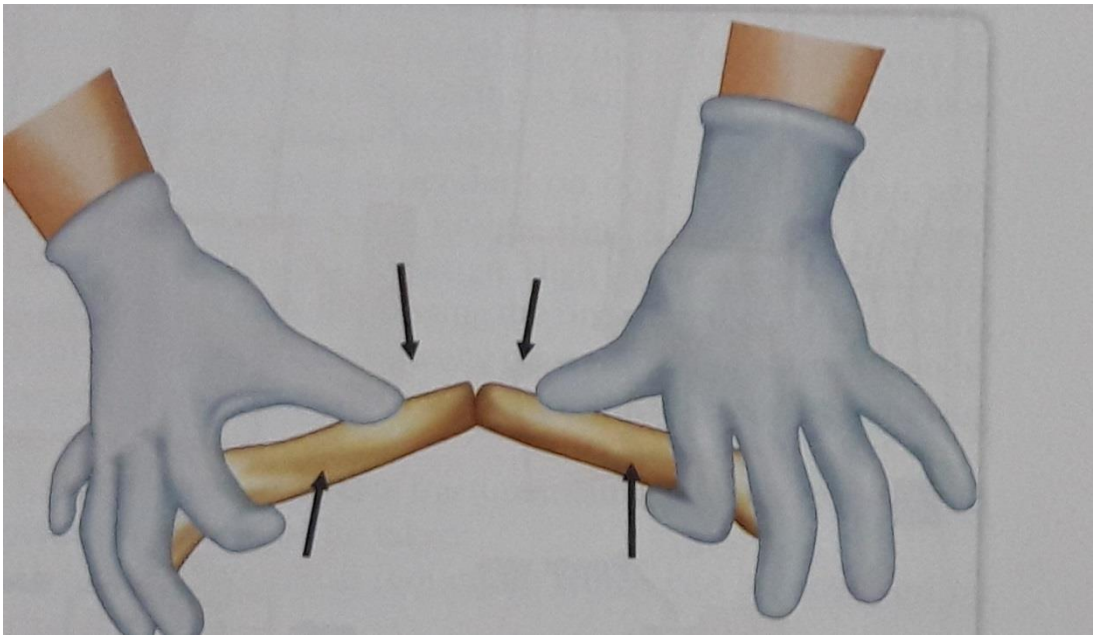
1. Two rings to which the hinges to be attached are perpendicular to each other.
2. The two hinges are located on opposite sides of the deformity are essential for stability.
3. The rotation axis of the hinges are must be on the horizontal level of the apex deformity. Two hinges must be in the same level.
4. The position of the hinges can be used to correct different types of deformity like open wedge, distraction, compression, translation, and derotation.
5. Movement of the axis of rotation of hinges to concave or convex sides of the deformity produces corresponding compression or distraction of the fragments.

RULE OF THUMBS

Four point bending is the principle of correction in angular deformities. Olive wires are placed at the fulcrum point on the opposite sides of deformity and at the distraction point at the ends of the bones. The location of the Olive wires can be remembered by thinking of the four points bending rule of thumb.

Olive wires are located at the point where the thumb presses the apex and the index fingers press on the ends of bones. The proximal and the distal wires are located on the concave and the central two wires are located on the convex sides of the deformity.

Figure 1 : Rule of Thumb



OPERATIVE TECHINIQUE

The stability of the fixator is the important factor in success of Ilizarov method of treatment of fractures. The stability of the fixator depends upon pro[per wire insertion, the spread of two wires, proper tensioning, number of wires, positioning and number of rings and final tightening of all nuts and bolts. The intrinsic factors are – area of contact between interlocking bone ends, gap and tension of the soft tissues.

Proper wire insertion technique is essential to achieve stability, to avoid pain, to maintain function and to hasten healing. Late frame instability is generally caused by loosening at the wire bone interface by wires that are not properly inserted.

PREVENTION OF THERMAL NECROSIS

1. Stop –start techinique.

2. Use low revolutions < 1500 per minute to prevent over heat and thermal necrosis .

3. Smoke indicate severe burns. Stop drilling and insert wire at a different site. Check sharpness of the tip.

4. Hold the wire with a betadine gauze.

5. Avoid scelerotic bones for wire insertion.

6. Two wires should be in parallel planes, and about 0.5 mm apart.

7. The wires should have bayonet tips which penetrates the diaphyseal bones easily.

8. The wires must be inserted in safe corridors so that the neurovascular structures are not in danger.

PRECONSTRUCTION OF ASSEMBLY

Preconstructed ring saves a lot of time during surgery. Size of ring is decided by measuring the circumference of the limb and 1/3 rd circumference plus 6 cm is the diameter of the ring required. Ring should be of same size which facilitates insertion of threaded rods easier.

Placement of the ring is decided by fracture pattern. Proximal and distal ring should be close to the joint as possible. Proximal ring should be at the level of fibular head and distal ring should be 3 cm away from the ankle joint.

WIRE FORMULA

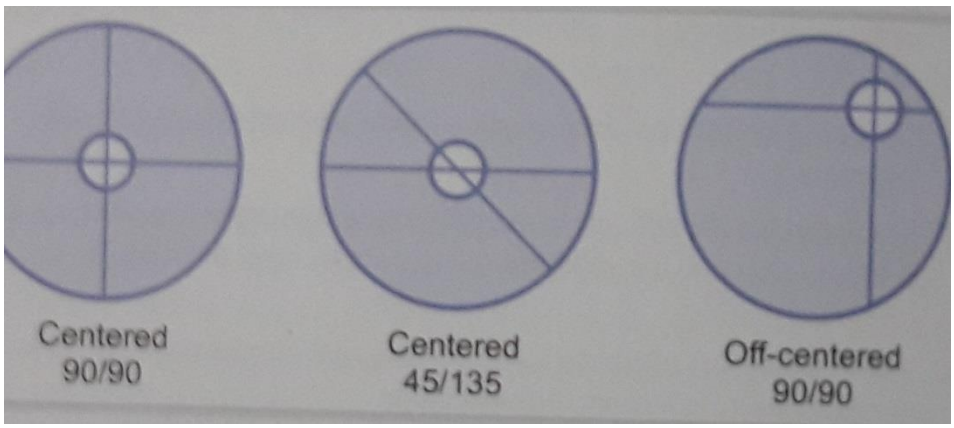
Under spinal anaesthesia, patient leg is painted and draped and the preconstructed ring is introduced into the leg and the rings fixed with reference wires by wire fixation bolts and adequately tensioned using wire tensioner.

The oblique wires are inserted 1 cm lateral to the tibial crest. The exit point should be in front of tibialis posterior tendon .Proximal and distal wires are parallel to the joints and through the fibula

At the distal level wire is inserted between tibialis anterior and extensor hallucis longus tendon. Wire is inserted from lateral to medial, aiming posteriorly 50 degree to the horizontal towards the posteromedial border

Half pins can also be used instead of wires. Corrective forces are transmitted through the wires and the pins to the bones.

Figure 2 : Wire Configuration



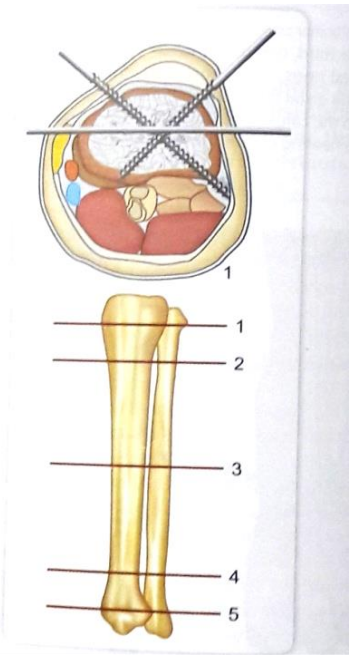
SAFE CORRIDOR

1. Wires are inserted considering the safe corridor for wire fixation Behrens to avoid injury to neurovascular structures.

2. Introduce the wire from the most vulnerable position .Eg. proximal wire in tibia inserted from lateral side to avoid injury to common peroneal nerve.

3. For maximum stability two wires to be inserted crossing at right angles. Unfortunately due to anatomical constraint transfixation wires are crossing at more acute angles diminishing the fixator stability.

Figure 3 : Safe Corridor for wire insertion



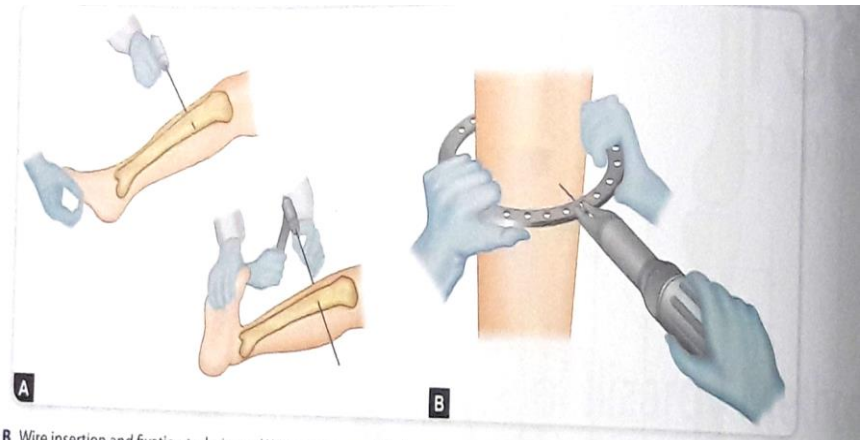
MUSCLE POSITIONING

1. Muscle must be positioned properly for wire placement to maximise the wire excursions of adjacent joints.

2. Prior to placement, each muscle is stretched to maximum adjacent to the joint.

   Eg. Ankle plantar flexors are stretched by maximum dorsiflexion of foot during wire passage and then foot is plantar flexed as the wires are passed dorsally

Figure 5 : Positioning of limb during wire insertion



4A and B Wire insertion and fixation technique: (A) Using a power drill, the wire is pushed through the skin and soft tissues down to bone. It is then ed through the first and second cortices of the bone. Hence, it is through the second cortex, it is tapped through to the other side rather than using drill. When the wire is inserted through the anterior compartment, the ankle is plantarflexed so as to transfix any muscles in their maximally stretched tion. Similarly, when the wire exits posteriorly, the ankle is first dorsiflexed so as to stretch the posterior compartments; (B) The wire is then fixed to the of the fixator using wire fixation bolts and is then tensioned to about 130 kg

SKIN POSITIONING

Skin must punctured on the entry side and after crossing the far cortex the wire tapped with a mallet while crossing the soft tissue to avoid tenting of skin.

ASSEMBLY OF RODS

The threaded rods used to connect the rings are placed parallel to each other and at same distance and parallel to mechanical axis of the limb. Rotational correction is done by placing the rods parallel to each other but obliquely in all holes adjacent to the perpendicular. As the nuts are tightened, rods become perpendicular to the rings by 10 degree per hole.

CORTICOTOMY

It is well established that periosteum is responsible for increase in bone width and endosteum carries out the phases of bone formation alternating with phases of bone resorption.

Ilizarov's observation confirms Wolf's law of bone formation.

Corticotomy techinique consist of cutting the bone through compact bone only and preservation of periosteum and bone marrow.

Corticotomy is done by various methods. Following steps of corticotomy are

1. Skin incision of about 5 to 10 mm long is made parallel to the tibial crest.

2. Cortex transection must be performed with small osteotome 0.5 mm. This guarentees that the edges does not penetrates into the periosteum and bone marrow.

3. After periosteum is cut, multiple drill holes are made in anterior, medial lateral cortex and cortex transaction is done by hammering the osteotome in a fan shape manner directing medially and laterally and posterior wall is transected and by externally rotating the rings completion of corticotomy is confirmed.

4. Wound is closed. Sterile dressing of the corticotomy is done.

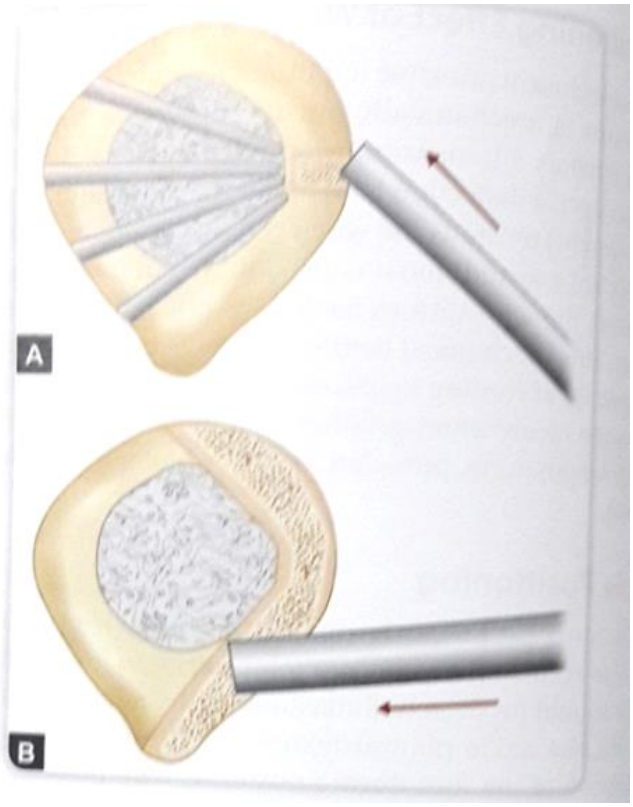
5. Minimal distraction of the corticotomy for several days before distraction is started. This space is filled with fracture hematoma and necessary for early development of microlacunae. This lacunae are the precursors of new blood vessels and this is the stage to start distraction and from this regenerate forms.

Metaphyseal segment of bone is the best segment for corticotomy.

Depending upon the goal of treatment in a particular patient, corticotomy can be monofocal or bifocal. Monofocal corticotomy is done for i) lengthening upto 5 cm ii) bone transport upto 5to 7 cm iii) gradual correction of deformity.

Bifocal corticotomy is done for i) lengthening upto 10 to 12 cm ii) bone transportation upto 10 to 16 cm transportation iii) simultaneous lengthening at one segment and deformity correction at other segment. iv) stimulation of osteogenesis in metabolic disorders.

Figure 6 : Technique of corticotomy



TENSIONING OF THE WIRES

The quality of regenerate formed depends upon the strength of wire tension. The exact wire strength depends upon i) local frame construct ii) local bone condition. iii) weight of patient. iv) functional wire loading.

Wires on half rings: 50 to 70 kg

Offset wire : 50 to 80 kg

Two to three wires on a ring : 110 kg

Single wire on a ring: 100 kg

Wire with olive stopper 100 to 110 kg

Guidelines for performing tensioning the wires:

1. Tensioning the wire must be done immediately after its introduction.

2. Tensioning must be done with one end fastened to the ring and tensioning is done directly opposite to the anchored end.

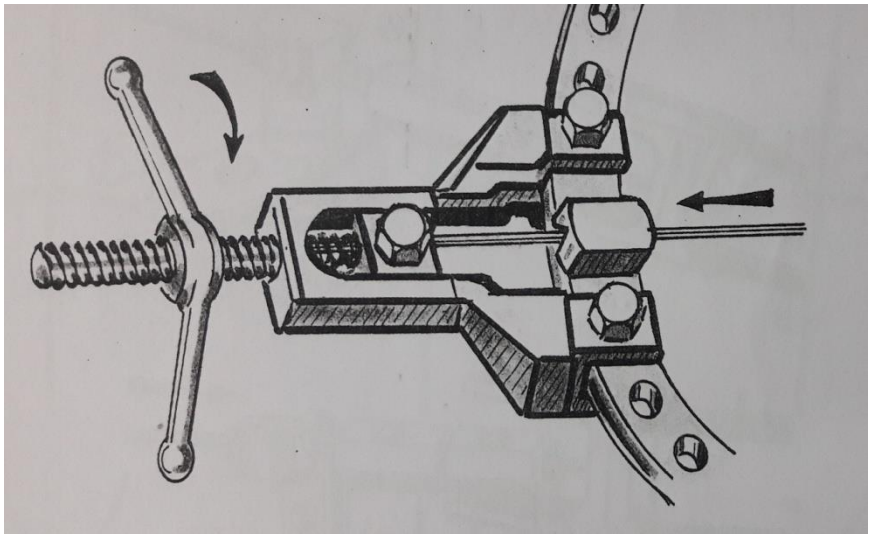
3. Tensioning of the wire with a stopper must be directed to the side opposite to the stopper.

The technique of tensioning by Ilizarov tensioner involves fastening the wire to the ring first followed by clockwise rotation of the tensioner.

The most recommended technique is tensioning by using dyanometric wire tensioner.

After tensioning the wires, the sharp ends are bent and twisted and cut so that it does injure the soft tissues.

Figure 7 : Method of Wire tensioning using ILIZAROV Wire Tensioner



RANCHO TECHINIQUE

Stuart Green, From Rancho Los Angels Medical center first applied the ring fixator using half pins instead of transfixation wires for mounting the fixator. Since then various modifications has been done. The decision to use half pins to fix the proximal and distal segments were based on the observation that good regenerate was formed in the distraction gap when the half pins are used for elongation ,provided the surgeon follows the principles of Ilizarov like periosteal preservation and stability and latency . They avoided the cantilever mechanism by

inserting pins in different directions. The use of titanium half pins reduces the incidence of pin site infection and the bone to metal bonding incase of titanium pins are very high when compared to stainless steel pins. This method of Ilizarov technique is useful in Femur and Humerus where the insertion of transfixation wires is difficult and associated with neurovascular complications.

Figure 8 : ILIZAROV Ring Fixation for infected Non-Union

COMPLICATIONS OF ILIZAROV METHOD

INTRAOPERATIVE COMPLICATIONS:

1.Injury to Nerves.

2. Injury to vessels.

3. Improper alignment of fragments.

4.Incomplete corticotomy.

LATE POSTOPERATIVE COMPLICATIONS:

1. Breakage of wires.
2. Pin tract infection.
3. Infection of the bone at the distraction site causing inadequate consolidation.
4. Nonunion at docking site.
5. Joint stiffness

MATERIALS AND METHODS

This is a prospective study conducted at The Department of Orthopaedics, Govt. Stanley Medical College & Hospital, Chennai - 01 during the period August 2015 to July 2016. Patients admitted with infected non-union, fracture of long bones and Gap non-union of long bones due to various causes and was treated with Ilizarov ring fixation method and were studied for the functional outcome, complications, fracture union.

INCLUSION CRITERIA

- Age more than 18 years.
- Both Genders.
- Patient presented with infected non-union fracture of long bones
- Fracture of long bones with bone defect due to trauma, wound debridement, segmental bone loss due to resection of bone tumours.

EXCLUSION CRITERIA

- Patients aged less than 18 years.
- Patient with psychotic disorders.
- Patient unwilling for long term treatment and uncooperative for post operative rehabilitation.

METHODS

- General information like Name, Age, Sex, Occupation, Address were noted.
- Mode of injury like Motor vehicle accident, Assault, previous surgeries for infected non-union of fractures, industrial injury, etc were collected
- General examination like Anemia, Jaundice, lymphadenopathy, blood pressure were noted.
- Systemic examination like Cardiovascular system , respiratory system were examined.

- Open fractures of long bones with bone defect and infected non-union of fractures were debrided and skeletal stabilisation done using AO external fixator.

- Large soft tissue loss were treated with split skin grafting and myocutaneous flap by the plastic surgeon.

- Infected non-union of fractures of long bones were classified using UMAIROV's classification of infected non-union of fractures of long bones and Kulkarni classification of infected non-union fracture of long bones.

- All patients have preoperative X - rays of the affected limb for the assessment of level of fracture, type of non-union, rotational deformities, shortening and bone defects.

- Culture swab taken from the wounds and treated with intravenous antibiotics according to the sensitivity pattern.

- Preoperative counselling given to the patient regarding the mode of treatment, duration of treatment and post operative rehabilitation and complication related to the surgery.

- Ilizarov ring fixator was constructed on the previous day and sent for sterilization.

- Under subarachnoid block, involved limb painted and draped, preconstructed Ilizarov ring was introduced into the limb and fixed with K – wires and tensioned adequately using wire tensioner and Schantz pin. Hybrid Ilizarov method using wires and half pins was followed in most of cases.

- Corticotomy was done if necessary and fibular osteotomy in case of bone transport and bone transport was done after the latency period of 14 days.

- Distraction was done at the rate of 1mm /day and rhythm 0.25mm every 6th hourly.

- Patient were mobilised with partial weight bearing immediately and full weight bearing once tolerated. Method of Distraction of bone segment, Pin site care, joint mobilisation exercises were taught and patient discharged.

- Routine follow up done at monthly intervals with X rays for assessment of fracture healing, quality of regenerate in distraction osteogenesis and to assess any deformity.

- After completing the bone transport, patient is kept on ring fixator for a period double the time till satisfactory union is achieved.

- If there is any deformity then realignment of fixator was done accordingly.

- Dynamisation of the fixator was done to achieve union at the docking site.

- Fracture healing assessed radiologically by appearance of bony trabecules at the fracture in at least three of four cortices in AP and lateral views, clinically by absence of pain and absence of abnormal mobility.

- Once the fracture healed Ilizarov fixator was removed after releasing the wire tension and plaster of Paris cast was applied for a period of six weeks and cast was removed then patient allowed to bear weight.

- Results were assessed using the criteria laid down by ASAMI (THE ASSOCIATION FOR THE STUDY AND APPLICATION OF THE METHODS OF ILIZAROV) scoring system.

EVALUATION OF THE OUTCOME

For evaluating the results of treatment of infected non-union and gap non-union of fractures by Ilizarov method, We used the Association for the Study and Application of the Methods of Ilizarov (ASAMI) Scoring system.[1,18]

It has two components:

1. BONE RESULTS
2. FUNCTIONAL RESULTS

BONE RESULTS

Excellent	Union, No infection,< 7 degree deformity, Limb length inequality < 2.5 cm
Good	Union + any two of the following: No infection, Deformity < 7 degree, Limb length discrepancy < 2.5 cm
Fair	Union + only one of the following : no infection, deformity < 7 degree, limb length discrepancy , 2.5 cm
Poor	Non union/ refracture / union+ infection+ deformity > 7 degree + limb length discrepancy > 2.5cm

FUNCTIONAL RESULTS

Based on the five criteria

1. Observable limp
2. Stiffness (loss of > 15 degree of knee extension and or > 15 degree of ankle dorsiflexion)
3. Reflex sympathetic dystrophy
4. Pain that reduced activity or disturbed sleep
5. Inactivity (due to unemployment or Inability to carry out daily activities)

The functional results were classified as follows

Excellent- If the patient is active, able to do his / her daily activities, and absence of other four criteria.

Good – If the patient is active but one or two of the other criteria are present.

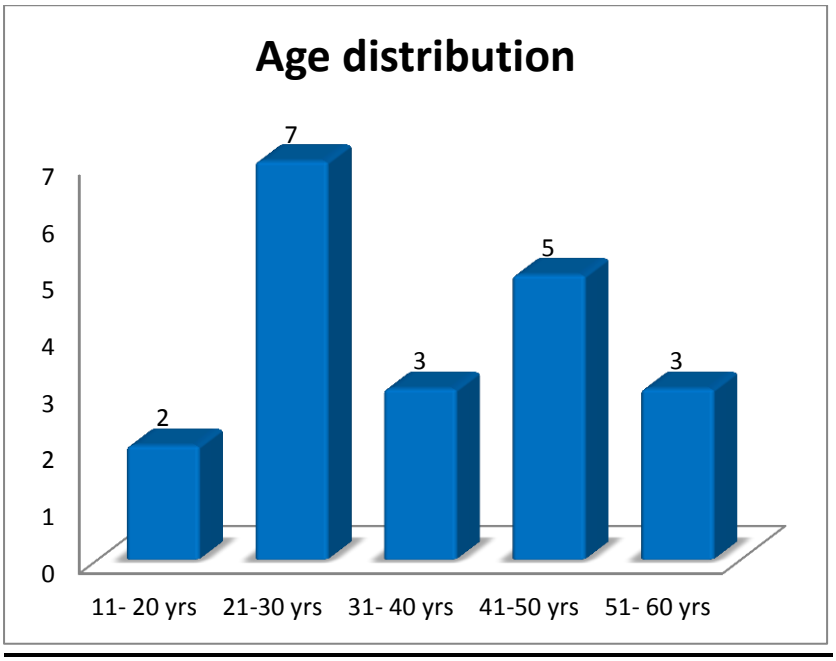
Fair –If the patient is active, with the presence of three or four of the other criteria.

Poor – If the patient is inactive, regardless of the presence of other criteria.

OBSERVATION

I. AGE DISTRIBUTION

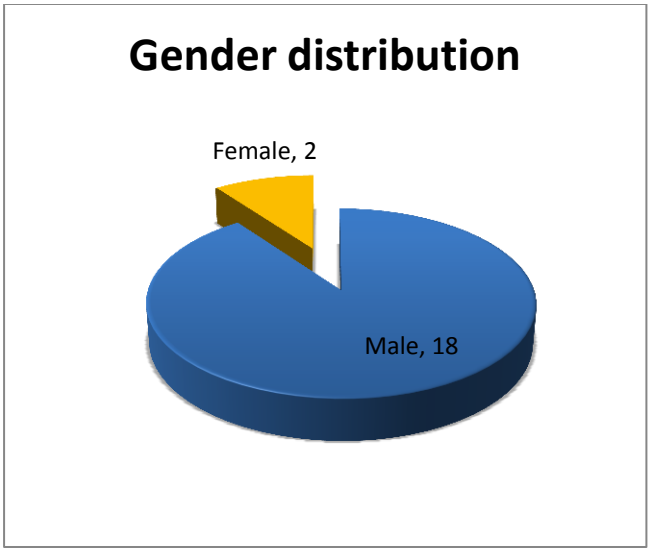
Age in years	No. Of cases	Percentage
11- 20	2	10%
21-30	7	35%
31-40	3	15%
41-50	5	25%
51-60	3	15%



The age group varies from 18 years to 60 years with maximum incidence between 21 to 30 years mostly the young individuals .

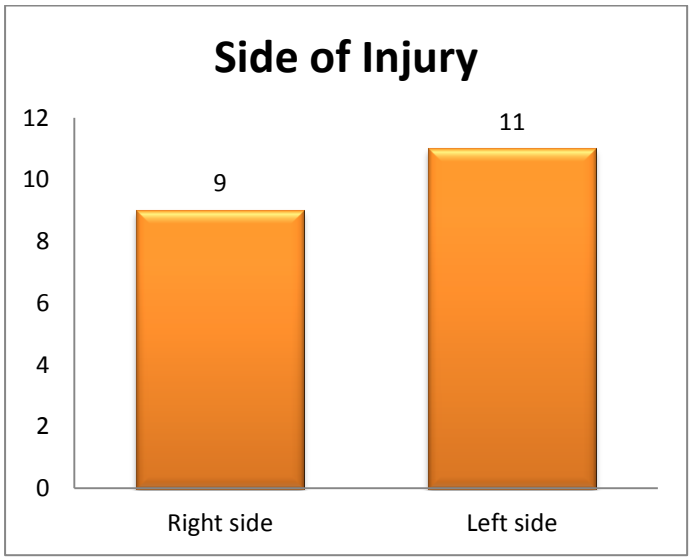
II. SEX DISTRIBUTION

Among 20 patients included in this study, males were predominant accounting to 18 numbers.



III. SIDE OF INJURY

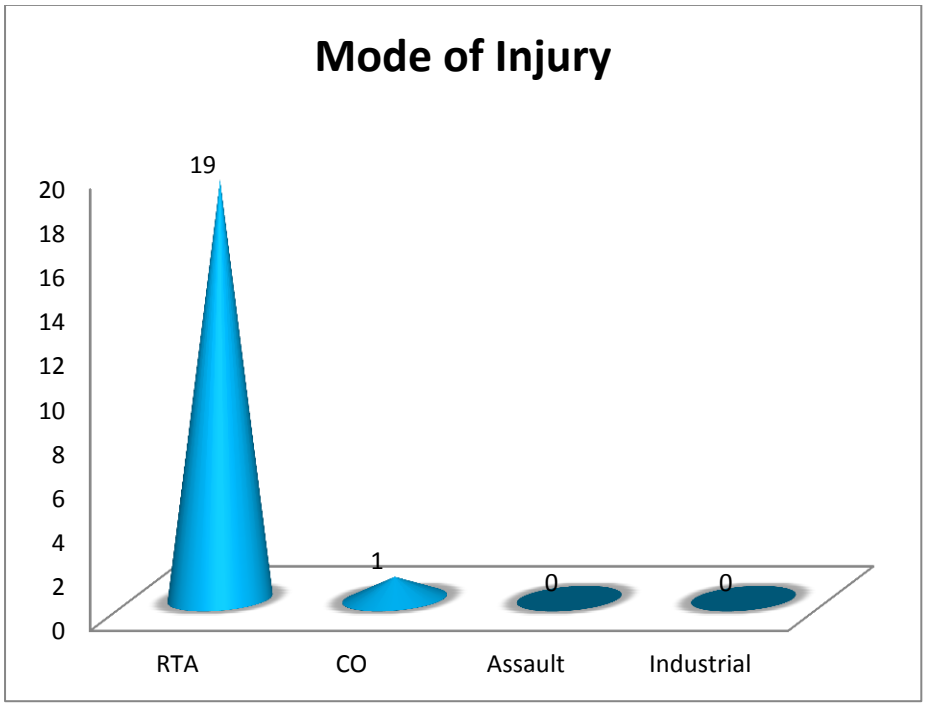
In our study, left side of the limb is common.



IV. MODE OF INJURY

The most common mode of injury is road traffic accident. Only one case is due to chronic osteomyelitis, sequestrectomy done and the defect was treated with Ilizarov bone transport.

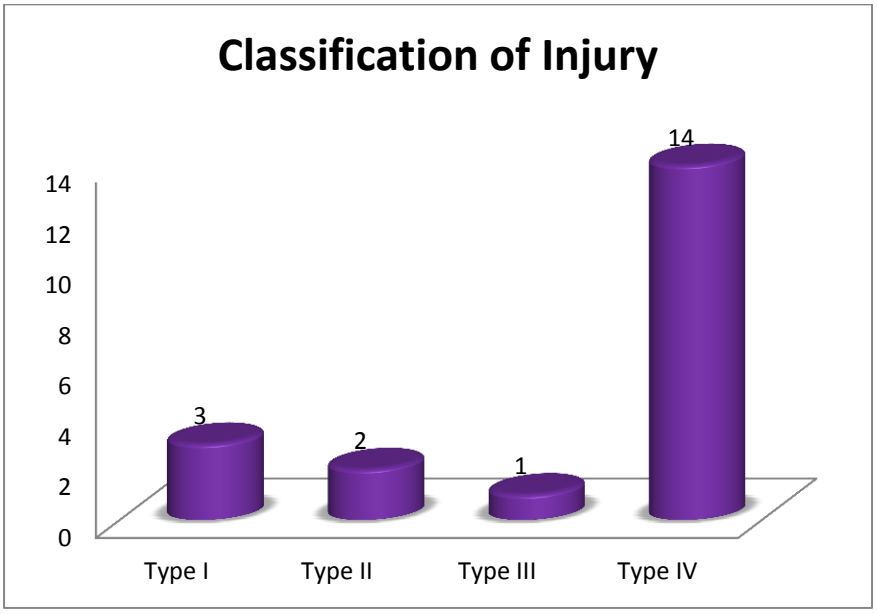
Mode of injury	Mode of Injury	Percentage
Road Traffic Accident	19	95
Infection	1	5
Industrial Injury	0	0
Assault	0	0



V. CLASSIFICATION

In our study , most of the cases belongs to Umairov's Type IV

Classification of Injury	Number of cases	Percentage
Type I	3	15%
Type II	2	10%
Type III	1	5%
Type IV	14	70%

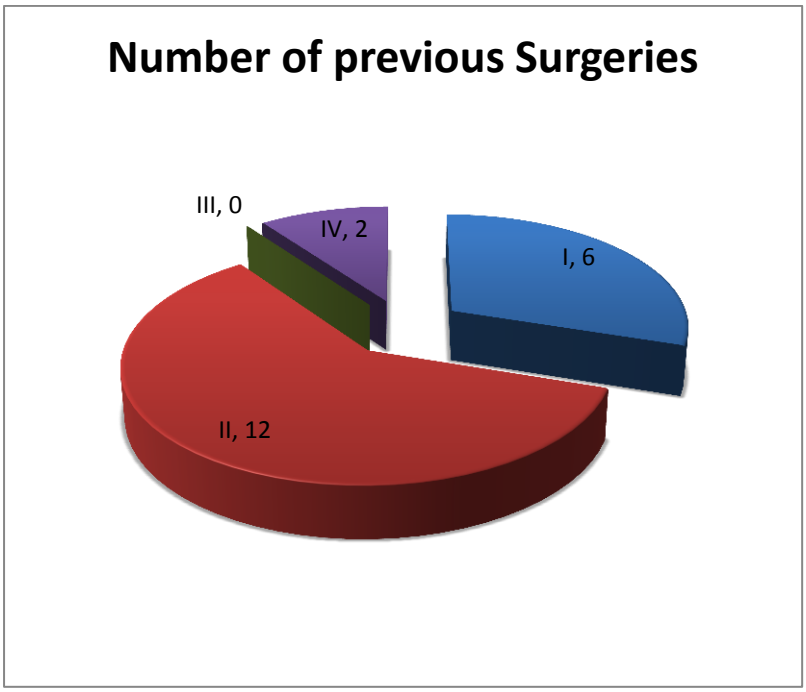


VI. ASSOCIATED INJURIES

1. Fracture of Opposite tibia- 1 case
2. Fracture of shaft of femur -2 cases
3. Intertrochanteric fracture- 1 case
4. Foot injuries-1 case

VII. NUMBER OF PREVIOUS SURGERIES

No. Of previous surgery	No. Of cases	Percentage
1	6	30%
2	12	60%
3	0	0
4	2	10%



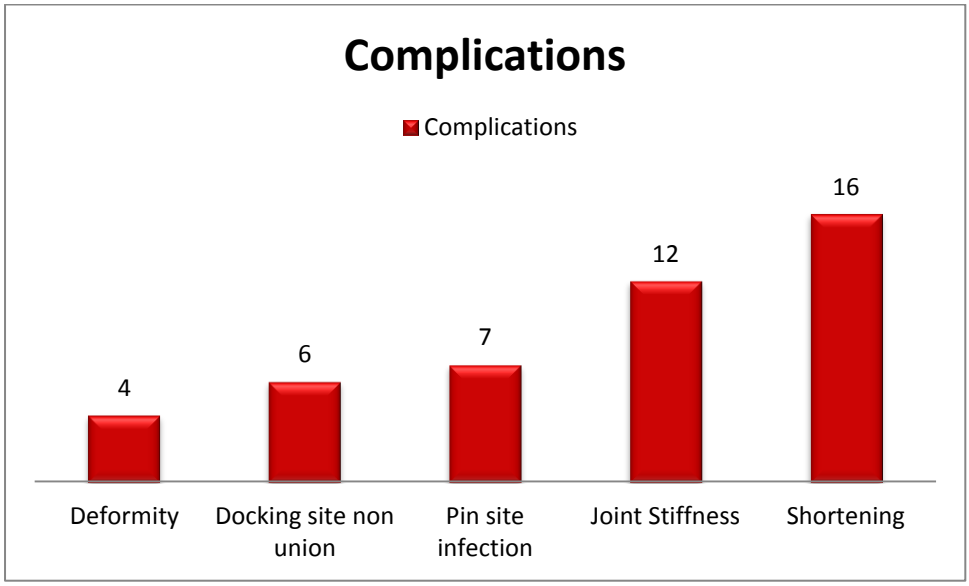
The modal distribution of previous surgeries in our study group is 2.

VIII. DURATION OF TREATMENT

The duration of treatment varies from minimum of 5 months to maximum of 13 months with mean duration of 8.8 months.

IX. COMPLICATIONS

S.No.	Complication	No. Of cases	Percentage
1.	Deformity	4	20%
2.	Docking site non union	6	30%
3.	Pintract infection	7	35%
4.	Joint stiffness	12	60%
5.	Shortening	16	80%



Among the complications, shortening is the most common complication which constitutes 80% of cases, and the average shortening was about 2 cm which was within the acceptable limit. The second common complication in the study was joint stiffness which constitutes 60% mostly equines deformity.

RESULTS

In our study of 20 cases with infected non union of tibia, 19 cases were due to open fractures of tibia which was initially debrided and external fixation was done followed by Ilizarov ring fixation, and in one case of chronic osteomyelitis with pathological fracture sequestrectomy followed by Ilizarov bone transport.

In 17 cases with bone defect which varied from 1 cm to 6 cm, acute docking was done in 9 cases and corticotomy and bone transport was done in 8 cases.

The fracture healing time varied from 5 months to a maximum of 13 months.

COMPLICATIONS AND THEIR MANAGEMENT

1. Limb length discrepancy

In our study of 20 patients about limb length discrepancy was found in about 16 cases (80%) which varied from minimum of 1 cm to a maximum 3 cm which was in the acceptable limit and was managed by appropriate foot wear modification.

2. Joint stiffness

In our study of 20 cases, joint stiffness was found to be the second most complication accounting for about 12 cases among which both knee joint and ankle joint was involved in 1 case and isolated ankle joint stiffness was found in 10 cases and isolated knee joint stiffness was found in only one case. Joint stiffness was treated by passive stretching and active mobilisation exercises and soft tissue release was performed in 1 case and ankle deformity correction was done with Ilizarov method in 3 cases.

3. Pin site infection

In our study pin site infection occurred in 7 cases which constituted 35%. Most of them are superficial infections and were managed by pin site care and antibiotics.

Protocol for management of pin site infections

TYPES	CHARACTERISTICS	TREATMENT
1	Serous discharge	Local pin site care
2	Superficial infections	Local pin site care + oral antibiotics
3	Deep infections	Local pin site care + i.v antibiotics
4	Sequestrum	Pin removal + sequestrectomy

4. Docking site non union

In our study of 20 cases docking site non union was seen in 6 (30 %) cases out of 9 cases of bone transport which was due to relative avascularity of the transporting segment and was treated by dynamisation in three cases and bone grafting in three cases.

5. Deformity

3 cases (20 %) had varus angulation with varus deformity around 5 degrees which was within the acceptable range.

6. Non union

In our study all 20 cases (100 %) had bony union

7. Neurovascular injury

In our study there was no case of nerve palsy and vascular deficit was noted.

8. Realignment of fixator

In our study realignment of fixator was done in 7 cases mostly due to loosening of pins.

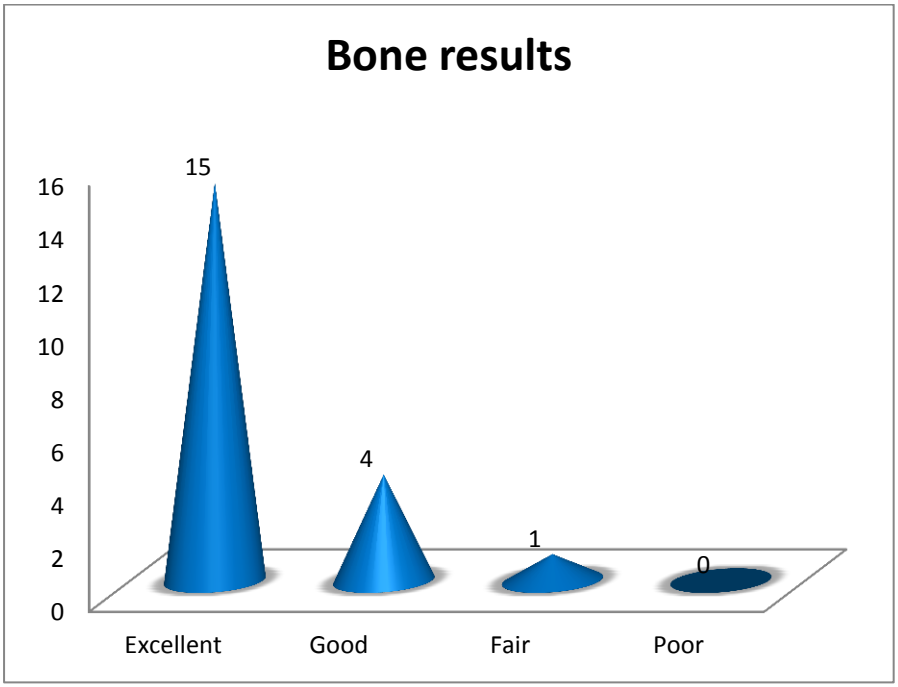
S.No.	Complication	No. Of cases	Percentage
1.	Deformity	4	20%
2.	Docking site non union	6	30%
3.	Pintract infection	7	35%
4.	Joint stiffness	12	60%
5.	Shortening	16	80%
6.	Non union	0	0
7.	Neurovascular injury	0	0
8.	Realignment of fixator	7	35%

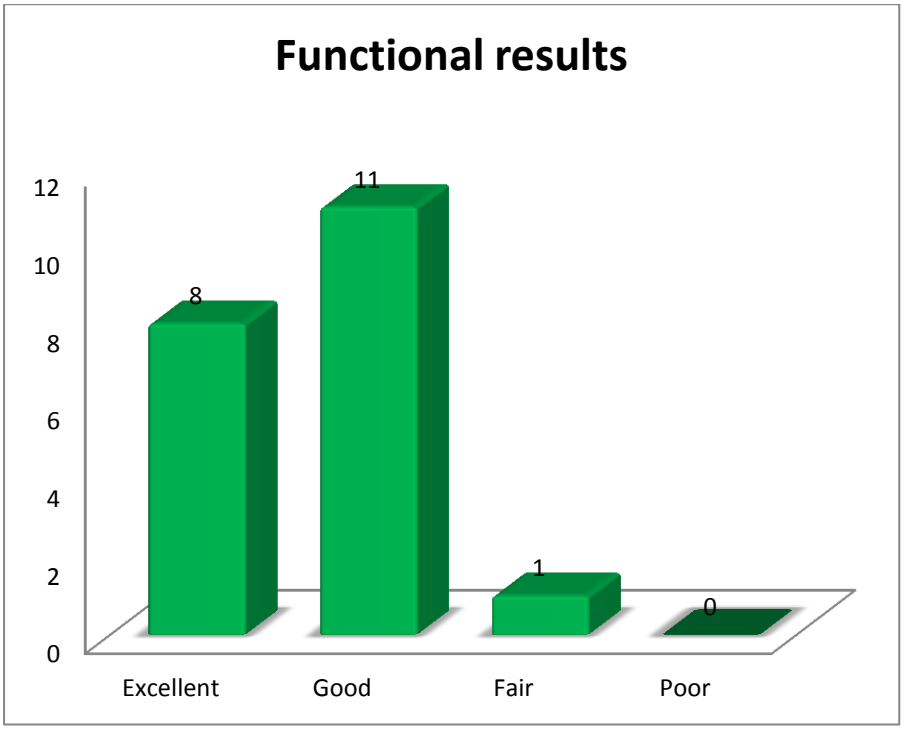
ANALYSIS OF RESULTS

The results were analysed using the Association for the Study and Applications of the Methods of Ilizarov (ASAMI) scoring system and the results are

GRADING	BONE RESULTS		FUNCTIONAL RESULTS	
	No of cases	Percentage	No of cases	Percentage
Excellent	15	75 %	8	40 %
Good	4	20 %	11	55 %
Fair	1	5 %	1	5 %
Poor	0	0	0	0

Analysis of Results





DISCUSSION

Infected non union and gap non union are the greatest challenge to the practising orthopaedic surgeons. Infected non union is usually associated with limb length discrepancy, multi drug resistant organism, soft tissue defects, deformities etc. Although many methods and techniques are available in the treatment of infected non union, all the problems cannot be addressed simultaneously. By using the Ilizarov method most the problems associated with infected non union can be addressed by this technique. But it is technically demanding and time consuming. The patient's acceptance plays an importance role in the success of this modality of treatment.

In most of the circumstances patient has undergone many number of surgical procedures and had lost considerable time and lifestyle from his job and personal well being. The psychological and physical trauma to the patient when faced with the thought of another surgery is often underestimated.

Bone transport is one of the most innovative contributions of Ilizarov to orthopaedic surgery. With the different methods of segmental bone transport, long osseous tissue can be reconstructed without the

need for bone grafting. Ilizarov apparatus is axially elastic and weight bearing forces are applied to the bone ends and maintaining in the weight bearing function of the limb is one of the prerequisite for the success for the treatment. Cyclical telescoping mobility, not rigidity at the non union site is the most important requirement for the formation of callus. Ilizarov experimentally showed that when gradual distraction tension stress is applied to the corticotomy site the vascularity of the entire limb is increased which in turn enhances the ability of the bone ends to unite.[14]

In our study bone results were excellent in 75 % of cases and good in about 20 % of cases, fair in 5 % of cases and none of the cases showed poor outcome. Functional results were 40 % excellent while 55 % showed good results, 5 % showed fair results and none showed poor results. In our study age group ranges from 18 – 60 years, with males amounting 18 and females contributing to 2 cases. Whilst 19 cases were due to motor vehicle accident the lone person in our study was a case of chronic osteomyelitis, sequestrectomy followed by Ilizarov bone transport. Left sided injury was predominant in most of the cases. Most of the cases (70%) classified under Umairov type IV and 15% of cases were found to be of type I, type II – 10% and type III – 3% of cases. The

duration of treatment varies from minimum of 5 months to maximum of 13 months with mean duration of 8.8 months. Most of the cases had 2 previous surgeries. The bone defect varies from 1 cm to 6 cm with average of 3 cm.

Among the complications shortening of the limb was the most common complication occurring in about 80% of cases varying from 2cm – 3 cm which was within the acceptable limit corrected by foot wear modification. Joint stiffness the second most common complication in our study which constituted to 60% of cases, of which ankle joint involvement was predominant which was corrected by active and passive mobilisation exercises, soft tissue release and Ilizarov foot assembly was added to correct the deformity in 2 cases. Pin site infections was seen in 35% of cases which was managed by local pin site care and oral antibiotics. Despite being advised of the proper pin site care, very few patients adhere strictly to the instructions which accounts for the low functional results when compared to bone results.

Docking site non union is the relatively common complication in case of bone transport due to relative avascularity of the transporting segment. Among the 9 cases where corticotomy and bone transport done, docking site non union was seen in 6 cases which was managed

by dynamisation and bone grafting. Angular varus deformity occurring as a complication in about 20% of cases around 5 degree which was within the acceptable limit. There was no complication of non union and neurovascular deficit in our study.

Comparison of different studies:

	Our study	**Paley D et al**	**Dendrinos et al**	**Farmanullah et al**	**Madhusudan et al**
Bone results					
Excellent	75	60.87	50	58.9	22
Good	20	26.09	29	20.7	36.34
Fair	5	8.7	3.6	13.8	22
Poor	0	4.35	17.4	8.6	18.18
Functional results					
Excellent	40	64	60	56.9	5.56
Good	55	28	32	31.1	22.22
Fair	5	4	4	6.9	33.33
Poor	0	4	4	5.1	38.89

In the study of *Paley D et al*; [19]bone results were excellent in 60.87 % of cases, good in 26.09 %, fair in 8.7 % and 4.37% of the cases showed poor results. The functional results showed excellent in 64% of cases, good in 28 % of cases, fair in 4% and poor in 4% of cases. The average duration of healing was 13 months. The average age distribution was 19 – 62 years.

Another study by *Dendrinos et al*;[20] bone results were excellent in 50 % of cases, good in 29% of cases, fair in 3.6 %and poor in 17.4% of cases. Functional results were excellent in 25% of cases, good in 39.2% of cases fair in 14.13 % and poor in 2.25% of cases. The mean duration of treatment was 10 months. The limb length discrepancy was corrected to less than 2.5 cm

Another study of *Farmanullah et al*;[21] bone results were excellent in 58.9% of cases, good in 20.7% of cases, fair in 13.8% of cases and poor in 8.6% of cases. Functional results were excellent in 56.9% of cases, good in 31.1% of cases, fair in 6.9% of cases and poor in 5.1% of cases.

Another study of *Madhusudan et al* ;[22] bone results were excellent in 22% of cases, good in 36.34% of cases, fair in 22% of cases and poor in 18.18% of cases. Functional results were excellent in 5.5% of cases, good in 22.22% of cases, fair in 33.33% of cases and poor in 38.89% of cases. The average duration of fixation was 9.3 months (6.5 – 13 months)

If we compare our study with national and international studies, the result are almost the same which shows that union was achieved in all cases by the end of treatment. The patients were able to perform their normal daily activities which were not possible before trearment.

LIMITATIONS

The main limitation of the study was the sample size which was small and short duration of follow up.

FUNDING

No internal or external funding was provided for this study.

CONCLUSION

The goal of treatment in cases of infected non union and gap non union fracture of long bones is to have a well aligned, painless, healed and functional limb.

Conventional Ilizarov assembly is a better option for treatment of infected non union fracture of long bones and with bone transportation bone defects are easily corrected. Considering the complexity of the condition, it is the treatment of choice as it addresses the problems of non union, infection, deformity correction and limb length discrepancies. Sound patient selection with realistic treatment goals is the key for successful management.

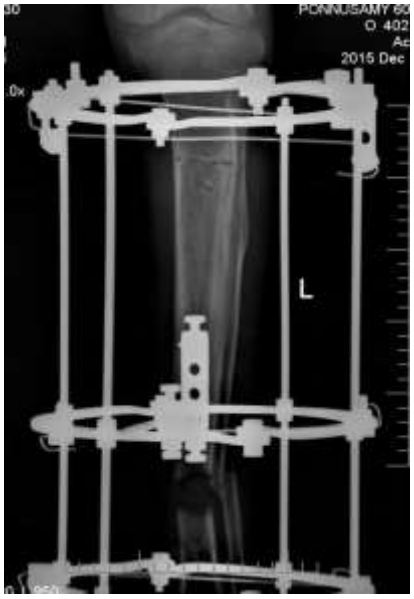
It offers a comprehensive approach in management of such difficult cases, making it a technique par excellence in treatment of infected non union and gap non union fracture of long bones.

CASE ILLUSTRATIONS

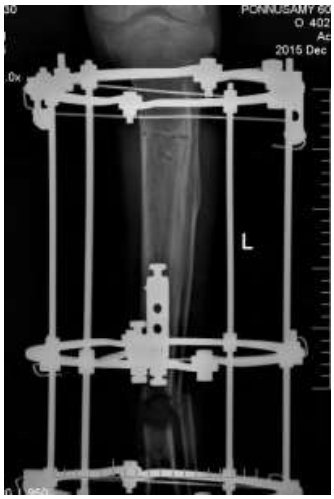
CASE : 1 Mr. PONNUSAMY 60/M

Pre-op Pictures

Immediate Post-op Pictures



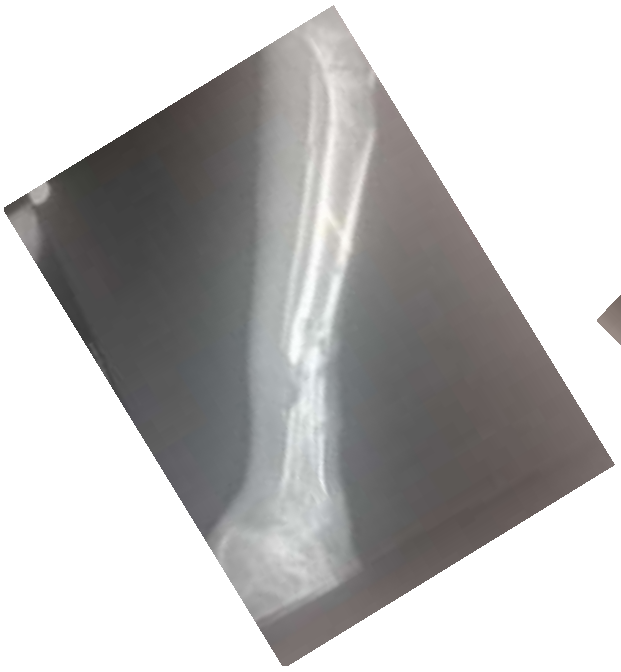
Immediate Post-op Pictures **3 months follow-up**




7 months follow-up


8 months follow-up

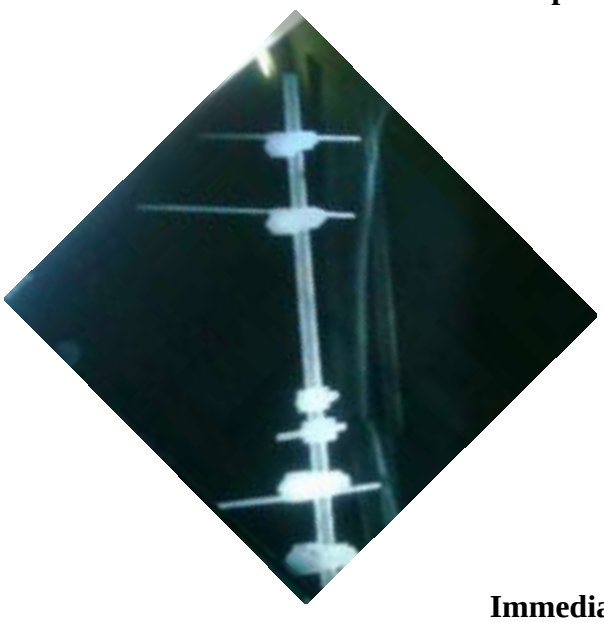
9 months follow-up – After Fixator Removal



9 months follow-up – After Fixator Removal

CASE – 2 : Mr.VASUDEVAN 55/M

Pre-op X-rays



Immediate Post-op X-rays

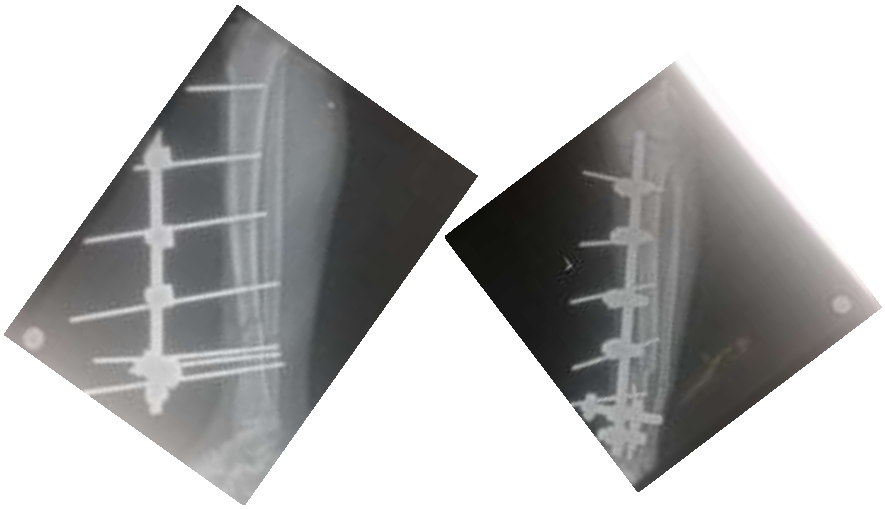
4 months follow-up

After fixator removal - 5 months follow-up

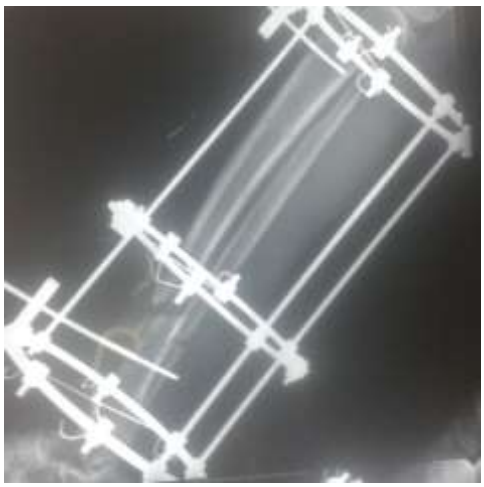
After fixator removal - 5 months follow-up

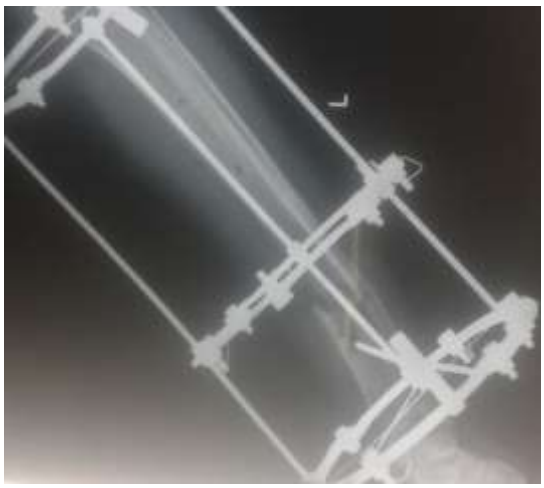
CASE – 3 : Mr.MURUGESAN 45/M

Pre-op Picutres



Immediate Post-op Picutres





5 months follow-up



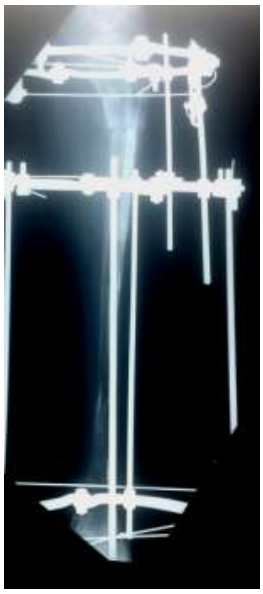
After Fixator Removal – 7 months follow-up




CASE – 4 : Mr.BALAKUMAR 44/M

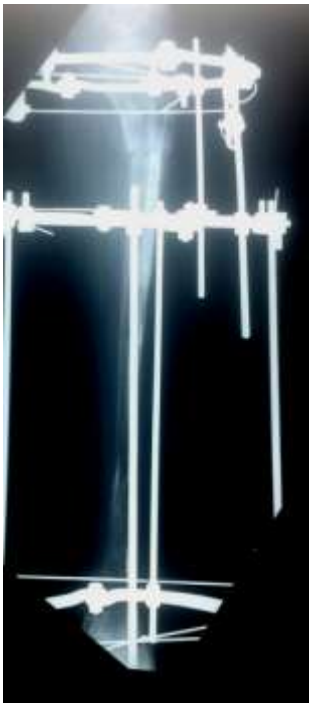
Pre-op Picutres

Post-op Picutres



8 months follow-up

13 months follow-up



Clinical Picture

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PROFORMA

EVALUATION ON OUTCOME OF MANAGEMENT OF INFECTED NONUNION AND GAP NONUNION FRACTURE OF LONG BONES BY ILIZARO METHOD

Case no: ..... Unit: .....

Name: ..... Age / Sex: .....

I .P.No.: ..... Occupation : .....

Address : .....
.....

Mobile No.: .....

Date of Injury:.....

Date of Admission: .....

Date of Surgery : .....

Date of discharge : .....

Date of previous surgery (if any) :.....

Mechanism of injury:

Road traffic accident ii) Accidental fall iii) Industrial injury

iv) Assault

Co morbidities:

i) Diabetes mellitus ii) hypertension

iii) bronchial asthma iv) TB

v) Cardiovascular disease vi) peripheral vascular disease

General examination:

Conscious

Oriententation to time ,place, person

Febrile/ afebrile

Side of involvement:

Right
Left

X RAY Findings

TYPE OF NONUNION

(ACCORDING TO PALEYS CLASSIFICATION/ KULKARNI MODIFICATION OF CLASSIFICATION / UMAIROV CLASSIFICATION)

Associated injuries: (yes/ no)
If any
Treatment history :
Treatment elsewhere:.
Treatment in our institution:
I nitial management:

Time interval between initial fixation and definite fixation :.....
Operative notes:

Anaesthesia:.....

Procedure

Post Operative complications : I f any .....

CORTICOTOMY AND BONE TRANSPORT : (If any)

Distraction started on..... Rate :.....(mm/ day)

Rhythm :.....

Distraction stopped on.....

Realignment of the fixator : I f any .....

Bone grafting for Docking site .....

Dynamisation of the fixator .....

Duration of consolidation : .....

Date of removal of the fixator :.....

Physiotherapy .....

Post Operative mobilisation :

Duration of immobilisation with P LASTER OF PARIS cast following removal of the fixator:.....

FOLLOW UP VISITS:

MONTHS	X rays	REMARKS
1		
2		
3		
4		
5		

COMPLICATIONS: IF ANY

1. Shortening :.....
2. Deformity :.....
3. Joint contractures .....
4. pin tract infection .....

BONE RESULTS (ASAMI CRITERIA).....

FUNCTIONAL RESULTS:.(ASAMI CRITERIA

MASTER CHART

S.NO.	NAME	AGE	SEX	I.P.NO	SIDE OF INJURY	MODE OF INJURY	TYPE OF NONUNION	NO. OF PREVIOUS SURGERIES	DURATION OF FIXATOR (MONTHS)	BONE DEFECT ((CM)	PINTRACT INFECTION	DEFORMITY	SHORTENING	REALIGNMENT	DOCKING SITE NONUNION	SOFT TISSUE PROCEDURE	KNEE MOBILITY	ANKLE MOBILITY	BONE RESULTS	FUNCTIONAL RESULTS
1.	VASUDEVAN	55	M	68967	R	RTA	IV/3A	2	5	2	-	5	2	-	-	SSG	N	S	E	G
2	VIJAYAKUMAR	55	M	68940	L	RTA	I/2	1	7	-	--	-	-	-	-	-	N		E	E
3	SIMON	50	M	60453	L	RTA	I/2	1	11	-	YES	-	-	-	-	-	N		G	E
4	SUDHA	40	F	35601	R	RTA	IV/3A	4	7	4	YES	-	1	-	-	SSG	S	S	G	G
5	RANJITH KUMAR	18	M	18228	L	RTA	IV/3A	2	12	5	YES	-	1	YES	-	SSG	S	-	E	G
6	PONNUSAMY	60	M	63018	L	RTA	IV/3A	2	9	5	-	3	1	-	YES	-	S	-	E	G
7	NELSON	38	M	61432	L	CO	IV/3A	1	11	2	-	-	-	-	-	-	N	N	E	E
8	SAMPATH	50	M	69161	R	RTA	II/3A	1	7	1	-	-	1	-	-	-	N	N	E	E
9	VINOTH KUMAR	25	M	44684	R	RTA	IV/3A	2	10	2	-	-	2	YES	-	SSG	N	N	E	E

M-MALE, F-FEMALE, R-RIGHT, L-LEFT, RTA- ROAD TRAFFIC ACCIDENT, SSG-SPLIT SKIN GRAFTING, CO- CHRONIC OSTEOMYELITIS
S- STIFFNESS, DCI- DEFORMITY CORRECTION BY ILIZAROV, N-NORMAL , TL- TENDOACHILLES LENGTHENING,
E-EXCELLENT, G-GOOD, F-FAIR, P-POOR

S.NO.	NAME	AGE	SEX	I.P.NO	SIDE OF INJURY	MODE OF INJURY	TYPE OF NONUNION	NO. OF PREVIOUS SURGERIES	DURATION OF FIXATOR (MONTHS)	BONE DEFECT ((CM)	PINTRACT INFECTION	DEFORMITY	SHORTENING	REALIGNMENT	DOCKING SITE NONUNION	SOFT TISSUE PROCEDURE	KNEE MOBILITY	ANKLE MOBILITY	BONE RESULTS	FUNCTIONAL RESULTS
10	RAMESH JONH BOSCO	46	M	58538	R	RTA	I/3A	1	7	1	YES	-	-	-	-	-	N	N	G	E
11	MURUGAN	30	M	556916	L	RTA	IV/3C	2	10	-	YES	-	3	2	YES	-	N	DCI	F	F
12	VIJAY	18	M	322129	R	RTA	IV/3A	4	8	5	-	-	1	YES	YES	SSG	N	DCI	E	G
13	BALAKUMAR	44	M	45751	L	RTA	IV/3A	2	13	6	-	5	1	YES	YES	FLAP	S	S	E	G
14	ARUNAGIRI	38	M	92089	R	RTA	IV/3A	2	8	5	YES	-	I	YES	YES	-	N	N	E	E
15	VINOTH	23	M	94619	R	RTA	IV/3A	1	6	1	-	-	1	-	-	SSG	N	S	E	G
16	DILLIBABU	29	M	40392	R	RTA	IV/3A	2	11	6	-	-	2	YES	YES	SSG	N	S/ TL	E	G
17	JANAKIRAMAN	23	M	32312	L	RTA	IV/3A	2	7	2	-	-	2	YES	-	-	N	S	E	G
18	MURUGESAN	45	M	93512	L	RTA	II/3A	2	7	1	-	3	2	-	-	-	N	N	E	E
19	SELVARANI	30	F	62208	L	RTA	IV/3A	2	8	2		-	2	-	-	-	N	S	E	G
20	JEGAN	28	M	66496	L	RTA	III/II	2	11	0	YES	-	1		-	SSG	N	S	G	G

M-MALE, F-FEMALE, R-RIGHT, L-LEFT, RTA- ROAD TRAFFIC ACCIDENT, SSG-SPLIT SKIN GRAFTING, CO- CHRONIC OSTEOMYELITIS
S- STIFFNESS, DCI- DEFORMITY CORRECTION BY ILIZAROV, N-NORMAL , TL- TENDOACHILLES LENGTHENING,
E-EXCELLENT, G-GOOD, F-FAIR, P-POOR

INSTITUTIONAL ETHICAL COMMITTEE, STANLEY MEDICAL COLLEGE, CHENNAI-1

Title of the Work : Evaluation on the Outcome of Management of Infected Non-Union and Gap Non-Union fracture of long Bones by ILIZAROV method.

Principal Investigator : Dr. P Balasubramaniyan

Designation : PG MS (Orthopedics)

Department : Department of Orthopedics
Government Stanley Medical College,
Chennai-01

The request for an approval from the Institutional Ethical Committee (IEC) was considered on the IEC meeting held on 29.09.2015 at the Council Hall, Stanley Medical College, Chennai-1 at 2PM

The members of the Committee, the secretary and the Chairman are pleased to approve the proposed work mentioned above, submitted by the principal investigator.

The Principal investigator and their team are directed to adhere to the guidelines given below:

1. You should inform the IEC in case of changes in study procedure, site investigator investigation or guide or any other changes.
2. You should not deviate from the area of the work for which you applied for ethical clearance.
3. You should inform the IEC immediately, in case of any adverse events or serious adverse reaction.
4. You should abide to the rules and regulation of the institution(s).
5. You should complete the work within the specified period and if any extension of time is required, you should apply for permission again and do the work.
6. You should submit the summary of the work to the ethical committee on completion of the work.

MEMBER SECRETARY, 15/9/15
IEC, SMC, CHENNAI

MEMBER SECRETARY
ETHICAL COMMITTEE,
STANLEY MEDICAL COLLEGE
CHENNAI-600 001.