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Primary Bone Graft and External Fixation Versus External Fixation Alone in Treatment of Distal Tibial Fracture

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Abstract: Background: The distal tibia has a precarious blood supply that renders the bone into delayed healing when fractured. This challenge makes the orthopedic surgeons to address it as unstable fracture that requires surgical intervention. Aim of Study: To evaluate the immediate bone graft with the use of external fixation of distaltibial fractures and compare it to non-grafted fixation. Patients and Methods: This is a prospective study conducted on 30 patients with distal tibia fracture that were dealt with in the orthopedic department,at Al-Kindy Teaching Hospital and Imamein Al-Kadhumein Teaching Hospital, during the period from October 2013 till June 2015. Included patients were those with closed tibial fracture of distal third grade 0 and grade 1 according to Oestern and Tscherneclassification,anddistal third tibial fracture with open grade I according to Gustillo classification. They were randomly divided into two groups in every other patient; these groups are allocated as followed: A-Group I: (8 males and 7 females) in this group of 4 patient had open Gustillo I fracture and 11 had closed distal third tibial fractures, that were prepared for external fixation with autogenous bone graft. B-Group II: (9 males and 6 females) in this group of 4 patients open Gustillo I fracture and 11 had closed distal third tibial fractures that were prepared for external fixation alone. Results: there were 6 patients in (3 patients in each group had complications of pin track infection,6 had delayed union (3 of group I and 3 in group II), none had malunion, and 2 patients of group II had nonunion. There was a significant difference both clinically and statistically in using the graft technique in the distaltibial shaft fracture treatment. Conclusion: Early autogenouscancellous bone grafting for any closed and grade I open low-energy open fracture is very effective.

Keywords: distal tibia, external fixation, immediate grafting.

INTRODUCTION

Epidemiology: The most common site of bone loss after fractures in human skeleton is the tibia, because of its subcutaneous position which predisposes it to open fracture and extrusion of bone. Open fractures of the upper limb and axial skeleton are less common and bone loss is seldom encountered in these locations. In Edinburgh, 68% of all fractures with bone loss were in the tibia and 22% in the femur, with the remainder occurring sporadically at other sites [Court-Brown, C. M. *et al*., 2006; Rutter, R. *et al*., 2000]. The diaphysis is the most common site of involvement. When bone is lost from the metaphyseal or articular areas, the injury is often devastating because of the high degree of energy transfer at the time of the injury. In the Edinburgh Trauma Unit, 69% of all fractures with bone loss were in the diaphysis, with the remainder having either loss of metaphyseal bone or the articular surface, or both [Rutter, R. *et al*., 2000].

Management

1. Initial assessment and decision making:

The majority of these patients present as an emergency with an open fracture. A careful clinical assessment of the vascular and neurological status of the limb is required. The first decision is to determine whether limb salvage should be attempted. Poor prognostic signs for limb salvage are a major soft-tissue injury, an ischemic time in excess of six hours, the presence of significant neurological deficit, especially of the tibial nerve, and other major organ injuries [Lange, R. H. *et al*., 1985].

Gustilo and Anderson—Based on the size of the open wound, amount of muscle contusion and soft-tissue crush, fracture pattern, amount of periosteal stripping, and vascular status of the limb. This classification has been shown to have poor interobserver reproducibility [Gustilo, R. B. *et al*., 1984]:

a-Grade I: Clean skin opening of <1 cm, usually from inside to outside with minimal muscle contusion. The fracture pattern usually is simple transverse or short oblique.

b-Grade II: A laceration >1 cm long, with extensive soft-tissue damage and minimal to moderate crushing component. The fracture pattern usually is simple transverse or short oblique with minimal comminution.

c-Grade III: Extensive soft-tissue damage, including the muscles, skin, and neurovascular structures. These are high-energy injuries with a severe crushing component.

IIIA: Extensive soft-tissue damage but adequate osseous coverage; there is no need for rotational or

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free flap coverage. The fracture pattern can be comminuted and segmental.

IIIB: Extensive soft-tissue injury with periosteal stripping and bone exposure requiring soft-tissue flap closure. These injuries usually are associated with massive contamination.

IIIC: Indicates a vascular injury requiring repair.

Oestern and Tscherne Classification of Closed Fractures: (table 1) [Tscherene, I. *et al*., 1984]

Table 1: Oestern and Tscherne Classification of Closed Fractures [Tscherene, I. *et al*., 1984]

Grade	Soft Tissue Injury	Bony Injury
Grade 0	Minimal soft tissue damage Indirect injury to limb	Simple fracture pattern
Grade 1	Superficial abrasion/contusion	Mild fracture pattern
Grade 2	Deep abrasion with skin or muscle contusion Direct trauma to limb	Severe fracture pattern
Grade 3	Extensive skin contusion or crush Severe damage to underlying muscle Subcutaneous avulsion Compartmental syndrome may be present	Severe fracture pattern

However, a recent multicentre prospective evaluation was not able to validate the clinical usefulness of any of the lower-extremity injury-severity scores. Low scores were found to be useful in predicting the potential for limb salvage but high scores were not good predictors of amputation. In patients with serious soft-tissue, vascular or neurological problems the opinion of other relevant specialists must be sought [Bosse, M. J . *et al*., 2001].

CT scans or MRI are most useful in evaluating articular defects, but may be of limited value if there are metal implants adjacent to the joint. Films measuring leg length will be of value in patients who have undergone shortening as part of the initial treatment, in order to plan subsequent lengthening [Gregor, S. *et al*., 2008].

2-Options for surgical management:
The main aims of treatment are skeletal stabilization, restoration of length and alignment, and preservation of optimum function. Modern orthopedic techniques offer a bewildering selection of options for treatment. There is rarely a perfect solution; most options for treatment have drawbacks as well as advantages. Because these cases are uncommon there are no large comparative clinical studies on which to make an informed choice. However, the available literature is sufficient to draw general conclusions and make specific recommendations for management. The initial choice of skeletal stabilization is particularly important as it will influence subsequent treatment. The following options may all be considered[Court-Brown, C. M. *et al*., 2006; Rutter, R. *et al*., 2000; Gregor, S. *et al*., 2008; Keating, J. F . *et al*., 2005] .

Types of fixation:
Intramedullary nailing: Interlocking nails have become the treatment of choice for managing open diaphyseal and metaphyseal fractures of the femur and tibia (Fig. 1). In patients with metaphyseal bone loss, nails have some particular advantages (Table 2). They confer excellent stability and allow restoration of length and alignment. The soft tissues can be readily accessed for further wound debridement and soft-tissue cover, and joints can be mobilized readily. Lengthening over a nail is an option in the femur or tibia and may be a useful method of dealing with a long defect. Nails are not the choice when distraction osteogenesis or free tissue transfer is being considered to fill the defect, unless an intramedullary lengthener is being considered for subsequent distraction osteogenesis [Robinson, C. M . *et al*., 2009].

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Figure 1: Radiographs showing Anteroposterior and lateral films of intramedullary nail of Distaltibial fracture [9]

Plates: Plating is technically difficult. Extensive exposure may be required, particularly if there is a segmental defect to bridge (Table 2). It may be particularly difficult to judge the correct length and rotational alignment. The presence of segmental defects will compromise the stability of plate fixation. Plating is biomechanically unfavorable in the presence of a defect due to cantilever loading. New designs of plates, such as locking compression plates and minimally invasive systems, are now available and may have an advantage over conventional plates [Shlickewei, W. *et al*., 1992; Perren, S. M, 2002].

Figure 2: Radiographs pre- and postoperative Distaltibial fracture with minimally invasive plate fixation[11]

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***External fixation**:* External fixation is a versatile method of treating fractures with bone loss and may be deployed in almost any location (Table 2).

Table 2: Skeletal fixation: the advantages and disadvantages[11]

Advantages	Disadvantages
Intramedullary nails	
• Stable fixation • Can bridge long defects • Can be inserted with minimally invasive surgery • Low rates of malunion • Shortening and lengthening can be accomplished relatively easily • Can be used in conjunction with external fixation to lengthen bone • Allow easy access to soft tissues for bone grafting/flap cover	• Not applicable for all metaphyseal fractures • Not suitable for use in the forearm • High complication rate when used in the humerus • Not suitable alone for defects > 6 cm
Plates	
• Versatile method of treating upper/lower limb metaphyseal fractures • Good treatment for forearm/humeral diaphyseal fractures • Minimally invasive plate designs now available	• Poor results in tibial and femoral diaphyseal fractures • Standard plating technique requires extensive dissection • Plate failure may occur in situations where prolonged union times are expected • Does not easily allow shortening and lengthening • Cannot easily be used in conjunction with external fixation • Not suitable alone for defects > 6 cm
External fixation	
• Versatile method of treatment • Can be used on upper/lower limb for metaphyseal/diaphyseal fractures • Can be used to shorten or lengthen bone • Bone transport possible • Can be used to compress the fracture site to stimulate healing • Correction of angular or rotational deformity possible Long defects (> 6 cm) can be treated	• Cumbersome, poor patient acceptance • Frame may have to left on for prolonged periods • Pin-track infection • Risk of septic arthritis when used close to a joint, especially the knee • Not ideal on the femur or humerus

Modern frames have a number of advantages. Circular frames such as the Ilizarov are useful with extensive defects, particularly if distraction osteogenesis is being planned, or if there is an additional deformity requiring correction. Shortening of the bone can be used to facilitate closure of soft tissue defects, with the frame being subsequently used to restore length [Shlickewei, W. *et al*., 1992] (Fig. 3).

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Figure 3a: – Bone transport in the tibia being carried out using a circular frame. Figure 3b – Long leg radiograph showing outcome after union[12].

External fixators can be used in the lower limb in conjunction with intramedullary nailing for bone transport. Frames have the advantage that they can be used in any location and in peri-articular defects with short juxta-articular segments. Depending on the design of the frame they can be used to lengthen and transport bone, and correct deformity. As with other methods, external fixation has specific drawbacks. It may not be possible to remove the frame for many months and pin-track infections may require medical or surgical treatment. This is particularly the case in the femur and humerus. Fine-wire fixators applied too close to joints, particularly the knee, can result in septic arthritis. In the lower limb, the unilateral frames designed for fixation of fractures are not strong enough to maintain alignment in the presence of a segmental defect, resulting in an increased risk of malunion. Compliance with frames when they are in place for long periods can be a problem [Hutson, J. J . *et al*., 2007].

- Severe fractures of the tibia, frequently fail to unite or are slow to unite after the first intervention.When measured as the need for an additional intervention to promote healing, the rates of delayed union have ranged from 43% to 100% [Dickson, K. F . *et al*., 1998].
- The likelihood of nonunion in patients with these severe fractures has led some clinicians to advocate the use of bone-grafting as part of a staged procedure aimed at achieving union [Stegemann, P . *et al*., 1995; Bone, L . *et al*., 1994. B; Burgess, A. R. *et al*., 1987].
- Staged, planned bone-grafting of open tibial fractures, performed between six and twelve weeks after the injury has been associated with union rates ranging from 81% to 100% [Karlstrom, G . *et al*., 1983].
- Although this procedure has been found to be efficacious, the donor-site morbidity associated with the harvesting of autogenous bone graft and the potentially limited supply of suitable autogenous bone in some patients have prompted some surgeons to evaluate alternative grafting materials for clinical use [Vaccaro, A. R . *et al*., 2002].
- One alternative is allograft bone, which retains most of its inherent osteoconductive properties after processing to minimize donor-host disease transmission. However, the osteoinductive capacity of processed (frozen or freeze-dried) allograft is uncertain because osteoprogenitor cells are destroyed during tissue-processing. The result is that the osteoinductive material is only partially retained, potentially yielding a suboptimal clinical effect [Gazdag, A. R . *et al*., 1995].
- Bone morphogenetic proteins (BMPs), the family of osteoinductive proteins in bone

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matrix, were first identified by Marshall Urist in 1965. The first clinical reports on the use of human BMP extracts from demineralized bone were published in the 1980s [Johnson, E. E. *et al*., 1988; Johnson, E. E. *et al*., 1988]. Although those investigations yielded promising results, clinical applications were constrained by the limited supply of human BMP that could be extracted from allograft. Cloning of the complementary DNA encoding the human BMP-2 sequence [Celeste, A. J Johnson, E. E . *et al*., 1990; Wozney, J. M . *et al*., 1988] allowed the manufacture of large quantities of highly purified rhBMP-2 with consistent biological activity for use in clinical investigations.

Application of External fixation

- *Anatomic Review: [*Goss, C.M, 1973; Last, R. J, 1984; Richard, S. S, 1986*]*

The tibia is the largest bone of the leg. It articulates above with the condyles of the femur forming a synovial joint of the modified hinge variety with flexion, extension and some degree of rotation, and with head of the fibula forming synovial plain joint. It articulates below with the talus and distal end of the fibula forming synovial hinge joint, and with the distal end of the fibula forming fibro-osseous (syndismosis) joint. The tibia has an expanded upper end, a smaller lower end and a shaft. The shaft is triangular in cross-section. It’s anterior and posterior borders, with surface between them, are subcutaneous. The subcutaneous surface receives the tendons of sartorius, gracilis and semitendinosus at its upper end, and behind these the tibial collateral ligament is attached. The surface is continued at its lower end into the medial malleolus. The anterior border is sharp above, where it shows a medial convexity imprinted by tibialis anterior. This border becomes blunt below, where it continues into the anterior border of the medial malleolus. The blunt posterior border runs down into the posterior border of the medial malleolus. In front of the interosseous border is the extensor surface of the shaft. This surface runs from the upper end below the lateral condyle to spiral over the front of the lower end of the tibia. Tibialis anterior arises from the upper two thirds or less of the surface. Below the muscle, the extensor surface of the tibia is bare.The lower tibia is defined as the distal part of tibia above the square that its diameter width of the same intermalleolar distance. Behind the interosseous border is the flexor surface of the shaft. Its upper part is distinguished by the soleal line, which runs down obliquely from just below the tibio-fibular joint across this surface to meet the posterior border one third of the way down. Popliteus arises from the popliteal surface of the tibia above the soleal line; the popliteal fascia, a downward extension from semimembranosus tendon, is attached to the line. Below the soleal line the flexor surface shows a vertical ridge. Tibialis posterior arises between this ridge and the interosseous border (it crosses the interosseous membrane to arise also from the fibula). Medial to the ridge, between it and the posterior border, flexor digitorum arises. The upper part of this surface is perforated by a large nutrient foramen direct downward. The lower part of this surface is a bare bone, crossed by tibialis posterior and the overlying flexor digitorumIongus. Nutrient artery to the tibia is the largest nutrient artery in the body. It arises from the posterior tibia. Artery near its origin and, after supplying a few minute muscular branches, runs downwards to enter the nutrient canal in the bone, at point immediately below the soleal line.

Important neurovascular structure [Richard, S. S, 1986***]:***

1. **Common peroneal nerve**, this nerve is the smaller terminal branch of the sciatic nerve; it leaves the popliteal fossa by crossing superficially the lateral head ofgastrocnemius muscle. It then passes behind the head of fibula, winds laterally behind the neck of the bone pierces the peroneus longus muscle, and divides into two terminal branches, the superficial and deep peroneal nerves. As the nerve lies on the lateral aspect of the neck of the fibula, it is subcutaneous and can easily be rolled against the bone and more susceptible to injury.

2. The superficial peroneal nerve arises in the substance of the peroneus longus muscle on the lateral side of the neck of the fibula. It descends first between the peroneus longus and brevis and the extensor digitorum longus. In the lower part of the leg, it pierces the deep fascia and becomes cutaneous branch supplies the skin on the lower part of the front of the leg and the dorsum of the foot. The superficial peroneal nerve supplies peroneus longus and brevis

3. The deep peroneal nerve arises in the substance of the peroneus longus muscle on the lateral side of the neck of the fibula. The nerve enters the anterior compartment by piercing the anterior fascial septum. It then descends deep to the extensor digitorum longus muscle, first lying

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lateral, then anterior and finally lateral to the anterior tibial artery. Then the nerve passes behind the extensor retinacula, then enters the foot the deep peroneal nerve supplies muscles of anterior fascial compartment of the leg (tibilais anterior, extensor digitorum longus, peroneus tertius, extensor hallucis longus and extensor digitorum brevis).

4. Arterial supply of lower tibia:The posterior tibial artery, the larger and more direct terminal branch of the popliteal artery, provides the blood supply to the posterior compartment of the leg and to the foot. It begins at the distal border of the popliteus as the popliteal artery passes deep to the tendinous arch of the soleus and simultaneously bifurcates into its terminal branches. Close to its origin, the posterior tibial artery gives rise to its largest branch, the fibular artery, which runs lateral and parallel to it, also within the deep subcompartment. During its descent, the posterior tibial artery is accompanied by the tibial nerve and veins. The artery runs posterior to the medial malleolus, from which it is separated by the tendons of the tibialis posterior and flexor digitorumlongus. Inferior to the medial malleolus, it runs between the tendons of the flexor hallucis longus and flexor digitorum longus. Deep to the flexor retinaculum and the origin of the abductor hallucis, the posterior tibial artery divides into medial and lateral plantar arteries, the arteries of the sole of the foot.

5. The fibular artery, the largest and most important branch of the tibial artery, arises inferior to the distal border of the popliteus and the tendinous arch of the soleus. It descends obliquely toward the fibula and passes along its medial side, usually within the flexor hallusis longus. The fibular artery gives muscular branches to the popliteus and other muscles in both the posterior and the lateral compartments of the leg. It also gives rise to the nutrient artery of the fibula. Distally, the fibular artery gives rise to a perforating branch and terminal lateral malleolar and calcaneal branches. The perforating branch pierces the interosseous membrane and passes to the dorsum of the foot, where it anastomoses with the arcuate artery. The lateral calcaneal branches supply the heel, and the lateral malleolar branch joins other malleolar branches to form a periarticular arterial anastomosis of the ankle.

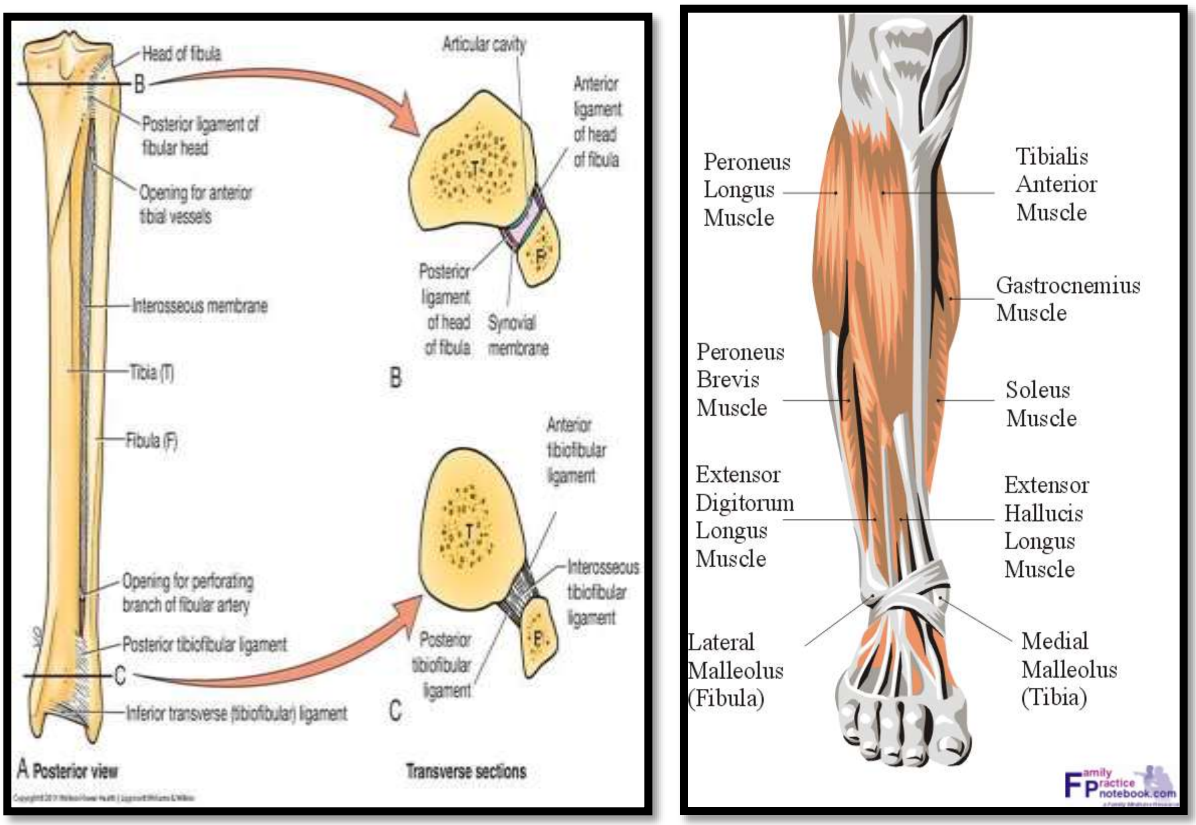

Figure 4: A. tibia articulations anatomy, B. muscular attachments to tibia[Burgess, A. R. *et al*., 1987]

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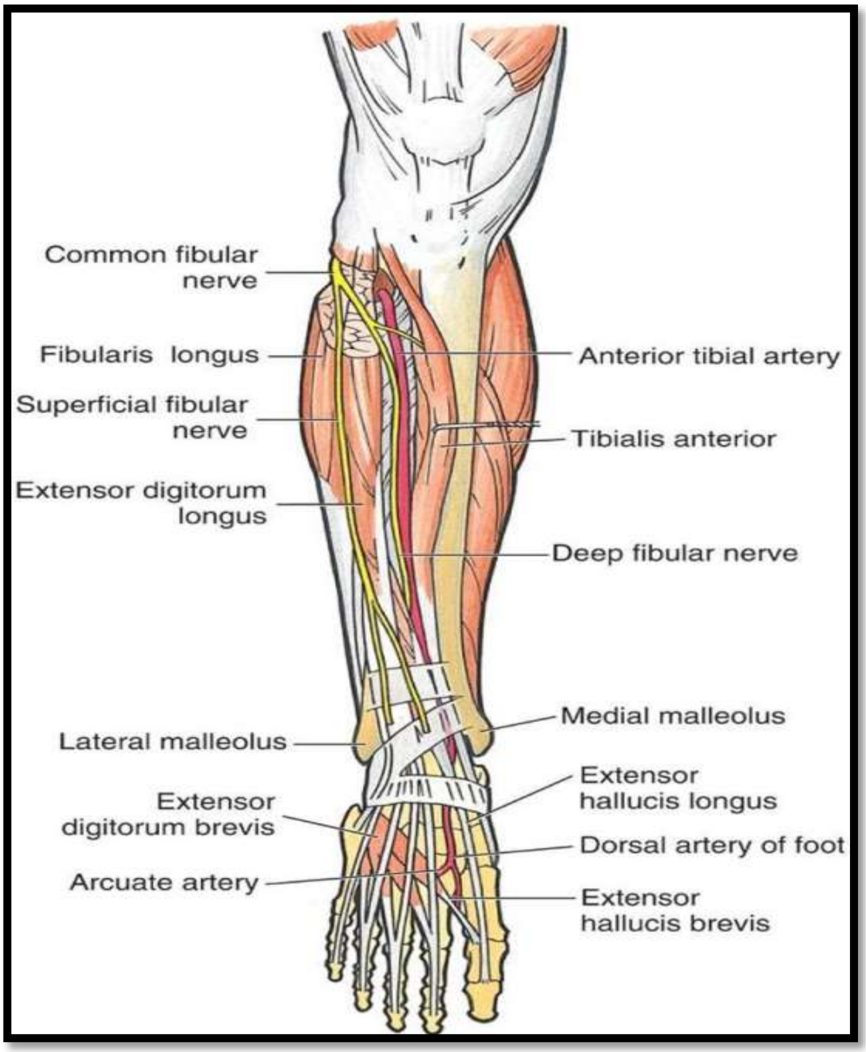

Figure 5: the neurovascular structures of the leg[Goss, C.M, 1973]

The corridor of the tibia[Behrens, F. *et al*., 1981***]:*** The safe soft-tissue corridor for pin insertion is determined by the anatomy. Cross-sectional area (safe corridor) of the tibia arranged into five groups corresponding to areas most commonly used for external fixation. (Figure 6, 7, 8)

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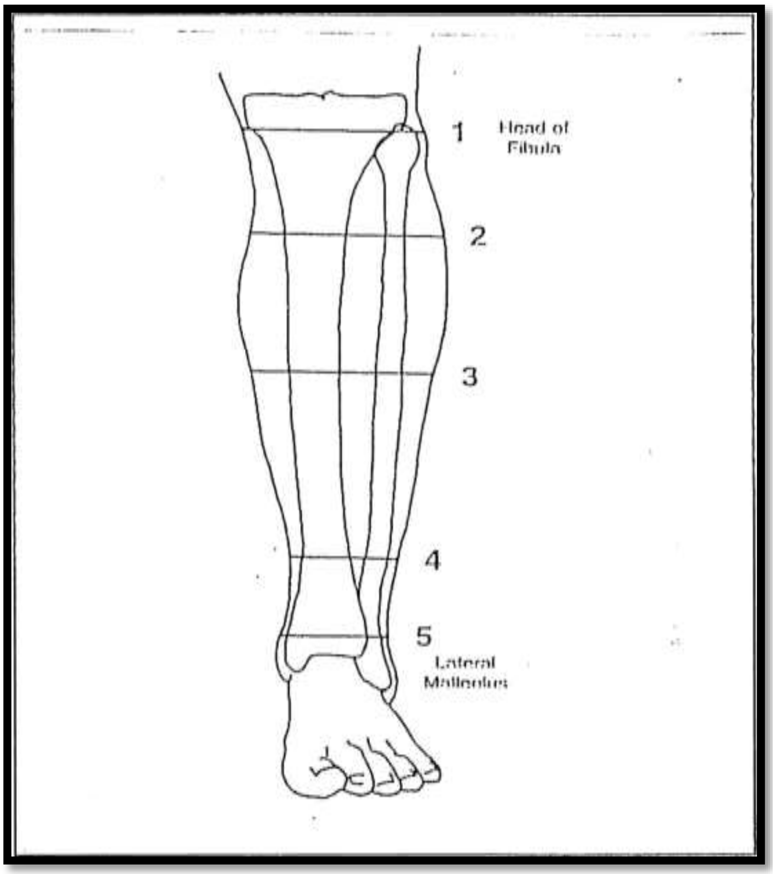
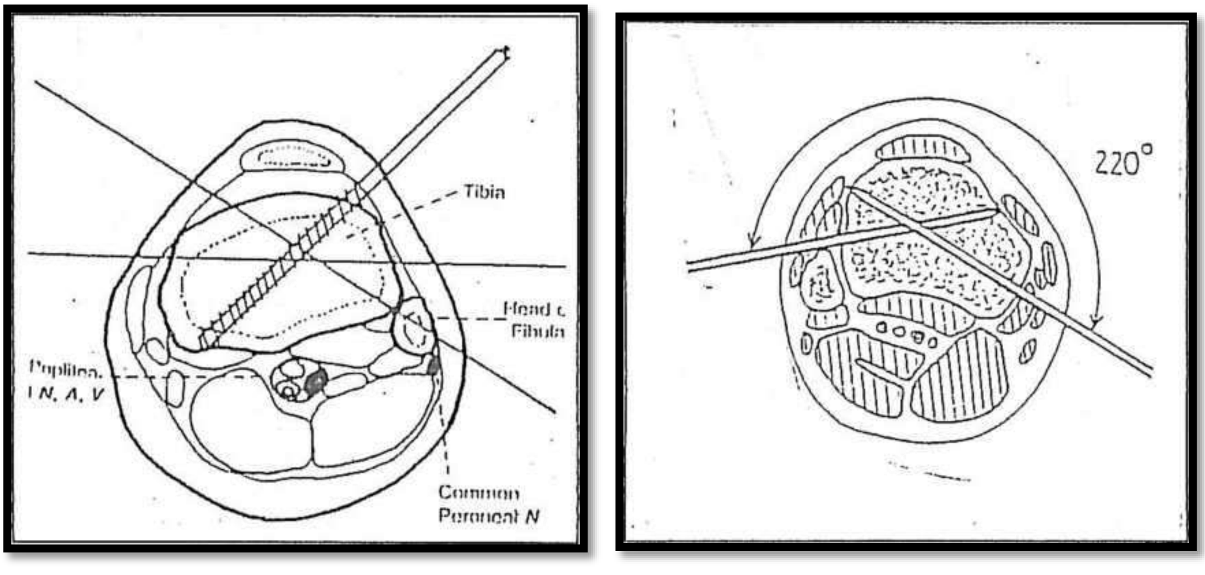


Figure 6: The bony landmark in the proximal part of the tibia is the head of the fibula, and in the distal part is the lateral malleolus.



A: B:

Figure 7: A and B proximal tibial safe corridors ' angles

This cut crosses the medial and lateral plateau just below the knee joint. The tibia is palpable along its circumference except posteriorly. Other land marks include the lateral collateral ligament, the biceps tendon and the patellar tendon. The major neurovascular structures are posterior and slightly lateral, except the lateral common peroneal nerve and the medial saphenous nerve. At this level the peroneal nerve is situated posterior to the biceps femoris. The schanz screws placement is safe within a 220° arc from the posteromedial border of the tibial plateau to the tibio-fibular joint(figure 7).

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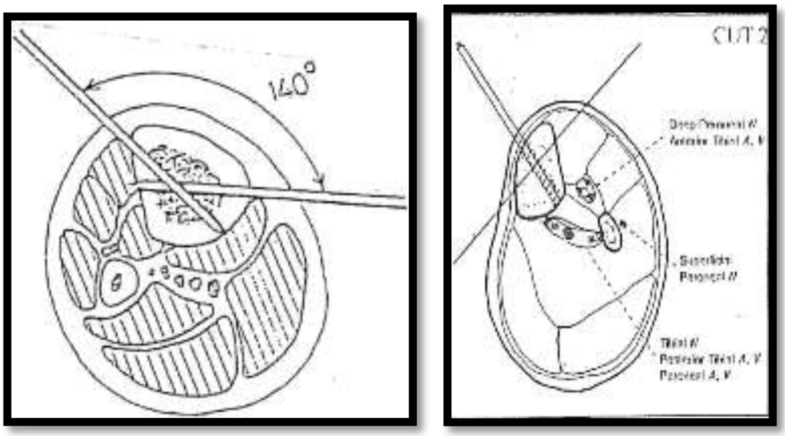
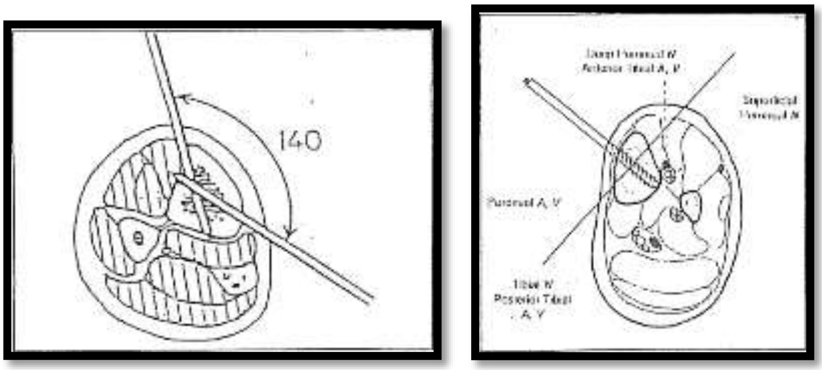


A: *B:*

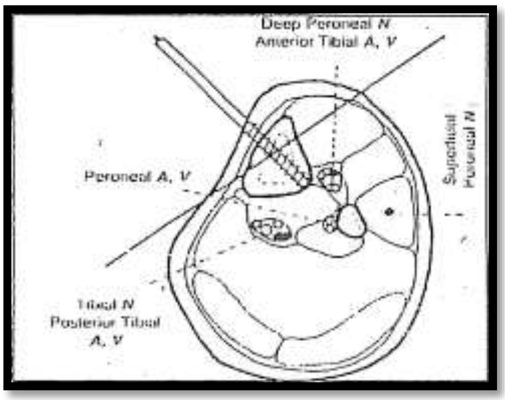
Figure 8: A and B: Safe corridors in mid tibial shaft[30]

The entire anteromedial border of the tibia is palpable, which provides reliable information as to the size of this bone. Compared to their position at more proximal level, the major neurovascular structures lie more centrally. The anterior bundle lies anterior to the interosseous membrane in the sagittal axis. The schanz screws can be safely inserted within an arc of 140°, posterior pin exit areas may injure posterior tibial neurovascular structure. (figure 8) The tibia maintains its dense cortex and medial subcutaneous position. The muscular contribution remains similar with one significant change being the increasing mass of the gastrocnemius muscle. The anterior tibial artery, vein and deep peroneal nerve continue their course along the interosseous membrane.

The posterior tibial artery, vein and tibial nerve run posterior and lateral to the tibia at the confluence of the soleus, tibialis- posterior muscle, and the flexor digitorumlongus muscle. The peroneal vessels remain medial in relation to the fibula.



A: B:



C:

Figure 9: A, B and C: mid and lower third tibial cross section for half pin fixator[Behrens, F. *et al*., 1981]

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The tibia remains palpable along its medial surface, but it relatively displaced anteriorly because the increasing posterior musculature. The anterior tibial vessels and the deep peroneal nerve run in a more posterior position, now lie adjacent to the interosseous membrane. These structures are covered by the tibialis anterior and the extensor halluces muscles. The posterior tibial vessels and tibial nerve are located centrally between the soleus muscle and the deep posterior compartment. The schanz screws can be safely inserted within an arc of 140°, but anterior tibial vessels and deep peroneal nerve become vulnerable as they cross the lateral tibial cortex. (Figure 10)

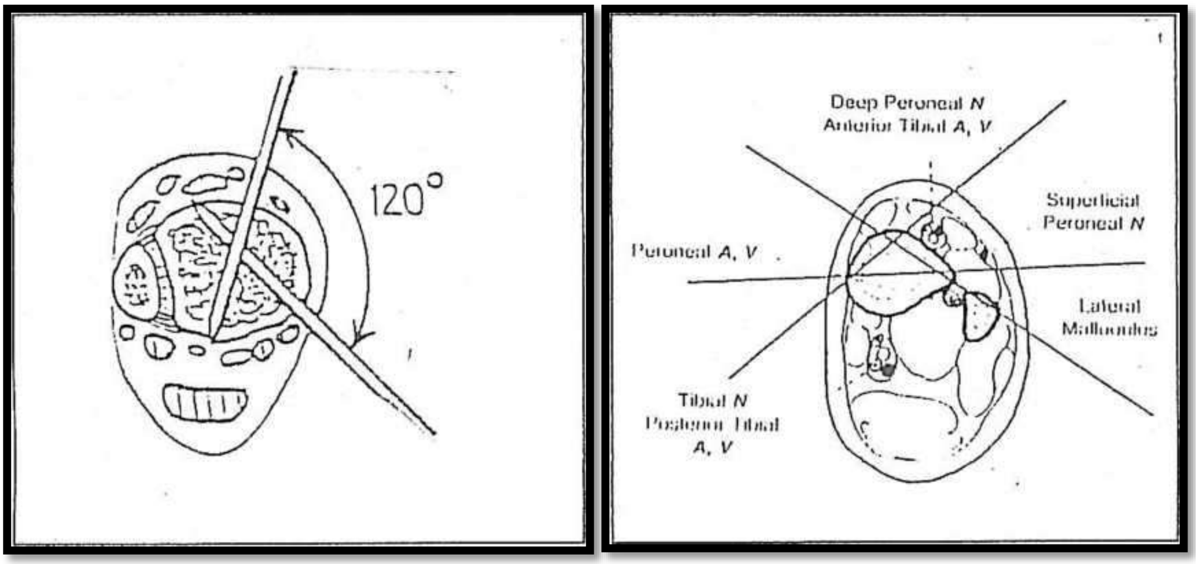

Figure 10: distal tibial safe zones [Behrens, F. *et al*., 1981].

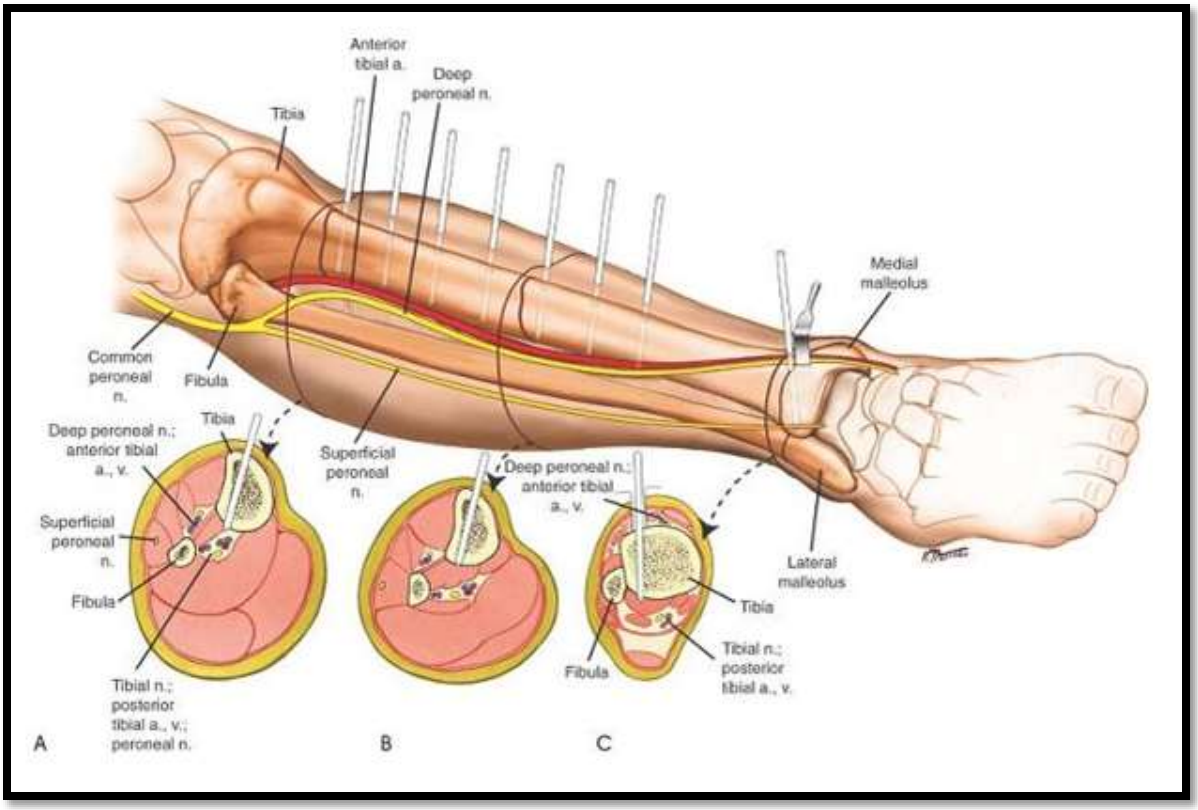

Figure 11: Because the neurovascular bundles lie largely posterior to the tibia and it has a subcutaneous surface, pin placement is relatively straightforward. (A) Proximal third: Insert anterior half pins through the subcutaneous surface of the bone. If half pins are used, avoid penetrating the bone too far to protect the anterior neurovascular bundle, the anterior tibial artery, and the peroneal

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nerve. (B) Middle third: Insert anterior half pins through the subcutaneous surface. (C) Distal third: Insert anteriorly placed half pins.[Burgess, A. R. *et al*., 1987]

Complications of external fixation[Behrens, F. *et al*., 1981; Hoppenfeld, S . *et al*., 2009; Thakur, A. J. *et al*., 1991]***:***
Complications can be minimized by adherence to basic principles and use of proper technique. The complications can be summarized by:

I. Pin tract infections: - It's the most common complication, occurring in 30% of patients. It varies from minor inflammation remedied by local wound care, to superficial infection requiring antibiotics; local wound care and occasionally pin removal, to osteomylitis requiring sequestrectomy. Anterior frame using 5 mm half-pins require that pins traverse only the skin and minimal subcutaneous tissue before gaining tibial purchase; minimal tissue interface seems to reduce pin tract problems. Attention to surgical detail is manifested in the following pin insertion protocol: -

1. .All pins are placed through stab wounds (should be more than the diameter of the pin).
2. All half-pin are predrilled using fresh sharp drill.
3. Bicortical purchase minimizes heat necrosis.
4. All drilling and pins application is done through sleeve trocar units to prevent winding and necrosis of subcutaneous tissue.
5. Pins are located by hand not power.
6. Tented skin pressure is exerted near the pin site. Pins sites are cleaned at least once a day; occlusive ointments are never used.
7. To minimized heat generation around the drill, and by which decreasing the risk of ring osteonecrosis or ring sequestration, it's preferable to use drill with low speed, and still better to irrigate the site of drilling, really, recently, there is automated drill with irrigation device and vacuum.
8. Threaded portion of pin should introduce beyond the skin.

II .Joint stiffness
Ankle stiffness is a frequent complication, especially if multidirectional pins and multiple transfixing pins are used due to muscle or tendon impalement.

This complication can be reduced when the following precautions are considered: -
1. Avoid pin insertion through a muscle bellies and tendons.
2. Bilateral splints are stiffer than unilateral splints.
3. Increasing pin numbers stiffened both bilateral and unilateral external fixation splints.
4. Decreasing side bar distance to bone from 1.5 cm to 1 cm to 0.5cm increase stiffness of both bilateral and unilateral splints.
5. Widening pin spacing from 1.67 cm to 2.5 cm increased stiffness in cranio-caudal bending only.
6. Decreasing the distance between pin groups from 5.84 cm to 2.5 cm increase stiffness in torsion between 23% (unilateral splint) and 45% (Bilateral splints).
7. Altering pin clamp configuration so that bolts of the clamp were inside the side bar rather than outside the side bar increased stiffness in axial compression only.
8. Conforming the lateral side bar to the tibia increased only axial compression stiffness by 77%.

III. Neurovascular impalement:
The anterior tibial artery and peroneal nerve at the junction of third and fourth quarters of the leg are the structures most often involved. Thus the surgeon must be familiar with the cross-sectional anatomy of the leg, and with the relatively safe zones and dangerous zones for pin insertion.

IV. Muscle or tendon impalement:
Pin insertion through, tendons or muscle bellies restrain the muscle from its normal extrusion and can lead to tendon rupture or muscle fibrosis. Ankle stiffness is frequent if multiple transfixing pins are used and in multidirectional pins.

V. Delay union:
The rigid pins and frames can "unload" the fracture site, with cancellation and weakening of the cortex. The callus produced is entirely endosteal, and delay union in 20% to 30%, and with prolonged use of rigid fixator may reach 80%).

***VI. Fracture*:**
Union due to rigid fixation is largely endosteal, with very little peripheral callus formation. Re-fracture is possible after fixator removal unless crutches, supplemental casts or supports adequately protect the limb.

***VII. Limitation of further alternatives*:**
Such methods as open reduction become difficult or impossible if pin tracts become infected.

VIII. Compartmental syndrome.

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Bone Graft [Thakur, A. J. *et al*., 1991; Springfield]***:***

- Autogenous bone graft in which bone is removed from one place to another in same individual, is considered the best method and material for enhancement of the fracture repair process. Autogenous cancellous bone grafts are the most effective graft materials because they provide the three elements required for bone regeneration; osteoconduction, osteoinduction and osteogenic cells.

- Osteoconduction in cancellous grafts occur because of the porous, 3-dimensional architecture of cancellous bone that allows for rapid ingrowth of fibro-vascular tissue in the host bed. In its matrix, cancellous bone contains growth factors, especially bone morphogenic protein (BMP), which by osteoinduction encourages the growth and differentiation of mesenchymal cells to osteoblastic lineages. Finally, living periosteal and other osteoblasts transplanted with the graft are osteogenic, producing new bone directly. After implantation, cancellous grafts are invaded by surrounding tissues. New bone formation occurs on the cancellous trabeculae, and the graft integrates with preexisting osseous structures. The graft is then remodeled under the influence of local mechanical stresses and gains structural strength and integrity [Springfield, 1987]

- Within the first two days, cancellous bone graft is entirely covered by blood vessels, and presumably within hours, whether by spontaneous vascular anastamosis or by actual ingrowth of host capillaries into the marrow interstices, revascularization is initiated and completed within two weeks. As vascular invasion proceeds, accompanying primitive mesenchymal cells differentiate into osteoprogenitor cells, then these cells in turn differentiate into osteoblasts that line the surface of dead bone.

- Finally, each trabeculum is composed of the original dead trabeculum enclosed by newly deposited viable bone having the appearance of woven bone, the bone mass is increased. Subsequently, the woven bone and the entrapped cores of the necrotic bone are gradually resorbed by osteoclasts and the new trabeculum is gradually reformed. The first phase of increase bone mass produces an increased radiodensity. Within the transplanted area; the second phase of resorption, which goes hand-in-hand with replacement by new lamellar bone, restores the original radiodensity [Thakur, A. J. *et al*., 1991].

- Fresh autogenous cancellous bone provides the largest number of surface cells, the viability of which must be protected in order to ensure early incorporation of the transplant into the host bed. So, for survival of a maximum number of potential osteoblasts, the following precautions must be considered:

1. The 'cancellous bone slivers should not exceed 5mm in thickness to permit rapid and complete revascularization.
2. Exposure of bone to air for more than 30 minutes resulted in significant decrease in the viability of the surface cells.
3. Physiologic saline solution is toxic after long-term immersion.
4. Elevation of ambient temperature above 42°C from exposure to operating room lights kills these cells.
5. Chemical sterilization (e.g. by mercurial) is lethal to cells.
6. Antibiotic (e.g. bactracin and neomycin) destroy cells.

- In the interval between procurement and implantation, bone can be wrapped is a blood-soaked sponge; heat must be avoided. For storage at longer interval up to several days, 10% human serum in 90% balanced saline solution (Hank’s, Earle’s or Ringer’s, Tyrode) at 3°C preserve the surface cells [Patzakis, M. J . *et al*., 1974].

- Adequate diffusion of nutrients at the recipient site must be facilitated. Interposition of dead space; hematoma or necrotic tissue between the transplant and its bed must be studiously avoided. The total mass of the transplant must not be so thick as to impede nutrient diffusion from underlying bone bed [Springfield, 1987; Chapman, M. W. *et al*., 1996].

- The autogenous cancellous bone graft is considered superior than cortical bone graft for enhancement of the fracture repair process. This is because; first, cancellous bone graft are more rapidly incorporated due to increased surface area as compared to cortical bone graft in which the process are slow due to density of cortex and lack of porosity. Second, cancellous bone graft undergoes bone formation before

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bone resorption, while in cortical bone graft bone resorption must take place before new bone formation. Disadvantages of autogenous bone graft include donor site morbidity, limited supply, and occasionally inferior biochemical strength of the graft [Chapman, M. W. *et al*., 1996].

PATIENTS AND METHODS

This is a prospective study conducted on 30 patients with tibial shaft fracture that were dealt with in the orthopedic department, Al-Kindy Teaching Hospital and Imamein Al-Kadhumein Medical City, during the period from October 2013 till June 2015 including the followup . The age ranged from 21-45 years (mean = 37)

Inclusion Criteria:

1. Patients with closed tibial fracture of distal third tibia grade 0 and gradeI.
2. Patients with open grade I distal tibial fracture according to Gustillo classification.

Exclusion Criteria:

1. Patients with co-morbid disorders as diabetic and cardiovascular diseases.
2. Age more than 50 years.
3. Comminuted fracture of distal tibia.

Thirty patients were selected according to inclusion criteria, of these patients 8 have open grade I Gustillo fractures, and 22 had closed fractures. The closed fractures were assessed according to Tchrene classification and patients were selected as they had grade 0 and grade I. The statistical analysis was performed independently, that all selected patients were randomly divided into two groups in every other patients; these groups are allocated as the following:

A. Group I: (8 males and 7 females) in this group of 4 patient had open Gustillo I fracture and 11 had closed distal third tibial fractures, that were prepared for external fixation with autogenous bone graft from ipsilateral illiac spine.
B. Group II: (9 males and 6 females) in this group of 4 patients open Gustillo I fracture and 11 had closed distal third tibial fractures that were prepared for external fixation alone.

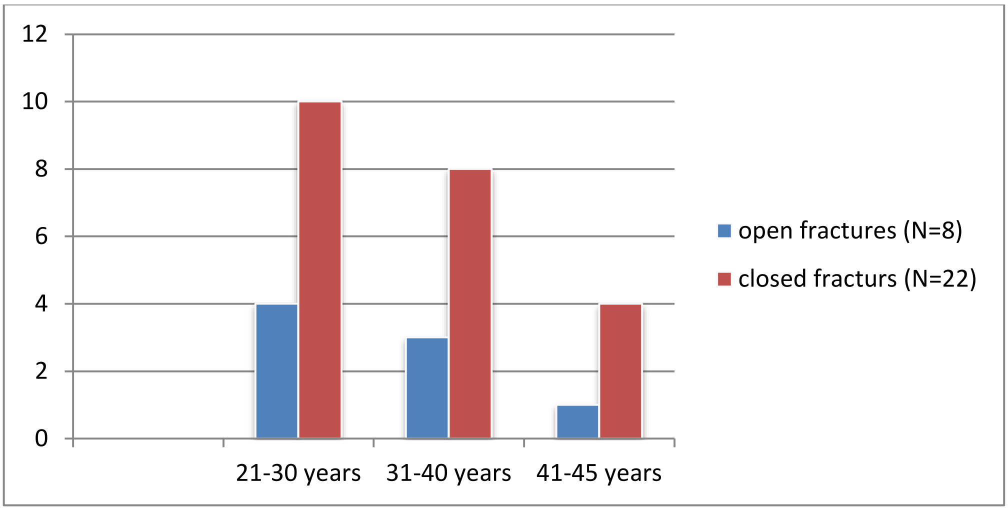

Figure 12: Patients age distribution in opened and closed tibial fractures

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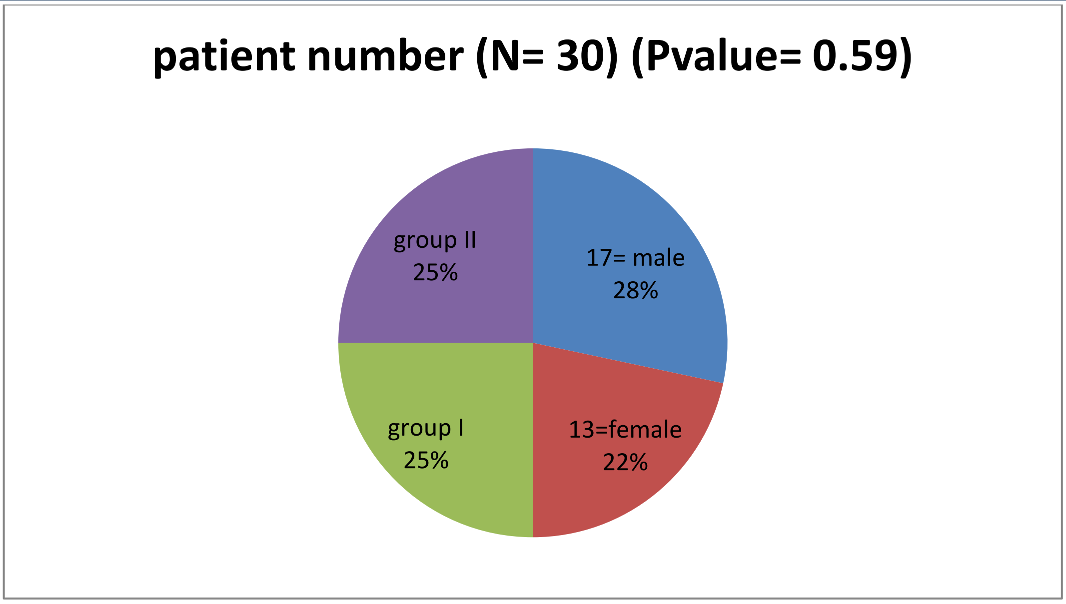

Figure 13: Gender distribution

All patients were evaluated by detailed history, thorough physical examination with radiological and other laboratory investigations. Systemic physical examination was performed for all patients. With special emphasis on examination and assessment of viability of the extremity, these include: soft tissue status, vascular integrity neurological integrity, bone construct and movement of the distal joints.The status of the soft tissue was classified according to Tscherene classification for those with closed tibial fracture were grades 0 and I, while patient with open fracture are classified according to Gustilo classification for type I only. Plain radiographs of broken leg, both antero-posterior and lateral views, were obtained in all patients, in some of them radiographs of other part of the body were also included-

Table 3: Mechanism of injury in all patients

Mechanism of Injury	Number of Patients (N=30)	%
1. Open fracture	*N=8*	*100*
• MVA*	6	75
• Blunt trauma	2	25
2. Closed fractures	*N= 22*	*100*
• MVA*	16	72.2
• Blunt trauma	2	9.09
• Fall from height	4	18.18

***** Motor Vehicle Accident***

Operative Technique:

- All injured patients from group II were taken to the operative room when they were stabilized in the emergency room after mean time of 12 hours,while patients from group I was operated after 2-3 days(for revascularaty).
- All patients were prepared for general anesthesia.
- Patients were positioned in supine.
- Skin preparation using Povodine Iodine.
- Pneumatic tourniquet was used above knee (not for all patients).
- Pre-drilling: It is advisable to pre-drill the tibial diaphysis in order to avoid heat damage to the bone and to ensure that both cortices are engaged correctly. Use an appropriate sleeve when pre-drilling to protect soft tissues.
- Insertion of Schanz screws: Insert Schanz screw into each main fragment using a trocar sleeve protector. Ensure that the opposite cortex is engaged. Correct depth insertion may be achieved by feeling the opposite cortex. Note that intraoperative x-rays can be deceptive. If the control x-ray shows an empty hole in the opposite cortex, the screw has not been inserted far enough.
- Self-drilling Schanz screws may be used. However, the thick tibial cortex should be predrilled first. These pins are inserted through

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the near cortex until they just penetrate into the far cortex, but do not pass through it. Self-drilling screws may be inserted into cancellous bone without pre-drilling.

- Half pins were inserted near the fracture site (mean 3 cm), by making stab incision on the tibial crest according to the safe zones of half pin angles.
- Reduction was performed manually, and then the rest of half pins were inserted and combined with the bar of external fixator.
- We use static external AO/ASIF biplanar type with a half-pin anteromedial frame, with “single- stacked” pin clamp. Three shanz 5 or 4mm half- pins are placed medial to tibial crest anteriorly in a wide grouping above and below the fracture site. The pin clamp is single-stacked and connecting road attached at both levels. The clamps are placed about one inch away from the skin to permit wound access.
- An incision (mean 5 cm) was made for the Group I patients on anterior superior iliac spine for taking autogenous cancellous graft, then another incision (mean 5 cm) was make on the fracture site to fill the fracture by graft.
- For both (closed and open fracture) postoperatively the leg was maintained in elevation. Dry dressings were put onto the wound and changed once daily. Stitches were removed usually within 10-14 days.

Active and passive ankle and knee movement started after 24 hrs and the patients were ambulated with crutches in three to four days by non-weight bearing walk. Partial weight- bearing was permitted 6 weeks after index surgery for both groups; the load was gradually increased as pain permit and full weight- bearing was allowed 3 months after operation. Patients were leave hospital as soon as possible having been taught how to keep the shanz and the external fixator clean. At the first radiographic indication of periosteal callus formation (usually within 6-8 weeks), the external fixator was dynamized by loosening and tightening the clamps in across-wise order as described by Allgower and Sequin, 1987. The fixators were removed after 20 weeks mean. Patients were followed up every other week for three months, then monthly till the fracture consolidate. Patients walking after 2 weeks by non weight bearing using walkers or canes, 6 weeks partial and mean of 12 weeks full weight bearing walk, all patients returned to pre-injury level of function. After fractures healing (mean 12 weeks), the external frame had been dynamized by moving the bar away from the leg, then after 4 weeks the distal half pin that is nearest to fracture site was removed for all patients.

Figure 14: A. Anteropsterior view of 44female with Distaltibial fracture, B. Lateral radiograph.

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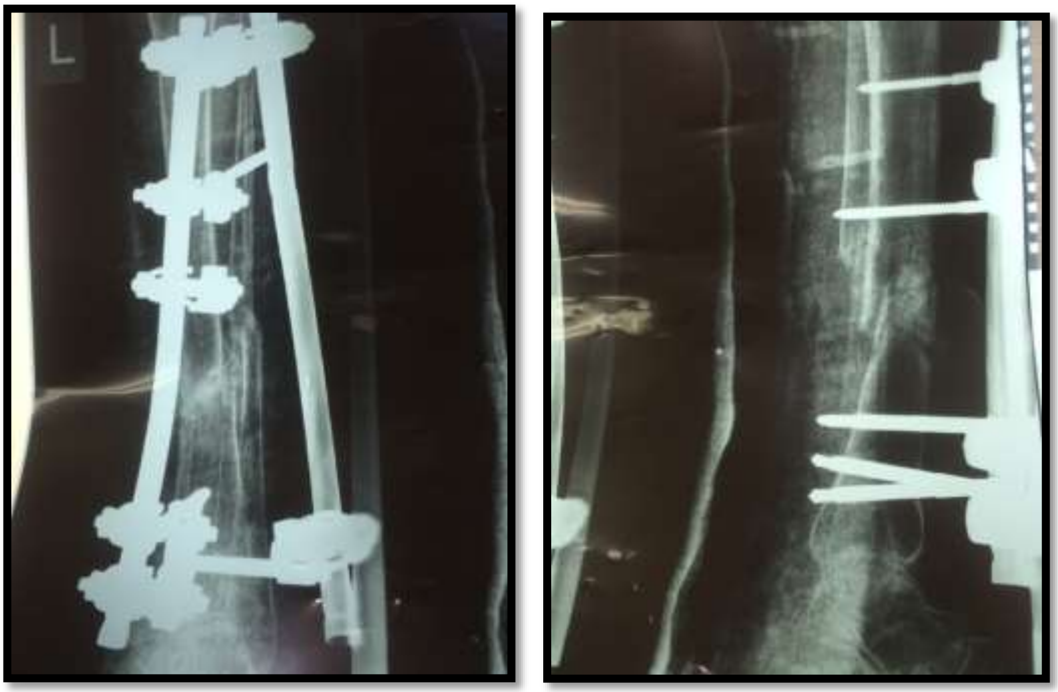
A B C

Figure 15: A. Intra-operative photo shows the reduction of fracture, B. intra-operative photo shows augmentation of bone graft with external fixation, C.post-operative photo of the donor site incision after closure.



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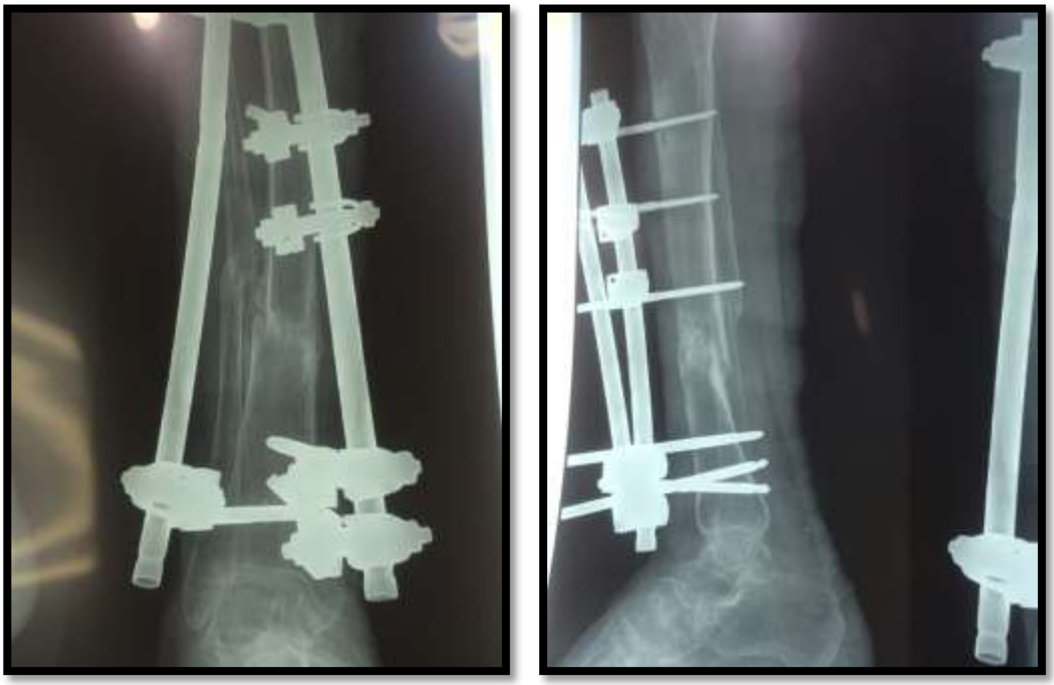

B

Figure 16: A. post-operative radiograph of same patient after 2 month of index surgery.B.post-operative radiograph of same patient after 4 month of index surgery.

RESULTS

A total of 30 consecutive patients with fracture tibial distal third (closed and open) were included in this series. 17 males (28%) and 13 females (22%) . Obviously there is strong correlation between the severity of injury, and incidence of the delayed and nonunion, the incidence of delayed union and non union is directly related to the severity of injury. Tables 4 and 5 demonstrate the difference between those patients who had bone graft and those without it and. There is high incidence of nonunion among those did not subjected to bone graft as compared with second group who subjected to bone graft. In Group I, there were 8 patients had minimal contusion of skin (according to Tchrene classification), and 3 patient had blister formation and moderate muscular contusion for the closed distal tibial fractures, while in same group there were 4 patients had open grade I fractures of distal tibia (table 4). On the other hand, in Group II there were 7 patients had hematoma around the wound and moderate muscular contusion in 4 patients. The complications in this study are : (Table 6)

- Pin track infection: there were comparable results in both groups, 3 patients each group, that were covered by antibiotics both systematically and locally, as well as local care for the pin track.
- Fortunately there was no difference both clinically and statistically (P value= 0.92) regarding the chronic infection as none of all patients developed sequestra formation.
- In regards of the delayed union, there was no significant statistical nor clinical difference in both groups (P= 0.22). for these patient both got improved after encouraging full weight bearing after 10 weeks mean.
- Re-fracture after removal of external fixation had occurred in one patient of Group I, and 2 patients in Group II that shows significant difference both clinically and statistically (P=0.02).this was occurred after mean time of 3 months, all 3 patients were elected by re-fixation and healed after a mean of 8 weeks with good callus formation, one patient delayed full weight bearing after 12 weeks of last surgery.
- Of all patients in both groups, none of them had malunion.
- Non-union occurred in 2 patients of Group II as compared from none in group I both clinically and statistically. That was occurred in 8 months mean, all these patients were elected for open reduction and plate fixation with iliac crest autogenous bone graft.
- The overall complications in both groups were significant differs from those in group I (7 patients, 46.6%), and in group II 11 (73.7%) patients, that show statistical different in both

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groups (P= 0.035).

Table 4: Correlation of bone graft, with delayed and nonunion in closed fracture according to Tscherene classification:

Bone graft	Tscherene type	Number of patients (N=22)	Pattern of fracture		Delayed union	Nonunion
			oblique	transverse	Number (%)	Number (%)
Group I (N=11)	T0	8	3	5	0 (0.0%)	0 (0.0%)
	T1	3	0	3	1 (33.3%)	0 (0.0%)
Group II (N=11)	T0	7	5	2	1 (14.28%)	1 (14.28%)
	T1	4	2	2	1 (25%)	0 (0.0%)

Table 5: Correlation of bone graft, with delayed and nonunion in open fracture according to Gustilo classification:

Bone graft	Gustilo type	Main Number of patients	Pattern of fracture			Delayed union	Nonunion
			comminuted	oblique	transverse	Number (%)	Number (%)
Group I	I	4	0	2	2	2 (50%)	0 (0.0%)
Group II	I	4	0	3	1	1 (25%)	1 (25%)

Complications related to the use of external fixation:

Obviously pin tract infection is the main problem related to use of external fixation (table 4) which is account 64%, for ankle stiffness and equinus deformity comes next.

Table 6: complications of patients in both groups

Complications	Group I(N=15)	Group II(N=15)	*P value*
Pin track infection	3(20%)	3(20%)	0.92
Sequesrum ring formation	0(0%)	0(0%)	0.0
delayed union	3(20%)	3(20%)	0.22
Re-fracture	1 (6.66%)	2(13.3%)	0.02
Malunion	0(0%)	0(0%)	0.97
Non union	0(0%)	2(13.3%)	0.03
total	**7(46.6%)**	**11(73.7%)**	**0.035**

DISCUSSION

Fracture shaft tibia is a common and frequently perplexing problem in our locality. Fractures of the tibia reported (22.4%) of all fractures hospital admission. The current rationale for the management of open fractures is based on work of Mendoza and Williams, (1984) ,Gustilo,(1990) and Candle and Stern, (1987). In this study adapt this system to classify open fracture, and in this study depend on Tschrene system (1984) to classify closed one. In this study agree with Andrew and Commander, (1987) that initial management of open tibial fracture especially type I is irrigated thoroughly with copious amount of normal saline. The injury can be categorized in terms of the quantity of energy transmitted to the tissues, whether this was high or low energy. Large wounds in soft tissue, a segmental pattern of the fractures and significant displacement all

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reflect the violence of the forces that causes these fractures[Burgess, A. R. *et al*., 1987].The use of the AO tubular external fixation for open tibial fracture is not a new subject. It is simple, safe and a satisfactory method of fixation for that particular fracture (probably the commonest). It improves the functional result of severely injured limb, and there are indications that it aids in soft tissue healing and in preventing wound infection [Gustilo, R. N. B . *et al*., 1990]. After a century of doubt regarding the safety and the proper indications for external fixation, it has recently gained acceptance as the preferred method of stabilization for open tibial fracture and some closed one [Candle, R. J . *et al*., 1987]. Some authors abounded the use of one-plane unilateral frame calming that it is inadequate and introduce what is called quadrilateral frames [Edwards, C. C . *et al*., 1988]. Still in this study believe that the bilateral frame is adequate, reliable, safe and effective choice for management tibial shaft fracture, this is parallel to result of Shakur and Pantanker, (1991), Behrens and Searls, (1984) and Hamdan, (1998) that the biplaner external fixation provided good early stability, the use the AO tubular components, as 90% of all tibial fractures can be stabilized with, bilateral frame. External fixation was investigated and best described by Behrens and his colleagues [Behrens, F. *et al*., 1981] they demonstrated the biomechanical and anatomic advantages of bilateral frames. They reported quite satisfactory results in form of high union rate and good limb function. So that the external fixation is versatile, easy to apply with minimum operative trauma, offers access to the wound and reduce probably the surgery time. The excellent functional result and the low rate of complications, external fixation has become the readily acceptable method of treatment in this community. If too much rigidity is going to interfere with callus formation, the frame should be removed and POP applied cast or simply by change the frame to a dynamic one, the later can be achieved by sequential disassembly of the frame.The goals of soft- tissue coverage of open fractures are to achieve a safe, early closure of the wound within seven to ten days after the injury, to avoid infection and optimize the milieu for healing, to obliterate dead space and establish durable converge, and to facilitate future reconstruction[Gustilo, R. B. *et al*., 1984]. In this study all wounds in patients with type I are closed by direct suturing being clean wounds either open fractures from within or by penetrating injury. In this study are usually using dry dressings rather than moist one and are changed once daily. Gothman, 1962; clearly showed that bone and the surrounding soft tissue share numerous vascular micro-anastomoses. The proliferation of vessels supplying the muscles and the periosteum accommodates the fracture callus response and re-vascularized bony fragment. In this study the average time of union vary from 10-15 weeks (group 1),in adult fracture of distal tibial shaft, the speed of healing decreasing rapidly with the fracture increasing in initial severity of the fracture.The definition of delayed union remains unsettled. Clancey and Iiansen[51] considered delayed union as failure to show any clinical or radiological evidence of healing by 4 months. A more widely accepted definition is healing requiring a period longer than the anticipated amount of union for the type of fracture- usually at 6 months for the tibia, delayed union is a clinical diagnosis. Cross motion or pain at the fracture site and the radiographic evidence of persistent radiolucency are factors suggesting failure of healing [Johnson, E. E. *et al*., 1988]. Nicoll, (1964) considered nonunion of a tibia as that time in which the surgeon believed that the radiographic and clinical signs show that the fracture no longer has any potential for union and that the fracture will not heal unless some form of intervention is undertaken. Nonunion is also defined as state in which all healing processes have ceased before complete healing has occurred. In this study considered delayed union was there is no evidence of any clinical or radiological sign of bone healing by 6 months and nonunion by 8 months.

Delayed union, there was no significant statistical nor clinical difference in both groups (P= 0.22), this is explained by the use of external fixation as a definitive treatment.

Non-union occurred in 2 patients of Group II as compared from none in group I both clinically and statistically which explains the healing potential using primary autograft.

This study agree with Thakur, (1991). Andrew &commander, (1987) whom suggested the use of early cancellous bone graft as the best method of management of fracture tibial shaft especially open one. As with Fischer, at al., (1988) for timing of bone graft, in his study recommend cancellous bone graft performed after 2-3 days is better than during first day, in order to give time for vascularization of soft tissues. Autogenous cancellous bone graft is arise as good option to facilitate fracture healing, providing that stability

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is established and maintained between the two fracture site. This may be due to peculiar anatomical characteristic in which the distal third of the tibia is devoid of any muscle attachment and only surrounding tendenous tissue and secondly the nutrient artery to the tibia enter the nutrient canal at point immediately below soleus line so any fracture distal to this area interrupt the nutrient artery.

In this study the following complications are:
1 - Pin tract infection:- Irritation of the pin tract with inflammation of the skin at the interface between the bone and the pin is a common problem. Hamdan, (1998) and Green, 1994. Pin loosening and infection is the notorious complications and are reason why external fixation' has sometime fallen into disrepute[47]. Pin tract infection is present in a variety of ways varies from mild erythema about the pin remedied by local wound care, to superficial infection requiring antibiotics, local wound care and occasional pin removal, to osteomylitis requiring sequestrectomy [Thakur, A. J. *et al*., 1991]. In this study: 6 patients (20%) developed pin tract infection these- treated by antibiotics, local wound care. Fortunately, this incidence of pin tract infection was acceptabl as compared with other studies. (27%) by Cthist Brown and Hughe’s series, (1982), (42%) by Edge and Denham, (1981), (35.6%) by Thakur and Patankar studies, (1991), and (49 %) by Hamdan, 1998,and higher than (12%) by Behrens and Searls studies, (1986).

This suggestion that pin tract problems can be reduced or even eliminated by three ways:

- Firstly, by the reduction of soft tissue irritation around the pin, this can be done by pin placement only when the tibia is subcutaneous and by using in this study stiffer pins which have smooth shafts at skin level.
- Secondly, by the pre-drilling of each pin tract with a sharp drill bit protecting by drill sleeve (Green, A.R, 1994) which eliminates heat necrosis of soft tissue and bone
- Thirdly, by effective pin and frame care, together with the transfer of the major responsibility for their care to the patients (Searls, *et al*., 1983).

2-Re-fracture:- In this study 1 patient in Group I and 2 patients in Group II develop refracture after healing caused by a minor injury (10%). This result was higher than what reported by De Bastiani, when orthofix was used for tibial fracture effecting 3% of patients. (De Bastiani, Al degheri and Brivio, (1984), and 6% by Krettek, Haas and Tscherne,1991; and low to what reported by Thakur &Patonker, 1991, when represented 11%.

3-Non-union:- Only two patients from Group II had developed nonunion after 8 months of follow up, and was hypertrophic type, that was scheduled for open reduction and rigid internal fixation using compression plate and screws with autogenous bone graft.

CONCLUSIONS AND RECOMMENDATIONS

1-Early cancellous bone graft is recommended for open Grade 1 and closed Grade 0 and 1 fractures of distal tibia especially if combind with external fixation.
2-Bilateral frame is a good method for stabilization of distal tibial fracture especially opens one.
3-It isrecommend that the external fixation is not only used as temporary form of immobilization but can be used as a definitive stabilizing procedure until consolidation of the fracture.
4-Dynamization of the fixator strongly recommended.

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