INTRODUCTION

The tibia is one of two bones that comprise the leg. As most of the weight is transmitted through tibia, it is significantly larger and stronger than its counter bone, fibula. The tibia forms the knee joint proximally with the femur and forms the ankle joint distally with the fibula and talus. The tibia runs medial to the fibula from just below the knee joint to the ankle joint and is connected to each other by the interosseous membrane.[1]

The proximal end of the tibia consists of a medial and lateral condyle, which combine to form the inferior compartment of the knee joint. Between the two condyles lies the intercondylar area, which is where the anterior collateral ligament, posterior collateral ligament, and menisci are attached.[1]

The shaft of the tibia is triangular in cross-section with three borders and three surfaces. The anterior border divides the medial and lateral surface, the medial border divides the medial and posterior surface, and the interosseous border divides the lateral and posterior surface. While the medial surface is mostly subcutaneous, the lateral surface abuts the anterior compartment of the leg, and the posterior surface abuts the posterior compartment.[1]

Fractures of long bones constitute the majority of emergency operating room procedures in most trauma centres. Of these long bone injuries, tibial fractures are the most common. The National Centre for Health Statistics (NCHS) reports an annual incidence of 492,000 fractures of the tibia and fibula per year in the United States. Patients with tibial fractures remain in hospital for a total of 569,000 hospital days and incur 825,000 physician visits per year in the United States.[2,3,4]

Tibial fractures are prone to complications. The lack of a circumferential soft tissue envelope around the bone makes the bone ends more likely fail to unite (non-union). Approximately 50,000 North Americans suffer from these non-union complications each year. Other complications include infection, malunion, malalignment etc that sometimes necessitate additional operations. Management strategies to best minimize these frequent complications and resulting re-operations have been proved controversial.[2,3,4]

While deciding the treatment strategy, the treating surgeon must consider the patient's condition, the mechanism of injury, and the fracture type. Although some of the most impressive injury patterns are from highenergy mechanisms, more commonly, patients present with an open fracture from a simple low-energy mechanism such as a fall. Each fracture could conceivably be treated quite differently, ranging from external fixation and delayed closure or fixation to immediate irrigation, debridement, and primary closure. The status of the soft tissues surrounding the fracture site is of paramount importance in this decision-making process, which usually influences the initial management.[5]

Complications are also more in open fractures which may lead to non-union of these bones. Fracture of the shaft of long bone should not be considered a nonunion until at least,[6,7,8,9] months post injury. Non-union are more common when the fractures are open, infected, segmental, comminuted, insecurely fixed, immobilized for an insufficient time. They are also common if treated by ill-advised open reduction, distracted either by traction or by plates, screws and irradiated bones. Two types of non-union has been described in literature, Hypervascular non-union in which ends of the fragments are capable of biological reaction and avascular or atrophic non-union in which ends are inert and incapable of biological reaction.[6]

There are several procedures of surgery depending upon the type of fractures such as plating, nailing, bone grafting, external fixation, ring fixation etc.[3]

Every method has got its own merits and demerits. One of the most reliable techniques is application of ring fixators e.g. Illizarov but it has some disadvantages followed by dissatisfaction with patients. It causes various complications such as persistent pain, discomfort and heaviness. It has been seen in several studies, that the Limb reconstruction surgery (LRS) through Monorail system is superior to ring fixator.[5] Monorail system has more advantage for patients and for surgeon as well due to its light weight and uniplanar application. This mono rail device is cost effective and it's easier for the patient to move which promotes healing.[3]

Moreover, the anatomical and mechanical axis of the tibia is parallel to each other as a result it does not cause displacement of the bone. It also provides axial compression which promotes union and the patient can start walking even though undergoing treatment.

Monorail system is an external fixator which provides an easy access without excessive vascular injury to the soft tissues and to the bone. It causes minimal anatomical loss or displacement, and minimal complications considering the knee joint and ankle joint both.[3]

Surgical Anatomy

Surgical Anatomy of Leg[1]

The leg has 3-compartments:

1. Anterior compartment
2. Lateral compartment
3. Posterior compartment – This compartment is subdivided in-

a. Superficial posterior compartment

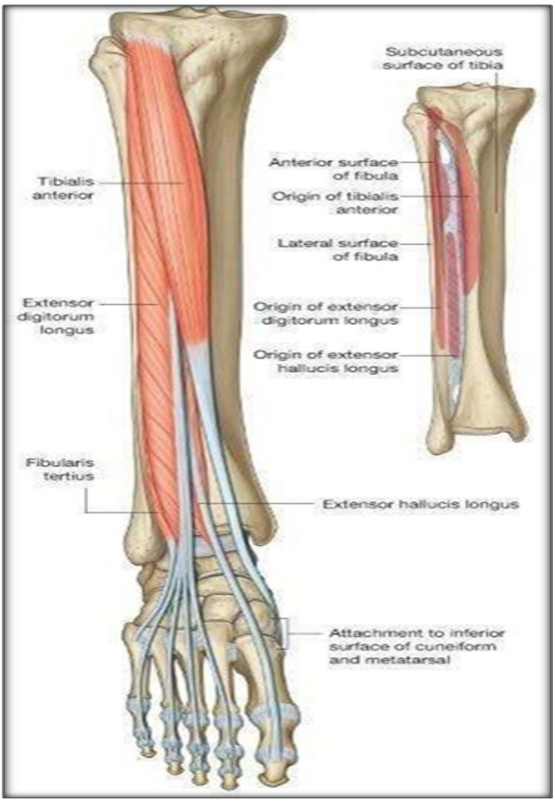
b. Deep posterior compartment

Anterior Compartment:

- The muscles of the anterior compartment of the leg are extensor hallucis longus, extensor digitorum longus, tibialis anterior, and peroneus tertius.

- The primary function of anterior compartment is dorsiflexion of ankle and foot. Inversion of foot caused by tibialis anterior, extension of hallux by extensor hallucis longus and extensor digitorum longus perform extension of toes.

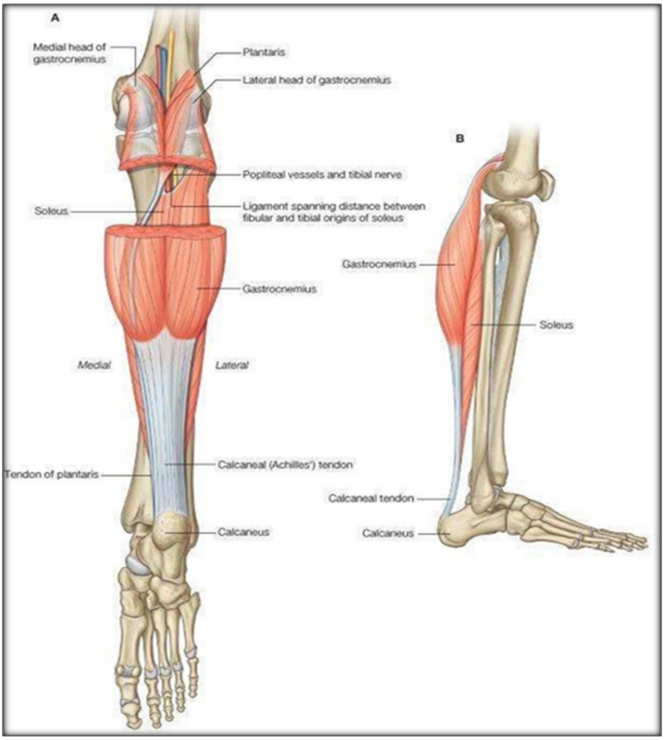
The muscles in the anterior compartment are enclosed with fascial covering, which makes the anterior compartment more at risk for compartment syndrome. Tendons of extensor digitorum longus, tibialis anterior, and extensor hallucis longus are close to the distal end of tibia. These muscles may get injured and incorporated by the callus formation during fracture healing



Muscles of Leg-Anterior view

Lateral Compartment

The muscles in this compartment are the peroneus brevis and longus. Their function is eversion of foot. The peroneus longus everts and plantar flexes the foot. Compartment syndromes are much less common in lateral compartment as compared to the anterior compartment.



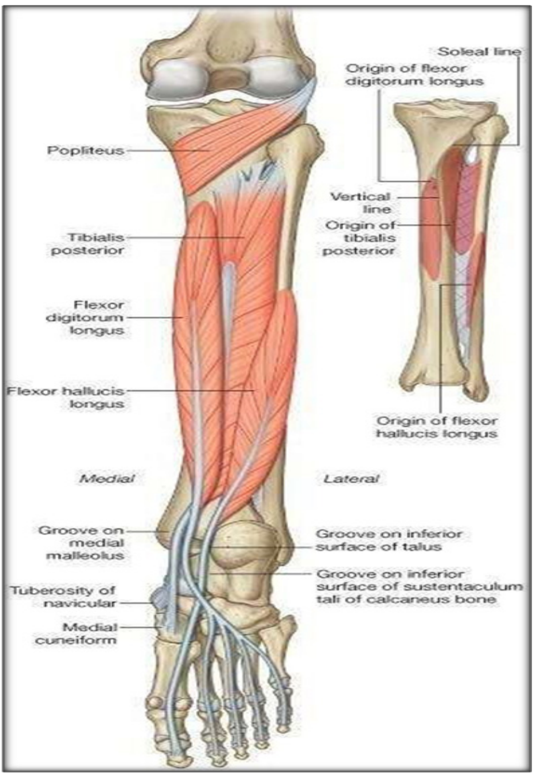
Muscles of Leg – Posterior View 1

Superficial Posterior Compartment

- The muscles of Superficial posterior compartment are gastrocnemius, soleus and plantaris.
- The Gastrocnemius muscles crossing both knee and ankle are primarily responsible for the flexion of the knee and ankle joints.

- Gastrocnemius tendon joins soleus tendon in distal third of the leg to form triceps surae or Achilles tendon.
- Plantaris has no anatomical significance, but may serve as a source of tendon graft.
- Deep Posterior Compartment
- This compartment contains flexor digitorum longus, flexor hallucis longus, tibialis posterior and popliteus.
- The function of these muscles are plantar flexion and inversion of foot.

Popliteus muscle is an internal rotator of tibia, leg flexor, and knee flexion initiator.



Muscles of Leg – Posterior View 2

Structure and Function

The tibia is the second largest bone in the body. One of the main actions of this bone is weight transmission. The majority of the weight load.[7] It also serves as the origin or insertion site for 11 muscles; these allow for extension and flexion at the knee joint and dorsiflexion and plantar-flexion at the ankle joint.

Tibial Osteology

The Proximal Tibia:

- Lateral condyle - lateral proximal part of the tibia that articulates with the femur.
- Medial condyle - medial proximal part of the tibia that articulates with the femur.
- Lateral tibial plateau - the superior articular surface of the lateral condyle.
- Medial tibial plateau - the superior articular surface of the medial condyle.

Intercondylar area:

- Anterior area: located anteriorly between the medial and lateral condyle. The attachment point of the anterior cruciate ligament.
- Posterior area: located posteriorly between the medial and lateral condyle. The attachment point of the posterior cruciate ligament.
- Intercondylar eminence (tibial spine): located between the articular facets and consists of a medial and lateral tubercle. The depression posterior to the intercondylar eminence serves as attachments for the cruciate ligaments and menisci.

The Tibial Shaft:

The shaft of the tibia is prism-shaped and has 3 surfaces (lateral, medial/anterior, and posterior) and 3 borders (anterior, medial, and interosseous).

- Anterior border: divides the medial and lateral surface.
- Medial border: divides the medial and posterior surface.
- Interosseous border: divides the lateral and posterior surface.
- Medial/anterior surface: palpable down the lower leg, commonly referred to as the shin. It contains the tibial tuberosity.
- Tibial tuberosity: bony projection of the anterior tibia where the patellar ligament inserts.
- Lateral surface: presents the border where the interosseous membrane is attached which connects the tibia and fibula.
- Posterior surface: presents the soleal line.
- Soleal line: an oblique line located on the posterior surface of the tibia and serves as the origin for the soleus, flexor digitorum longus, and tibialis posterior muscles.

The bone serves as the site of origin or insertion point of many muscles including tibialis anterior, extensor digitorum longus, soleus, tibialis posterior, flexor digitorum longus, sartorius, gracilis, quadriceps femoris, semimembranosus, semitendinosus, and popliteus muscles.[8]

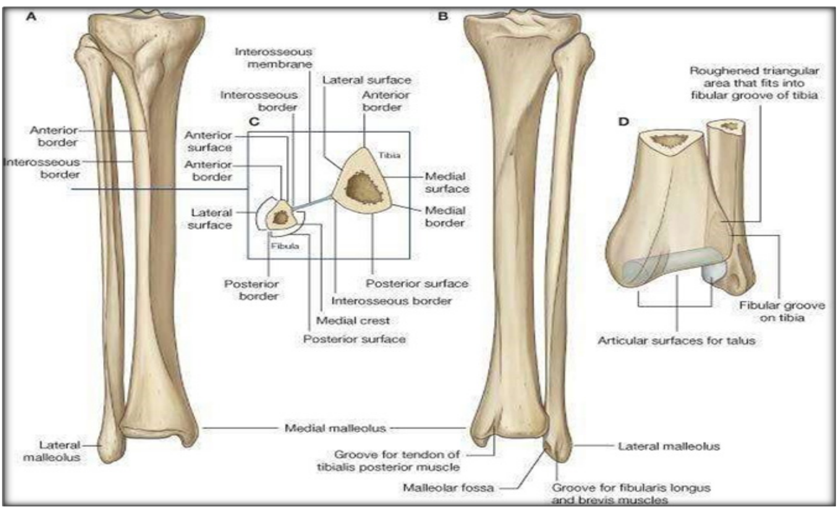
The Distal Tibia:

The distal end of tibia is box shape.[9] There are five surfaces that make up the distal tibia.

- The inferior surface provides a smooth articulation with the talus.

- The anterior surface is covered by extensor tendons and provides an area for the capsular attachment of the ankle joint.

- The posterior surface has a groove for the tibialis posterior muscle.
- The lateral surface has a fibular notch which gives attachment for the interosseous membrane.
- The medial surface is a large bony prominence that makes up the medial malleolus.
- Medial malleolus: distal projection of the tibia which articulates with the talus
- Groove for the tendon of tibialis posterior is located on the posterior aspect of the medial malleolus.
- Fibular notch: location of the tibiofibular joint



Bones of the Leg – Tibia and Fibula

Embryology

The tibia has three ossification centres: one for the diaphysis and one for each epiphysis. It begins in the shaft at around the seventh week in utero. The proximal ossification centre starts at birth and closes at the age of 16-17 in females and the age of 18 in males.[10] The distal ossification centre starts at first year of age and closes at the age of 15 in females and the age of 17 in males.

Blood Supply and Lymphatics

The nutrient artery and periosteal vessels supply the blood to the tibia. The nutrient artery arises from the posterior tibial artery and enters the bone posteriorly distal to the soleal line. The periosteal vessels stem from the
Anterior tibial artery.[11]

Nerves

The nerves that supply the tibia are all branches of the main nerves that supply adjacent compartments.[12] In the posterior compartment of the leg, the tibial nerve gives off branches that supply the posterior aspect of the tibia, and in the anterior compartment of the leg, the deep peroneal nerve gives off branches that supply the anterior aspect of the tibia

Muscles

Muscles Originating from the Tibia,

- Tibialis anterior originates from the upper two-thirds of the lateral tibia.
- Extensor digitorum longus originates from the lateral condyle of the tibia.
- Soleus and flexor digitorum longus originate from the posterior aspect of the tibia on the soleal line.

Muscles Inserting on the Tibia,

- Tensor fasciae latae inserts on the lateral tubercle of the tibia which is known as the Gerdy's tubercle.
- Quadriceps femoris inserts on the base, lateral and medial borders of the patella which continues as the ligamentum patellae and gets attached to the lower part of the tibial tuberosity.
- Sartorius, gracilis, and semitendinosus insert medially

on the upper part of the tibia as the hockey stick insertion which are called as the guy rope muscles.

- Horizontal head of semimembranosus muscle inserts on the medial condyle.
- Popliteus inserts on the soleal line of the posterior tibia.

Mechanism Of Injuries[13,14]

The tibial shaft fracture is caused by a significant amount of force. To appreciate the bone fractures in certain patterns, one must understand that bone is weakest in tension and strongest in compression. Therefore, when a force creates tensile stresses in a particular region of a loaded bone, failure will occur first in that region. A transverse fracture created in a long bone subjected to pure bending. As because the upper convex surfaces undergoes the greatest elongation, it is subjected to maximum tensile stresses and failure (indicated by a crack) initiates there. The crack then progresses transversely through the material. The layer just below the outer layer became subjected to high tensile force, until they get cracked as well. In this manner, the crack progresses through the bone transversely until it fails.

The concave surface is subjected to compression because of that the crack does not initiate there. The fracture line or crack that occurs when a bone is subjected to torsion or axial twisting resulting into a spiral fracture.

A rectangular area present on the surface of a long bone is loaded in torsion. The rectangle distorts when the bone get twisted with one diagonal of the rectangle elongating and the other shortening alongside the direction of the twist. A crack will form perpendicular to the diagonal that is elongating and it progresses around the perimeter of the bone results in a spiral fracture. The region with the smallest diameter usually has the greatest distortion as it allows the largest amount of twists. This explains why torsional fractures of the tibia often occur in the narrow distal third of the shaft.

A compressive load results in failure of cortical bone by shear, indicated by slippage along the diagonal because bone is weaker in shear than in compression (The stresses 45^0 to the compressive force within the material are shear stresses). In such case, compression causes the surface of the bone at 45^0 to the applied load to slide along an oblique surface.

At very high loads such as during impact fractures, crushing or comminution of bone also occurs, especially at the weaker metaphyseal ends of a long bone. The trabecular bone at the metaphyseal ends is weaker in compression than the diaphyseal cortical bone is in shear. Because of this it is unlikely that shearing failure will occur in the diaphysis due to pure compressive forces.

The butterfly fracture result from combined bending and compression. Bending load causes the fracture to start failing in tension producing a transverse crack. But as the crack progresses and remaining intact bone weakens, it starts to fail in compression causing an oblique (shear) fracture line. As the ends of the failing bone are driven together, the third fragment and the butterfly may result as because the oblique fragment splits off.

The production of a butterfly fragment probably depends on the timing and magnitude of the two basic applied loads, compression and bending.[13]

There are five principal causes of tibial diaphyseal fracture. These are falls, sports injuries, direct blows or assaults, motor vehicle accidents and gunshot injuries. Falls may be subdivided into simple falls. The simple falls are those in which the patient falls from his or her height, falls from down stairs or slopes and falls from a height.

Motor vehicle injuries usually affect motor cyclists, pedestrians or automobile occupants. The gunshot injuries may vary according to the type of the gun that has been used. Other causes of tibial diaphyseal fractures include land mines or other explosions. But these types of injuries are uncommon.

The tibial fracture with simple fracture pattern tends to result from simple falls, fall down stairs, sports injuries and direct blow to the tibia. However, falls from a height and motor vehicle accidents are associated with a much higher incidence of Gustilo-Anderson type 3A, B and C fractures, which are more difficult to treat.[14]

Classification of Tibial Fractures

There are so many literatures on the classification of the compound tibia fractures. Several attempts have been made by the authors in the past.

Ellis classified fractures into three basic groups.[15]

1. Mild

A mild fracture is a fracture with a minor degree of comminution or a minor open wound by low energy trauma and due to helical injury mechanism.

2. Moderate

It is the total displacement or angulation of fragments with a small degree of comminution or a minor open wound by moderate energy trauma and due to oblique oriented forces.

3. Severe

Here is the complete displacement of the fracture fragments with more than two fragments with major degrees of comminution or a major open wound with high energy trauma.

Fracture description:

While describing the X-ray, the fracture is classified according to the anatomical location of the fracture as in proximal, middle or distal third.

The nature of fracture radiologically: Transverse, oblique or spiral, comminuted and segmental. Angulation is measured in both anteroposterior and lateral view. The angulation is measured in the direction of the apex of the fractured fragments. Thus, it is anterior or posterior angulation and in anteroposterior view, the angulation is varus and valgus.

In addition shortening, overlapping and distraction to be noted. Rotation is difficult to judge on the X-rays and must be measured clinically.

Gustilo open fracture classification system[16,17]

Gustilo type	Definition	Example fracture patterns
I	Open fracture, clean wound, wound <1 cm in length	Simple transverse or short oblique fractures
II	Open fracture, wound > 1 cm in length without extensive soft-tissue damage, flaps, avulsions	Simple transverse or short oblique fractures
III	Open fracture with extensive soft-tissue laceration, damage, or loss or an open segmental fracture. This type also includes open fractures caused by farm injuries, fractures requiring vascular repair, or fractures that have been open for 8 h prior to treatment	High energy fracture pattern with significant involvement of surrounding tissues
IIIA	Type III fracture with adequate periosteal coverage of the fracture bone despite the extensive soft-tissue laceration or damage	Gunshot injuries or segmental fractures
IIIB	Type III fracture with extensive soft-tissue loss and periosteal stripping and bone damage. Usually associated with massive contamination. Will often need further softtissue coverage procedure (i.e. free or rotational flap)	Above patterns but usually very contaminated

IIIC	Type III fracture associated with an arterial injury requiring repair, irrespective of degree of soft-tissue injury.	Above patterns but with vascular injury needing repair

As classified by Gustilo-Anderson, 1976,[4]
Type-I fracture: Open fracture with clean wound < 1cm long.
Type-II fracture: Open fracture with laceration > 1cm long without extensive soft tissue damage.
Type-III fracture: Open segmental fracture, open fracture with extensive soft tissue damage.
As classified by Gustilo & Mendoza- 1984 further subdivision of grade-III. Grade- III a: high energy regardless of wound size, adequate soft tissue.
Grade- III b: Extensive soft tissue with periosteal stripping and bone exposure, major wound contamination, bone loss.

Gustilo-Anderson's Classification System for Open Fractures[17]

Type	**Wound**	**Level of contamination**	**Soft tissue injury**	**Bony injury**
I	< 1 cm long	Clean	Minimal	Minimal comminution
II	> 1 cm long	Moderate	Moderate, some muscle damage	Moderate comminution
IIIa	> 10 cm long	High	Severe with crushing	Includes segmental comminuted fractures. Soft tissue coverage of bone possible.
IIIb	> 10 cm	High	Extensive soft tissue injury with periosteal striping	Bone exposed, soft tissue reconstruction required

IIIc	Regardless of size	High	Extensive soft tissue injury with vascular injury	Vascular and soft tissue reconstruction / repair required.

Segmental fractures, farmyard injuries, fractures occurring in a highly contaminated environment, shotgun wounds or high velocity gunshot wounds automatically result in the classification as a Type III open fracture.

This classification system has prognostic significance.

Byrd Classification[18]

Believing in the fact that the vascular status to be the most important character, Byrd classified as:

Type I Low energy forces causing a spiral or oblique fracture pattern, skin laceration less than 2 cm and relatively clean wound.

Type IIModerate energy force causing comminuted or displaced fracture pattern with skin laceration more than 2 cm with moderate adjacent skin and muscle contusion but without devitalized soft tissue.

Type IIIHigh energy forces causing a significantly displaced fracture pattern with a severe comminution / segmental fracture or bone defect with the extensive associated skin loss and devitalized tissue.

Type IVFracture pattern as in Type III but with extreme energy forces as in high velocity gunshot.A history of crush injury or degloving injury and associated vascular injury requiring repair.

MONORAILFIXATOR (Limb Reconstructive System)

Limb Reconstructive System (LRS) is a modular unilateral frame consisting of Shanz pins, rail rods and sliding clamps. It is simple, effective, adjustable, light weight and offers rigid stabilization of fracture fragments along with the access to wound dressing. The management of open fractures with the LRS fixator allows immediate functional stabilization of fractures, weight bearing and axial fracture site movement promoting an early callus formation and fracture union. It can induce and enhance fracture healing by compression and distraction osteogenesis as well as bone transport can also be done easily in cases of bone loss.[19]

Advantages:[5]

It interferes with the soft tissue minimally.

- It causes less damage to the blood supply of bone.
- Fixation is adjustable without surgery.
- Stabilisation in open fractures.
- Technically less demanding.