MANAGEMENT OF DISTAL TIBIA FRACTURES: REVIEW ARTICLE

Yousef El Sayed Zoghli Attia *, El Sayed El Etewy Soudy , Mohamed Mansour El Zohairy, and Ahmed Mohamed Abdelwahab

Orthopedic Surgery Department, Faculty of Medicine, Zagazig University

***Corresponding Author: Yousef El Sayed Zoghli Attia**
E-mail: youssefattia450@gmail.com

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Abstract:
Over the past two decades, management of open distal tibial fractures has evolved such that a staged approach, with external fixation and débridement during the index procedure, followed by definitive fixation and wound closure at a later date, is often considered the standard of care. Although definitive treatment of these complex injuries is often done by a multidisciplinary team of surgeons well versed in periarticular fracture repair and soft-tissue coverage in the distal extremity, the on-call orthopaedic surgeon doing the index procedure must understand the principles and rationale of the staged treatment algorithm to avoid compromising definitive treatment options and ensure the best possible patient outcome. The mechanism of injury, neurovascular status, size and location of soft-tissue injury, fracture pattern, and concomitant injuries in the polytraumatized patient should direct the treatment plan and anticipated outcomes. This review focuses on evaluation and management of these complex injuries with an emphasis on early aggressive debridement, principles of initial fracture fixation, and modern options for soft-tissue coverage, including local and free tissue transfer.

Keywords: Tibia Fractures, Closed Reduction, Fixation.

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Introduction:

Distal tibial metadiaphyseal fractures are frequently a consequence of high-energy trauma and should be managed according to Advanced Trauma Life Support (ATLS) principles in the first instance as discussed before **(1).**

Open fractures require the prompt administration of antibiotics and urgent washout and debridement should be performed. The risk of compartment syndrome should also be considered and urgent four compartment fasciotomy undertaken if suspected **(2).**

Splintage of the fracture with an inflatable device or plaster back slab should be instituted pending definitive treatment of the fracture. Early administration of broad spectrum antibiotics, ideally within 3 hours of injury, is critical, reducing the risk of subsequent infection six folds in some cases **(3).**

Figure (1): Ext. Fixator for open distal tibial fractures **(4).**

Examination

Examination of the soft tissue envelope is of critical importance in the complete assessment of fractures of the distal tibia fractures and should be performed in a logical, consistent, and circumferential manner **(5).**

A) Inspection

- The degree of swelling
- Deformity or dislocation.
- Severity of contusions

B) Palpation

- Tenderness
- Neurovascular status

The circulatory status is evaluated by palpation and/or Doppler ultrasound examination of the pedal pulses, and by noting the color and temperature of the foot. The dorsal and plantar aspects of the foot are examined for alterations in sensation **(6).**

Special situations

1- Joint dislocation or gross deformity

Emergent reduction should be attempted prior to radiographic examination, to minimize further vascular compromise to the local skin and soft tissues **(7).**

2- Compartment syndrome

Fullness or tenseness of any compartment in the leg and severe pain on passive stretch of the muscles in the specific compartment are fairly accurate indications of increased compartment pressure **(8).**

3- Open fractures

- Begin immediate antibiotic therapy.
- Immediately debride the wound using copious irrigation and, repeat the debridement in 1-3 days to dilute bacterial inoculum.
- Stabilize the fracture with minimum soft tissue damage.

Definitive closure can be done or delayed primary closure **(9).**

4- Fracture blisters

Distal tibia fractures are frequently accompanied by the presence of fracture blisters. Development of fractures blisters typically occurs rapidly after injury, often within hours, but may take up to 2 to 3 days. There are two clinical types of fracture blisters, clear filled and blood filled **(10).**

Imaging and Other Diagnostic Studies for distal tibia fractures

1- Plain radiographs:

- AP shows side to side displacement, medial malleolus, lateral malleolus fracture and degree of articular comminution.
- Lateral views of the ankle shows antroposterior displacement and posterior malleolus fracture.

Mortise shows tibiofibular syndesmotic disruption **(11).**

2- Computed tomography (CT):

Axial CT scans are routinely obtained for many or most distal tibia fractures. They provide excellent details of the fracture pathoanatomy and serve as a critically important aid to preoperative planning for operative approaches and fixation techniques. CT typically demonstrates more articular displacement and comminution than is apparent on plain films **(12).**

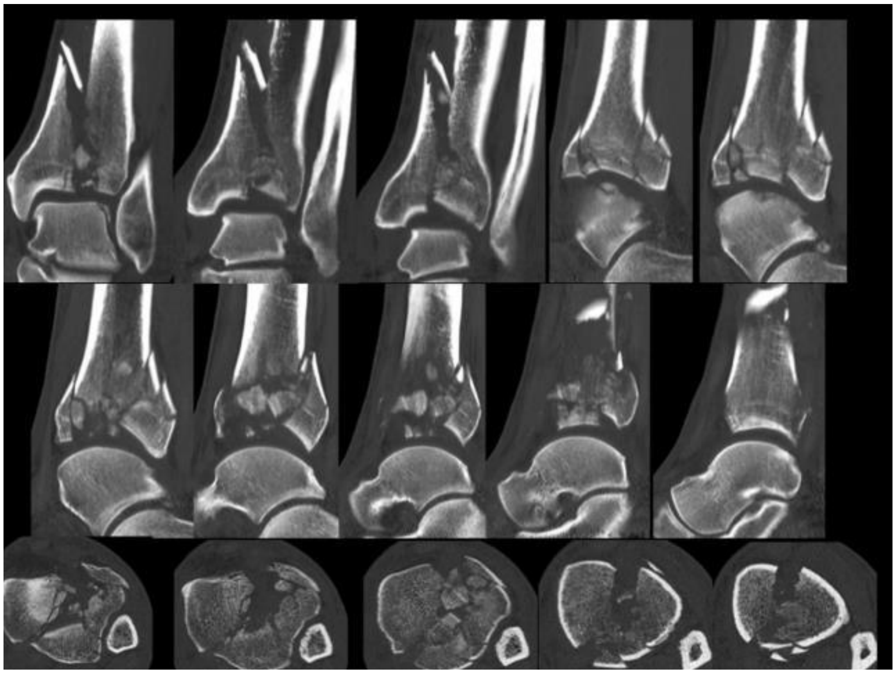

Figure (2): Computed tomography scan of complex distal tibia fracture with the articular surface in more than 2 pieces **(10).**

Non-operative management:

1) <u>Closed Reduction and Casting.</u>

Non-displaced fractures can be treated in non-weight bearing casts. These need to be long-leg casts for rotational stability. Weight bearing should be restricted for 4 to 6 weeks. This is most appropriate for AO type A1, B1, and C1 fractures with less than 2 mm of articular displacement (Fig. 3,4). When in doubt, plain or computed tomography (CT) can aid in determining articular congruity **(13).**

Disadvantage: Casting prevents observation of swelling and the skin, and loss of reduction is common with progressive angular deformity and shortening, stiffness, and loss of ROM **(13).**

<u>Traction:</u>

Traction of the fracture using calcaneal traction may result in satisfactory alignment of comminuted distal tibia fractures through ligamentotaxis if the central portion of the articular surface is not crushed and impacted. Management by traction requires the patient to remain in bed until early evidence of union has occurred, usually a minimum of 6 weeks. Calcaneal pin traction has been essentially replaced by external fixation. Traction is used as a temporary measure to keep the ankle joint reduced while soft-tissue swelling decreases. This is done in AO type B3, C2, and C3 fractures when a splint will not hold the talus centered under the tibia (Fig. 5) **(14).**

Figure (3): Distal tibial fracture conservative management (15).

Figure (4): Above knee cast (15).

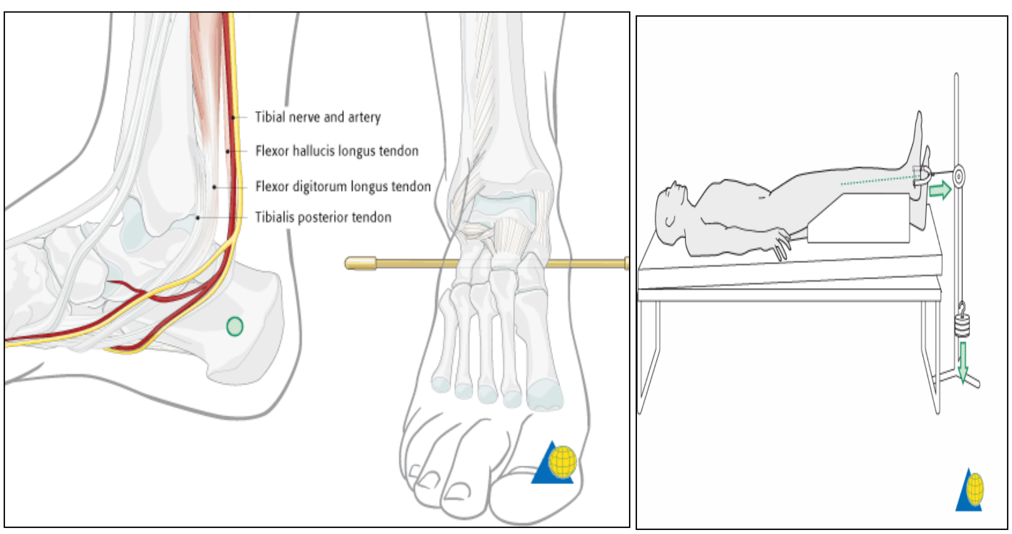

Figure (5): ***Böhler*** **(16)** traction.

Operative management:

The majority of displaced distal tibial fractures are managed operatively. However, the ideal operative treatment modality has yet to be determined. Unstable, displaced extra- articular distal tibial fractures can be treated with numerous techniques including external fixation, open or percutaneous reduction and plate fixation, intramedullary nailing, and combinations thereof. The fracture pattern and conditions of the local soft tissue envelope are the major determinants for the surgical technique chosen **(17).**

I- One stage protocol

Plating modalities

Plates may be applied in various modes according to the function required. These include:

- Protection (neutralization)
- Compression
- Bridging
- Buttress (antiglide)

NB: *The terminology may be confusing; these names refer to the mode in which the plates are applied and are not specific to a particular plate.*

Plate designs

Various plate designs are available. These may be larger or smaller, thicker, or thinner as appropriate to various anatomic sites and the loads to which they will be subjected **(17)**.

The holes in the plate may be designed for locking screws, non-locking screws, or either and designed to facilitate dynamic compression **(17)**.

Plate contouring

The plate must fit the shape of the bone. The midshaft of many long bones is straight so plates applied to these regions may not need to be contoured **(15)**.

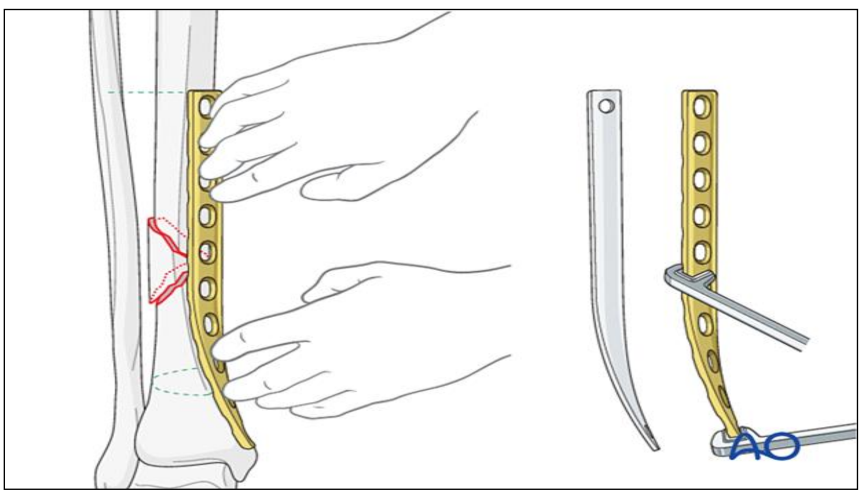

Figure (6): Anatomic plates are pre-contoured to fit the region they are designed for but beware that this is for an average patient, and they may still need to be adjusted to fit individual patients **(15)**.

1. Protection (neutralization) plates

- ***Function***

A protection plate neutralizes bending and rotational forces to protect a lag screw fixation. This is equally true of plates with locking or non-locking screws **(17)**.

2. Compression plates

- ***Function***

The plate produces compression at the fracture site to provide absolute stability **(16)**.

3. Buttress (antiglide) plates

- ***Function***

Buttress plates are often used to supplement lag screw fixation of metaphyseal shear or split fractures in the metaphyseal regions. The lag screws may be inserted either through or outside of the buttress plate **(13)**.

Open reduction internal fixation (ORIF):

Open reduction and internal fixation of distal tibial fractures initially appears to offer significant benefits in specific fracture types (Fig. 7) **(17)**.

The key to avoiding most common and indeed the most devastating complications associated with operative management of this injury is determining the proper surgical timing. The extent of soft tissue injury associated with these fractures is dependent on the amount of energy absorbed and the patient‘s innate physiological response to trauma. Inappropriate timing can result in inability to close the incisions at the conclusion of the procedure, closing the incisions under considerable tension (which can lead to further soft tissue injury), or the need for multiple relaxing incisions in the vicinity of the primary incision. Each of these situations increases the risk of wound complications and long-term morbidity (Fig. 8). Alternative approaches to the distal tibia via a posterolateral or anterolateral approach have been proposed to improve the soft tissue cover of plates **(18)**.

Plates that have been used include dynamic compression plates (DCP), limited contact dynamic compression plates (LC-DCP) and more recently the anatomically contoured locking compression plates (LCP). LCP is preferable as the locked fixed angle construct means the plate can sit off the bone, preserving periosteal blood supply. Anatomical contouring reduces the prominence of the plate, helps restore the normal anatomy and reduces varus/valgus or rotational deformity (Fig. 9) **(19)**.

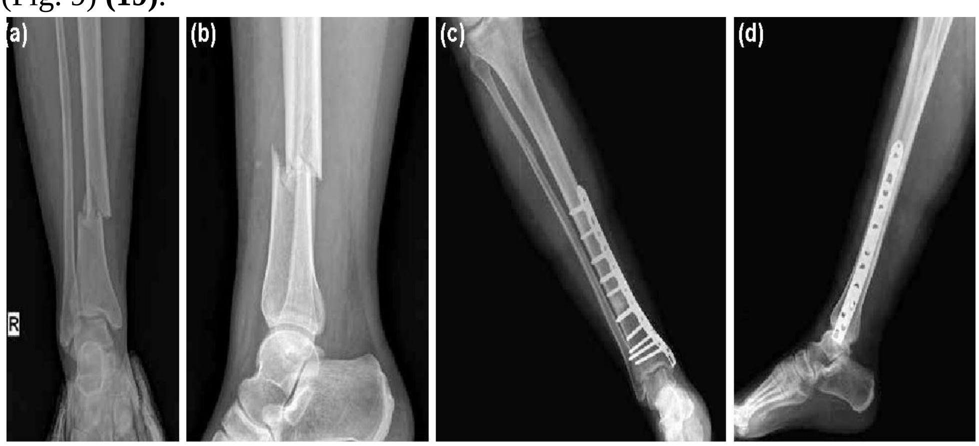

Figure (7): Right distal tibial fracture, treated by ORIF **(19)**.

Figure (8): Skin complication of ORIF **(18).**

A) Narrow DCP **B) Locked DCP** **C) Distal tibia locked**

Figure (9): Various type of plates for distal tibia **(20).**

Minimally invasive percutaneous plate osteosynthesis (MIPPO):

Biomechanics of locked plates

Axial loading

In locked plating, the screws lock into the plate and do not rely on the frictional force between the plate and the bone but on the compressive strength of bone. A locked plate converts an axial load shear force into a compressive stress at the screw bone interface (Fig. 10) **(21).**

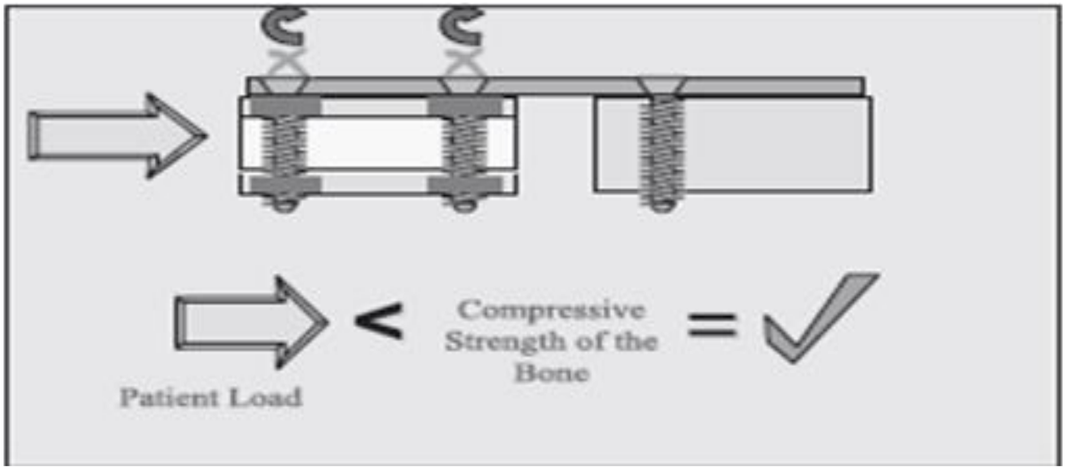

Figure (10): Locked plate relies on the compressive strength of bone to resist the axial load **(22)**.

Bending

In locked plating, because of the screws lock into the plate, they must all either fail simultaneously as the plate backs directly out (Fig. 11) or more likely a preferential failure of the screw bone interface **(23)**.

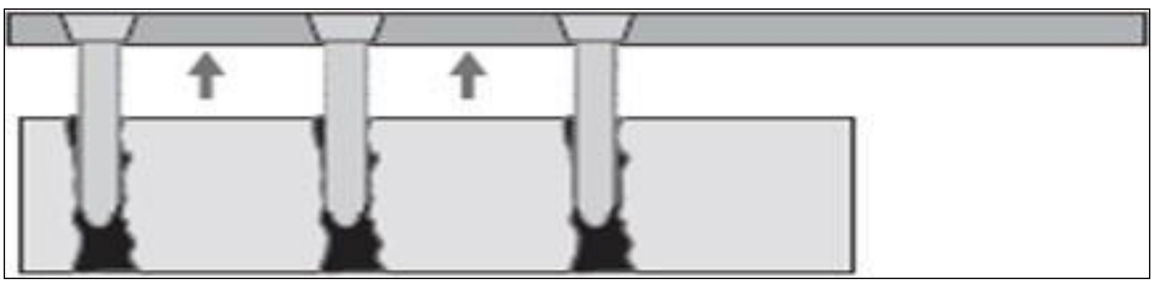

Figure (11): Failure of locked plating with pure pullout of the screws is rare compared with Figure 10 but still requires all screws to fail simultaneously as opposed to conventional plating shown in Figure **(23)**.

Clinically the purchase of the locked screws in the bone can be so strong that failure could occur by the plate displacing from the bone and taking a large section of bone still attached to the locked screws. In essence the fixation strength of locked plating equals all bone screw interfaces, thus providing a very rigid construct **(24)**.

Torsion

The torsional stability of a construct is more dependent on the number of screws rather than whether the screws are locked or conventional. Given this, a slight motion is possible between the screw head and the plate in the conventional plating depending on the torque used to place the screw, the size of the screw head, the design of the plate, and the material used in conventional screws **(25)**.

Biology

In managing fractures, a surgeon must be familiar with management of the soft tissue. Typically, bony injury associated with high-energy trauma causes a significant soft tissue injury that may compromise the options available to the surgeon. Classically, stripping the soft tissue to obtain anatomic reduction of each piece has lead to an increase in infection rates and delayed healing of the fracture. Anatomic alignment of the bone is required but not anatomic alignment of each piece in a shaft fracture **(26)**.

Main principle of biological fixation by minimally invasive percutaneous plate osteosynthesis (MIPPO) in lower extremity long bone fractures is relative stability which is provided by using long plate with limited number of screws **(27)**.

The basic principles of this technique include indirect closed reduction, extraperiosteal dissection, anatomic alignment and relative stability which permits limited motion at the fracture site and create secondary bone healing with callus formation **(28)**.

II- Two stage protocol

1- External fixation:

External fixation may be used either for temporary stabilization or for definitive fixation. Temporary fixation with a uniplaner or multiplaner frame. spanning the ankle joint is advocated by some as the initial management of distal tibial fractures, particularly in high energy injuries. The role of external fixation as definitive treatment has been of interest in recent years particularly for benefits it provides with respect to minimal interference with the soft tissue **(29)**.

Hybrid or Ilizarov type fixators are often more appropriate for definitive fixation of periarticular fractures with the passage of wires or pins into the distal fragment instead of spanning the ankle joint (Figs. 12 & 13) **(15)**.

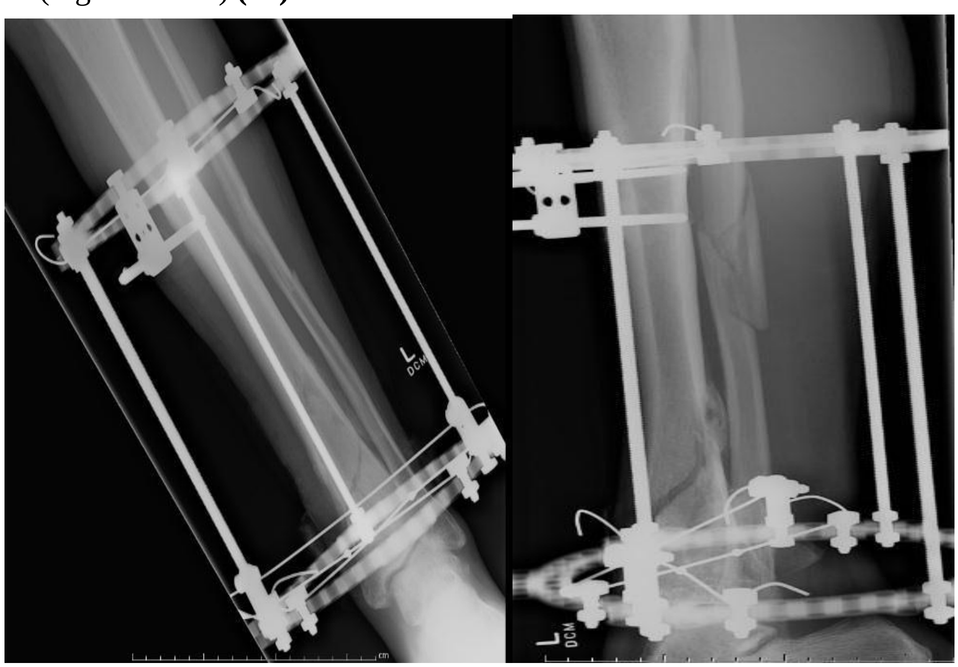

Figure (12): Distal tibial fracture managed by Ilizarof **(15)**.

Regarding the optimal treatment method there is the general belief that there is not a single method of fixation ideal for all distal tibia fractures suitable for all patients. The wide variety of instruments and techniques that are available provide satisfactory and comparable results when used for specific indications and by experienced surgeons **(30)**.

Some authors prefer the two stage protocol in dealing with such complicated fracture. The first stage, performed as soon as possible after the patient is fully assessed, is ORIF of fibula and application of a triangular external fixator spanning the ankle joint (Figs. 13) **(31)**.

After the acute phase has been passed. The skin condition improved. Patient can have the second stage in the form of external fixator that usually spans the ankle (Fig. 13) **(32)**.

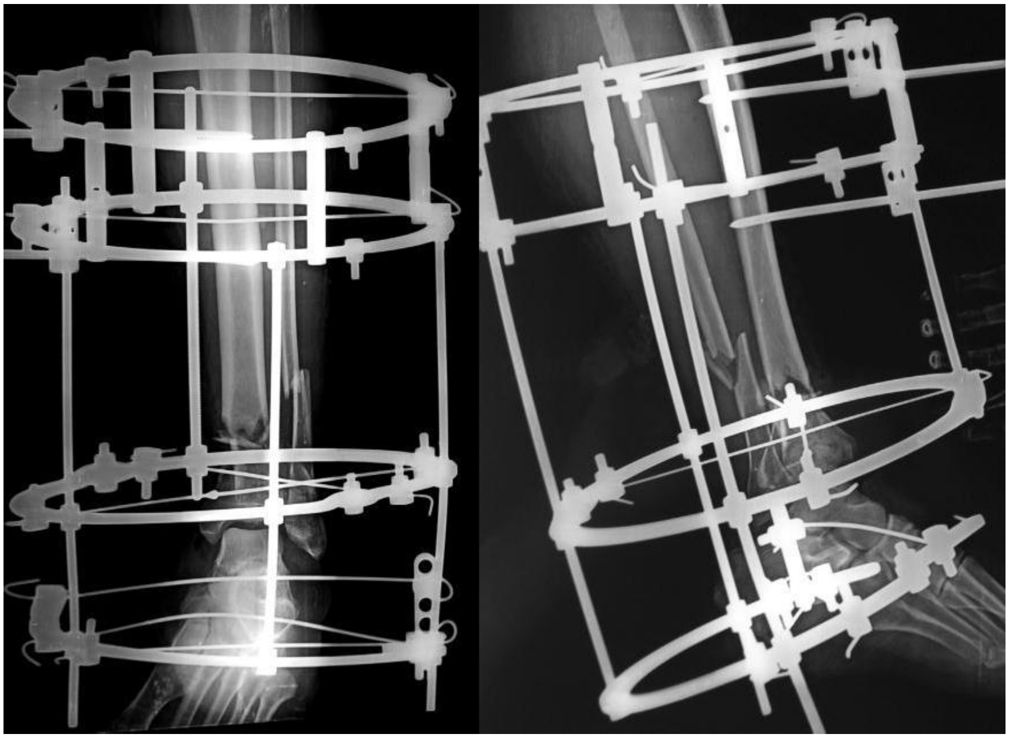

Figure (13): A ring fixator spanning the ankle joint AP and Lateral views **(32)**.

Ring fixator

1- Biomechanics of the Ilizarov apparatus in fracture fixation

The Ilizarov frame and other circular ring fixators offer certain advantages compared with unilateral and bilateral frames. In general, circular fixators exhibit more isotropic mechanical properties in bending, nonlinear axial stiffness, and the ability to readily create configurations for complex corrections **(33)**.

A- Elasticity

Monolateral fixators support the bone by cantilever loading and this leads to concentrated high stresses on the near cortex (Figs. 14). Repeated cyclic loading during gait is probably the cause of loosening that occurs. Circular frames using tensioned transfixion wires support bone by beam loading and provide variable (multimodal) elastic support to the bone **(34)**.

Calhoun et al. (35) found the compression stiffness of the Ilizarov fixator to be greater than its distraction or torsional stiffness. This has been demonstrated for other external fixators.

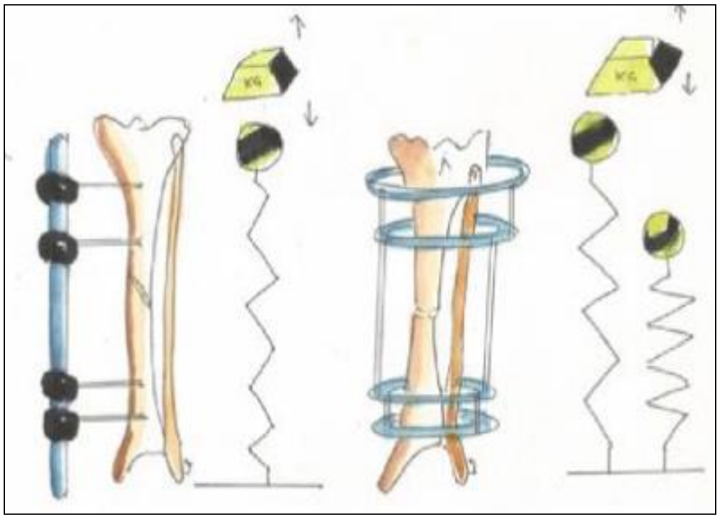

Figure (14): Resistance to collapsing is axial stiffness **(34)**.

Ilizarov frame is less stiff in axial loading than other frames **(36)**.

B- Stability of the fixator

It depends on the following variables:

1. Rigidity of the assembly.
2. Connection between the apparatus and the bone.
3. Intrinsic (or internal) stability of the treated segment.

1- <u>Rigidity of the assembly:</u>

- **The material** from which the half rings are made must be extremely solid to allow minimal bending when subjected to loading and wire tensioning.
- **The diameter** of the ring is inversely proportional to the rigidity of the frame. It is recommended that a minimum distance of 2 cm between the soft tissues and the frame be maintained to be increased to 3 cm where significant swelling may occur.
- **The number of rings** is directly proportional to the stability of the system. Therefore, it is better to construct frames that have two rings per segment.
- **The number of connections** between the rings is directly proportional to frame stability. The minimum number for adequate stability is at least four.
- **The stability of the apparatus is inversely proportional to the distance** between the rings **(37)**.

2- <u>Connection of the apparatus to the bone:</u>

A- Wires:

Important wire parameters are size, tension, orientation, and number.

- **The diameter** of the wire is directly proportional to the stability of the assembly. Wires of 1.5, 1.8, and 2 mm are commonly used.

- **Tension** of the wires also affects frame stiffness, particularly axial (Fig. 15). Maximum limits are 90 kg for 1.5-mm wire and 110-130 kg for 1.8-mm wires. Wires tensioned to 130 kg are comparable to a 4-mm half pin **(38)**.

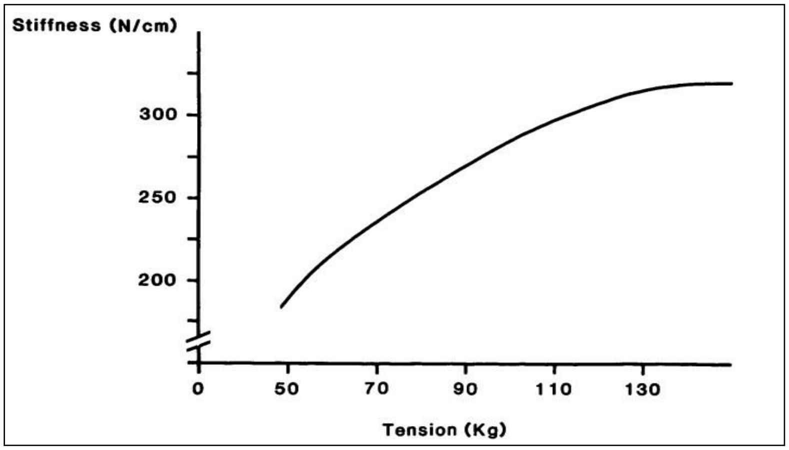

Figure (15): Effect of wire tension on axial stiffness (1.8-mm wire and 150 mm ring) **(38)**.

The angulation between crossing wires is another factor that affects bending stiffness and stability (Fig. 16). The best configuration is 90° between one wire and another. Unfortunately, anatomic structures about the knee or ankle do not make this possible. Studies have shown that maintenance of at least 60° between wires, which is obtainable, leads to improved fixation and stiffness. Below 45°, stability decreases rapidly in the plane of the obtuse angle **(39)**.

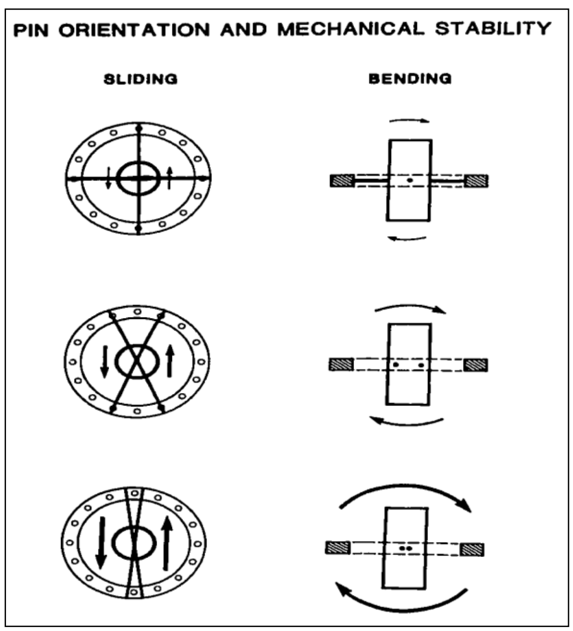

Figure (16): Effect of angle of crossing of wires on stability in bending and sliding. Size of the arrows indicates relative resistance to movement i.e. longer arrows implies easier movement**(39)**.

<u>Number of wires:</u>

It was discovered that increasing the number of wires resulted to a greater total stiffness (Figs. 17 & 18). The insertion of a third wire at the same level of attachment resulted in a 54 percent increase in overall stiffness. In comparison to two wires at one level of attachment, four wires at one level enhanced overall stiffness by 129 percent **(40)**.

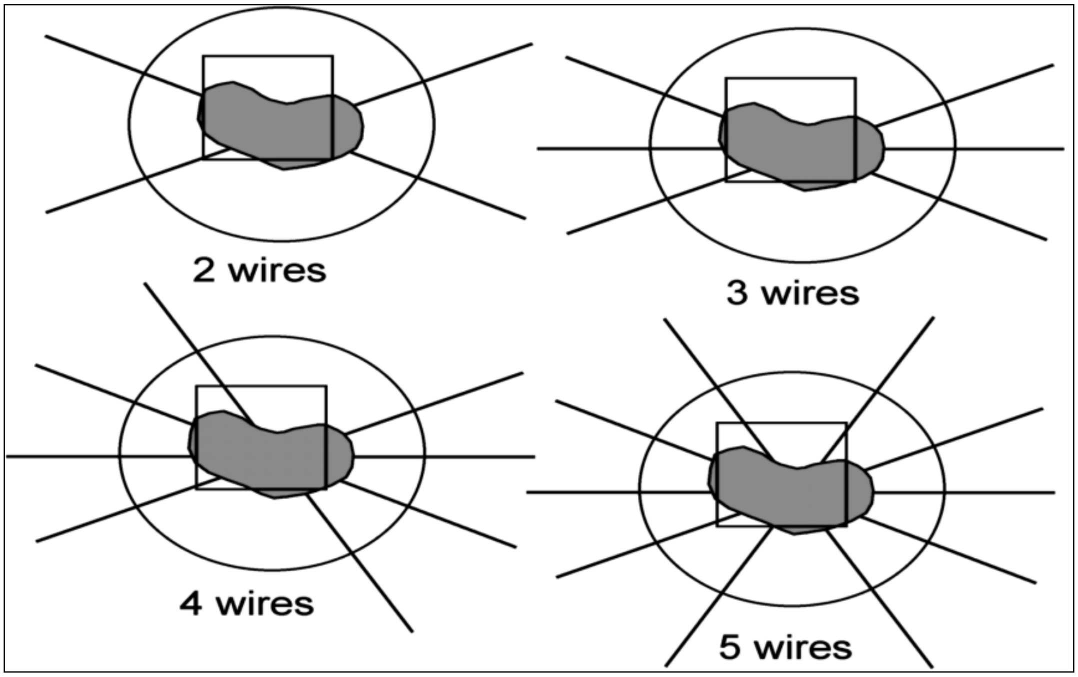

Figure (17): The placement of wires during testing the effect of increasing wire number at one level of fixation on the stiffness. The starting configuration used 2 wires crossed at a 60° angle**(40)**.

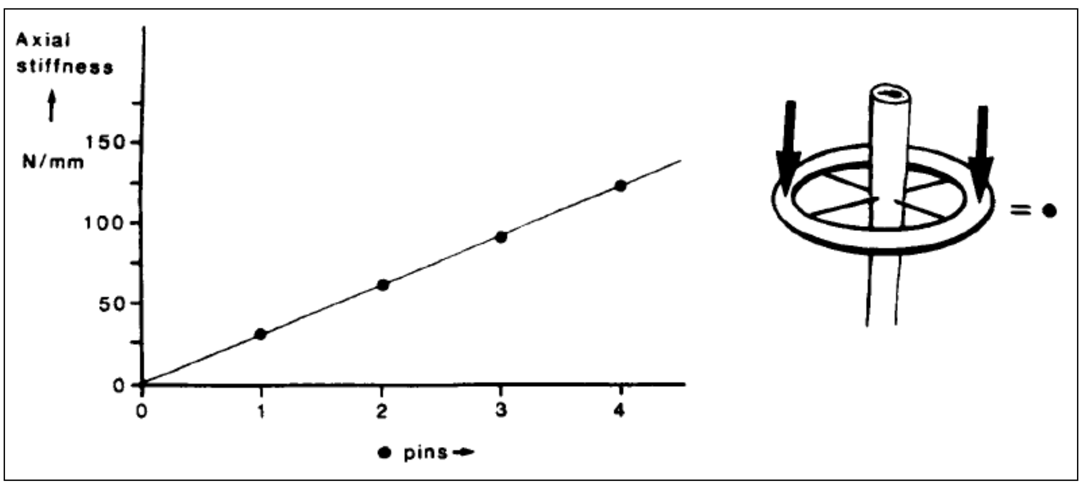

Figure (18): Effect of wire number on axial stiffness **(40)**.

B- Pins:

This invention mentioned by Catagni-Cattaneo boosted the stability of the entire system by using pins with a diameter of 5 to 6 mm **(39)**.

3- ***Internal stability:***

Internal stability is extremely vital to the system's overall stability. The Surface Area (SA) of the injury site must first be assessed when analysing a fracture: The larger the SA, the more stable the system **(40)**.

Some of the most important considerations for stability include the following* (40)*:

- Use the smaller rings possible (allowing for soft tissue swelling).
- Minimize the unsupported length between rings; use more or larger ring connectors or an intermediate free ring.
- Use olive wires for control of bone segments, particularly in compression.
- Use larger wires or a greater number with maximum tension.
- Attempt to provide wire crossing angles of at least 60°, where this is not possible, add an offset wire [or another ring with wire(s)] at least 4 cm away.

Neurovascular bundles cross the ankle:

1- Between the TA and the EHL tendons, the anterior neurovascular bundle (anterior tibial artery (ATA) and deep peroneal nerve) crosses the ankle beneath the ER.
2- The posterior neurovascular bundle (posterior tibial artery (PTA) and tibial nerve) passes behind the medial malleolus within the FR, between the FDL and FHL tendons **(41)**.

II- Graft

In cases of bone loss, marked comminution, or non-union, bone grafting is routinely done to aid bone healing **(42)**.

III- Approaches

1- Medial approach
2- Anterolateral approach for lateral column
3- Anteromedial Approach for Fractures of medial column
4- Posterolateral Approach if the fragment is located posterolaterally
5- Posteromedial Approach The distal tibial articular surface can be visualized through the unreduced medial malleolar fracture, which provides direct reduction of the posterior malleolar fragments
6- Modified posteromedial Approach An option to expose the entire posterior distal tibia, it provides visualization from medial to lateral without extensive soft tissue retraction **(43)**.

Assessment of articular fragments reduction was made according to criteria described by ***Ovadia and Beals*** **(44)** (Table 1).

Table (1): ***Ovadia and Beals*** **(44)** score

Classification of fracture reduction			
	Good	Fair	Poor
Malleolus			
Lateral	Anatomical or ≤1.0 mm displacement	2.0–5.0 mm displacement	>5.0 mm displacement
Medial	≤2.0 mm displacement	2.0–5.0 mm displacement	>5.0 mm displacement
Posterior	Proximal displacement ≤2.0 mm	Proximal displacement 2.0–5.0 mm	Proximal displacement >5.0 mm
Mortise widening	≤0.5 mm	0.5–2.0 mm	>2.0 mm
Talus			
Tilt	≤0.5 mm	0.5–1.0 mm	>1.0 mm
Displacement	≤0.5 mm	0.5–2.0 mm	>2.0 mm

The score sets a value of (0 for poor results), (2 for fair results), and (3 for good results).

Adding the six variables, if the score goes from (0 to 6, it is poor); if it goes from(7 to 12, it is fair); if it goes from (13 to 18, it is good).

Table (2): The American Orthopedic Foot and Ankle Society (AOFAS) **(45)**

I. Pain (40 points)

☐ None:	+40
☐ Mild, occasional	+30
☐ Moderate, daily	+20
☐ Severe, almost always present	+0

II. Function (50 points)

Activity limitations, support requirements

☐ No limitations, no support	+10
☐ No limitation of daily activities, limitations of recreational activities, no support	+7
☐ Limited daily and recreational activities, cane	+4
☐ Severe limitation of daily and recreational activities, walker, crutches, wheelchair, brace	+0

Maximum walking distance, blocks

☐ Greater than six	+5
☐ Four-six	+4
☐ One-three	+2
☐ Less than one	+0

Walking surfaces

☐ No difficulty on any surface	+5
☐ Some difficulty on uneven terrain, stairs, inclines, ladders	+3
☐ Severe difficulty on uneven terrain, stairs, inclines, ladders	+0

Gait abnormality

☐ None, slight	+8
☐ Obvious	+4
☐ Marked	+0

Sagittal motion (flexion plus extension)

☐ Normal or mild restriction (30° or more)	+8
☐ Moderate restriction (15° - 29°)	+4
☐ Severe restriction (less than 15°)	+0

Hindfoot motion (inversion plus eversion)

☐ Normal or mild restriction (75% - 100% normal)	+6
☐ Moderate restriction (25% - 74% normal)	+3
☐ Marked restriction (less than 25% of normal)	+0

Ankle-hindfoot stability (anteroposterior, varus-valgus)

☐ Stable	+8
☐ Definitely unstable	+0

III. Alignment (10 points)

☐ Good, plantigrade foot, ankle-hindfoot well aligned	+10
☐ Fair, plantigrade foot, some degree of ankle-hindfoot malalignment observed, no symptoms	+5
☐ Poor, nonplantigrade foot, severe malalignment, symptoms	+0

IV. Total Score (100 points):

_____ Pain Points +

_____ Function Points +

_____ Alignment Points =

_____ Total Points/100 points

The accredited AOFAS ankle-hindfoot score considers as “excellent, ” scores of 90 to 100 points; “good, ” scores of 80 to 89; “fair, ” scores of 60 to 79; and “poor, ” scores less than 60 points.

Advantages and disadvantages of ILIZAROV device

Advantages:

There are several advantages offered by the ring external fixators in the treatment of distal tibia fractures **(46)**.

1- **Reduction:** The circular fixation apparatus facilitates a better overall reduction than was possible with closed reduction alone or with traction treatment methods.

2- **Stability:** The circular fixation frame allows excellent stabilization of the fracture for early ambulation of the patient, reducing the length of hospital stay and the cost compared to prolonged traction treatment.

3- **Skin care:** The use of an external fixation frame allows access to the skin for continued care of skin abrasions or wounds. This is not possible with cast treatment.

4- **Minimal soft tissue trauma:** The use of the closed reduction technique or the percutaneous limited open reduction eliminated further soft tissue trauma, which is a major benefit.

5- **Support and load tolerance:** The tensioned transfixion wires allow capture of small periarticular fracture fragments and provide a support for the soft cancellous osteoporotic bone. A subchondral cluster of K-wires has been proven bimechanically to enhance load tolerance of the tibial plafond articular cartilage.

6- **Interfragmentary effect:** Olive wires are particularly helpful in obtaining a better reduction of the metaphyseal fracture component.

7- **Axial motion:** The elasticity of the thin wires used allows for axial motion (loading) of the fracture compressing the fracture gap to achieve bone-to-bone contact without additional bone grafting.

8- **Preservation of joint:** By using circular frames, surgeons are able to stabilize periarticular injuries without having to span the joint. Such placement would allow early ROM and improve the viability of the articular cartilage.

9- **Maintainance of length:** A circular fixator can maintain length and alignment while spanning a zone of comminution.

10- **Bracing of associated ligamentous injury:** The circular fixation provides adequate bracing for any form of management of ligament disruption.

Disadvantages (47)*:*

1- **Long learning curve:** as the assembly of the apparatus is much more complex and time consuming than the uniaxial frame.

2- **Careful monitoring and patient co-operation:** the patient has to clean at least 10 to 20 pin sites each day. the surgeon has to closely monitor the frame.

3- **Pain:** Stretching process to bone and soft tissue not well tolerated by all patients.

4- **Possible neurovascular injury:** because a large number of pins are passed in various axes, the possibility of causing damage to blood vessels and nerves leading to aneurysms or neuroma.

5- **Psychological acceptance:** To retain the frame on the body and carry on with one's normal social activities requires a lot of psychological courage.

6- **Pin-tract infection (PTI)**

Incidence

The rates of infection range from 0.5% to 70%. ***Paley*** **(48)** grading for PTI. Grade 1: soft tissue inflammation grade 2: soft-tissue infection grade 3: bone infection.

Complications

1- Pin tract infections can decrease the stability of the pin-bone interface. Conversely, instability of the fixator-pin-bone construct can lead to half pin loosening and infection.

2- External fixation wires and pins are colonized with bacteria, usually The incidence of chronic osteomyelitis, after external fixation, has been reported to be 0% to 4% **(49)**.

Management

1- Local cleansing, protecting the pin site with dressing, 2-using an oral or Intravenous (IV) antibiotic,

2- Removing the pin or wire,

3- Performing surgical debridement **(50)**.

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