Outcome Of Reverse Dynamization In External Fixator Application In Compound Tibia Fractures

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Abstract: Background: Open tibial fractures are quite common due to their subcutaneous location, high energy trauma, which are frequently encountered during high speed moving vehicles, especially in our country with high vehicular congestion due to increased vehicle numbers, poor quality of infrastructure, poor vehicle maintenance, rashness and negligent driving by youth. External fixators are the preferred method of fixation in open tibial fractures. The concept of reverse dynamization arose as a means of stimulating endochondral bone formation. It is predicted that early exposure of the defect to loading would enhance the differentiation of mesenchymal progenitor cells into chondrocytes, a process accelerated by mechanical stimulation. Such loading, however, threatens to impair endochondral ossification by disrupting the formation of blood vessels within the ossifying structure. For this reason, it is proposed to increase the rigidity of fixation at the first radiologic sign of mineral deposition within the defect.

Objectives:
1) To evaluate the functional outcome of reverse dynamization of external fixators in the treatment of compound tibia fractures with reference to union of the fracture and reduction of postoperative complications.
2) To evaluate the clinical outcome of reverse dynamization of external fixators in the treatment of compound tibia fractures with reference to union of the fracture and reduction of postoperative complications.
3) To restore the anatomy and function of the long bone at the earliest.

Material and Methods:
This Descriptive Longitudinal type of Study was conducted on 44 patients of compound tibia fractures at department of Orthopaedics at Dr. Balasaheb Vikhe Patil Rural Medical College, PMT-PIMS (DU), Loni Hospital for a period of 23 months

Interpretation and conclusion:
- In present study most of the cases were observed having age from 20 to 40 years of age.
- In the present study 86.4% cases were male.
- Majority of the cases were belonging to Gustilo-Anderson type II – (56.8%)
- Out of 44 patients, 21 patients were applied Linear External Fixator, 14 patients were applied Illizarov ring fixator, 7 patients were applied hybrid external fixator and 2 patients were applied LRS fixator.
- Total 6 patients required secondary procedures out of 44 patients.
- Pin tract infection was most common complication
- 29 patients out of 44 patients showed excellent results, 13 had good result and 2 patient had fair result.

Keywords: Fracture, Reverse dynamization, External fixator

Introduction
Subcutaneous presence of tibial shaft makes it the most common site for an open fracture.¹ The protocol of treatment remains stabilization of the patient first with resuscitation measures like I.V. fluids, blood and nasal O2. Subsequently the fracture is treated by debridement and temporary external fixators.² The drawback of this procedure is the need for several surgical procedures and a longer hospital stay. The chances of infection in reamed interlocking nail post external fixator in open fracture is much high. So it clearly indicates that delayed intramedullary nailing in open fracture puts patients at a higher risk of infection and multiple procedures.³⁻⁵; our main aim is to convert a temporary procedure into a definitive one with a single step, and avoiding economic burden on poor patients. Flexibility of placing pins makes the external fixator an effective tool in the case of open fractures, especially type 3 Gustilo and Anderson.⁶ The
simplicity of the procedure does not require a steep learning curve, and the short procedure time makes it perfect for polytrauma patients. Monoframe with sufficient space and flexibility of pin placement make it suitable for complex plastic surgical procedures.

The external fixator was one of the most popular surgical options in the mid-20th century when it was introduced by Hoffman. Soon after that, Charnley popularized the knee arthrodesis with an external fixator. An external fixator causes less disruption of the soft tissue, periosteum, and osseous blood supply, which makes it a saviour in open injuries and compound fractures. The stiffness of the external fixator can be increased by many methods, like controlling near and far connecting rods, increasing the diameter of the pins, and using multiplanar fixation. That gives an additional advantage to controlling the stiffness of the implant, which is required for the initial duration of fracture management. It is always to use a multiplanar frame to increase the stability of the external fixator. For increased stiffness over the fracture callus, early weight bearing with an appropriate amount of motion over the fracture site is required. For a fracture to unite in an external fixator, a combination of blood supply, bony stability, and axial loading is necessary. The mechanical environment is largely determined by the stiffness of the implant used to stabilize the fracture and by weight-bearing. The size and quality of the callus formed at the fracture site depend on the magnitude of interfragmentary movements occurring between the fractured ends during weight-bearing and muscle contraction. Accordingly, stiff fixation that minimizes interfragmentary movements results in limited callus formation, whereas flexible fixation that increases interfragmentary movements results in the formation of a larger callus. The few papers on the influence of mechanics on the healing of large segmental defects largely addressed the strategy of dynamization, a modality in which the stiffness of fixation is initially high and is later reduced. The concept of reverse dynamization arose as a means of stimulating endochondral bone formation. It is predicted that early exposure of the defect to loading would enhance the differentiation of mesenchymal progenitor cells into chondrocytes, a process accelerated by mechanical stimulation. Such loading, however, threatens to impair endochondral ossification by disrupting the formation of blood vessels within the ossifying structure. For this reason, it is proposed to increase the rigidity of fixation at the first radiologic sign of mineral deposition within the defect.

With this strategy of reverse dynamization during the early stages of healing, the mechanical environment of the fracture site is manipulated in an attempt to accelerate progression toward union. To allow micromotion and encourage callus formation, the fracture is initially stabilized less rigidly. Once the callus has formed, the stabilization is changed to a rigid configuration, and the fracture is allowed to remodel.

AIMS AND OBJECTIVES

AIM

1) To study the outcome of reverse dynamization on the basis of ASAMI score in patients who underwent external fixator application in compound tibia fractures at Pravara Rural Hospital Loni.

OBJECTIVE

1) To evaluate the functional outcome of reverse dynamization of external fixators in the treatment of compound tibia fractures with reference to union of the fracture and reduction of postoperative complications.

2) To evaluate the clinical outcome of reverse dynamization of external fixators in the treatment of compound tibia fractures with reference to union of the fracture and reduction of postoperative complications.

3) To restore the anatomy and function of the long bone at the earliest.

Surgical Anatomy

A thorough understanding of both the topographic and structural anatomy of the leg is required when planning operative approaches to the extremity. The anteromedial surface of the tibia and the anterior crest are easily palpable from the tibial tuberosity and distally into the medial malleolus. For ease of description and location, the muscles, tendons, ligaments, and neurovascular structures in the leg are divided into anterior, lateral, and posterior compartments. The tibia is palpable subcutaneously along its anterior border for the most part. The diaphyseal portion is distinguished by a dense anterior tibial crest that extends proximally from the tibial tuberosity to just above the ankle. The anteromedial portion of the tibia's subcutaneous prominence lends itself to pin fixation.
1. Anterior or Extensor Compartment

The compartment is defined as the space between the deep fascia and the interosseous membrane, which is bounded medially by the tibial extensor surface and laterally by the fibula's extensor surface and the anterior intermuscular septum. The Tibialis anterior, extensor hallucis longus, extensor digitorum longus, and peroneus tertius are among the muscles contained within it, as are the deep peroneal nerve and anterior tibial vessels. It is a small space, and any further expansion of its contents, such as a hematoma or muscle oedema, could cause compression and ischemia of the compartment's neurovascular and muscular structures (compartment syndrome).

The deep fascia is thickened in its lower extent to form the superior extensor retinaculum, which is attached to the anterior borders of the tibia and fibula. Tibialis anterior, extensor hallucis longus, extensor digitorum longus, and peroneus tertius tendons run from medial to lateral in front of the lower end of the tibia.

Deep to the retinaculum are also the anterior tibial vessels and the deep peroneal nerve, which are located between the extensor hallucis longus and the extensor digitorum longus, with the vessels medial to the nerve.

Deep peroneal nerve

At the bifurcation of the common peroneal nerve, the deep peroneal nerve arises within the peroneus longus, over the neck of the fibula. It spirals around the fibula's neck before landing on the interosseous membrane, between the extensor digitorum longus and the tibialis anterior. The neurovascular bundle is located in the interosseous membrane between the tibialis anterior and extensor hallucis longus in the middle of the leg. The extensor hallucis muscle crosses the bundle from the front and is located on the bundle's medial side. All four muscles in the anterior compartment of the leg are supplied by the deep peroneal nerve.

Anterior tibial artery

The anterior tibial artery, which originates at the popliteal artery bifurcation in the calf, travels forward through the upper part of the interosseous membrane near the fibula's neck, with a companion vein on each side. The dorsalis pedis artery runs downward on the interosseous membrane, crosses in front of the ankle joint midway between the malleoli, and continues distally as the dorsalis pedis artery. It provides extensor compartment muscles with malleolar branches as well as an anterior recurrent branch that ends in anastomosis around the upper end of the tibia. The deep peroneal nerve runs alongside the artery.

TIBIOFIBULAR JOINTS

The superior tibiofibular joint connects the lateral tibial condyle to the fibular head via a synovial joint. The articulating surfaces are almost completely flat. Anterior and posterior ligaments support the capsule.

The inferior tibiofibular joint is a fibrous joint (syndesmosis) formed by the convex medial surface of the fibula's distal end and the concave fibular notch of the tibia's distal end. The anterior and posterior tibiofibular ligaments hold the bones together, and the interosseous tibiofibular ligament is very strong. Only minor movements occur at the tibiofibular joints, with the fibula rotating laterally slightly during ankle dorsiflexion.

LATERAL COMPARTMENT OF THE LEG

The anterior and posterior intermuscular septa separate this muscular compartment from the peroneal surface of the fibula and the deep fascia of the leg.

It includes the peroneus longus and brevis muscles, as well as the superficial peroneal nerve. It receives blood from branches of the peroneal artery that pierce the flexor hallucis longus and the posterior intermuscular septum. Its vein drains primarily into the small saphenous vein.

The superficial peroneal nerve is a branch of the common peroneal nerve that originates in the substance of the peroneus longus muscle, travels downward, and emerges at the anterior border of the peroneus longus muscle, behind the anterior intermuscular septum. It pierces the deep fascia between the middle and lower thirds of the leg and divides into medial and lateral branches, supplying both the peronei. It nourishes the skin on the anterolateral aspect of the lower leg.
POSTERIOR COMPARTMENT OF THE LEG

This is commonly referred to as the calf. The skin of the upper half of the calf is supplied by the posterior femoral cutaneous nerve's termination. Below this level, the sural and sural communicating nerves supply the back of the leg and the lateral side of the calf, while the saphenous nerve supplies the medial side.

The sural nerve runs alongside the short saphenous vein, which drains the lateral side of the dorsal venous arch and the lateral margin of the foot. It passes through the subcutaneous fat to the midline of the calf and pierces the deep fascia anywhere between the midcalf and the roof of the popliteal fossa. It enters the popliteal vein after running beneath the deep fascia. It communicates with the great saphenous vein via several channels. The flexor retinaculum is a thickening of the deep fascia that connects the deep flexor tendons and the neurovascular bundle. It extends posteriorly from the tip of the medial malleolus to the medial process of the calcaneus.

The calf muscles, located in the posterior compartment of the leg, are divided into superficial and deep groups, with the deep transverse fascia of the leg separating them. The gastrocnemius, plantaris, and soleus muscles all converge on a thick tendon at the back of the heel called the tendocalcaneus or Achilles tendon. They are the ankle's primary plantar flexors. Popliteus and flexor digitorum longus, flexor hallucis longus, and tibialis posterior pass deep into the sole of the foot to form the deep group.

The tibial part of the sciatic nerve is the nerve of the posterior compartment, and the arteries are the posterior tibial and its peroneal branch.

Posterior tibial artery

The popliteal artery divides into anterior and posterior tibial branches at the lower border of the popliteus. It runs from the origin of the soleus to the tibialis posterior, between the flexor digitorum longus and the flexor hallucis longus. It divides into medial and lateral plantar arteries as it passes beneath the flexor retinaculum. It is accompanied by two venae comitantes, which communicate with one another around the artery.

Pulsations of the artery can be felt 2.5 cm in front of the medial border of the tendocalcaneus, behind the medial malleolus.

Branches: (a) The peroneal artery: It appears 2.5 cm distal to the popliteus. It runs distally in a fibrous canal between the flexor hallucis longus and the tibialis posterior, supplying the calf muscles as well as the peroneus longus and brevis. It provides the fibula with a nutrient artery. It divides into a perforating branch that pierces the interosseous membrane to enter the extensor compartment and a lateral calcaneal branch that travels to the lateral side of the heel.

(b) Circumflex fibular artery: Passes laterally around the fibular neck to connect with the arterial anastomosis around the knee. It supplies the tibia with a nutrient artery that enters the bone just distal to the soleal line, and muscular branches supply the soleus and deep flexors. The flexor retinaculum is pierced by medial calcanean branches, which supply the medial side of the heel.

Tibial nerve: runs straight down the middle of the calf to the soleus muscle. The posterior tibial artery is initially lateral to it, but it then passes anterior to it and descends on its medial side. The nerve divides into medial and lateral plantar nerves midway between the medial malleolus and the tendocalcaneous and ends under the middle of the flexor retinaculum. It is the flexor compartment nerve, with branches to the soleus, flexor digitorum longus, hallucis longus, and tibialis posterior. It provides medial calcanean nerves that pierce the flexor retinaculum and supply the skin of the heel, including the weight-bearing surface.

Interosseous membrane: A strong sheet of fibrous tissue that closes the space between the tibia and fibula except at its upper end, where a small opening allows the anterior tibial vessels to pass. It prevents bone separation in fractures unless the bone is severely fractured. The interosseous membrane serves to distribute indirect violence acting on the tibia to the fibula because the majority of its fibers run downward and outward.

TIBIA

The tibia is situated medial to the fibula. Its shaft has a triangular cross section and expanded ends. From the smaller distal end, a strong medial malleolus projects distally. The anterior border is sharp and medially curves towards the
medial malleolus. It has three borders and three bony surfaces.\(^\text{16}\) Proximal end: The expanded proximal end serves as a bearing surface for body weight transmitted through the femur. It has a tibial tuberosity, medial and lateral condyles, and an intercondylar area. Condyles: The tibial condyles protrude from the shaft's proximal posterior surface. The proximal articular surfaces of both are separated by an irregular intercondylar area. The lateral condyle is more visible. The anterior margins of the condyles are palpable in the fossae flanking the patellar tendon in the passively flexed knee.

Figure 1: Osteology of tibia and fibula

The lateral condyle's fibular facet faces distally and posterolaterally. The superior tibiofibular joint's angle of inclination varies, but it can be horizontal or oblique. A sharp margin separates the anterolateral aspect of the condyle from the lateral surface of the shaft for the attachment of deep fascia. The iliotibial tract's distal attachment leaves a flat but distinct mark on its anterior aspect. Gerdy's tubercle, which is usually palpable, is a triangular facet which is situated on the anterolateral side of the lateral condyle at the proximal end of the tibia. The anterior condylar surfaces are continuous, with a large triangular area formed by the tibial tuberosity where the apex is distal, and the lateral edge is a sharp ridge between the lateral condyle and the lateral surface of the shaft.\(^\text{39}\) The lateral condyle's fibular facet faces distally and posterolaterally. The superior tibiofibular joint's angle of inclination varies, but it can be horizontal or oblique. A sharp margin separates the anterolateral aspect of the condyle from the lateral surface of the shaft for the attachment of deep fascia. The iliotibial tract's distal attachment leaves a flat but distinct mark on its anterior aspect. Gerdy's tubercle, which is usually palpable, is a triangular facet which is situated on the anterolateral side of the lateral condyle at the proximal end of the tibia. The anterior condylar surfaces are continuous, with a large triangular area formed by the tibial tuberosity where the apex is distal, and the lateral edge is a sharp ridge between the lateral condyle and the lateral surface of the shaft.\(^\text{16}\)

**Tibial tuberosity:** A truncated apex of a triangular area where the anterior condylar surfaces merge. It protrudes slightly and is divided into two regions: distal rough and proximal smooth. The subcutaneous infrapatellar bursa separates the distal region from the skin. The distal limit of the proximal tibial growth plate is marked by a line across the tibial tuberosity. The patellar tendon attaches to the smooth bone proximal to the line, with its superficial fibres reaching the rough area distal to the line.\(^\text{16}\) The shaft is triangular in cross section, with medial, lateral, and posterior surfaces separated by anterior, lateral (interosseous), and medial borders. It is thinnest at the intersection of the middle and distal thirds, then expands to both ends. The anterior border is subcutaneous from the tuberosity to the anterior margin of the medial malleolus. Its distal fourth is indistinct. The distal fourth has a sharp crest and turns medially. The interosseous border is indistinct proximally and begins distally and anteriorly to the fibular facet and descends to the anterior border.
of the fibular notch. The interosseous membrane runs the length of the bone, connecting the tibia and fibula. The medial border descends from the anterior end of the groove on the medial condyle to the medial malleolus's posterior margin. It is sharp in the centre but indistinct both proximally and distally. The anteromedial surface is broad, subcutaneous, and smooth between the anterior and medial borders. The lateral surface is also broad and smooth between the anterior and interosseous borders. The proximal three-fourths of the lateral surfaces face laterally and are transversely concave. Because of the medial deviation of the anterior and distal interosseous borders, its distal fourth swerves anteriorly. This section is convex. A rough, oblique soleal line runs distally and medially across the posterior surface between the interosseous and medial borders. The anterior border is connected to the deep fascia and the medial end of the superior extensor retinaculum. Above the soleal line, the posterior fibres of the medial collateral ligament, as well as slips of the semimembranosus and popliteal fascia, are attached to the medial border. The distal medial border joins the medial lip of a groove for the tibialis posterior tendon. Except at its extremes, the interosseous membrane is attached to the lateral border. The anterior boundary of the fibular notch, to which the anterior tibiofibular ligament is attached, forms the lateral border proximally. The anterior part of the medial collateral ligament is attached to the medial surface. The remainder of the surface is subcutaneous. The long saphenous vein, however, crosses it obliquely. The tibialis anterior is attached to the proximal two-thirds of the lateral surface. The tendons of the tibialis anterior and extensor hallucis longus, the anterior tibial vessels, and the deep peroneal nerve, extensor digitorum longus, and peroneous tertius cross in mediolateral order at its distal end. The Popliteus is attached to the posterior surface in a triangular area proximal to the soleal line. The soleal line is formed by the popliteal synovial membrane, the soleus and its fascia, and the deep transverse fascia. The tubercle is located on the medial end of the tendinous soleal arch, and the posterior tibial vessels and tibial nerve descend on the tibialis posterior. The attachments of the flexor digitorum longus and tibialis posterior are separated by a vertical line distal to the soleal line. 16

Distal end: The tibia's slightly expanded distal end has anterior, medial, posterior, lateral, and distal surfaces. The medial malleolus projects inferomedially. When compared to the proximal end, the distal end of the tibia is laterally rotated. Tibial torsion is 30° in Caucasians and Asians, but significantly higher in people of African descent. The smooth anterior surface bulges beyond the distal surface, from which it is separated by a narrow groove, and continues along the shaft's lateral surface. The ankle joint capsule is attached to an anterior groove near the articular surface. The medial surface is smooth and continuous above and below with the shaft and medial malleolus surfaces. It is both visible and subcutaneous. The posterior surface is crossed near its medial end by a conspicuous nearly vertical but slightly oblique groove that extends to the malleolus's posterior surface. It is smooth and continuous with the shaft's posterior surface elsewhere. The posterior groove is for the tibialis posterior tendon. It separates the flexor digitorum longus from the bone. Laterally, the posterior tibial vessels and nerve, as well as the flexor hallucis longus, make contact with this surface. 16 The anterior and posterior edges of the triangular fibular notch project and converge proximally to the interosseous border on the lateral surface. The notch's floor is roughened proximally by a large interosseous ligament but smooth distally. The anterior and posterior tibiofibular ligaments attach to the notch's edges. The distal surface articulates with the talus and is saddle shaped, being wider in front, concave sagitally, and transversely slightly convex. It continues medially into the malleolar articular surface.

The medial malleolus is a short, thick bone with a smooth lateral surface and a crescentic facet that articulates with the medial talar surface. Its anterior aspect is rough, and its posterior aspect continues with the groove from the shaft's posterior surface for the tibialis posterior tendon. The distal border is pointed anteriorly and posteriorly, and it connects to the deltoid ligament. The ankle joint capsule is attached to the anterior surface, and the flexor retinaculum is attached to the proximal medial border.16

Vascular supply: Metaphyseal vessels from the genicular arterial anastomosis supply the proximal end of the tibia. The nutrient foramen is located near the soleal line and transmits the posterior tibial artery branch. When it enters the bone, it produces more ascending branches than descending branches. The anterior tibial artery and muscular branches supply the periosteal supply to the shaft. Branches from the anastomosis around the ankle supply the distal metaphysis.

Innervation: The proximal and distal ends of the tibia are innervated by nerve branches from the knee and ankle joints. The shaft's periosteum is supplied by nerve branches that innervate the muscles attached to the tibia.

FIBULA:

The fibula is much thinner than the tibia and is not directly involved in weight transmission. It has a proximal head, a narrow neck, a long shaft, and a lateral malleolus at the distal end. 16 The fibula's head projects in front, behind, and laterally. A round facet on its proximomedial aspect articulates with a facet on the lateral tibial condyle's inferolateral surface. The apex of the head is palpable 2 cm distal to the knee joint and faces proximally from the posterolateral aspect of the head. The fibular collateral ligament connects to the apex. The tibiofibular capsular ligament is attached to
the articular facet margins. The common peroneal nerve crosses the neck posterolaterally and can be rolled against the bone there.16

**Shaft:** The shaft has three surfaces and three borders. The anterior border of the fibular head ascends proximally from the apex of an elongated triangular area that is continuous with the lateral malleolar surface. The posterior border of the lateral malleolus continues with the medial margin of the posterior groove, is usually distinct distally, and is rounded in its proximal half. The interosseous border is located between the medial and anterior borders and is usually more posterior. In its proximal three-fourths, the lateral surface faces laterally between the anterior and posterior borders. The distal quarter spirals to join the posterior groove of the lateral malleolus, and the lateral surface is connected to the peroneal muscles. The anteromedial surface between the anterior and interosseous borders is usually anteromedially oriented. It is linked to the extensor muscles. It is broad distally, narrows in the proximal half, and may become nothing more than a ridge. The flexor muscles are associated with the posterior surface between the interosseous and posterior borders. A longitudinal medial crest divides its proximal two-thirds. The posterior surface's distal half curves onto the medial aspect. This area is located proximally in the fibular notch of the tibia. The triangular area proximal to the lateral surface of the lateral malleolus is subcutaneous, and the rest of the shaft is covered by muscles. Distally, the anterior border is divided into two ridges that surround a triangular subcutaneous surface. The anterior intermuscular septum is connected to the proximal three-fourths of the septum. The superior extensor retinaculum's lateral end is attached distally on the anterior border of the triangular area. The superior peroneal retinaculum's lateral end is attached distally on the triangular area's posterior margin. The interosseous border terminates at the proximal limit of the interosseous ligament's rough area. The peroneal artery is connected to the medial crest of the posterior border. A layer of deep fascia attached to the medial crest separates the tendons of the tibialis posterior from the flexor hallucis longus and flexor digitorum longus.16

**Lateral malleolus:** The lateral malleolus is formed by the distal end of the fibula and projects distally and posteriorly.16 It has a subcutaneous lateral aspect, and a broad groove with a prominent lateral border on its posterior aspect. It has a rough, round, and continuous anterior aspect with the tibial inferior border. The medial talar surface has a triangular articular facet that is vertically convex and has a distal apex that articulates with the lateral talar surface. A rough malleolar fossa pitted by vascular foramina lies behind this facet. The posterior tibiofibular ligament and posterior talofibular ligament are connected in the fossa posteriorly. The anterior talofibular ligament connects to the lateral malleolus anterior surface. The calcaneofibular ligament connects to the notch just anterior to its apex. The peroneus brevis and longus tendons groove its posterior aspect, which is covered by the superior peroneal retinaculum.

**Vascular supply:** A nutrient foramen directed distally pierces the fibular shaft near the midpoint of the posterior surface, receiving a branch of the peroneal artery. The genicular and ankle arterial anastomoses supply metaphyseal vessels to the proximal and distal ends, respectively.

**Innervation:** The proximal and distal ends of the bone are supplied by nerve branches that innervate the knee and superior tibiofibular joint, respectively, and the ankle and inferior tibiofibular joint. The nerves that innervate the muscles attached to the fibula supply the periosteum of the shaft.
Figure 2: Attachments of muscles of leg
Muscles of Leg

**Table 1 - Muscles of extensor compartment**

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Name of the muscle</th>
<th>Origin</th>
<th>Insertion</th>
<th>Action</th>
<th>Nerve supply</th>
<th>Test to function</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Tibialis anterior</td>
<td>Upper 2/3rd of the extensor surface of the tibia, from the interosseous membrane, and from deep fascia overlying it.</td>
<td>Medial and inferior surfaces of the medial cuneiform and adjacent part of the first metatarsal bone.</td>
<td>Combined dorsiflexion of the ankle joint and inversion of the foot.</td>
<td>Deep peroneal and recurrent genicular nerves (L4).</td>
<td>Dorsiflex the foot against resistance.</td>
</tr>
<tr>
<td>2</td>
<td>Extensor hallucis longus</td>
<td>Middle half of the fibula and the adjacent interosseous membrane.</td>
<td>Base of the terminal phalanx of the great toe.</td>
<td>Dorsiflex the great toe and also it is a dorsiflexor of the ankle.</td>
<td>Deep peroneal nerve (L4).</td>
<td>Big toe is dorsiflexed against resistance.</td>
</tr>
<tr>
<td>3</td>
<td>Extensor digitorum longus</td>
<td>Upper three quarters of the extensor surface of the fibula, a small area on the lateral condyle of the tibia, and the interosseous membrane.</td>
<td>Divides into four slings and inserted into the lateral four toes. Dorsal extensor expansion over the proximal phalanges divides into three slips, the central slip being inserted into the base of the middle phalanx, two side, slips reunite after joining with tendons of interossei and lumbricales and inserted into base of distal phalanges.</td>
<td>To dorsiflex the lateral four toes.</td>
<td>Deep peroneal nerve (L4, S1).</td>
<td>Lateral four toes can be dorsiflexed against resistance.</td>
</tr>
<tr>
<td>4</td>
<td>Peroneus tertius</td>
<td>Lower third of the fibula.</td>
<td>Dorsum of the base of fifth metatarsal bone.</td>
<td>To dorsiflex and evert the foot.</td>
<td>Deep peroneal nerve (L4, S1).</td>
<td>Dorsiflex the foot against resistance.</td>
</tr>
</tbody>
</table>

**Table 2 - Muscles of lateral compartment of leg**

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Name of the muscle</th>
<th>Origin</th>
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<th>Action</th>
<th>Nerve supply</th>
<th>Test to function</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Peroneus longus</td>
<td>Head and the upper 2/3rd of the peroneal surface of the fibula and from the intermuscular septa.</td>
<td>Lateral side of the base of the first metatarsal and the adjoining part of the medial cuneiform.</td>
<td>Evertor and weakly plantar flexor of the foot. Peroneus longus is a factor in maintaining the lateral longitudinal arch and transverse arches of the foot.</td>
<td>Superficial peroneal nerve (L4, S1).</td>
<td>Foot is everted. The tendons are seen and felt below the lateral malleolus.</td>
</tr>
<tr>
<td>2</td>
<td>Peroneus brevis</td>
<td>Lower 2/3rd of the fibula in front of the origin of peroneus longus.</td>
<td>The tendon passes above the peroneal trochlea to be inserted into the tubercle at the base of the fifth metatarsal bone.</td>
<td>Everters and plantar flex the foot.</td>
<td>Superficial peroneal nerve.</td>
<td>The tendon can be seen and felt below the lateral malleolus when foot is everted.</td>
</tr>
</tbody>
</table>
Table 3 - Superficial muscles of Posterior compartment of leg

<table>
<thead>
<tr>
<th>Sl. No.</th>
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<th>Action</th>
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<th>Test to function</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Gastrocnemius</td>
<td>Lateral head of gastrocnemius arises on the lateral surface of the lateral femoral condyle from a smooth pit above that of popliteus. Medial head of gastrocnemius arises from the back of the medial condyle and popliteal surface of the shaft of femur.</td>
<td>Two head converge to lie side by side. Broad bellies of the muscle insert into a dense aponeurosis on their anterior surfaces, bearing on the soleus muscle. The aponeurosis blends with that of soleus to form tendocalcaneus, which is inserted into a smooth area on the middle 1/3rd of posterior surface of calcaneus.</td>
<td>Plantar flexor of the foot. This is also a flexor of the knee.</td>
<td>Tibial nerve (S₉₋₁₀) Each head of gastrocnemius receives a branch from the nerve in the popliteal fossa.</td>
<td>The foot is plantar flexed against resistance. The contracting muscle can be seen and felt.</td>
</tr>
<tr>
<td>2</td>
<td>Plantaris</td>
<td>Arises from the lower part of the lateral supracondylar line of the femur.</td>
<td>It is slender tendon runs distally deep to medial head of gastrocnemius and continues along the medial border of tendocalcaneus with which it fuses.</td>
<td>Planter flexion of foot.</td>
<td>Tibial nerve (S₉₋₁₀) branch to lateral head of gastrocnemius supplies plantaris as well.</td>
<td>Plantar flex the foot against resistance.</td>
</tr>
<tr>
<td>3</td>
<td>Soleus</td>
<td>The muscle arises from the upper quarter of the back of the tibia, including the head of the fibula; soleal line of the tibia, middle third of the posterior border of the tibia. The muscle has a dense aponeurosis upon either surface. Muscle fibres slope downwards from the anterior to posterior lamella. The posterior lamella is continued at its lower end into tendocalcaneus, it along with gastrocnemius inserted into a smooth transverse area on the middle third of the posterior surface of the calcaneum.</td>
<td>Chief plantar flexors of the foot. Soleus is an antigravity muscle is a slow plantar flexor of the foot.</td>
<td>Tibial nerve (S₁₋₂) it receives two branches one from above the muscle in the popliteal fossa and one on its deep surface in the calf</td>
<td>Plantar flex the foot against resistance. TA and muscle can be seen and palpated while contracting.</td>
<td></td>
</tr>
</tbody>
</table>
Table 4 - Deep muscles of Posterior compartment of leg

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Name of the muscle</th>
<th>Origin</th>
<th>Insertion</th>
<th>Action</th>
<th>Nerve supply</th>
<th>Test to function</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Flexor digitorum longus</td>
<td>Arises from the posterior surface of the tibia below the soleal line.</td>
<td>Arc inserted into the bases of distal phalanges of the lateral four toes.</td>
<td>Action is to plantar flex the lateral four toes. Secondarily to plantar flex the ankle joint. It helps in maintaining the longitudinal arch of the foot.</td>
<td>Tibial nerve (S1, S2)</td>
<td>Terminal phalanges of the other toes (lateral four) are flexed against resistance.</td>
</tr>
<tr>
<td>2</td>
<td>Flexor hallucis longus</td>
<td>It arises from the interosseous membrane and adjoining posterior surface of the both tibia and fibula below the soleal line.</td>
<td>Inserted mainly into the tuberosity of the navicular. Tendinous slips also pass to the sustentaculum tali, all three cuneiforms, cuboid, second, third, fourth metatarsals.</td>
<td>To invert, adduct the fore foot, and also to plantar flex the foot. It contributed to maintaining the medial longitudinal arch of the foot.</td>
<td>Tibial nerve (L4)</td>
<td>With the foot in slight plantar flexion, it is inverted against resistance, the tendon can be felt behind the medial malleolus.</td>
</tr>
</tbody>
</table>

CLASSIFICATION OF TIBIAL FRACTURES

In the literature of the past 25 years, there have been many attempts to classify tibial fractures. Ellis classified fractures into three basic groups.

1. Minor severity- a minor severity fracture is a fracture with a minor degree of comminution or a minor open wound.
2. Moderate severity- moderate severity is total displacement or angulation with a small degree of comminution or a minor open wound.
3. Major severity- here there is complete displacement of the fracture fragments with major degrees of comminution or a major open wound.

Description of a fracture

When describing the X-ray, the fracture is classified based on its anatomical location, such as proximal, middle, or distal third. Radiological fracture types include transverse, oblique, and spiral fractures, as well as comminuted and segmental fractures. Anteroposterior and lateral views are used to calculate angulation. The angulation is measured in the direction of the fractured fragments' apex. Thus, it is anterior or posterior angulation, and the angulation is varus and valgus in anteroposterior view. It's also worth noting the shortening, overlapping, and distraction. Rotation is difficult to assess on X-rays and must be assessed clinically.

Compound fractures are classified based on Gustilo-Anderson system of classification which is as follows:17

Type I - The wound is less than one centimetre long, indicating an open fracture. A moderately clean puncture through which a bone spike has pierced the skin is typical. There is little soft tissue damage and no evidence of a crushing injury. With little comminution, the fracture is usually simple transverse or short oblique.
Type II - The laceration is more than one centimetre long, with extensive soft tissue damage, a flap, or avulsion. Tissues are crushed slightly or moderately, with moderate comminution and contamination.

Type III - It is distinguished by extensive soft tissue damage, including muscles, skin, and neurovascular structures, as well as a high level of contamination. High velocity trauma frequently causes the fracture, resulting in significant comminution and instability. There are three subtypes:

Type IIIa - Despite extensive laceration or high energy trauma, soft tissue coverage of the fractured bone is adequate. This subtype includes segmental or severely comminuted fractures caused by high energy trauma, regardless of wound size.

Type IIIb - It is associated with extensive soft tissue loss, periosteal stripping, exposure of bone to massive contamination, and severe fracture comminution from high energy trauma. Following wound debridement and irrigation, a segment of bone is exposed, and a local free flap is required for coverage.

Type IIIc - It includes any open fracture associated with a neurovascular injury, regardless of soft tissue injury severity.

Table 5 - Gustilo-Anderson’s Classification System for Open Fractures

<table>
<thead>
<tr>
<th>Type</th>
<th>Wound</th>
<th>Level of Contamination</th>
<th>Soft tissue injury</th>
<th>Bone injury</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>&lt;1 cm in length</td>
<td>Clean</td>
<td>Minimal</td>
<td>Minimal comminution</td>
</tr>
<tr>
<td>II</td>
<td>&gt;1 cm in length</td>
<td>Moderate</td>
<td>Moderate, some muscle damage</td>
<td>Moderate comminution</td>
</tr>
<tr>
<td>IIIa</td>
<td>&gt;10 cm in length</td>
<td>High</td>
<td>Severe with crushing</td>
<td>Includes segmental comminuted fractures. Soft tissue coverage of bone possible</td>
</tr>
<tr>
<td>IIIb</td>
<td>&gt;10 cm in length</td>
<td>High</td>
<td>Extensive soft tissue injury with periosteal striping</td>
<td>Bone exposed, soft tissue reconstruction required</td>
</tr>
<tr>
<td>IIIc</td>
<td>Regardless of size</td>
<td>High</td>
<td>Extensive soft tissue injury with vascular injury</td>
<td>Vascular and soft tissue reconstruction/repair required</td>
</tr>
</tbody>
</table>

Byrd Classification

believing that the vascular status was the most important character:

Type I - A spiral or oblique fracture pattern caused by low energy forces, a skin laceration less than 2 cm in length, and a relatively clean wound.

Type II - Moderate energy force causing comminuted or displaced fracture pattern with more than 2 cm skin laceration, moderate adjacent skin and muscle contusion, but no devitalized soft tissue

Type III - High energy forces that result in a significantly displaced fracture pattern with severe comminution / segmental fracture or bone defect, as well as extensive skin loss and devitalized tissue.

Type IV - Fracture pattern, similar to Type III, but with extreme energy forces like a high velocity gunshot. A history of crush or degloving injury, as well as associated vascular injury that requires repair.
AO Classification of open fractures:

Skin, musculotendinous, and neurovascular injuries are classified separately in the AO group.

Classification of skin injuries

IO1 - Skin breakdown from within.
IO2 - Skin breakage from the outside in 5 cm contused edges.
IO3 - Skin breakage greater than 5 cm, increased contusion, and devitalized edges
IO4 - Significant, full thickness contusion, abrasion, and skin loss.
IO5 - Extensive skin degloving.

This skin wound grading system corresponds to the three-grade system for open fracture but adds a fourth grade. Because there may be significant injury to the muscle envelope and, in rare cases, the tendons may be exposed, and because this fracture is highly prognostic, a grading of the extent of muscle tissue and tendon involvement is essential.

Injuries to the musculotendons

Because there may be significant injury to the muscle envelope and, in rare cases, the tendons in open, and because this fracture is highly prognostic, a grading of the extent of muscle tissue and tendon involvement is essential.

MT1 - No muscle damage
MT2 - Muscle injury in a specific compartment
MT3 - Significant muscle injury in two compartments
MT4 - Muscle defect, laceration of a tendon, and extensive muscle contusion
MT5 - Compartment syndrome (crush syndrome with wide injury zone)

Neurovascular damage

NV1 - No neurovascular injury
NV2 - Isolated nerve injury
NV3 - Localized vascular injury
NV4 - Extensive segmental vascular injury
NV5 - Combined neurovascular injury resulting in partial or total amputation

CLINICAL FEATURES

Tibial fractures are distinguished by pain, inability to bear weight, swelling, and deformity. One of the first assessments required during the physical examination is the fracture's stability. Mechanical instability of the tibial diaphysis is confirmed by an obvious deformity or shortening.

Local swelling occurs quickly as a result of bleeding and soft tissue reaction. Swelling and oedema around the fracture site are time-dependent and depend on the leg's position.

Ecchymosis and tissue turgidity must be checked throughout the soft tissue envelope of the tibia. This is significant due to the link between compartment syndrome and tibial fracture.

Soft tissue damage is a prominent feature of open fractures. The entire leg should be examined to look for open wounds and see if they are communicating with the fracture site. A thorough vascular and neurologic examination, including both motor and sensory components, should be performed so that changes in neurologic or vascular status can be compared. Closed fractures rarely cause direct nerve damage. Fractures of the upper tibia where the anterior tibial artery
passes through the interosseous membrane can lacerate the artery or put pressure on it due to fracture displacement. Crush injuries severely affect both skin and soft tissues.

**Approaching an injured patient**

(a) **Recognizing life-threatening conditions**

Airway obstruction, severe shock, and haemorrhage in the injured area must all be evaluated. The Glasgow coma scale should be used to assess level of consciousness and CNS function. The chest and abdomen should be carefully examined to detect any damage to vital organs, followed by an examination of the spine, vertebral column, and extremities to rule out any injuries.

(b) **Physical examination of the injured limb**

Capillary refill and its time, vein filling, and the state of peripheral pulses should be determined and recorded in an injured limb to indicate the state of its blood supply. The peripheral nerves' integrity must be determined, including both sensory and motor function for each nerve.

(c) **Examination of the wound's condition**

The wound is classified according to Gustilo-classification Anderson's system for open fractures based on its location, size, shape, dimension, depth, underlying structures, edges, degree of contamination, severity of bleeding, and compound well, whether it communicates with the underlying fracture site or not.

(d) **Skin condition around wounds**

The skin around the wound should be examined for burns, contamination, wound size, colour, and whether the fracture site communicates with the outside world.

In these cases, it may be justified to invade the wound with a sterile blunt probe/gloved finger; if bone is contacted/felt, the answer is at hand, or saline may be injected through prepared skin, if the underlying haematoma escapes through the wound, establishing the fact that an open fracture exists. If the suspicion of an open fracture is confirmed, it will be easier to plan for the next course of action. Under strict aseptic conditions, the wound must be debrided.

(e) **The patient's medical history**

It is critical to inquire about the status of the patient's immunity to tetanus. The last date of immunization must be known; only toxoid may be required as a booster. If there is any doubt, 250 to 500 units of human tetanus immunoglobulin should be administered, especially if a tetanus-prone wound is present.

It is also beneficial to initiate active immunization for such patients at this time, but only for future injuries. Swabs for culture and sensitivity should be taken from the wound before any antibiotics are administered.

**Radiographic examination**

After the patient has been evaluated, any necessary X-rays should be taken. The adjacent joints of the fractured bone should be included in the X-ray.

Anteroposterior and mediolateral X-rays are the bare minimum for evaluating patients with tibial or fibular fractures. Tomograms may be useful in determining union, particularly if the fracture is obscured by the external fixator.

Technetium bone scans are highly regarded for detecting stress fractures.

**Management of soft tissue and bone injuries immediately following injury**

**Initial emergency management**

(a) on the scene of the accident

- Maintain calm and avoid chaos.
- Immediate assessment of the situation, e.g., notify ambulance, fire service, police, and so on.
- Any objects that are covering the victim are removed.
- Remove any airway obstructions.
- Check the pulse, blood pressure, head, chest, abdomen, and limbs.
- Apply a pressure bandage to the bleeding wounds.
- Maintains patient NBM (nil by mouth).
- Obtain I.V. access and begin fluid therapy with RL.
- Splinting of the injured or fractured limb.
- Transportation - Always follow the ABC of resuscitation.

(b) in the emergency ward

- ABC of Life Preservation (Airway, Breathing, Circulation)
- Preservation of limbs
- Prevention of infection
- Functional maintenance

For open injuries, Gustilo, Brugers, Tscherne, the AO-ASIF group, and others recommend the following steps. These objectives can be met by taking the recommended steps.

1. All open fractures should be treated as an emergency.
2. Conduct a thorough initial evaluation to rule out any other life-threatening injuries.
3. Begin and continue appropriate antibiotic therapy for 2 to 3 days.
4. Use copious irrigation to immediately debride the wound.
5. Secure the fracture.
6. Rehabilitate the affected limb.

- The operation should be performed as soon as possible. The golden hours are the first six hours of the day.
- After 6 hours, a contaminated wound is considered infected.
- The minimum time for an organism to establish itself in a wound and begin multiplying is 6 to 8 hours.
- Resuscitation, patient stabilization, bandaging and splinting, and a history including immunity to tetanus and Diabetes mellitus, chronic steroid use, drug hypersensitivity, and last meal time should be obtained.
- A thorough radiological examination should be performed.

**Open fracture treatment**

The treatment of open tibial fractures requires consideration of soft tissue, initial injury, and fracture stabilization treatment modality.

There are five keys to effective treatment. They are as follows:

1. Radical debridement and pulsed lavage irrigation
2. Fracture stabilization
(3) Antibiotic therapy
(4) Soft tissue coverage
(5) Functional rehabilitation and presumptive bone grafting in patients with high energy trauma and bone loss.

**The following are the various treatment modalities for open tibial fractures:**

1. Closed reduction with long leg pop cast application with drilling window
2. The pins and plaster technique, in which transfixing pins (such as Steinmann pins) are incorporated into a long leg pop cast.
3. Internal fixation with plates and screws:
   (a) Dynamic compression plates, static compression plates, neutralization plates, and buttress plates, for example.
   (b) Interlocking, intramedullary nails, either open or closed, reamed or unreamed.
4. Pin fixators, ring fixators, and hybrid fixators (using wires and half rings) are examples of external fixators. External fixation is usually recommended for type IIIB and type IIIC tibial open fractures.

**Prognosis**

In most closed low energy fractures, union takes 10 to 14 weeks. High energy fractures heal in 12 to 26 weeks on average. On average, open fractures take 16 to 20 weeks to heal. Consolidation of type IIIB and IIIC open fractures takes 30 to 50 weeks. Long-term outcomes are dependent on limb length restoration and knee and ankle range of motion. It is debatable whether joint motion is primarily determined by the length of immobilization or by the initial injury.

If complications such as infection, non-union, vascular disruption, or reflex sympathetic dystrophy do not ensure, the rule is to return to previous employment. Return to recreational sports is dependent on rehabilitation flexibility and strength. Long-term studies have shown that purely shaft fractures cause problems with knee and ankle motion. The degree of malunion cannot predict future functional difficulties.

**Complications**

1. skin loss
2. Vascular damage
3. Nerve damage
4. Bone defects
5. Embolism of fat
6. Infections
7. Compartments syndrome
8. Ankylosis and joint stiffness
9. Delay and non-unionization
10. Traumatic arthritis
11. Post-traumatic dystrophy
12. Deformity of the claw toe
Review of Literature

Hippocrates’ Treatise Medicatrix Nature provided early treatment advice for tibial fibula fractures. Splinting allows for rest and immobilization of the injured extremity, with fracture healing occurring over time.

Clayton Parkhil of Denver invented the first modern external fixator in 1897.

Albit Lambotte created a similar external fixator in 1906. Both were unilateral and allowed for the attachment of two sets of screws to each bone fragment.

Roger Anderson invented the Dr. Anderson frame in 1934, which included a threaded adjustment bar that allowed for distraction or compression across the fracture site.

Rawl Hoffmann invented the Hoffmann fixator in 1938, which was later modified by Vidal and Drey by using a multiplanar frame to increase rigidity and became known as the Hoffman-Vidal system. However, this framework was too rigid and static, frequently impeding union.

Court CM Brown and Hughes SP presented the findings of a prospective trial of the use of Hughes unilateral external fixator in the management of 48 tibial diaphyseal fractures in their study. In Grade II and Grade III Gustilo-Anderson fractures, good results were obtained. Good results were discovered to be dependent on the effectiveness of the initial reduction.

Charles C Edwards performed primary external fixation and serial wound debridement on 202 Gustilo-Anderson Grade III open tibial fractures. Staged soft tissue and bone reconstruction was performed on 176 patients who survived multiple injuries (skin grafts in 57%, muscle flaps in 32%, bone grafts in 28%). Infection occurred in 15% of cases and resulted in amputation in 7%. The infection rate was reduced to 9% in the second half of the series, owing primarily to the removal of all necrotic bone prior to wound coverage. Early posterolateral grafting and progressive fracture loading in the fixator reduced angulation (>10%) and delayed union. 93 percent of the fractures were repaired. The average time to remove a fixator is 87 days. Eighty-nine percent patients had a result that was satisfactory suggestive of staged reconstruction available for open tibia fractures.

Marsh JL and Nepola JV examined the outcomes of 35 open tibial fractures treated with a dynamic axial fixator. Thirty-three cases were successfully treated until the external fixator healed. An early callus response is promoted by early weight bearing and axial fracture site movement.

Joy Patankar and Anand J Thakur investigated the treatment of 79 open tibial fractures with uniplanar external fixation and early bone grafting. Weight bearing was possible due to the excellent stability. The time it took for bones to heal ranged from 11 to 40 weeks (mean 20 weeks). According to the findings, combining external fixation with early grafting is an excellent method.

Korovessis P et al. compared a series of patients treated exclusively with internal fixation to a series of patients initially treated with external fixation and later with “Sarmiento walking plaster” in their study. For open Grade II and Grade III tibial shaft fractures, the latter method was found to be a successful treatment and a viable alternative to internal fixation.

Tucker HL, Kendra JC, and Kinnebrew TE found that using the Ilizarov external fixator to treat unstable open and closed tibial fractures is slightly more complicated than using traditional large pin fixators and requires more attention intraoperatively and postoperatively, but it can be a versatile tool in the management of complex tibial shaft fractures.

In 1992, Schwartzman reported that the Ilizarov method and apparatus were used to treat 18 tibial fractures. There were four closed fractures and 14 open fractures among these patients, with three Grade I open, four Grade II open, and seven Grade III open tibial fractures. The average time from device application to complete fracture healing was 5.6 months, with a range of 3.25 to 13 months. His findings suggest that the Ilizarov method is a useful adjunct in the orthopaedic armamentarium for the treatment of either open or closed tibial fractures. There were no practical contraindications to using the Ilizarov device in the treatment of tibial fractures.

Checketts RG, Moran CG, and Jenings AG examined the outcomes of 134 tibial shaft fractures treated with a dynamic axial fixator. There were 48 cases of open fractures. The length of the union was proportional to the severity of the soft tissue injury. The averageunion time for Grade II open fractures was 5 months and 6 months for Grade III open fractures. The study concluded that the Dynamic Axial Fixator is a safe and dependable device for tibial fracture repair.
Tu YK, Lin CH, Su UI, Hsu DT, Chen RJ investigated the use of an unreamed interlocking nail versus an external fixator for open type III tibial fractures. The findings indicate that the unreamed interlocking nail is a good choice for treating open type III tibial fractures, but it is not recommended for treating open type IIIB tibial fractures with interlocking nail due to the high infection rate. 32

Henley MB, Chapman JR, Agel J, et al. conducted a prospective study on the treatment of type II, IIIA, and IIIB open tibial shaft fractures. Unreamed interlocking intramedullary nails and half pin external fixators, particularly for limb alignment maintenance. However, the severity of soft tissue injury, rather than implant selection, appears to be the most important fixator influencing bone healing speed and injury site infection rate. 33

Bhandari M, Gugatt GH, Swiout Kowski MF, and Schemitsch EH investigated the effect of alternative methods of open fracture stabilisation on reoperation rates. When compared to plate fixation, one study found that using an external fixator reduced the need for re-operation significantly. 34

Sultan S and Shah AA conducted research on the management of open tibial fractures. The management and outcome of 32 open Grade III tibial fractures were examined. The patient was treated with an AO external fixator. All received standardised wound care, which included surgical debridement and delayed wound closure. Once the soft tissue injury and fracture had healed, the sticky external frame was removed and a patella tendon bearing cast was applied. Unionization was achieved in 31 cases in 32 weeks. Deep infection rate was 13% and pin tract infection rate was 10%. 35

Zalavras CG and Patzakis MJ pioneered approaches to the treatment of open fractures. Treatment goals include infection prevention, fracture union, and function restoration. All open fractures must be classified based on the type of fracture, associated soft tissue injury, and presence of bacterial contamination. Tetanus prophylaxis and intravenous antibiotics should be started right away. The wound should be thoroughly cleaned. Extensive soft tissue damage may necessitate the repair of a local or free muscle flap. Stabilization techniques are determined by the anatomic location of the fracture and the nature of the injury. 36

G. Hosny reported 34 open tibial diaphyseal fractures in 2003, all of which were debrided and fixed with the Ilizarov device. Thirty patients were evaluated out of 34, with a mean follow-up after fracture union of 40.5 (24-80) months. He came across There were two grade I fractures, 16 grade II fractures, six grade IIIA fractures, five grade IIIB fractures, and one grade IIIC fracture. Soft-tissue healing was achieved through split thickness skin grafting, pedicle flaps and Z-plasty, delayed primary closure, and he stated that all fractures were united in an average of 5.6 (3-15.4) months. He described 28 patients who had excellent or good functional outcomes, one who had a fair outcome, and one who had a poor outcome; his conclusion was that regardless of how many complications arise, Ilizarov external fixator provide definitive fracture stability. 37

Sen-Cengiz, Kocaoglu Mehmet, Evalp Levent, Gulsen Mahir, and Cinar Murat investigated the efficacy of bifocal compression distraction in the acute treatment of open tibial fractures with bone and soft tissue loss. Out of 24 patients with open tibial fractures with a mangled extremity severity score of 6 or less indicating viability, 14 had Grade IIIA fractures and the other ten had Grade IIIB fractures. The patient's average age was 30.6 years. The average bone defect was 5 cm, with a 2.5 x 3.5 cm soft tissue loss. To achieve opposition of bone ends, the fracture site was shortened. Leg length discrepancy was corrected by corticotomy at either the proximal or distal level, depending on fracture location. 38

The average period of follow-up was 30 months. The average time for bone healing was 7.5 months. The average duration of external fixation was 7.1 months. Paley bone and functional assessment scores were used to evaluate the results. The bone assessment results were excellent in 21 patients, good in three, and fair in one. The functional assessment scores were excellent in 19, good in four, and fair in one. The infection rate at the pin site was 10.7%. The average complication rate per patient is 2.08%, with 48.1% being minor complications such as soft tissue inflammation and infection, translation, angulation, and delayed maturation during distraction, all of which can be treated non-operatively. Major complications such as pin tract infection, equinus deformity, frame failure, and premature consolidation necessitated surgical correction in 38.5% of cases. Leg length discrepancy, loss of knee / ankle range of motion, knee flexion contracture, malalignment, and chronic osteomyelitis accounted for 13.4% of the cases. According to the findings of the study, bifocal compression distraction osteosynthesis is a safe, dependable, and generally successful method for treating open tibial fractures with bone and soft tissue loss. 38

A study on external skeletal fixation of tibial shaft fractures was conducted by Milenkovic S, Mitkovic M, and Radenkovic M. They concluded that external fixation of tibial shaft fractures is a simple and effective method for allowing safe fracture healing, early mobilisation, early weight bearing, and early rehabilitation. Tibial shaft fractures
were fixed unilaterally with convergent pins, with the possibility of compression and distraction. External fixation produced excellent or good results in 94.07% of cases and poor results in 5.08% of cases.  

Pagdin J, McKeown E, Madan SS, Jones S, Davies AG, Bell MJ, and colleagues investigated pin site infections. The purpose of this study was to determine the prevalence of pin site infections. Between 1985 and January 2002, 812 patients were studied. Several external fixators were used, including the limb reconstructive system (LRS) 549, the Ilizarov 397, the Sheffield ring fixator (SRF), the dynamic axial fixator (DAF) 35, the LRS / sequoia 8; the LRS / Garche 7; and the Pennig 5.

The pin site infections were graded on a scale of 0 to 6. (Saleh and Scott). In 206 segments, there were no infections (out of 1042 limb segments). Infections were significantly lower with Ilizarov's fixator than with half pins used with mono-lateral external fixators (p 0.0001). 48 patients required hospitalization for IV antibiotics. There was no case of long standing infection or chronic osteomyelitis.  

Said Saghieh, Elie Ghanem, Bernard Saghierian, Maria Karam, and Nadim Afeiche investigated distraction osteogenesis in a delayed segmental tibial union. In their study, fractures were initially stabilised with a monolateral bridging external fixator, and there was no evidence of callus formation 6 weeks later. After 6 weeks of compression, the proximal fracture was used as "an osteotomy" for bone transport. The successful outcome in this patient demonstrates that distraction of a delayed union, even when it is mobile, can result in bone formation and delayed union healing.  

M. Foxworthy and R. M. Pringle, in 1995 reported the effect of dynamization timing on healing rates when using the Dynamic Axial Factor to treat tibia fractures. Sixty-nine patients with 71 fresh fractures were retrospectively grouped based on age, Gustilo and Anderson wound grading, tibia fracture site, and presence of an intact fibula or stable fibular fracture. The pairs were then generated chronologically to compare healing rates in patients dynamized before and after 4 weeks. Their healing times were compared using a paired t-test, and the group dynamized within the first 4 weeks healed significantly faster (P 0.05).  

In 2010, Naveed Wani reported a series of sixty patients with type II (11 patients), type IIIA (13) and type IIIB (36) tibial diaphyseal fractures who underwent emergency debridement and minimal bone fixation (with external fixator), followed by definite fixation with the IEF after three to five days. He concluded that all fractures united with an average union time of 21.1 weeks (standard deviation [SD] 3.18) in type II fractures, 21.7 weeks (SD 3.57) in type IIIA fractures, and 24.9 weeks (SD5.14) in type IIIB fractures. The best outcomes will be obtained by Because of its good functional and radiological results, early application of the Ilizarov fixator is an excellent management of open tibial fractures, particularly types II, IIIA, and IIIB. Despite technical difficulties and minor complications, IEF may be the preferred method for open tibial fractures, particularly types II and III.  

V. Glatt et al, in 2012 conducted a study to investigate modulation of the mechanical environment as a means of improving bone healing in the presence of bone morphogenetic protein (BMP)-2 in large segmental bone defect in Rat femur and concluded that reverse dynamization provided marked acceleration of the healing process by all of the criteria of the study.  

Ma Jihai et al. in 2018 retrospectively evaluated the clinical data of 26 cases of open tibia and fibula fractures treated by external fixation divided in two groups into elastic dynamic group (group A, n=13) and constant elastic fixation group (group B, n=13). All patients were followed up 4-13 months, with an average of 5.7 months. During the treatment, there was no complication such as loosening or breaking of the external fixator fracture displacement, or re-fracture. Fracture healing time in group A (23.04 ± 1.30 weeks) was significantly less than in group B (32.46±1.66 weeks) suggesting that dynamization leads to early healing of fracture.  

In 2019, Kevin Tetsworth and Vaida Glatt stated that successful regeneration and healing of bone rely on a synergy between the various biological factors and mechanical forces are governed by the timing and spatial relationship of their introduction. Optimizing the nature of these mechanical cues and the biological responses to them at various levels is most important, as this will determine the type and the amount of tissue formed, thereby controlling the rate of the healing process and in order to achieve accelerated bone healing they suggested to allow limited motion during the immediate post fracture period and then restrict motion completely after abundant callus has already formed, rather than dynamizing and allowing motion.  

V Glatt et al. in 2021 found in a study that a small amount of flexibility or micromotion at the fracture gap during the initial stage of healing improves bone healing and challenges the clinical consensus that fracture stability/rigidity is
critical. Furthermore, it has become clear that micromotion or flexible fixation at the fracture site is only required for the first 2 to 4 weeks of the healing process before converting to more rigid fixation.45

Elaine et al, in 2022 reviewed 40 articles on dynamization and its effect on bone healing found, that staged 2-part surgeries or dynamic implant designs can achieve faster fracture healing rates. Temporal dynamization, which involves the static fixation of bones followed by the introduction of micromotion and controlled loading, has been shown to increase callus volume and speed up healing. Reverse dynamization, in which micromotion is encouraged during early callus formation and then stopped, could be a significant step forward in the treatment of critical defect injuries.46

MATERIAL AND METHODS

A. Type of study- Descriptive Longitudinal study

B. Place of study - This study was carried out in Department of Orthopaedics at Pravara Rural Hospital, a tertiary care teaching hospital located in rural area of central India for a period of two years.

C. Sample Size: 44

D. Duration of study- 23 months (1st January 2021 to 1st December 2022)

E. Study population –All compound tibia fracture patients treated with external fixator application

F. Inclusion criteria-
   1. Patients who have evidence of compound tibia fracture with external fixator application Pravara Rural Hospital, Loni.
   2. Patient willing to give consent for the study
   3. Gustilo and Anderson type 2, type 3a, 3b and 3c
   4. Medically fit patient

G. Exclusion Criteria –
   1. patients not willing for the study
   2. patients with compound tibia fracture not treated with external fixator application
   3. Gustilio and Anderson type 1.

We studied 44 cases of open tibia fractures at our institute, Balasaheb Vikhe Patil Rural Medical College, Loni, from January 2021 to January 2023, under the Department of Orthopedics. The study included both male and female patients. The majority of patients were between the ages of 20 and 40. Patients were initially seen in the emergency room. A thorough examination was performed to rule out other forms of systemic injury such as head injury, cardiorespiratory status, and abdominal status. Patients suffering from hypovolaemic shock were given IV fluids such as plasma expanders, dextrose, normal saline, and ringer lactate solution. Intravenous antibiotics were administered immediately, as well as intramuscular tetanus toxoid and tetanus immunoglobulin. Meanwhile, the airway and breathing were kept open. Clinical evaluation and primary wound debridement were performed after the patient was hemodynamically stabilized. Wounds were classified as Type I, 2, 3A, 3B, or 3C based on the size of the wound, the degree of soft tissue injury, the level of contamination, the degree of bony injury, and the presence or absence of neurovascular injury. Type II, IIIA, and IIIB were the most common in our study. Wound debridement was performed using 5 to 6 litres of normal saline, betadine, and hydrogen peroxide. Antiseptic solution irrigation is used to clean the wound. Thorough wound debridement was performed on type II and type IIIA and IIIB fractures before being transferred to the radiology department for X-ray evaluation. Compound mid shaft tibia fractures were more common in our series. The right leg is slightly more common than the left. Following investigations, an external fixator was used in a major OT.

CLASSIFICATION OF EXTERNAL FIXATOR

External fixators:

- Pin fixators
- Ring fixators
(According to Behrens)
Classification according to frames

Pin fixators: (a) Unilateral
1. Plane
2. Plane
(b) Bilateral
1. Plane
2. Plane
(c) Modular
(d) Multiplanar

**Pin fixators** 47

Advantages: Can be used quickly to stabilise most diaphyseal fractures of long bones.

- Wound access is excellent, and soft tissue injury fixation is close to ideal.
- The majority of these frames are dynamizable.

Disadvantages

The presence of fixation rods away from the bone axis limits their ability to accommodate angular or rotational deformations. Since the cantilever method does not apply an axial load to the fracture site like a ring fixator, the rate of delay and non-union increases unless the fixator is remodeled or bone grafting is not performed early. They cannot be used to gradually correct severe or complete malformations.

Ring fixator 48

1. Complete rings
2. Partial parts

Advantages

- These frames are strong enough to support the most complex diaphyseal fracture complexes.
- It functions like an exoskeleton because it has a long tubular bone structure. They have elastic fixings and taut wires. Weight loading induces axial micromotions that promote osteosynthesis.

Disadvantages

- Heavy and cumbersome.
- Planning and building frames take time.
- Limited access to soft tissue.
- Risk of damage to neurovascular structures.
- Pintrack infection.
- Edema is fairly common.

- **External fixators pins are divided into four categories.** 49

i. Tip: Cut your own threads into the pre-drilled bone.

ii. Thread: Depending on the length of the threaded portion of the post, one or both cortices can be grasped. The pin has a short thread (14mm) that engages only the distal cortex of the bone. A solid bar across the near cortex. This makes
both cortices stiffer than long threaded pins. This is because stiffness is proportional to the shaft diameter, not the core diameter. There are two types of threads:

(a) self-tapping and cutting threads, which are used for cortical bone. It has a pitch of 1.75 mm.

(b) Self-tapping and compressive: Applied to cancellous bone. It has a 3 mm pitch.

iii. Core

v. Shaft: The smooth shaft is larger in diameter and thus stiffer.

Schanz pins are frequently used with external fixators. It’s similar to a Steinmann pin, but with threads in the middle of the shaft to improve purchase in the bone.

Although unreamed IM nailing is rapidly invading this area, open tibial fracture is a classic indication for external fixation.

Benefits of external fixators

1. The method provides rigid fixation of the bones in cases where other forms of immobilization are ineffective for one reason or another. This is most commonly used in severe type II and III open fractures where casts or traction methods would not allow access for soft tissue wound management and where exposure and dissection to implant and internal fixation appliance would devitalize and contaminate large areas, potentially increasing the risk of infection.

2. Compression, neutralisation, or fixed distraction of fracture fragments is possible with LRS and other ring fixator type external fixators, depending on fracture configuration. Uncomminuted transverse fractures can be optimally compressed, comminuted fractures can have length optimally maintained by pins in the major proximal and distal fragments (neutralisation mode), and fractures with bone loss in one of the paired bones can have fixed distraction.

3. The method allows for direct monitoring of limb and wound status, including wound healing, neurovascular status, and tissue viability.

4. Associated treatment: Wound dressing, skin grafting, bone grafting, and wound irrigation are all possible without disrupting fracture alignment or fixation. Rigid external fixation allows for aggressive, concurrent treatment of bone and soft tissue.

5. Proximal and distal joints can move immediately. This aids in the reduction of limb oedema and the nutrition of articular surfaces, as well as the reduction of joint stiffness and the prevention of muscle wasting and osteoporosis.

6. Early mobilisation of patients is permitted. The limb can be moved and positioned without fear of losing the fracture position with rigid fixation. Early ambulation is usually possible in fractures that are stable and uncomminuted.

7. If the patient's general medical condition is such that a spinal or general anaesthetic is not appropriate, the fixator can be inserted under local anaesthesia, though this is not ideal.

8. In the case of infected acute fractures or nonunions, rigid external fixation methods can be used. In this case, rigid fixation of bone fragments in infected fractures or cases with infective non-unions is critical in controlling and eradicating the infection. This is not possible with the other fracture fixation / treatment methods.

External fixators' disadvantages

1. To prevent pin tract infection, meticulous pin insertion technique and regular aseptic dressing around the pin tract are required.

2. Untrained surgeons / beginners may find it difficult to assemble the pins and fixator frame mechanically.

3. Fracture through pin tracts is possible.

4. Refracture after frame removal is possible if the limb is not adequately protected until the underlying bone becomes accustomed to stress again.

5. The equipment is expensive.
6. A disobedient patient may cause the appliance adjustments to be disrupted.

7. To provide compression and distraction alternately, this method requires patient cooperation and patient training. This is challenging for illiterate patients.

8. Joint stiffness may occur if the fixator is required to immobilize the adjacent joint due to the fracture. Common with proximal or distal bone fractures, with the major fragments providing insufficient pin purchase and necessitating a set of pins and a frame above the joint. 51

9. Though uncommon, pins can cause injury to neurovascular structures.

External fixator indications

Indications are classified into three types.

1. Accepted
   2. Possible

1. Accepted indications1,23
   (a) Severe Type II and IIIA, IIIB, and IIIC open fractures.
   (b) Fractures with significant bone loss.
   (c) Fractures that necessitate cross leg flaps, free vascularized grafts, or other reconstructive procedures.
   (d) Fractures that necessitate distraction. For example, those linked to significant bone loss.
   (e) Limb lengthening
   (f) Correction of the affected limb's deformity.
   (g) Treatment option for infective nonunions.

2. Potential indicators
   (a) Fracture with neurovascular injury necessitating vascular / nerve repair / reconstruction.
   (b) Limb replacement.
   (c) Multiple closed fractures are fixed.
   (d) Ligamentotaxis: This term, which is common in the European literature, refers to the treatment of certain intra-articular fractures with external fixation using traction by the fixator on the capsular and ligamentous structures surrounding the joint. This concept works well in comminuted intra-articular distal radius fractures.
   (e) Fracture fixation in patients with head injuries. Rigid external fixation may be used to temporarily immobilise fractures in patients with severe head injuries who are experiencing seizures or continuous spasms, making traction, casting, or other forms of immobilisation impractical.
   (f) Fracture repair in patients who need to be transported frequently for diagnostic testing or other surgical procedures. In cases where traction does not allow patient transportation, external fixation allows transportation without interfering with fracture reduction.
   (g) Floating knee fracture fixation: External fixation of ipsilateral femoral and tibial fractures that are not amenable to open reduction and internal fixation allows for early knee function. 52

EXTERNAL SKELETAL FIXATION GENERAL PRINCIPLES AND TECHNIQUES53

Regardless of the specific fixator chosen, the general techniques for using external fixators are demanding. Attention to detail is critical if the device is to be used effectively and potentially serious complications are to be avoided. The following treatments must be considered first: irrigation, debridement, and reduction of the severe open fracture,
drainage, and sequestrectomy of the infected fracture. Prior to the application of a fixator, appropriate primary treatment in these conditions must be administered. Before attempting to treat a fracture, a complete set of external skeletal fixator equipment must be available, regardless of the type of device preferred. The surgeon should be well-versed in the equipment, preferably through prior experience or practice with such equipment in a workshop or psychomotor skills laboratory. Prior to using the device, it is best to review the equipment and general technique that will be used on the patient. Before beginning the procedure, the desired pin placement, frame length, clamp design, and clamp placement should be determined.

Will the fracture configuration permit compression, neutralisation, or distraction? The pin location should be chosen to make subsequent dressing changes, skin grafts, or other procedures easier. The patient's convenience and comfort should also be taken into account. The external fixator should be used in the operating room under general or spinal anaesthesia, under strict aseptic / sterile conditions, ideally with image intensification and fluoroscopic control. Before inserting pins into an open fracture, the soft tissue and bone fragments should be irrigated and debrided, and the bone length, rotation, and general alignment of the limb should be restored. Inserting pins prior to fracture reduction will complicate the procedure, resulting in significant soft tissue shifting and impalement on the pins where they entered the skin. If the open wound allows, anatomic restoration of the fracture fragments should be performed under direct vision. If possible, stabilise unstable fragments with Kirschner wires or screws before inserting fixation pins and frames. The fracture should be reduced as anatomically as possible. Because the healing of a fracture with rigid external fixation is similar to that of a fracture with rigid internal fixation, i.e. largely endosteal.

Many delayed unions and non-unions are the result of large fracture gaps in an environment with little callus production. In such cases, supplemental internal fixation with a Kirschner wire or interfragmentary fixation, as well as early bone grafting if a gap remains, will help to reduce late complications. If desired, the Kirschner wires or screws can be removed after the external fixator has been applied and the fracture has been rigidly immobilised. Compressing the fracture site with a compression distraction unit connected between the two clamps on either side of the fracture site is preferable.

Pins

There are two kinds of pins: half pins and transfixation pins. A threaded section at the end or centre of the pin provides pin purchase in the bone. Threaded sections are self-tapping. Smooth pins should be avoided. Half pins are threaded at various lengths from the tips, with the thread length corresponding to the diameter of the bone to be traversed. Through the soft tissues, the proximal bone cortex, the medullary canal, and the distal cortex, half pins are inserted.

The pins do not exit the soft tissue on the opposite side of the insertion point. When a more rigid fixation is required, Schanz fixation pins with a threaded centre portion are frequently used. They are inserted similarly to half pins, except that the pin tip continues through the distal cortex and soft tissue and exits opposite the insertion point. Either type can be self-drilling or inserted through a predrilled hole. Predrilling is preferred because it improves thread purchase in the cortex and reduces the possibility of thermal necrosis around the hole. The use of self-drilling half pins may result in suboptimal thread purchase in the proximal cortex. The threaded proximal cortex may be stripped and fixation in that cortex compromised as the drilling tip traverses the medullary canal and encounters resistance from the distal cortex. Improved fixation and fewer pin tract issues. The predrilled technique, for example, causes loosening, infection, and ring requestra.

The pin should be chosen so that the thread length is approximately equal to the bone diameter. A pin thread that is too short may result in poorpurchase, while a threaded section that is too long may cause soft tissue damage. Half pins must also be chosen with care to ensure that the threaded area is the correct length. This can be done accurately by inserting a depth gauge into predrilled holes or carefully measuring the diameter of the bone on roentgenograms if a self-drilling pin is used.

Insertion of a pin

The pins should be inserted through large skin and fascial incisions (1.0-1.5 cm). To avoid spearing a muscle or tendon with the pin, dissection to locate a natural interval between adjacent muscle bellies is preferable if the pin must traverse a muscle compartment. Soft tissue wounds, safe zones, fracture comminution, and other factors all influence location. Pins should be inserted through the bone's maximum diameter, which can be estimated by probing the opposite cortices with the pin, drill tip, or Kirschner wires prior to pin insertion, or by drilling the pin hole.
Avoiding pin placement through the dense anterior cortex of the tibia is especially important, as this frequently results in thermal necrosis around the pins and subsequent pin tract infection. Heat is produced during drilling. The heat causes osteonecrosis and may cause pins to loosen. As a result, soaking in saline during drilling is safe and reduces this risk.

Depending on the clamps and frame used, the additional pins are inserted using pin guides. Following pins are inserted in the proper axis so that the pins form a straight line. They should also be aligned along the bone's axis. A minimum of two pins in the major fragments above and below the fracture is generally recommended.

Following the insertion of each pin, the joint should be moved through a small range of motion to ensure that the pins have not impaled a tendon or muscle and will not limit future joint motion. If pins are to be used to traverse the anterior compartment of the leg, they should be inserted with the ankle held in maximum dorsiflexion by an assistant. If this practical point is not observed, crossing the anterior muscle compartment may result in dorsiflexion and equinus contracture.

Following frame applications, take care of the extremity.

The responsibility of the surgeon does not end with the treatment of the primary condition with the pins and frame. To avoid problems that are common with external fixators, extreme care must be taken with the extremity. Important factors to consider include

1. Elevating the extremity to reduce oedema. This may be supplemented by tying the fixator to the bed's overhead frame with ropes or by keeping the limb in a Bohler Braun's splint. Elevation may not be desirable if arterial supply to the limb is compromised.

2. Use of dressing pads or slings to support the dependent posterior soft tissue. This technique also helps to prevent edoema and haemorrhage in these tissues.

3. Ankle support with appropriate splinting to prevent contractures. Slings, rubber hose, or specially designed commercial splints that attach to the frame can help with this. If this crucial factor is overlooked, heel cord tightness or contractures are common.

4. Exercise the joints near and far from the fixator.

5. Keeping the pin site clean on a regular basis. Cleaning must be done with care and under sterile conditions. The crust of dried blood or drainage must be removed, and soft tissue must be pushed away from the pins. The application of antiseptic / antibiotic cream to the pinskin interface is optional. Unless required by the dressings for associated soft tissue injuries, the pin skin junction is usually not bandaged. Although the use of this technique may reduce pin tract problems, no prospective study comparing these methods of pin tract management has been reported to date. The occurrence of pin tract problems gradually increases with the length of time the fixator is in place.

6. Keep an eye out for changes in skin tension around the pins as the swelling goes down. When the swelling goes down, an initially adequate skin portal may become strained as the skin shifts. If this happens, the skin and fascia around the pins' bases should be incised under local anaesthesia.

If the pain and discharge from the pin insertion site persist despite treatment, the pin should be removed. Local or systemic antibiotic therapy may be used, but it will not cure a significant pin tract infection on its own. For the first seven to ten days, the compression should be gradually increased by adjusting the CD unit connected between the clamps. Individualization of the time the fixator remains in place based on the nature of the primary condition, soft tissue condition, and so on. If used for severe, open Gustilo's type II or type III fractures, the fixator should be left in place until the wound is stable and the skin is covered. Time spans range from two to three weeks in the same situation to 12 to 14 weeks in others. In general, the fixator used in fracture management should be removed once the fracture has been closed and appropriate internal fixation or cast techniques can be applied.

**External skeletal fixation complications**

External skeletal fixators (ESF) are notorious for causing complications.

Some of the issues have workable solutions. Delayed union can be avoided by performing accurate reduction, early bone grafting, and removing the external fixator as soon as possible. Nerve and vessel injury can be avoided by paying close attention to the anatomy of the third and fourth quarters of the leg. Pin tract infections continue to plague the
external skeletal fixator system, but they are being reduced by paying close attention to tissue necrosis at the pin-skin and pin-bone interfaces. External fixators are frequently used to provide immediate bone and soft tissue immobilisation while allowing wound access in severe open fractures. This stable mechanical environment aids in soft tissue healing and helps to prevent wound sepsis.

1. Tardy Union
2. Fixator issues
3. Nerve and vessel damage
4. Infections of the pin tract

**Operative Technique**

**The use of LRS in the tibia**

Following part preparation, three Schanz pins were inserted into the tibial condyles just below the articular surface anteromedially. This three pins are attached to the proximal clamp of the LRS. We must measure the distal fragment to determine the length of the distal fragment before applying Schanz pins. If the distal fragment is two-thirds of the tibia, 2 clamps and 6 Schanz pins are required. 1 clamp and 3 Schanz pins for one-third

Schanz pins should be inserted in the following manner:

(a) Assemble the triple trocar and penetrate soft tissue down to the bone surface (via a stab incision).
(b) Remove the trocar and use a long 3.5 mm drill bit to drill through both cortices.
(c) Remove the drill sleeve and drill the near cortex with a long 4.5 mm drill bit through the remaining 6 or 5 mm sleeve. It is recommended to use an oscillating attachment in conjunction with a three fluted drill bit.
(d) Hook the far cortex with the depth gauge probe through the probe sleeve.
(e) Tighten the locking pin after advancing the knurled disc to the top of the drill sleeve.
(f) Take out the probe. Insert the threaded tip of the Schanz pin into the knurled disk's Schanz pin recess.
(g) Slide the universal chuck over the Schanz pin's non-threaded end until the tip of the probe touches the end of the universal chuck. In this position, tighten the universal chuck onto the Schanz pin.
(h) Insert the Schanz pin until it nearly touches the top of the drill sleeve; the Schanz pin is now fully inserted into the far cortex.
(i) Disconnect the drill sleeve and secure the adjustable clamp.

![Figure 3 – Implants used in LRS](image-url)
Because the distal fragment is movable, it requires more stability. Following application, this must be secured with nuts located at the back of the railing using a spanner. The compression distraction clamp must be secured between the proximal clamp of the proximal segment and the distal fragment's distal first clamp.
Application of Ilizarov in tibia

WIRES INSERTION

The wire was crucial in successfully controlling the biology of healing. Proper wire insertion techniques are essential for avoiding pain, maintaining function, and accelerating healing. Trocar tips are reserved for metaphyseal cancellous bone, whereas bayonet wire tips on 1.5 to 1.8mm diameter wires are specifically designed for hard cortical bone.

Of course, by being aware of the anatomy, nerves and vessels must be avoided during wire passage. Before drilling, manually push the wire into the bone. Drill both cortices, then hammer the wire through the opposing soft tissues.

To maximize the excursion of adjacent joints, muscles must be properly positioned for wire placement. Each muscle should be stretched to its maximum length at the adjacent joint prior to impalement. The ankle plantar flexors are stretched in the example by maximum dorsiflexion of the foot during posterior wire passage and then maximal plantar flexion as the wire passes out dorsally.

The same technique is used to insert wires with stoppers, but a small incision is required when the stopper reaches the skin to allow it to pass through the soft tissue to the bone.

Transosseous wires are a foreign body that passes through the muscular and tendinous planes, limiting joint movement. It is a good rule of thumb to insert the fewest wires possible while maintaining the assembly's stability.

ATTACHMENT OF THE WIRES TO THE RINGS

The size of the rings (two half-rings) is determined by the maximum diameter of the limb. It is recommended that a two-to-three centimetre gap be left circumferentially between the internal part of the ring and the soft tissue.

The limb segment (not necessarily the bone) is placed in the centre of the ring during the ring assembly.

THREADED RODS ASSEMBLY TO CONNECT THE RINGS

The rods (threaded) that connect the rings are parallel to one another and must also be parallel to the mechanical axis of the bone. On the circumference of the ring, the rods must be approximately equal distance apart. To connect rings, three or four rods are used.

In fractures, after the apparatus has been correctly assembled and the longitudinal distraction of the segments has been completed, the nuts and bolts are tightened will produce reduction automatically.

Figure 7 – Intra-operative Ilizarov ring fixator application
Observations and Results:

Table No. 6 - Age wise distribution of the patients with compound tibia fracture

<table>
<thead>
<tr>
<th>Age in years</th>
<th>Frequency</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;20</td>
<td>2</td>
<td>4.5</td>
</tr>
<tr>
<td>20 to 40</td>
<td>22</td>
<td>50</td>
</tr>
<tr>
<td>40 to 60</td>
<td>15</td>
<td>34.1</td>
</tr>
<tr>
<td>&gt;60</td>
<td>5</td>
<td>11.4</td>
</tr>
<tr>
<td>Total</td>
<td>44</td>
<td>100</td>
</tr>
</tbody>
</table>

Graph 1 - Age wise distribution of the patients with compound tibia fracture

Majority 50% cases were in age group of 20 to 40 years. Mean age was 40.45 + 15.7 years, ranging from 18 to 81 years.
Table No. 7 - Gender wise distribution of the patients with compound tibia fracture

<table>
<thead>
<tr>
<th>Gender</th>
<th>Frequency</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>38</td>
<td>86.4</td>
</tr>
<tr>
<td>Female</td>
<td>6</td>
<td>13.6</td>
</tr>
<tr>
<td>Total</td>
<td>44</td>
<td>100</td>
</tr>
</tbody>
</table>

Graph 2 - Gender wise distribution of the patients with compound tibia fracture

Male preponderance was seen. 86.4% were males and 13.6% were females.

Table No. 8 - Type of fixator applied to compound tibia fracture patients

<table>
<thead>
<tr>
<th>Type of fixator</th>
<th>Frequency</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hybrid External Fixator</td>
<td>7</td>
<td>15.9</td>
</tr>
<tr>
<td>Illizarov Ring Fixator</td>
<td>14</td>
<td>31.8</td>
</tr>
<tr>
<td>Linear External Fixator</td>
<td>21</td>
<td>47.8</td>
</tr>
<tr>
<td>LRS fixator</td>
<td>2</td>
<td>4.5</td>
</tr>
<tr>
<td>Total</td>
<td>44</td>
<td>100</td>
</tr>
</tbody>
</table>

Graph 3 - Type of fixator applied to compound tibia fracture patients

Most commonly linear external fixator was used 47.8%, followed by 31.8% Illizarov ring fixator, 15.9% hybrid external fixator and for 4.5% LRS fixator was used.
Table No. 9 - Site of fracture in compound tibia fracture

<table>
<thead>
<tr>
<th>SOF</th>
<th>Frequency</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Distal 1/3</td>
<td>14</td>
<td>31.8</td>
</tr>
<tr>
<td>Mid shaft</td>
<td>19</td>
<td>43.2</td>
</tr>
<tr>
<td>Proximal 1/3</td>
<td>9</td>
<td>20.5</td>
</tr>
<tr>
<td>Segmental</td>
<td>2</td>
<td>4.5</td>
</tr>
<tr>
<td>Total</td>
<td>44</td>
<td>100</td>
</tr>
</tbody>
</table>

Graph 4 - Site of fracture in compound tibia fracture

Mid shaft (43.2%) was most common site of fracture, followed by distal 1/3 (31.8%), then proximal 1/3 (20.5%) and only 4.5% had segmental fracture.

Table No. 10 - Type of fracture according to Gustilo Anderson classification

<table>
<thead>
<tr>
<th>TOF</th>
<th>Frequency</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>II</td>
<td>25</td>
<td>56.8</td>
</tr>
<tr>
<td>III A</td>
<td>10</td>
<td>22.7</td>
</tr>
<tr>
<td>III B</td>
<td>9</td>
<td>20.5</td>
</tr>
<tr>
<td>Total</td>
<td>44</td>
<td>100</td>
</tr>
</tbody>
</table>
Graph 5 - Type of fracture according to Gustilo Anderson classification
Majority 56.8% had grade II, 22.7% had IIIA and 20.5% had IIIB type of fracture.

Table No. 11 - Secondary procedures following external fixator application

<table>
<thead>
<tr>
<th>Secondary procedure</th>
<th>Frequency</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Not needed</td>
<td>38</td>
<td>86.4</td>
</tr>
<tr>
<td>Fibulectomy</td>
<td>1</td>
<td>2.3</td>
</tr>
<tr>
<td>Skin grafting</td>
<td>1</td>
<td>2.3</td>
</tr>
<tr>
<td>Flap coverage surgery</td>
<td>4</td>
<td>9.1</td>
</tr>
<tr>
<td>Total</td>
<td>44</td>
<td>100</td>
</tr>
</tbody>
</table>

Graph 6 - Secondary procedures following external fixator application
Only 13.6% cases needed secondary procedures. Among them 9.1% needed flap coverage surgery, fibulectomy and skin grafting was needed for 2.3% cases each respectively.

Table No.12 - Complication

<table>
<thead>
<tr>
<th>Complication</th>
<th>Frequency</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>No complications</td>
<td>35</td>
<td>79.5</td>
</tr>
<tr>
<td>Deformity</td>
<td>1</td>
<td>2.3</td>
</tr>
<tr>
<td>Pin tract infection</td>
<td>2</td>
<td>4.5</td>
</tr>
<tr>
<td>Pin tract infection and deformity</td>
<td>1</td>
<td>2.3</td>
</tr>
<tr>
<td>Shortening</td>
<td>5</td>
<td>11.4</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>44</strong></td>
<td><strong>100</strong></td>
</tr>
</tbody>
</table>

Graph 7 – Complication
20.5% cases had complications. Among them majority 11.4% had shortening, 4.5% had pin tract infection, and deformity and both pintract infection and deformity was seen in 2.3% cases each respectively.
Table No. – 13 Post operative parameters

<table>
<thead>
<tr>
<th>Parameter in months</th>
<th>Mean</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fracture union</td>
<td>5.04</td>
<td>0.76</td>
</tr>
<tr>
<td>Removal of fixator</td>
<td>6.14</td>
<td>0.74</td>
</tr>
<tr>
<td>Duration of functional cast</td>
<td>1.03</td>
<td>0.074</td>
</tr>
</tbody>
</table>

Graph 8 – Post operative parameters
Fracture union was seen at an average of 5.04 months with average removal of fixator in 6.14 months.

Table No. 14 - Final outcome

<table>
<thead>
<tr>
<th>Final outcome</th>
<th>Frequency</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Excellent</td>
<td>29</td>
<td>66</td>
</tr>
<tr>
<td>Good</td>
<td>13</td>
<td>29.5</td>
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<tr>
<td>Fair</td>
<td>2</td>
<td>4.5</td>
</tr>
<tr>
<td>Total</td>
<td>44</td>
<td>100</td>
</tr>
</tbody>
</table>
Graph 9 – Final outcome
On final outcome majority 66% cases had excellent results, 29.5% had good and 4.5% had fair results.

Table No. 15 - Association between Type of fixator used and final outcome

<table>
<thead>
<tr>
<th>Type of fixator</th>
<th>Final outcome</th>
<th></th>
<th></th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Excellent</td>
<td>Fair</td>
<td>Good</td>
<td></td>
</tr>
<tr>
<td>Hybrid External Fixator</td>
<td>5</td>
<td>2</td>
<td>0</td>
<td>7</td>
</tr>
<tr>
<td>Illizarov Ring Fixator</td>
<td>9</td>
<td>4</td>
<td>1</td>
<td>14</td>
</tr>
<tr>
<td>Linear External Fixator</td>
<td>14</td>
<td>6</td>
<td>1</td>
<td>21</td>
</tr>
<tr>
<td>LRS fixator</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>Total</td>
<td>29</td>
<td>13</td>
<td>2</td>
<td>44</td>
</tr>
</tbody>
</table>

Graph 10 - Association between Type of fixator used and final outcome
Applying ANOVA, p value <0.05 shows statistical significance.

**Discussion**

Open fractures are surgical emergencies that should be considered incomplete amputations. There is a personal and economic loss of staggering proportions as a result of the open fracture of the tibia. All doctors who make health-care decisions must strive for life preservation, limb preservation, infection avoidance, and limb functional preservation.

The following parameters were investigated in relation to the patients and the types of fractures that occurred.

1. **Incidence of age**

All of the patients in the current study ranged in age from 18 to 81 years old. The majority of patients (50%) were between the ages of 20 and 40. In our study, the average age was 40.45±15.7 years. While in Singh A et al, study also majority of cases were in 20-40 age group, ranging from 20-62 years. In Jain et al, mean age was 34.4 with patients ranging from 18-59 years. In Chandan gupta et al, mean age was 37.84 year with patient ranging from 18-70 years.

2. **Sex Incidence**

In our study, 86.4% of the patients were male, indicating that men have higher levels of activity and mobility than women. Female patients made up the remaining 13.6% of the study group. While in Sing A et al, study 57 out of 68 patients were also male. In Jain et al, out of 57 patients 45 were male and remaining 12 were female. In Chandan gupta et al., out of 25 patients, 20 were male and 5 were female.

3. **Classification - Fracture Type**

According to Gustilo-Anderson's classification we included individuals ranging from type II to type IIIb in our study. The majority of patients in our study (56.8%) belonged to the Type II Gustilo-Anderson's. The Type IIIA and Type IIIB groups came next, accounting for 22.7% and 20.5% of the total. In Jain et al., majority of the cases were Gustilo-Anderson's type IIIb including 31 (54.39%) patients out of 57 included in the study.

4. **Fracture site**

In our study, 43.2% of the fractures were in the middle third, 31.8% were in the lower third, 20.5% were in the proximal third, and 4.5% were segmental fractures. In Kumar et al., also most common fracture site was middle third - 26 out of 37 cases (70.27%), 9 cases (24.32%) were in the lower third and remaining 2 cases (5.40%) cases were in proximal third.

5. **Type of Fixator applied**

In our study out of 44 patients studied, 21 (47.8%) were applied Linear external fixator, 14(31.8%) were applied Ilizarov ring fixator and remaining patients were applied Hybrid external fixator and LRS fixator, each type applied to 7(15.9%) and 2(4.5%) respectively.

6. **Other secondary procedure**

In our series, a total of 6 patients required secondary procedures after fixation of fracture. Out of which, 4 patient required flap coverage surgery, 1 patient required skin grafting and 1 patient required fibulectomy to avoid complication of non-union in the patient.
7. Complications

The most common complication in our study was limb shortening, which occurred in 5 patients (11.4%). Three patients developed pin tract infections. These pin tracts were treated. All three cases responded well to appropriate parenteral antibiotics after culture and sensitivity testing. Poor hygiene was thought to be the source of the infection. Patients' nutritional status, nosocomial infection, and inability to afford expensive antibiotics.

8. Post-operatively

There was union at fracture site in 5.04 months (20 weeks) amongst all 44 patients with removal of fixator at a mean of 6.14 months, followed by functional cast of a mean of 1.03 months. Whereas in study conducted by Sing A et al., the mean duration of union at fracture site was 6 months (22-26 weeks). In Jain et al., all the patients were dynamized at 7.44 weeks and the mean duration of union was 22.4 weeks (15-29 weeks). In beltsios et al., mean duration on union in 139 open tibia fractures was 25 weeks.

9. Final Outcomes

In our study, results were compared according to ASAMI scoring system

<table>
<thead>
<tr>
<th>ASAMI scoring</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Excellent</td>
<td>Active, no limp, minimum stiffness (loss of &lt;15 knee extension/ &lt;15 dorsiflexion of ankle), no reflex sympathetic dystrophy (RSD), insignificant pain</td>
</tr>
<tr>
<td>Good</td>
<td>Active, with one or two of the following: limp, stiffness, RSD, significant pain</td>
</tr>
<tr>
<td>Fair</td>
<td>Active, with three or all of the following: limp, stiffness, RSD, significant pain</td>
</tr>
<tr>
<td>Poor</td>
<td>Inactive (unemployment or inability to perform daily activities because of injury)</td>
</tr>
<tr>
<td>Failures</td>
<td>Amputation</td>
</tr>
</tbody>
</table>

Table No. 17 – ASAMI scoring

we obtained excellent results in 29 patients (66%), good results in 13 patients (29.5%) and fair results in 2 patients (4.5%). In study conducted by Chandan gupta et al., out of 25 cases, 5 cases showed excellent result, 8 patients showed good result, 5 patient showed fair result, 7 patient showed poor result and 2 patients ended up with amputation.

Conclusion

Once external fixator has been applied various environmental factors affect the rate of healing of fracture site as stated in various studies.

Most accepted protocols followed globally are to maintain rigidity during the first 4-6 weeks of external fixator application and further manipulation of the fracture environment only if the fracture has not demonstrated any sign of union, and only then will the surgeon introduce limited motion at the fracture site via dynamization. However, it is highly unlikely that this traditional dynamization method contributes to early fracture healing.

However, the concept of Reverse Dynamization states that the mechanical environment of the fracture site is manipulated during early stage of healing in an attempt to accelerate progression towards union. The fracture is initially stabilized less rigidly to allow micromotion and encourage callus formation. Once callus has formed, stabilization is converted to a rigid configuration, and fracture is then allowed to remodel, as confirmed by our study, in which union was seen at the fracture site as early as 16 weeks (4 months).

In our study, following surgery all the external fixator were kept less rigid for 6 weeks and patients were encouraged to mobilize from day 2 of surgery. Following 1st follow-up after 6 weeks the entire construct of external fixator was converted to a rigid fixation, and patients were asked to continue mobilization as before. Our study has revealed early union at fracture site as compared to other studies which compared dynamization of external fixator following 4-6 weeks
of initial rigid fixation. Our study found that reverse dynamization is the key to tipping the balance in favour of more reliable and rapid union at the fracture site.

CASE ILLUSTRATIONS

Case 1

Patient name: Kailash Bhiwaji Varpe

Diagnosis: Fracture Proximal Shaft of Tibia with Neck of fibula

Patient had puncture wound over proximal tibia with superficial skin infection

Pre op Xrays

Clinical Picture

Post op xrays
6 weeks followup

3 months followup

6 months followup
Case 2

Patient name: Vinod Jagtap

Diagnosis: Proximal 1/3rd tibia fracture
Patient had a compound wound over the proximal tibia

Pre op

Post op
6 months
CASE 3

Patient name: Gaurav Tupe
Diagnosis: Compound # shaft tibia left side
Pre Op

Post Op
3 weeks

6 weeks

3 months
Post removal of fixator
Case 4

Diagnosis: Compound shaft tibia left side

Post op
Post Removal
Clinical Photo:
Case 5

Patient name: Pritesh Shinde

Diagnosis: compound fracture shaft tibia left side

Pre Op:
Clinical photos:

3 weeks
6 weeks
3 months

5 months
Post removal

Bibliography


46. Elaine C. Schmidt, Lauren M. Judkins, Guha Monogharan, Samir Mehta, Michael W. Hast;Current concepts in fracture healing: temporal dynamization and applications for additive manufacturing.Schmidt et al. OTA International (2022) e164


