MANAGEMENT OF INFECTED NONUNION OF LONG BONES BY BIFOCAL OSTEOSYNTHESIS OF ILIZAROV'S PRINCIPLE WITH THE LIMB RECONSTRUCTION SYSTEM.

Dissertation submitted for

M.S. DEGREE EXAMINATION
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DECLARATION

I declare that this dissertation entitled **'MANAGEMENT OF INFECTED NONUNION OF LONG BONES BY BIFOCAL OSTEOSYNTHESIS OF ILIZAROV'S PRINCIPLE WITH THE LIMB RECONSTRUCTION SYSTEM'** is a record of work done by me in the Department of Orthopaedics and Traumatology, Thanjavur Medical College, Thanjavur, during my Postgraduate course from 2006-2009 under the guidance and supervision of my Unit Chief and Head of the Department of Orthopaedics, **PROF. DR. R. RATHINASABAPATHY, M.S. ORTH., D.ORTH**. It is submitted in partial fulfillment for the award of **M.S.DEGREE EXAMINATION BRANCH-II ORTHOPAEDIC SURGERY** to be held in March 2009 under the **Tamilnadu Dr. M.G.R. Medical University, Chennai.** This record of work has not been submitted previously by me for the award of any degree or diploma from any other university.

DR.KANAGASARATHY.K.

CERTIFICATE

This is to certify that dissertation entitled ‘‘**MANAGEMENT OF INFECTED NONUNION OF LONG BONES BY BIFOCAL OSTEOSYNTHESIS OF ILIZAROV’S PRINCIPLE WITH THE LIMB RECONSTRUCTION SYSTEM’** is a bonafide record of work done by **Dr.KANAGASARATHY.K.** in the Department of Orthopaedics and Traumatology, Thanjavur Medical College, Thanjavur during his Postgraduate course from 2006-2009 under the guidance and supervision of **PROF. DR. R. RATHINASABAPATHY, M.S.ORTH., D.ORTH.** This is submitted in partial fulfillment for the award of **M.S.DEGREE EXAMINATION -BRANCH-II (ORTHOPAEDIC SURGERY)** to be held in March 2009 under the **Tamilnadu Dr.M.G.R. Medical University, Chennai.**

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INTRODUCTION

INTRODUCTION

Nonunion of long bone fractures has become a common problem in orthopaedic practice. Non union of a fracture can occur both in conservative as well as in operative treatment. When infection is added to non union, the condition becomes intractable. The treatment gets prolonged over many years and sometimes it ends in amputation.

It is difficult to treat the non unions, more so in the case of infected non union because of the following reasons.

1. Usually the non union had been operated more than 3 to 4 times resulting in cicatrisation of the soft tissue with an avascular environment around the fracture site.

2. The sinus tract formation, leading on to the fracture site indicating dead bone or sequestrum inside.

3. To a considerable distance from the non union site of long bones, due to the thrombosis of blood vessels of Haversian cannals, resulting in necrosis of bone.

4. Prolonged immobilization, multiple operative procedures with fibrosis of the muscles leads on to a stiff joint and may have fracture disease.

5. The microorganism develops resistant to the antibiotic therapy and also poses a problem in controlling the disease.

In the past, there were several authors, who put their mind in solving the problem by many methods, where in all the factors of non union like deformity, shortening, infection and abnormal movement were managed with questionable success.

Muller[18], Thomas[26], Kousik[15] and Harrington[8] used metallic intramedullary device to solve this problem with some success.

Phemister[25] and Judet[12] concentrated on the viability of the fracture ends by massive onlay bone grafting that is also not very much useful.

Meyer et al[20] used plate osteosynthesis and an additional external fixator to increase the stability of non union site.

In all the above methodology, there is no way, by which vascularity of the non union site could be improved.

Later, the Russian Surgeon **G.A.Ilizarov** devised a method by which the basic factors of infected non-union like abnormal movements, gap, sinus and the poor vascularity of the ends were managed by a single procedure with predictable success.

The concept of ***Bifocal osteosynthesis*** is distraction at osteotomy site and compression at non-union site.

Rhythmical distraction leads on the neo-osteogenesis and consolidation of corticotomy site. This procedure of transporting a segment of bone increases the vascularity of the fracture ends.

Once the vascularity of the fracture ends increases, the infection will be eradicated and there will be healing of non-union.

Hence we have decided to study the effect of segmental transport in the management of infected, non-union of long bones by **Ilizarov's** concept using the **Limb Reconstruction System**.

AIM OF THE STUDY

AIM OF THE STUDY

The aim of the study is to treat the intractable infected non-union of long bones by bifocal osteosynthesis of **Ilizarov's** principle with Limb Reconstruction System.

HISTORICAL REVIEW AND LITERATURE

HISTORICAL REVIEW

In 1900s, **CodiVilla**[3] published the first results of a method of elongation of lower extremity.

In 1911, Bosworth reported that **Dr.O.Lambotte**[18] of France was the first to use the technique of distraction and transfixation.

In 1918**, Putti**[27] utilized Piano wires in his distraction apparatus.

In 1936, **Anderson**[2] reported on his experience in femoral lengthening.

Many types of fixators and different techniques have been used for lengthening (distraction histogenesis) and to fill in the Osseous defects (distraction Osteogenesis). The concept of segmental transport by distraction Osteogenesis has been credited to **Gavrill Abramovich Ilizarov**, a Russian Orthopaedic Surgeon who, through his research in soft tissue and bone regeneration, has filled large segmental defects.

Until recently the Russian Research and clinical experience was virtually unknown to other parts of the world, because of travel barriers and general unfamiliarity with Soviet publications.

In 1951, **Ilizarov** conceived his methods in Kurgan, Siberian. It is said that one patient accidently turned the connecting rods between the rings in distraction rather than compression.

Ilizarov observed new bone formation radiologically following this distraction. Recognizing the potential significance of this observation, he initiated a series of experimental work in animals.

Ilizarov's methodology marks the beginning of a new scientific and practical concept, which has allowed the evaluation of new, previously unknown biologic laws regarding bone transmission, osteoinduction and tissue neogenesis.

As early as 1983, prominent Orthopaedic Surgeons like **Sarmiento and Macewan** were first to export Prof.Ilizarov's work.

Green[7], one of the pioneer in this subjects of non union has applied Prof.Ilizarov's technique in the management of infected non union in United States.

Over the years, the method proved to be so widely applicable and effective that the Association for the Study and Application of the Methods of Ilizarov **(ASAMI)** was established in Lecco, Italy, in 1982.

Further development of the method and devices has extended its indications in the treatment of fractures and their complications, especially to chronic osteomyelitis accompanied by the bone loss, infected nonunion, shortening of extremities, deformaties, and joint contracture.

Patients with such diagnoses have usually been treated by a series of different surgical treatments, including sequestrectomies, drainage, and massive cancellous bone grafts. These techniques are often unsuccessful, because the infection is difficult to eradicate due to poor vascularization of the bone. In addition, the grafts introduce a foreign body, and the resistant bacteria may develop as the result of a long-term antibiotic administration. Such patients are the candidates for treatment by the Ilizarov method.

Ilizarov method consists of extensive removal of all infected tissues, application of an external fixator, and correction through distraction osteogenesis, deangulation, and compression. The most important element of the Ilizarov treatment is distraction osteogenesis, which involves bone transport and the formation of new bone by intramembranous ossification.

Distinct advantage of the Ilizarov treatment is active use of the affected limb to improve its physiological function, which consequently minimizes the development of disuse osteoporosis and atrophy of soft tissues.

However, there exists some subjective discomfort regarding the use of Ilizarov fixator in proximal femoral nonunions. This led to the emergence of more patient-friendly modification of the apparatus.

In 1979, **De Bestiani** introduced a new design of external fixator (**Orthofix**) and reported their results in 1984. The purpose of this study is to review our results using this device in the management of infected non union of long bones.

The Original **Orthofix Dynamic Axial Fixator** , often referred to as the “DAF”, was designed by **De Bastiani** to allow the release of axial forces in the external frame at an appropriate point in the healing cycle, thus transferring a progressive load to the fracture site.

CLASSIFICATION OF INFECTED NON-UNION AND ITS MANAGEMENT

CAUSES AND CLASSIFICATION OF NON-UNION

CAUSES OF NON UNION:

1. Excess motion

   Due to inadequate immobilization

2. Gap between fragments
   a. Soft tissue interposition
   b. Malposition or over riding or displacement of fragments
   c. Loss of bone substance.
   d. Distraction by hardware or traction
3. Loss of Blood supply
   a. Damage to nutrient vessels
   b. Excessive stripping or injury to periosteum and muscles.
   c. Free fragment, severe comminution
   d. Avascularity, due to hardware
4. Infection
   a. Bone death (Sequestrum)
   b. Osteolysis (Gap)
   c. Loosening of implants (Motion)
5. General (Predisposing factors)

   Age, Nutrition, Steroids, Anticoagulants, Radiation etc.

CLASSIFICATION OF NON-UNION:

The non unions are classified into :

1. Viable non union.
2. Non-Viable non union.

The viable non-union further classified into :

1. Elephant foot type.
2. Horsehoof type.
3. Oligotrophic type.

Non-viable non-union further classified into:

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

The above classification based on the viability of fracture ends with or without infection. It is a radiological classification.

ILIZAROV'S CLASSIFICATION:

1. Stiff Non Union,
2. Mobile Non Union.

1. Stiff Non Union:

When the fracture ends are showing good hypertrophic new bone formation without evidence of movement, it heals readily under axial compression.

2. Mobile Non union:

Clinically the fracture site is mobile, relatively with poor vascularity with diffuse infection or presence of sequestrated bone. In this clinical situation, restriction of two ends so as to transform the type of non-union into loss of substance. Hence a bifocal osteosynthesis (segmental transport) is a method of choice.

CLASSIFICATION OF INFECTED NON-UNION AND ITS MANAGEMENT

The infected clinical non union is defined as that state of fracture healing when, after a duration of time (4 to 6 months) has elapsed, there is no evidence that the fracture will heal. Therefore other methods of treatment must be taken inorder to achieve fracture healing – ***Roman Gristilo***[25].

Fracture healing can occur,when there is a decreased bacterial activity provided there is stability of fracture with surrounding vascular environment. Therefore two goals are essential to be successful in the treatment of non union.

They are :

(i) Viable environment around the fracture site and

(ii) Fracture stability.

TYPES OF INFECTED NON – UNION

1. Infected Non draining non union
2. Infected Draining non union

Infected non draining non union are treated like non infected non unions, but potentially infected fibrous tissue or granulation tissue and sequestra are excised. They are fixed with plates and systemic appropriate antibiotics are used.

INFECTED DRAINING NON-UNION:

In this type, the treatment was eradicating the infection first. If the implant is infected and loosened, it should be removed. Sinus tract and infected soft tissue are excised. Thorough radical debridment to be done.

The direct attention was shown towards the healing of non union by various methods of stabilization like, external fixation, plating, intramedullary nailing, cancellous bone grafting and Papineau procedure.

In all these procedures, malposition, angulation, malrotation, translation or combination of these were present.

The most important difference between a potential success and a possible failure is considered to be the presence of either a fracture gap or a Necrotic bone at the fracture site.

According to **Ilizarov**, biological stimulation of corticotomy site eliminates infection and increases vascularization at the osteomyelitis site.

The treatment for hypertrophic nonunion with minimum amount of infection and no sequestrated bone is monofocal compression.

In atrophic nonunion with diffuse infection or sequestrated bone, open resection of the infected segment must be carried out, so as to transform this type of non union in to a loss of substance.

When an infected nonunion has a poor skin quality with numerous fistulae, stabilization with apparatus following necrotic bone resection leaves a gap non-union. This gap non-union should be treated by segmental transport.

GENERAL PRINCIPLES OF TREATMENT OF NON-UNION

GENERAL PRINCIPLES OF TREATMENT OF NONUNION

(1) The principles of treatment of nonunion **begins with** removal of all foreign materials including of all metallic fixators, necrotic infected bone, (Sequestrum). Fracture ends should be cut in such a way to increase the surface area of the opposing bone ends. The repairing process begun by restimulating a local inflammatory response. Stabilization with transosseous osteosynthesis allows the mechanical stimulus influence the local vascularization.

(2**) Second** objective is to mobilize the joint to avoid contracture and arthrofibrosis. This was well planned by an idea of full weight bearing in the lower limb and use of dumbles in the case of upper limb.

(3) **Third** objective is the union of bone in a reasonable amount of time. For a good successful treatment in this procedure, it is important to evaluate the personality and psychosocial status of the patient who had already undergone many procedures, long hours of rehabilitation, pain, economic distress and family problems.

(4) **Fourth** objective is eradicating the infection by the administration of antibiotics.

Multiple surgical procedures like sequestrectomy and multiple drilling are also performed in the case of infected non union.

The distraction compression osteosythesis increase the blood supply of the whole limb as well as the fracture site. When the patient is in full weight bearing, there will be interfragmentary compression at non-union site.

DISRACTION OSTEOGENESIS

DISTRACTION OSTEOGENESIS

Distraction Osteogenesis is the mechanical induction of new bone between bone surfaces, that are gradually pulled apart. It is a process initiated by the application of tension stress across the osteotomy / corticotomy site.

According to **Prof.Ilizarov**, the stimulation is represented by distraction at the corticotomy site and compression at the Non Union site.

There are two parameters know to affect the process of distraction osteogenesis.

1. BIOLOGIC FACTORS

These include the type of osteotomy, its level and latency period, before distraction.

2. MECHANICAL FACTORS

These include the stability of fixation, rate and rhythm of distraction.

Instability will cause a wandering type of regenerate bone formation and too rigid type of construct may lead to delay in consolidation.

BIOLOGY OF DISTRACTION OSTEOGENESIS

During distraction, a fibro vascular interface is aligned parallel to the direction of the distraction, while new bone columns add length to the gap.

When the biological and mechanical conditions during distraction are ideal, bone is formed by intra-membranous ossification.

HISTOLOGY

Biopsies were taken from mid-sagittal plane along the tibial crest of the experimental animal. A Bron will saw was used to section the bones. Back scattered scanning electron microscopy confirmed microradiographic measurements with three dimensional orientation and localized Calcium deposits by microprobe analysis.

Earliest specimen came from day 7 of distraction at a rate of one millimeter per day and a rhythm of 0.25 millimeter four times a day. At this point intime, a fibrovascular network bridged the distraction gap. There was no evidence of new mineralization.

Large vascular channels surrounded each micro-cone of bone on all surface. These vessels contained a thin lining of endothelial cells, with internal diameters upto 400 microns.

VASCULAR STUDIES

India Ink injection at sacrifice on day 35 demonstrated both afferent and efferent vessels across the osteogenic area. In coronal section, very few vessels crossed the fibrous interzone.

The vessels were clearly oriented parallel to the distraction force and the new columns of bone. Technetium scintigraphy provided an in Vivo measurements of blood flow and bone formation related to normal zone in the experimental model.

MINERAL DENSITY STUDIES

Plain radiography was adequate for documenting the weekly changes in bone alignment and gap formation during distraction. The bridging of the Osteogenic area and remodeling of the bony macrostructures into cortex and medullary canal was assed is Q.C.T. (quantitative computer tomography) clearly demonstrated the volume of mineralization with in Osteogenic area proceeded visualization by plain radiography.

Calcium quantification was done by two millimeter transverse sections taken through osteogenic area correlated with each corresponding QCT cut. (Quantitative Computer Tomography).

MECHANICAL FACTORS

The rate of distraction should remain with in a range of one millimeter per day. Slower rates allow normal fracture healing to proceed and prematurely bridge the gap. Faster rates seem to outstrip the advancing blood supply inhibiting mineralization.

Rhythm is defined by the number of actual distractions each day.

Adequate Osteogenesis occurred at rhythm of 0.25 millimeters every six hours. At one millimeter once daily, osteogenesis is significantly inhibited.

Latency is the time period between the operation and the initiation of distraction. The average recommended latency is from four to seven days. Osteogenesis will proceed in an angular fashion, but the angles may be unintended.

Jorge.E.Alonso[11] and Pietro Regazzoni, have divided the treatment period into three phases :

1. Transport phase
2. Maturation phase
3. Consolidation phase.

TRANSPORT PHASE

This phase is the period from the initial advancement of the segmental defect until the end of the transport, when the transported segment contacts the other fragment (Docking). Ilizarov has demonstrated that intramembranous ossification occurs during distraction.

MATURATION PHASE

During this phase, an increase in mineral content of the regenerate area can be seen. The quality of regenerate can probably be improved by soft tissue coverage of the open areas with rotational or free vascularized flaps.

CONSOLIDATION PHASE

This is the compression phase, during which the cortical bone content increases to about 80% according to **Prof.Ilizarov**. Once the segment reached the distal fragment, the interphase can be improved by methods like plating and cancellous autografting to reduce duration of the consolidation phase.

The term ***"Dynamization"*** was originally applied by **De Bastiani** to describe the transfer of a progressive load to the fracture site at a given point in the healing cycle.

The two main types of movement which fall under this category are:

- Cyclic micromovement
- Progressive loading.

MATERIALS AND METHODS

MATERIALS AND METHODS

The material for this study consists of 16 patients with infected non-union of long bones, who were admitted in Thanjavur Medical College Hospital from July 2006 to March 2008.

The Inclusion criteria for the study includes those with infected nonunion of long bones.

The Exclusion criteria includes :

(1) Noninfected nonunions,

(2) Intra-articular fractures and

(3) Fractures with neuro-vascular deficit.

Diagnosis was established in all patients by the history and physical examination and the investigations. A history is taken from the patient including the date of injury, the detail of original accident and subsequent treatment.

On presentation, the following were evaluated :

(1) limb length measurements,

(2) range of motion of the joint,

(3) condition of skin and vascularity,

(4) co-existing ligamentous instabilities and

(5) general medical condition.

The condition of soft tissue surrounding the non-union site is of paramount importance, because the presence of a cicatric, a draining sinus or a thin and un-yielding soft tissue envelope will certainly limit or redirect the surgical methods to be used.

Preoperative radiographs of the affected extremity were taken. Anteroposterior and lateral X rays were taken and evaluation were made.

EVALUATION OF RESULTS :

Bone healing and functional results were evaluated according to a modified Association for the Study and Application of the Method of Ilizarov **(ASAMI)** classification.

Bone healing was evaluated as follows:

An *excellent* result was defined as a union without infection , with less than 7° deformity and less than 2.5 cm leg-length inequality.

A *good* result was defined as a union, with two out of three criteria for an excellent result present.

A *fair* result was defined as union with one of the three criteria present.

A *poor* result was a non-union or refracture, without any of the above three criteria fulfilled.

Functional assessment was based on five criteria:

(a) Observable limp,

(b) Stiffness of knee or hip (loss of >70* of knee flexion, or loss of >15* of extension; loss of >50 % hip motion in comparison with the normal contralateral side),

(c) Soft tissue sympathetic dystrophy,

(d) Pain, that reduced activity or disturbed sleep, and

(e) Inactivity (because of unemployment or an inability to return to daily activities due to the injury).

The functional result was classified according to the following criteria:

An *excellent result* was if the patient was active, able to accomplish his/her daily activities, and the other four criteria were absent.

A *good result* was if the patient was active, but one or two of the other criteria were present.

A *fair result* was if the patient was active, with three or four of the other criteria present.

A *poor result* was if the patient was inactive, regardless of the presence of other criteria.

SURGICAL TECHNIQUES

SURGICAL TECHNIQUES

ANAESTHESIA

For upper limb, the surgery was performed under general anaesthesia. For lower limb, the patient was given spinal anaesthesia.

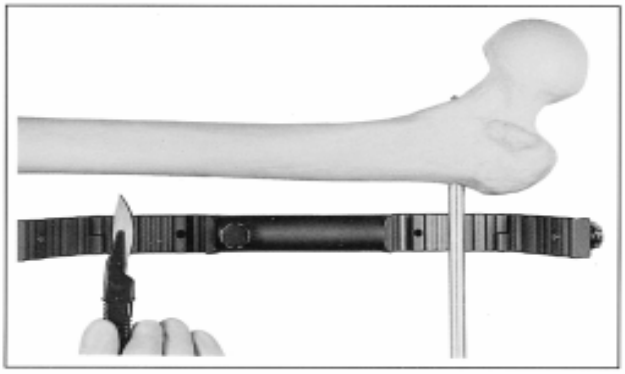
All operations were done at the regular operation theatre under aseptic precautions. Initially, a thorough wound debridement was done along with removal of sequestrum and infected, necrotic materials followed by application of Limb Reconstruction System. Intravenous antibiotics were given postoperatively.

As a secondary procedure, and open corticotomy performed. Among the other cases, where there was florid/active infection, corticotomy was deferred, until infection settled.

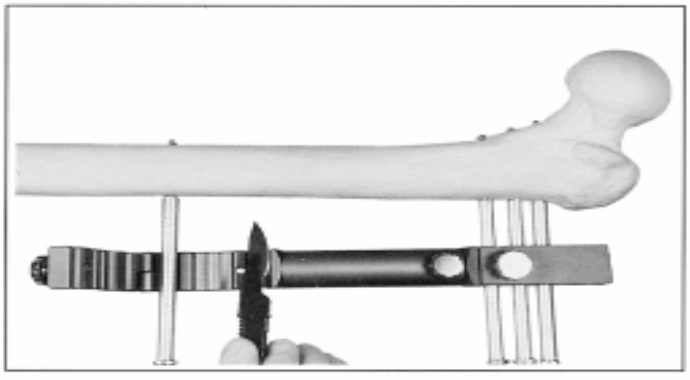
FIXATION

The first screw to be inserted is the most proximal one, which will engage the thick calcar bone at a point just above the lesser trochanter, avoiding the capsule of the hip joint. The appropriate screw guide is now selected and inserted using the trocar to locate midpoint of bone. It is then locked into 4^{th} seat of proximal clamp of bone. The correct length 4.8mm

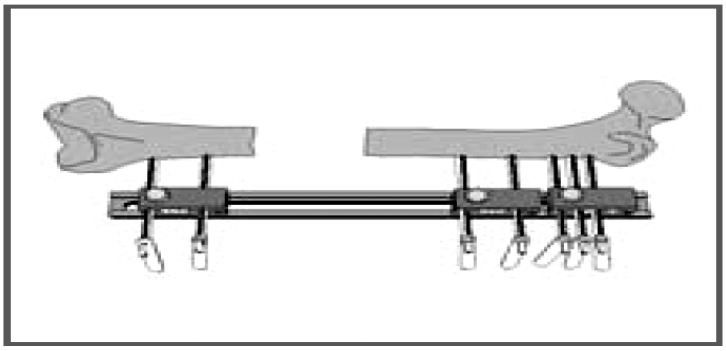
drillguide is now inserted into screw guide and using 4.8mm drill bit, first and second cortices are drilled. Both are then removed and Schanz screw is inserted using T-handle.



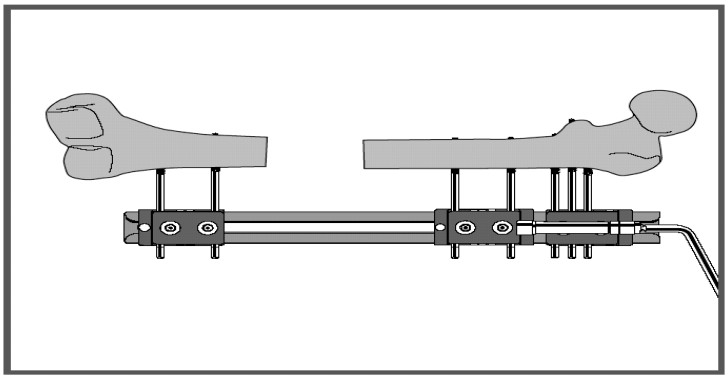
The next screw to be inserted is the most distal one. The position of distal screw is critical, since, if it is incorrectly placed, the screws in the middle clamp may miss the bone.



The screw seats **1, 2 and 4** (starting from proposed osteotomy site) in proximal clamp are used. Among the middle and distal clamps, screw seats **1 and 5** are used..



The remaining screws are inserted in a similar fashion and the clamp templates are locked to the rail. The Limb reconstruction system is now applied.The clamp templates are now removed and straight clamps are applied at distance of 2cm between the skin and the rail.



CORTICOTOMY :

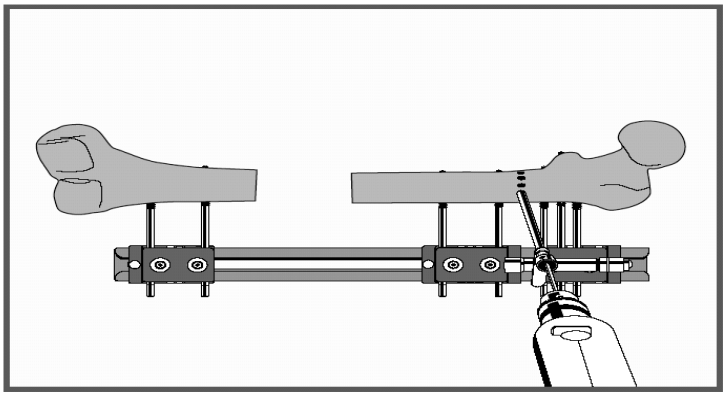
The original technique described by **De Bastiani** (De Bastiani et al. 1987) was a corticotomy rather than an osteotomy, since it was originally thought important to preserve the medullary blood supply. It is difficult to achieve a true corticotomy, however, and since there is now considerable

evidence of the rapid recovery of the medullary blood supply following a complete osteotomy, the latter is normally performed today.

It is important, however, to preserve the periosteum, since this layer has been demonstrated to be a most important site of osteogenesis **(Kojimoto et al)**. The site chosen for the osteotomy should ideally, be metaphyseal or immediately submetaphyseal, since this is a wider and more vascular region and has been shown to have better osteogenic potential than the diaphysis **(Aldegheri et al).**

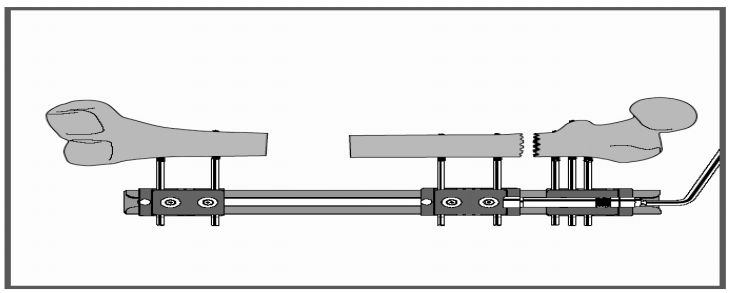
Once the frame has been constructed, attention is paid to the osteotomy site, the osteotomy is performed with a small, sharp osteotome. Three fourth of the bone circumference can be cut this way. The remaining portion must be fractured. This can be accomplished by leaving the osteotome 90 degrees or by turning the pins back and forth. Osteotomy was completed. The transport fragment is then advanced 1 mm to ascertain that the osteotomy is complete. Then the wound is closed without any distraction.

A screw guide with drill guide is now placed on the bone and a series of controlled drill holes made across the bone, penetrating the farcortex each time. A drill stop is used to prevent damage to the soft tissues.

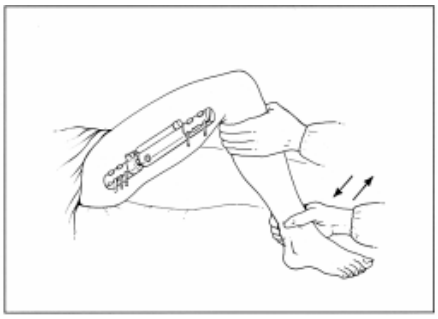


The holes are now connected with an osteotome and since the bone has been pre-tensioned the bone ends will gently drift apart once the osteotomy has been completed.

Completeness of the osteotomy is confirmed by exploration of the gap using a probe, assessment of the ease of distraction and the appearance under image intensification.



The osteotomy is then gently compressed, the periosteum reconstituted in cases,where it has bee incised, and the wound closed with a drain.



The knee is now flexed and extended to ensure that the skin around the screws is not under tension and to allow for easy movement of muscles and fascia. An X-ray is taken to check that the lengthener has been mounted parallel to the diaphysis.

POST OPERATIVE MANAGEMENT

Distraction started after a lag period of **7 to 10 days**, following which a distraction of **1 mm / day** was done. This distraction was done rhythmically at a rate of **0.25 mm every six hours.** The patient was given training in rhythmic distraction, and advised it was important to follow the same till the distraction is over. The rate of distraction should be temporarily increased, where rapid ossification is observed or reduced, if ossification is slow or if the patient complains of pain or muscle contraction.

The actual time points at which progressive loading and weightbearing will occur will depend upon whether the fracture is stable or unstable. As a general rule, however, it can be stated that in **stable** fractures, progressive loading should commence 2-4 weeks postoperatively, and in **unstable** fractures, 5-8 weeks post-operatively.

The patient should commence weight bearing with crutches the day after the operation. The waiting period before starting distraction is normally **ten days** in adults and about **five days** in children and patients with rapid ossification

After **1 cm** of lengthening has been achieved, an X-ray is performed to ensure that distraction is taking place correctly. The patient is then allowed to leave hospital.

OUTPATIENT FOLLOW-UP

An X-ray is then taken every **30-40 days** to check that osteogenesis is occurring, in which case lengthening is continued.

If the density of the lengthened portion is poor, but uniform, lengthening is stopped for one or two weeks. If the callus is irregular, the

segment is compressed by one or two centimetres at the same rate as for lengthening, until the callus is uniform, when lengthening is resumed.

At the end of lengthening, the X-ray should show a uniform callus. The lengthener body is now locked to maintain the new bone in stable neutralization. The compression-distraction unit is no longer required and is removed at this stage to make the assembly lighter.

When the X-ray shows that the segment is uniformly dense and opaque, dynamization is commenced by loosening the central body locking nut. During dynamization, weightbearing on the lengthened limb should be total.

FIXATOR REMOVAL

Pins were removed, once we see periosteal tube at the distraction site and atleast **3 cortices** in AP and lateral views. The lengthener is removed, once X-rays and clinical assessment indicate good bony consolidation. Radiological and clinical review should be carried out **6 months** after fixator removal.

First, the central body locking nut is tightened to maintain the exact length of the fixator prior to removal, in case the fracture should require a further period of fixation. The fracture can be manipulated after removal of the fixator to ensure that clinical healing has been achieved.

If there is any doubt regarding clinical and radiological healing and provided the screws are well-tolerated, the fixator can remain in situ for a further period of two weeks.

If the clinical and radiological healing has been achieved, the fixator and screws can be removed immediately as a simple outpatient procedure. The screw entry holes are then usually dressed every two days,until they close spontaneously, which normally takes place after **7-10 days.**

INSTRUMENTS AND IMPLANTS

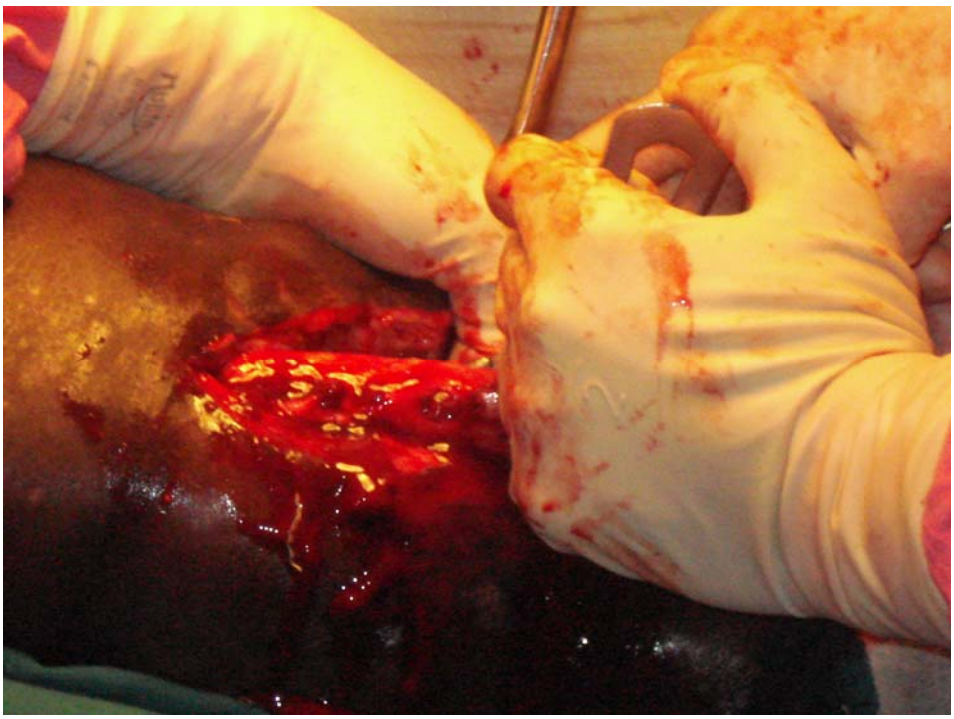
SURGICAL TECHNIQUES

Infected Non-union – femur

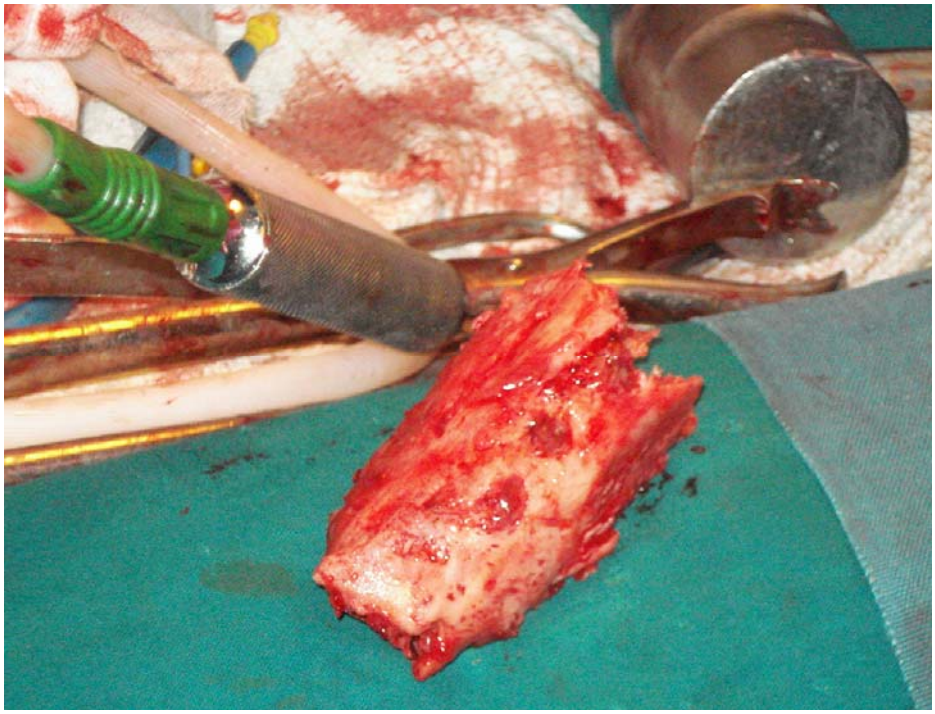
Regional Anaesthesia

Intra operative C-Arm guidance

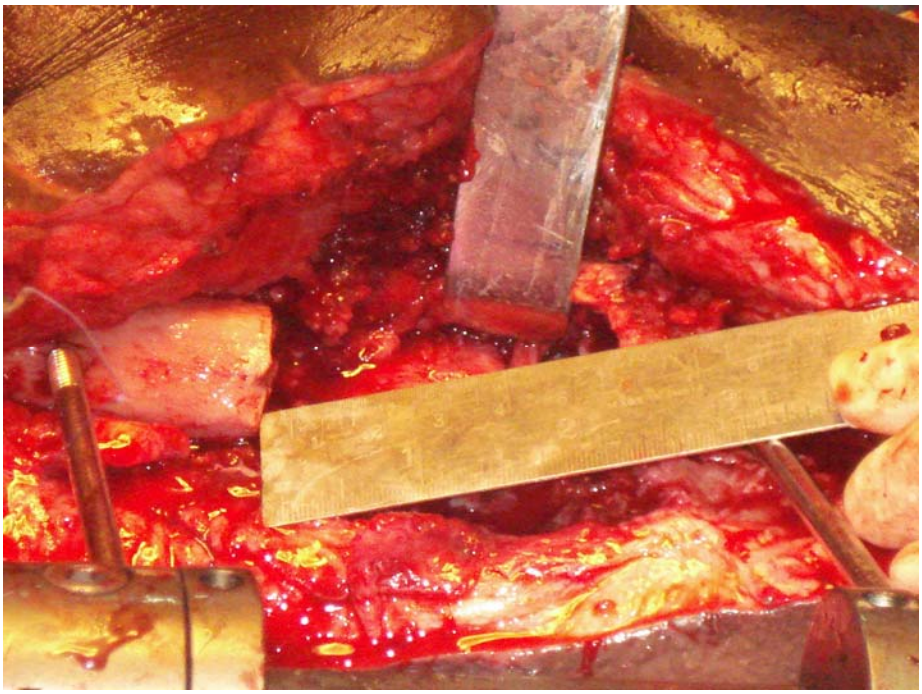
Sequestrectomy



Sequestrum



Post sequestrectomy defect measured



Corticotomy & bone transport

Follow - Up

Early Mobilisation

OBSERVATION AND RESULTS

OBSERVATION AND RESULTS

The site of nonunion and number of cases are shown in Table 1.

Table 1

Site of Non Union	No. of Cases
FEMUR	9
TIBIA	6
HUMERUS	1

The duration of nonunion varies from 6 months to 15 months. The details are given in Table II

Table II

Site of Non Union	Average duration of nonunion
FEMUR	8 months
TIBIA	7 months
HUMERUS	15 months

Twelve cases out of 16 cases were open fractures and 4 cases out of 16 were due to infected implants.

The gap at non union site varies from 1.2 cm to 6 cm.

Male patients 14 and female 2. The age group varies from 8 years to 46 years. Details were given in table III.

Table III

Age	No. of cases
Less than 20	2
20 – 29	2
30 – 39	6
40 - 49	6

All the 16 cases presented to us with discharging sinus except one case. Details are given in Table IV and V.

2 cases out of 16 cases went stiff non union. 14 cases out of 16 cases were mobile non union.

In the last 21 months, we treated 16 cases of infected nonunion. Our follow up varies from 4 months to 12 months, with an average of 8 months.

The nonunion site united in all the cases by the end of 12 week. The sinus got cleared in all the 16 cases by the end of 5^{th} week. There was no difficulty in this series as far as the transportation phase in concerned.

There was a considerably delay in the consolidation phase in all cases. Of them, 2 cases had pin tract infection. Hence the fixator was removed and functional cast brace was applied.

After a period of waiting for the consolidation to occur, the final result of the healing of the osteotomy with good bone healing in about 8 cases, a delay in healing in 6 cases, 2 cases had delayed union, which

needed bone grafting. In all the cases, there was no infection in the osteotomy site.

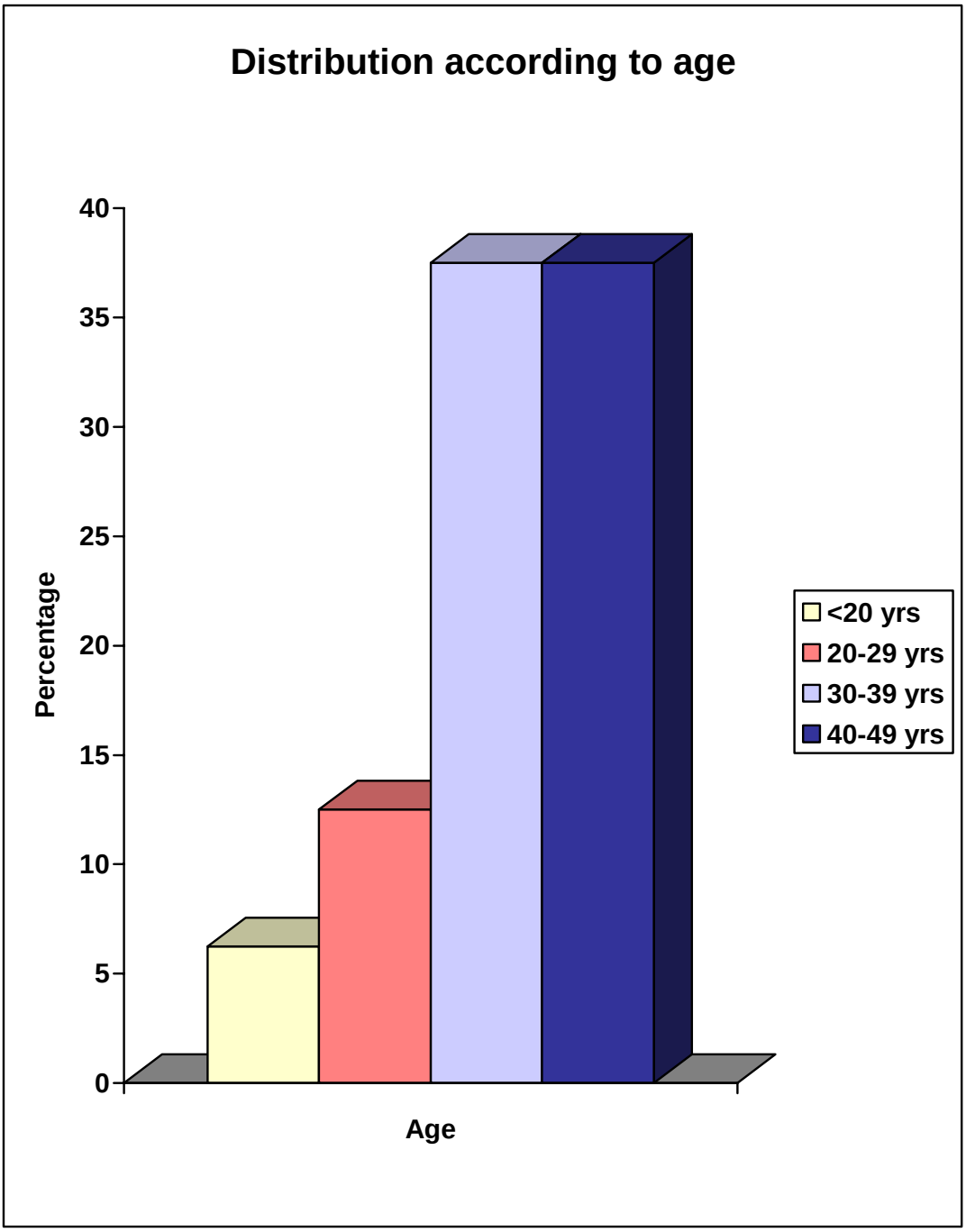
The pin tract infection was seen in 2 cases. Mostly in proximal pin site in 1 case and at distal pin site in 1 case.

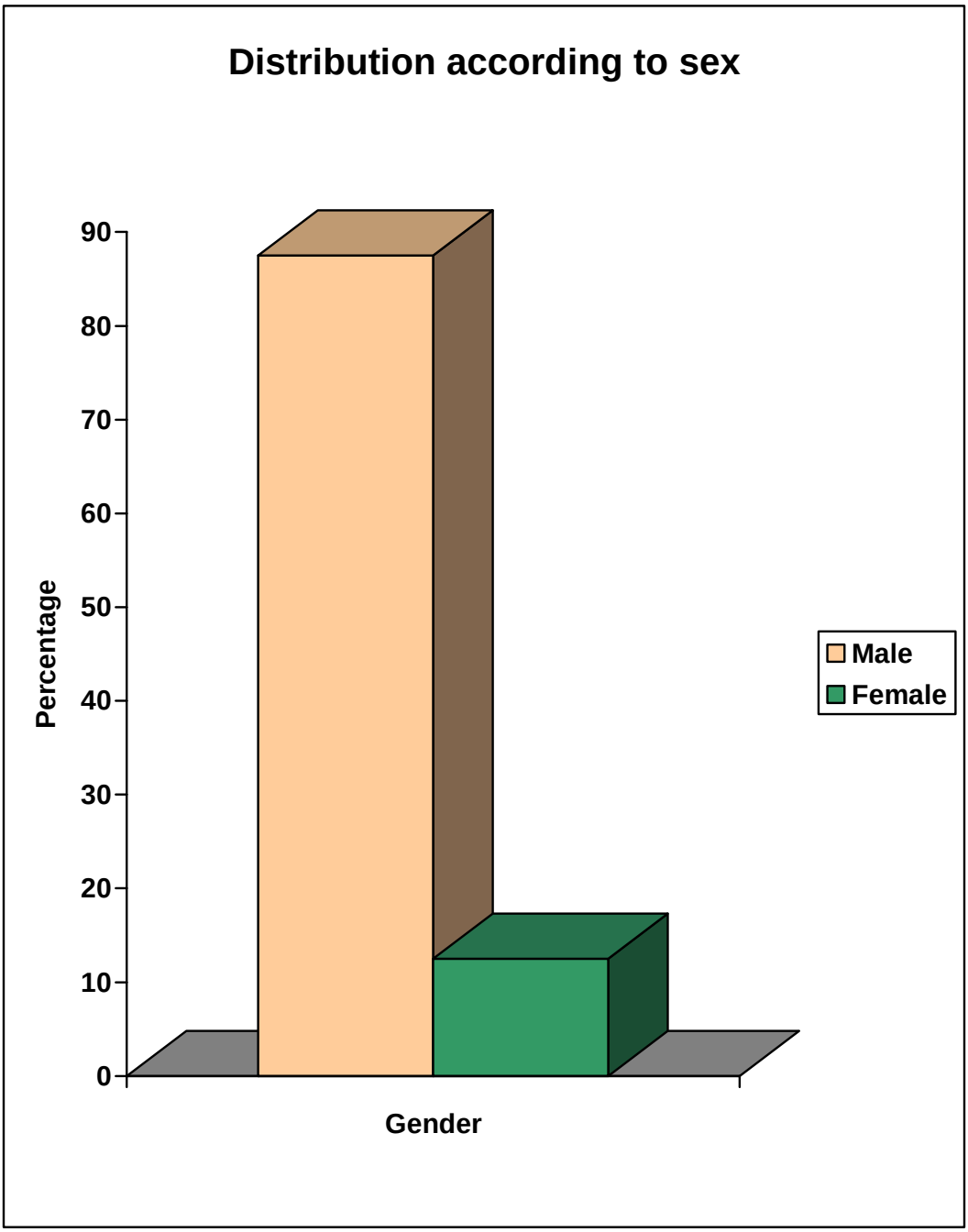
Refracture occurred in 1 case, which was treated by removal of the fixator and reapplication of fixator.**Premature consolidation** ofcorticotomy site occurred in 1 case, which was treated by recorticotomy and bone transport.

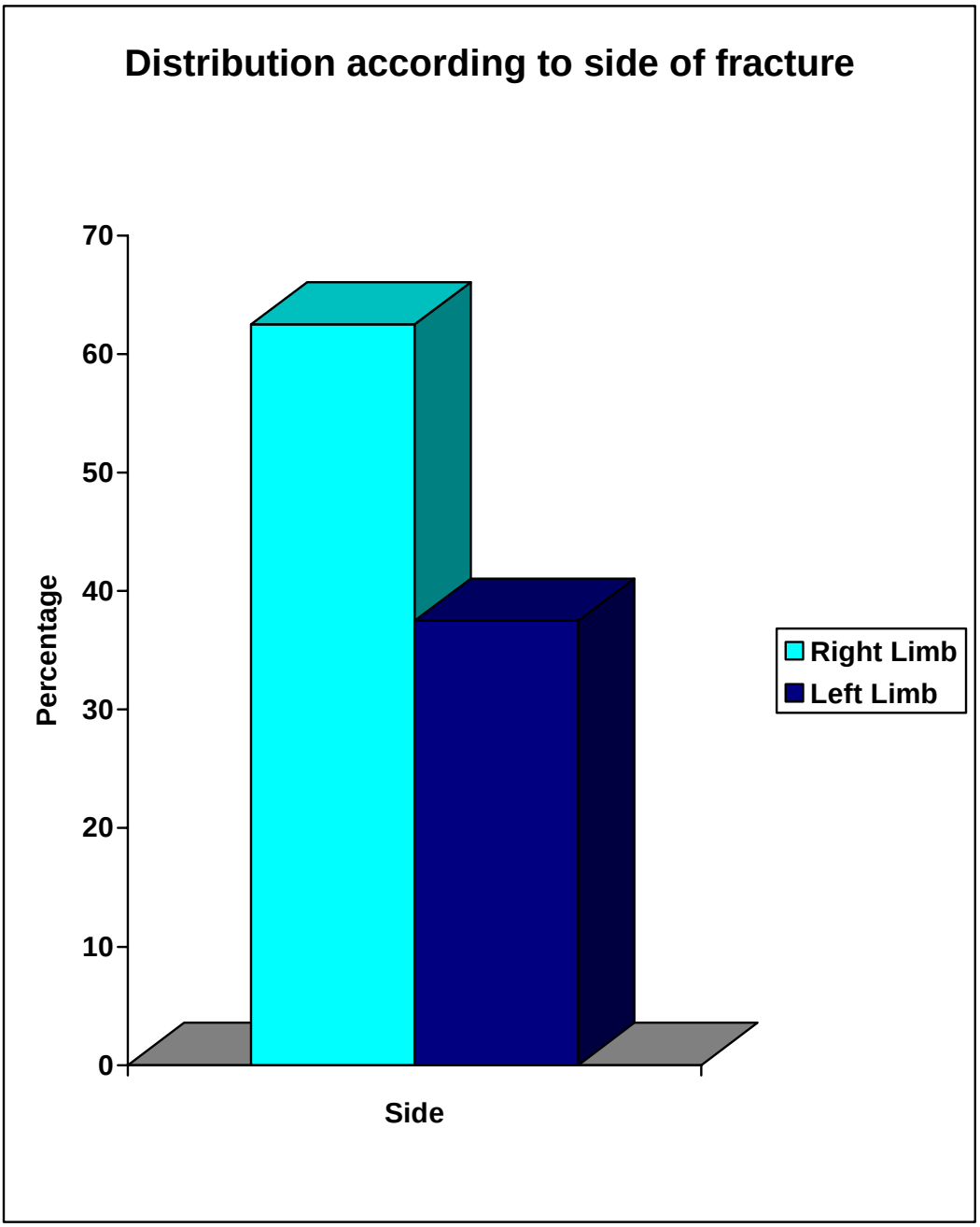
Axial Deviation occurred in 1 case on fixator removal, when the callus is still plastic and is due to increased muscular tension or weightbearing and early removal of fixator.

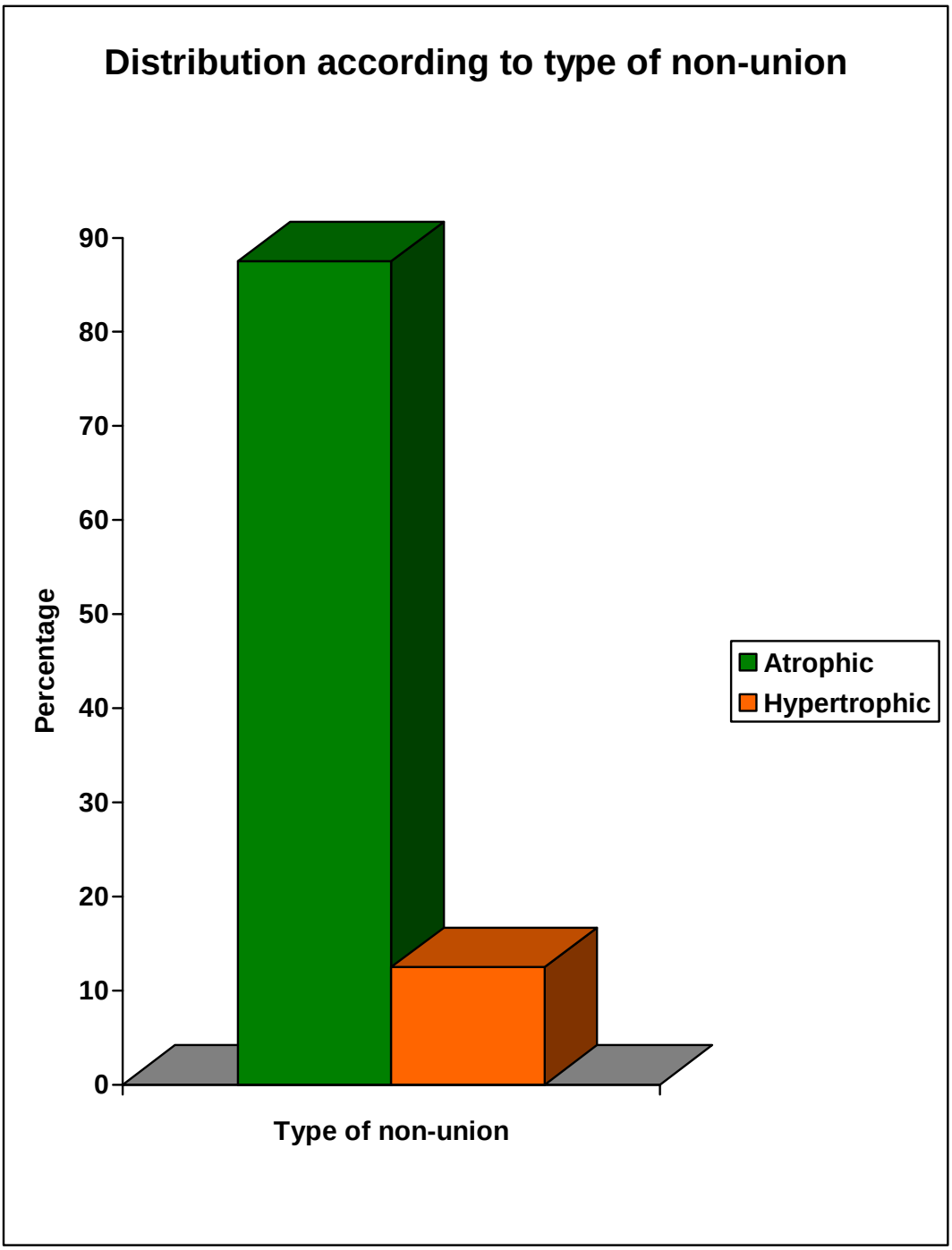
One patient was **HIV positive**, who had supracondylar femur fracture and fixator was applied spanning knee. But, due to florid, uncontrolled infection, the patient went in for above knee amputation.

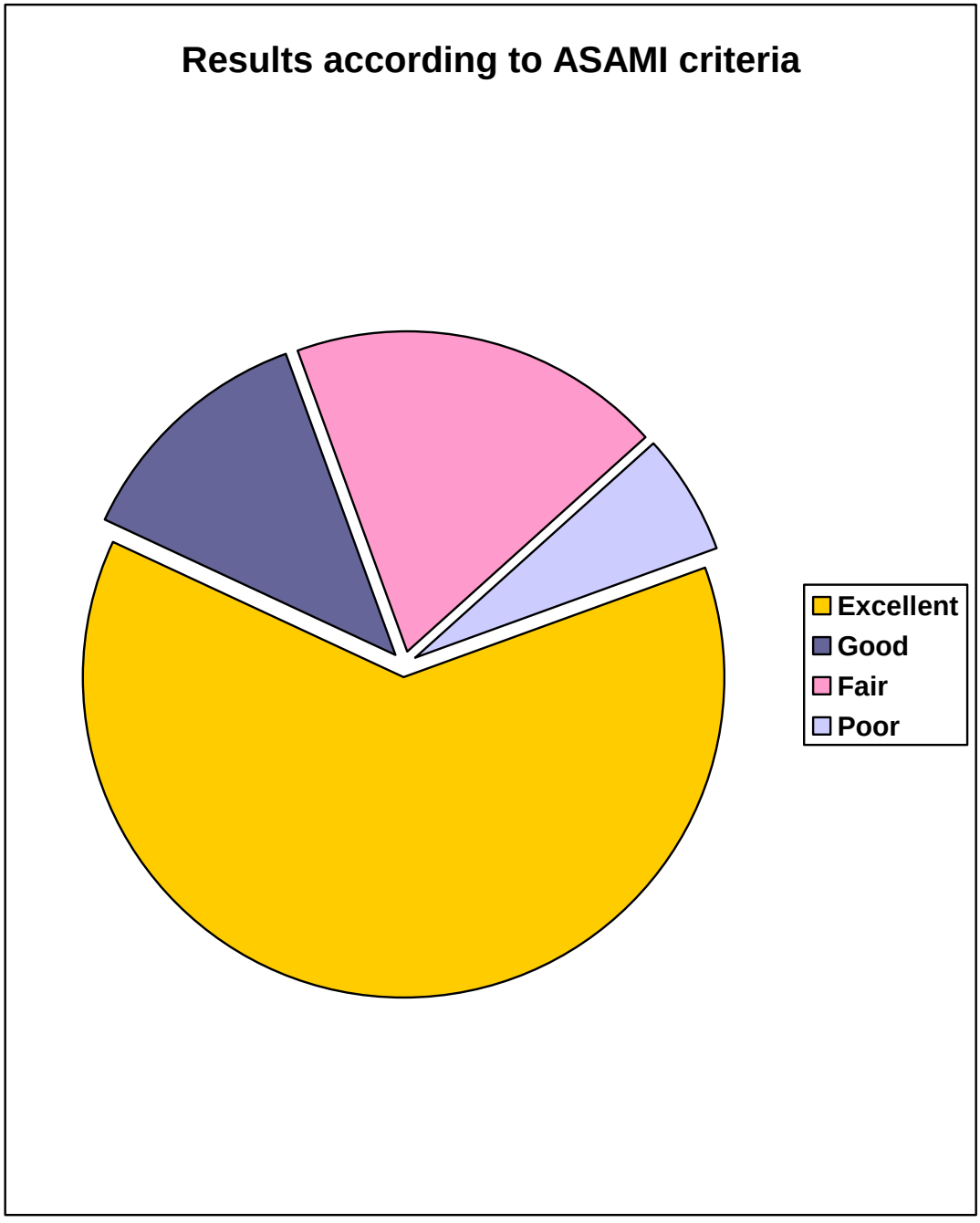
Of the 9 cases of Femoral non union, there were 3 cases of knee joint stiffness, but corrected to some extent later. Of the 6 cases of Tibial non union, 2 cases had shortening of leg with an average of about 1.5 cm. Of 1 case of Humerus nonunion,there was a shortening of 1.75 cm.


Distribution according to age
Percentage
40
35
30
25
20
15
10
5
0
Age
<20 yrs
20-29 yrs
30-39 yrs
40-49 yrs


Distribution according to sex
90
80
70
60
50
40
30
20
10
0
Percentage
Gender
Male
Female


Distribution according to side of fracture
70
60
50
40
30
20
10
0
Percentage
Side
Right Limb
Left Limb


Distribution according to type of non-union
90
80
70
60
50
40
30
20
10
0
Percentage
Type of non-union
Atrophic
Hypertrophic


Results according to ASAMI criteria
Excellent
Good
Fair
Poor

Preoperative
(With External Fixator)

Post Operative
(With LRS)

Corticotomy and Distraction

Follow Up

Knee Mobilisation

Preoperative

Hypertrophic non-union

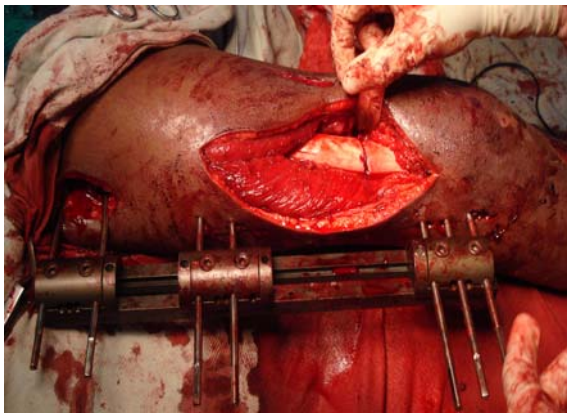
Post Operative

Acute Docking

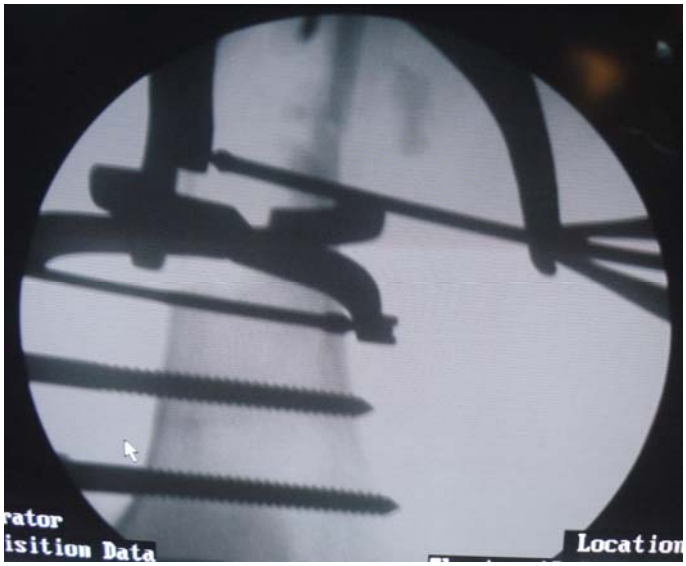
Follow Up

Pre Operative

LRS application & Corticotomy



C-Arm guidance



Follow Up

COMPLICATIONS

Shortening

Knee stiffness

COMPLICATIONS

Axial deviation

DISCUSSION

DISCUSSION

All over the globe, in the recent past, a tremendous interest has been shown in distraction osteosynthesis. The clinical fact that distraction can produce new bone formation was showed as early as 1900 by Codivilla. The effect of rhythmical distraction which generates new bone formation was enlightened by **Ilizarov** from 1951 onwards.

The effect of corticotomy on increased vascularity of the whole limb as well as the fixator in the fracture site was still under study. The distraction on tensile force at the corticotomy site, the lining cells covering the bone ends are able to differentiate into osteogenic and chondrogenic cells under an adequate stimulus and environment. This type of osteosynthesis even called as "**intramembranous ossification"** of **Ilizarov.**

This type of regeneration of bone can be obtained by an appropriate distraction rate. This rate appears to be critical in the new bone formation and maintenance of adequate blood supply. In the present study, monoplanar external fixator was used and appropriate rhythmical distraction was done. About 80% of cases showed good periosteal tube of new bone formation.

The effect of corticotomy on the healing of bone was also explained by intact intramedullary blood supply by microangiographic studies. It is experimentally proved by **Drey et al**[5] that there is no difference in regeneration to the healing sequence, in rhythmical distraction either after corticotomy or after osteotomy.

The microangiographic study is essential at this juncture to prove that there is intact medullary tube after corticotomy in this series.

The corticotomy was advised by **Prof.Ilizarov** mostly in the metaphyseal region, whereas in the present series, it has been done in the most of cases in the diaphyseal region, which may called in other words as "**callostasis"** or callus distraction.

Callostasis was usually done after a lag period of 2 weeks in adults and 10 days in children. In the present study, there was a considerable delay in the consolidation phase of many cases, which may be shortened in time by bone grafting and plating at the osteotomy site as advised by **Jeorge Alenso,** who also used a similar AO/ASIF tubular fixation in the segmental defect.

The present series showed a good response in eradicating the intractable infection within 5 weeks and union at non union site in 95% of cases, the healing the lesions has viewed critically for a period of 2-4 years before declaring the lesion is healed.

Union achieved by repairing defects with cancellous grafts as recommended by **Johnson et al** and **Lack et al** may prove to be acceptable alternatives. The biomechanical structure of the restored bone may require years to remodel to achieve the radiological appearance of that obtained by distraction regeneration of Ilizarov method.

Recent advances in microvascular anastomosis terchnology have permitted vascularised osseous transfers for dealing with missing bone tissue.In the lower limb,such grafts,whether fibula or iliac crest take years to hypertrophy and often fracture one or more times before complete remodeling. **Wood et al** showed that only 40% of patients with osseous sepsis went on to unite microvascular osseous transplants.

Indeed, it is a good method for the management of intractable infective non union of long bones with success rate of 95% as far as the eradication of infection and union at nonunion site is concerned.

CONCLUSION

CONCLUSION

The method of treatment of infected non-union by the monolateral external fixator with a predictable healing of nonunion and control of infection is well shown in this study.

Though there are some complications with this method, it can be overcome by careful preoperative planning, appropriate surgical techniques and adequate follow-up, which will definitely make this method a very successful one.

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APPENDIX-I

CONSENT PROFORMA

Title

Management of infected nonunion of long bones using Limb reconstruction system.

Aim

The aim of this study is to evaluate the outcome of management of infected nonunion of long bones using Limb Reconstruction system.

Consent

I have been explained about the nature of my injury, methods of treatment, potential complications and need for regular follow-up visits in my own vernacular language.

I hereby give my consent for including me in the study.

Signature

APPENDIX-II

CLINICAL PROFORMA

(1) Name

(2) Age

(3) Sex

(4) In-Patient no.

(5) Mode of injury

(6) Side of injury

(7) Dominant side

(8) Type of nonunion

(9) Associated injury

(10) Associated complications

(11) Date of injury

(12) Date of surgery

(13) Post operative complication

(14) Date of mobilization

(15) Date of suture removal

(16) Date of fixator removal

(17) Follow-up visits:

Date	ROM	Stiffness	Pin tract	Limb length measurements	Muscle Wasting	Neurovascular deficit

(18) RESULT : Excellent / Good / Fair / Poor.

APPENDIX - III

\ MASTER CHART

Sl.No.	Name	Age(yrs)	Sex	Side	Bone Involved	Type of Non-Union	Duration of Non-	Surgery	Corticotomy	Complications	Follow Up	Result
1.	Bhuvaneshwari	10	F	R	Tibia	Atrophic	6	WD,FA	+	-	6	E
2.	Firthose	20	F	R	Humerus	Hypertrophic	15	FA	-	-	10	E
3.	Sabapathy	45	M	R	Femur	Atrophic	8	WD,FA	+	PC,Pi	5	F
4.	Ponnusamy	46	M	R	Femur	Atrophic	15	WD,FA	+	Pi, Js	8	F
5.	Arul	40	M	R	Femur	Atrophic	7	WD,FA	+	-	12	E
6.	Paulraj	22	M	R	Femur	Atrophic	7	WD,FA	+	-	9	E
7.	Saravanan	36	M	L	Tibia	Atrophic	6	WD,FA	+	AD	5	F
8.	Ganapathy	30	M	L	Femur	Atrophic	9	WD,FA	+	Refr	4	P
9.	Kumar	34	M	R	Femur	Atrophic	10	WD,FA	+	-	2	E
10.	Mahesh	44	M	L	Tibia	Atrophic	12	WD,FA	+	-	11	E
11.	Rajendran	43	M	R	Tibia	Atrophic	11	WD,FA	+	-	12	E
12.	Marimuthu	49	M	R	Femur	Hypertrophic	7	FA	-	-	10	E
13.	Sekar	38	M	L	Femur	Atrophic	9	WD,FA	+	Js, DU	8	G
14.	Ravi	36	M	L	Tibia	Atrophic	10	WD,FA	+	-	9	E
15.	Rajasekar	32	M	L	Femur	Atrophic	13	WD,FA	+	-	10	E
16.	Vetrivel	37	M	R	Tibia	Atrophic	14	WD,FA	+	Js, DU	5	G

Key to Master Chart

Sex :

M	**-**	**Male**
F	**-**	**Female**

Side of Injury :

R	**-**	**Right**
L	**-**	**Left**

Surgery :

WD	**-**	**Wound debridement**
FA	**-**	**Fixator application**

Complications:

Pi	**-**	**Pin tract infection**
Js	**-**	**Joint stiffness**
AD	**-**	**Axial deviation**
Refr	**-**	**Refracture**
PC	**-**	**Premature consolidation**
DU	**-**	**Delayed union**