

Posterior Malleolar Fractures in Trimalleolar Ankle Injuries: Anatomy, Classification, Diagnosis, and Management; A Narrative Review

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Abstract

Background: The ankle joint is a modified hinge joint. It is a complex joint, as three bones and many ligaments share in its formation. Posterior malleolar fractures may affect articular congruity, syndesmotic stability, and ankle function.

Aim: To review the anatomy and biomechanics of the ankle joint, the classification and diagnosis of posterior malleolar fractures, and the available nonoperative and operative methods of management.

Conclusion: Plain radiographs remain the initial radiological examination, while computed tomography provides a better understanding of the size, morphology, and orientation of the posterior malleolar fragment. Treatment may be nonoperative or operative. Accurate reduction and stable fixation are required to restore ankle stability and reduce the risk of postoperative complications.

Keywords: posterior malleolus; trimalleolar ankle fracture; computed tomography; posterolateral approach; lag screw

Introduction

The ankle joint is a modified hinge joint. It is a complex joint, as three bones and many ligaments share in its formation, including the talofibular joint, subtalar joint, and distal tibiofibular syndesmosis. It is formed by the lower end of the tibia, medial malleolus, lateral malleolus, and body of the talus.

The stability and function of the ankle depend on the congruity of its articular surfaces, the integrity of the collateral ligaments, and the distal tibiofibular syndesmosis. The posterior malleolus contributes to the tibial articular surface and provides attachment for the posteroinferior tibiofibular ligament. Consequently, posterior malleolar fractures may affect articular congruity, syndesmotic stability, and ankle function.

This narrative review presents the anatomy and biomechanics of the ankle joint, the classifications and diagnosis of malleolar fractures, and the available methods for management of posterior malleolar fractures in trimalleolar ankle injuries.

Anatomy of the Ankle Joint

Ankle joint is a modified hinge joint. It is a complex joint as three bones and many ligaments share in formation of it (talofibular, subtalar joint and distal tibiofibular syndesmosis) (Fig.1).⁽¹⁾

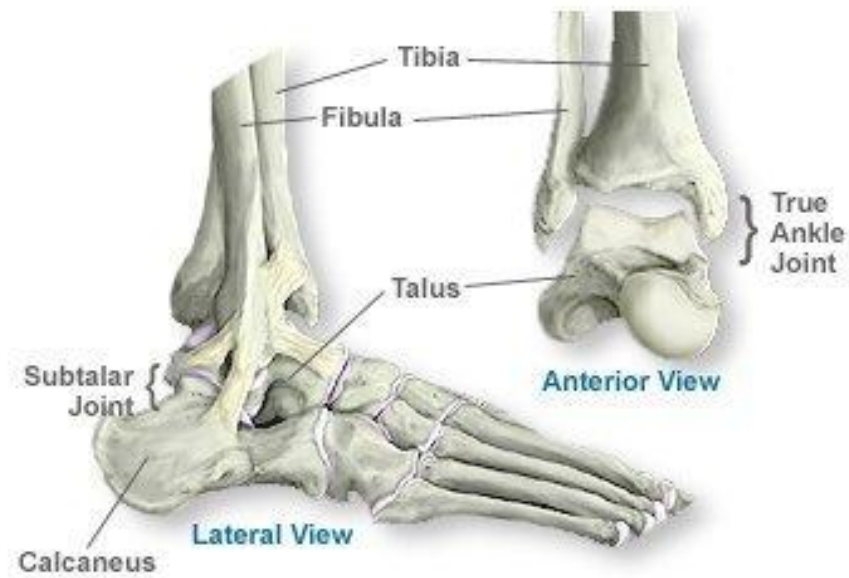


Figure (1): Anatomy of the ankle joint.⁽²⁾

The Tibiotalar Joint

It is made up of distal fibula, distal tibia (plafond) and talus. The plafond together with the medial malleolus and the lateral malleolus form the 'mortise' into which the trochlea of the talus, functioning as the 'tenon', fits. It allows dorsiflexion and planterflexion of joint in sagittal plane (hinge) (Fig.2).⁽³⁾

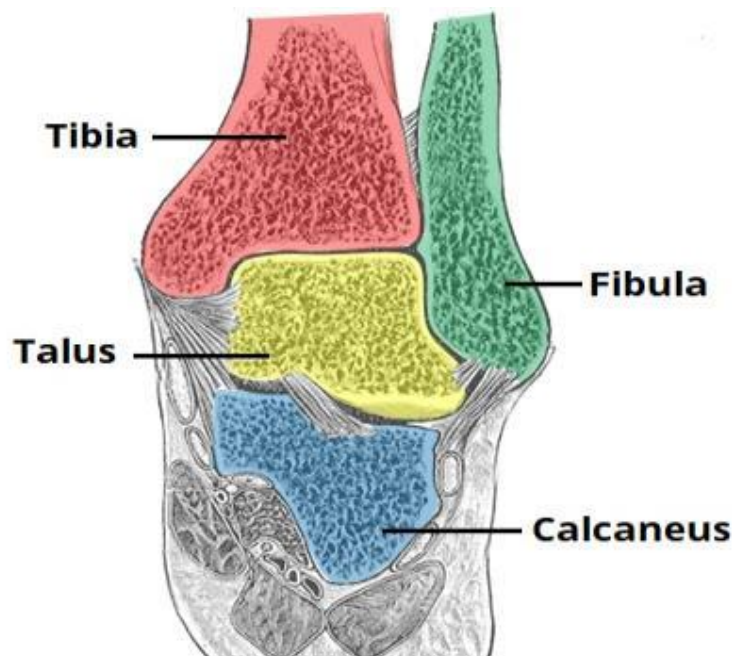


Figure (2): Diagram of the tibiotalar joint.⁽²⁾

The Subtalar Joint

It is responsible for inversion and eversion movement of the ankle through the articulation of the inferior surface of the talus (anterior and posterior facet) and superior surface of calcaneus (anterior and posterior facet) forming talocalcaneal joint (Fig.3).⁽⁴⁾

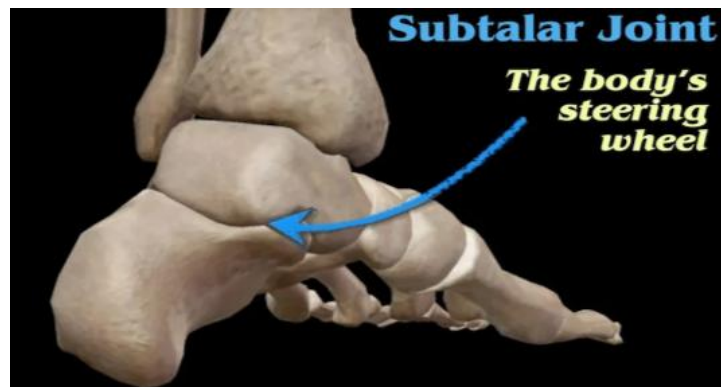


Figure (3): Diagram of the subtalar joint.⁽²⁾

Talocalcaneal joint with head of talus and navicular bone forms talocalcaneonavicular joint responsible for supination and pronation of the midfoot (Fig.4).⁽⁴⁾

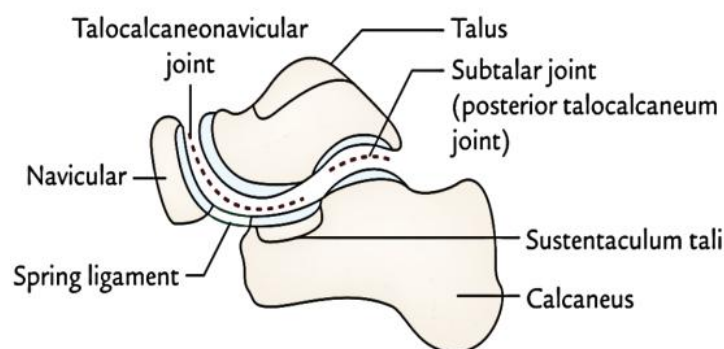


Figure (4): Diagram of the talocalcaneonavicular joint.⁽²⁾

Inferior Tibiofibular Articulation

The lower tibia and fibula make up a fibrous joint where minimal gliding motion proves crucial to the normal kinematics of the whole ankle complex. However, this joint mainly serves a stabilizing role to the foot and ankle.⁽⁵⁾

Ligaments of the Ankle

There are three distinct groups of ligaments:

Lateral Collateral Ligament Complex

Three ligaments are attached from distal fibula to lateral aspect of tarsal bones to limit inversion of the ankle and varus stress.

Anterior Talofibular Ligament

This ligament is the first to be affected in ankle trauma. It attaches to the anterior fibular malleolar border and the talar body. It plays a crucial role in preventing anterior talar displacement as well as limiting ankle plantarflexion, during which position the ATFL is highly strained and easily prone to injury (Fig.5).⁽⁶⁾

Calcaneofibular Ligament

This ligament runs obliquely downwards and backwards from the fibular malleolus anteriorly towards the calcaneal posterolateral surface. It remains tense throughout the entire arc of dorsiflexion and plantar flexion. However, when the ankle is in valgus the CFL is relaxed while it is tense in varus. Therefore, the CFL can be injured even in the absence of any ankle movement in the sagittal plane (Fig.5).

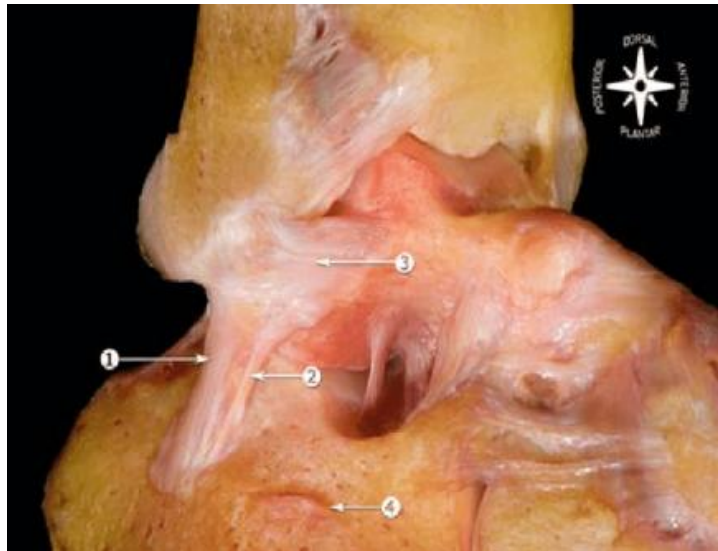


Figure (5): Osteoarticular dissection of lateral ankle ligaments. 1 Calcaneofibular ligament; 2 anterior talofibular ligament. ⁽⁶⁾

Posterior Talofibular Ligament

This ligament courses in a horizontal orientation between the fibular malleolus and the posterolateral talus. The PTFL relaxes in plantarflexion and tenses in dorsiflexion, in contrary to the ATFL. It is also the ligament that is least prone to injury.⁽⁶⁾

Medial Collateral Ligament

Supporting the medial aspect of the ankle joint, reducing eversion, and limiting valgus stresses, the fan shaped medial collateral ligaments (MCL), or the deltoid ligament is generally considered to be composed of superficial and deep layers. As proposed by Milner and Soames, the multifascicular ligament is composed of 6 bands: three of which are always present whereas the other three may not be present. The three major components include the tibiospring ligament, tibionavicular ligament, and deep posterior tibiotalar ligament. The extra variable components include a superficial posterior tibiotalar ligament, tibiocalcaneal ligament, and deep anterior tibiotalar ligament (Fig.6).

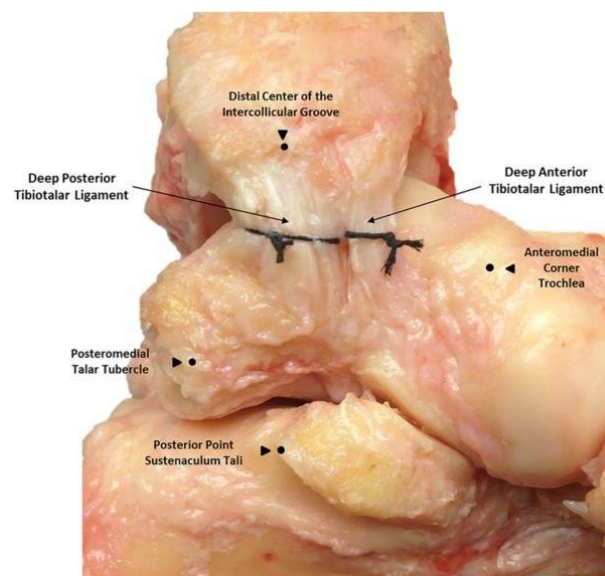


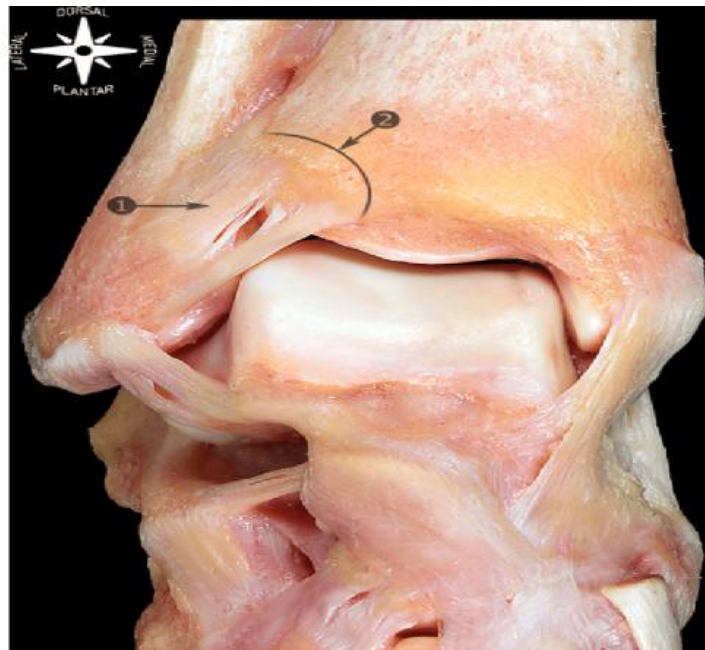
Figure (6): Osteoarticular dissection of the major bands of the deltoid ligament. 1 Tibionavicular ligament; 2 tibiospring ligament; 3 tibiocalcaneal ligament; 4 deep posterior tibiotalar ligament; 5 spring ligament complex. ⁽⁷⁾

Syndesmotic Ligament Complex

This ligament complex functions to resist the different forces separating the tibia and fibula and ensures the stability of the distal tibiofibular joint.

Anteroinferior Tibiofibular Ligament

This ligament attaches medially to the distal anterior tibial tubercle and laterally to the anterior fibular malleolar border. The distal fascicle of this ligament has been implicated in the anterolateral soft tissue impingement responsible for chronic anterolateral ankle pain (Fig.7).



Figure(7): Anterosuperior view of talocrural joint, 1 Anterior tibiofibular ligament 2 Anterior lip of distal tibia.⁽⁸⁾

Posteroinferior Tibiofibular Ligament

The superficial portion, being the counterpart of the AITFL, runs proximally and medially from the posterior fibular malleolus border to the posterior tibial malleolus. The deep portion, or transverse ligament, runs horizontally between both malleoli and connecting with the posterior tibial edge (Fig.8).

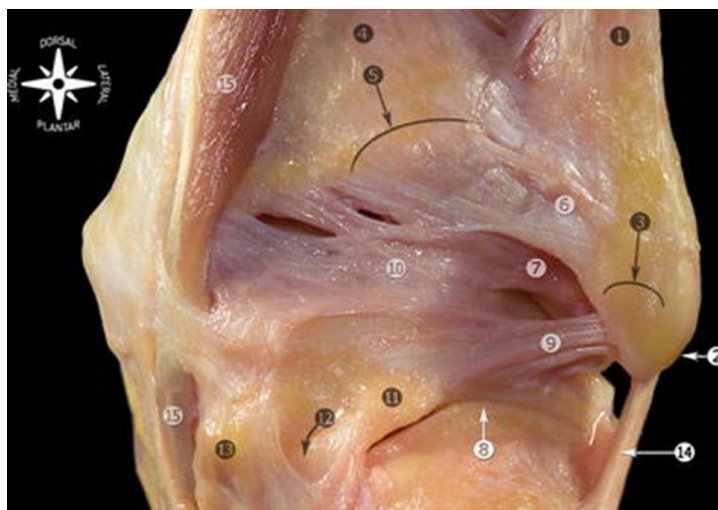


Figure (8): Anatomic dissection of posterior ankle ligaments, 6 superficial PTFL; 7 deep PTFL.⁽⁸⁾

Interosseous Tibiofibular Ligament

This ligament is a thickening of the tibiofibular interosseous membrane above the ankle joint (Fig.9).

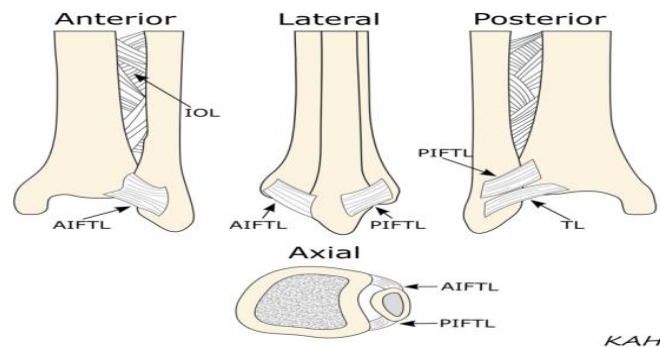


Figure (9): Ligaments of the distal tibiofibular syndesmosis. The lower part of the interosseous membrane thickens to form the interosseous ligament (IOL). Just above the plafond lie the anterior inferior tibiofibular ligament (AITFL) and the posterior inferior tibiofibular ligament (PITFL), with more distal fibers called the inferior transverse ligament (ITL).⁽⁸⁾

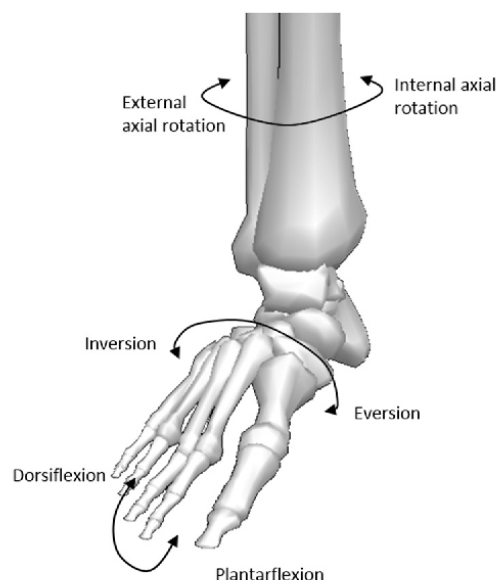
Neurovascular Anatomy

The ankle joint receives its neurovascular supply from branches of the anterior tibial, posterior tibial, and fibular arteries, which form a rich periarticular anastomotic network. Neural innervation is provided by the deep fibular, superficial fibular, tibial, sural, and saphenous nerves. The sural nerve courses along the posterolateral aspect of the ankle, passing posterior to the lateral malleolus with the small saphenous vein.

It provides sensory innervation to the lateral foot and is an important structure at risk during lateral ankle surgery and arthroscopy.⁽⁸⁾

Biomechanics of the Ankle Joint

The ankle joint complex has various movements in the different planes of the body; plantar-dorsiflexion in the sagittal plane, abduction-adduction in the transverse plane, and inversion-eversion in the frontal plane. Moreover, a supinated foot with the sole facing inward is achieved by combining plantar flexion, adduction, and inversion, while a pronated foot with the sole facing outwards is achieved by combining dorsiflexion, abduction, and eversion (Fig.10).



3 Diagram illustrating relative motions of the ankle joint

Figure (10): Diagram illustrating relative motions of the ankle joint complex.⁽³⁾

The ankle joint is important during standing and walking. The axis of motion of the ankle passes between the tip of the malleoli both posteriorly and inferiorly from medial to lateral. It is externally rotated to the axis of the knee joint and is inclined slightly laterally since the fibular malleolus is lower than the tibial one (Fig.11).

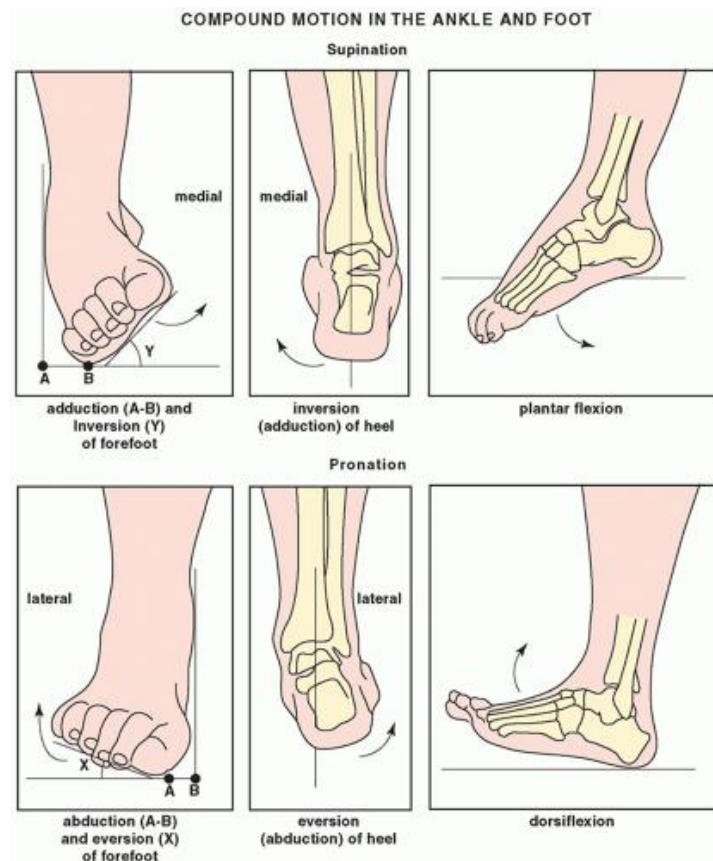


Figure (11): The obliquity of the ankle axis produces relative medial deviation of the foot (internal rotation) with plantar flexion and relative lateral deviation of the foot (external rotation) with dorsiflexion.⁽³⁾

The ankle and subtalar joints are biomechanically related. The horizontal rotation between the leg and the foot is accommodated by the obliquity of the ankle axis and by the subtalar joint. The inferior tibiofibular joint is mechanically linked to the ankle. The width of the trochlear surface of the talus is wider anteriorly so the intermalleolar space must vary within certain limits being smallest during plantar-flexion and greatest during dorsiflexion (Fig.12).

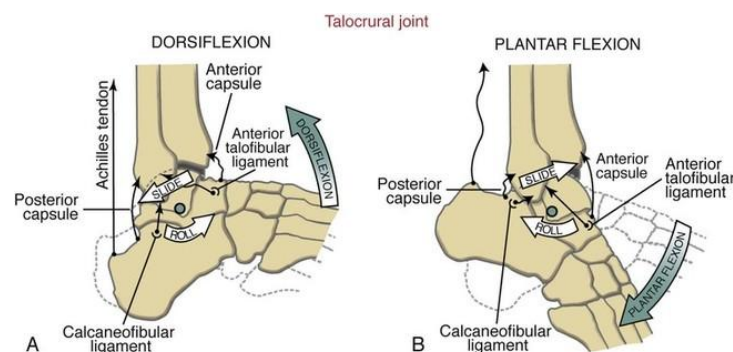


Figure (12): (A) Trochlear surface of the talus. (B): Intermalleolar space becomes greatest during dorsiflexion and smallest during plantar flexion.⁽³⁾

Classification of Malleolar Fractures

Percival Pott was the first to provide the world with a classification method for ankle fractures. His simple classification stratified malleolar fractures according to how many malleoli were fractured into unimalleolar, bimalleolar, or trimalleolar.⁽⁹⁾

Lauge–Hansen Classification

Lauge-Hansen classified ankle fractures into four classes: supination-adduction, supination-eversion, pronation-abduction, and pronation-external rotation. Each class gets its nomenclature according to firstly the initial position of the foot at injury (supinated/pronated), and secondly how the ankle deformation force is directed (abducted/adducted/externally rotated). Each class is further subdivided into stages, and these stages cannot be skipped as the injuries occur in a predictable sequence.^(10,11)

Supination–External Rotation

This is the most common ankle trauma mechanism. Initially, laterally located elements are stressed, and as the deforming blow continues backwards with the talus rotating laterally, the medial structures are ultimately compromised (Fig.13).

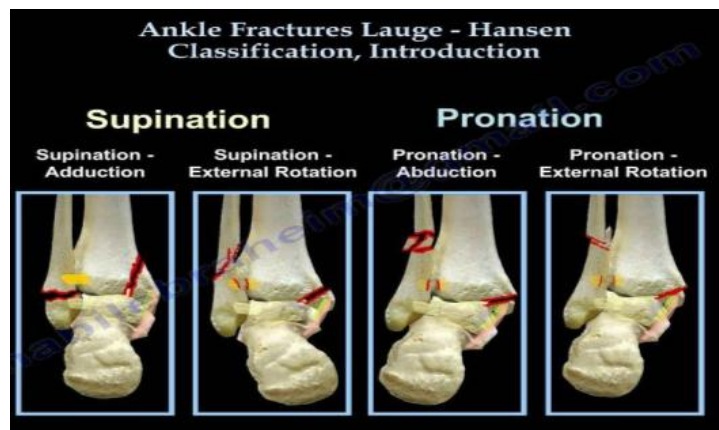


Figure (13): Lauge-Hansen: Supination-External rotation mechanism of trauma.⁽¹²⁾

Supination–Adduction

Supination adduction injury has two stages. The talus adducts compressing the medial aspect of the ankle and tensioning the lateral aspect (Fig.14).

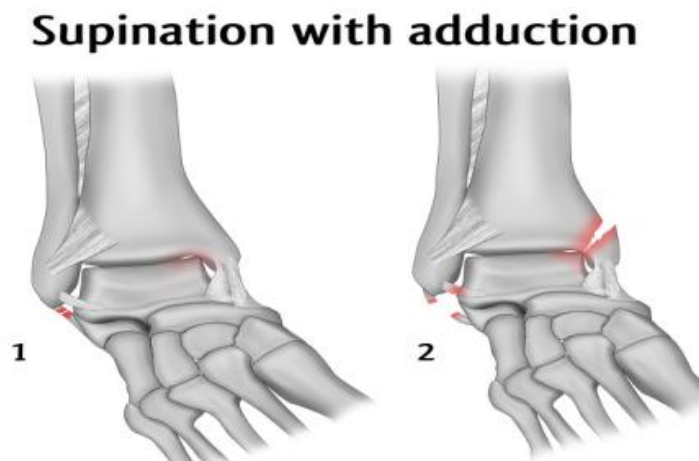


Figure (14): Lauge-Hansen: Supination-Adduction mechanism of trauma.⁽¹²⁾

Pronation–External Rotation

Medially located structures are under stress and deforming forces rotates forward laterally then posteriorly (Fig15).

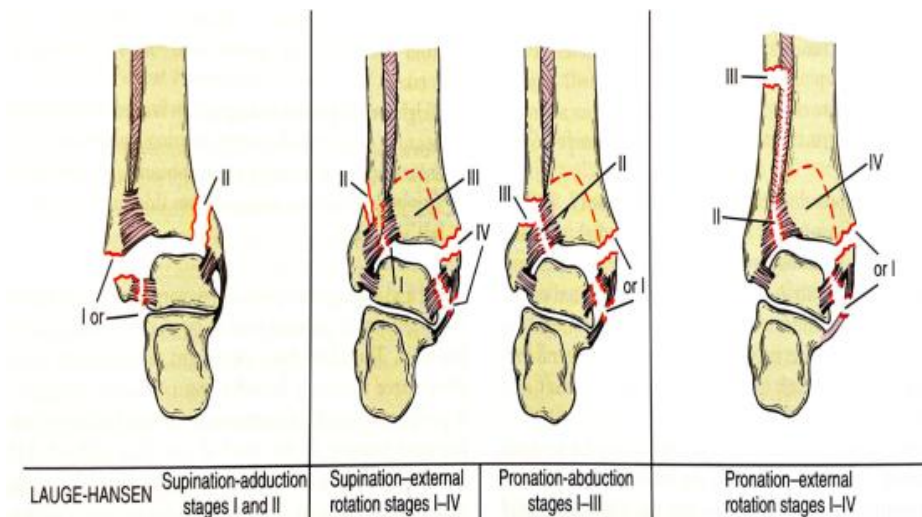


Figure (15): Lauge-Hansen: Pronation-External rotation mechanism of trauma.⁽¹³⁾

Pronation–Abduction

The abducting talus causes traction on the medial ankle structures, and as the abduction force continues the posterior followed by the lateral structures fracture (Fig.16).

Pronation with abduction

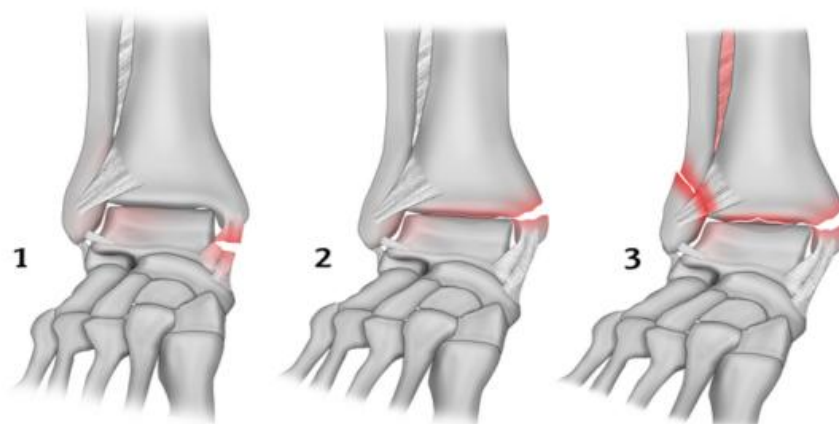


Figure (16): Lauge-Hansen: Pronation-Abduction mechanism of trauma.⁽¹²⁾

Danis–Weber Classification

According to position of fibular fracture line, this classification was formulated

Type A: Fracture below the syndesmosis; usually stable with an intact syndesmosis. Type B: Fracture at the level of the syndesmosis; stability depends on the extent of ligament injury. Type C: Fracture above the syndesmosis; usually associated with syndesmotic disruption and an unstable ankle, often requiring surgical fixation (Fig.17).

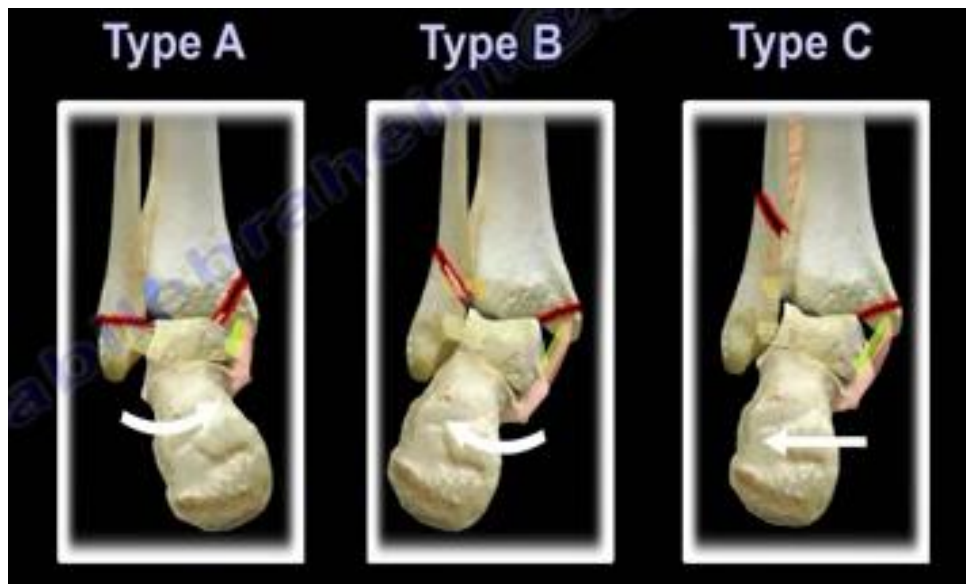


Figure (17): Danis Weber classification.⁽¹⁴⁾

AO/OTA Classification

In their latest compendium in 2018, the AO foundation/Orthopaedic Trauma Association (AO/OTA) based their latest classification of ankle malleolar fractures on the Danis-Weber classification, and added a variety of groups, subgroups, and fracture qualifications to provide a more comprehensive description of the fractures (Figure 18).

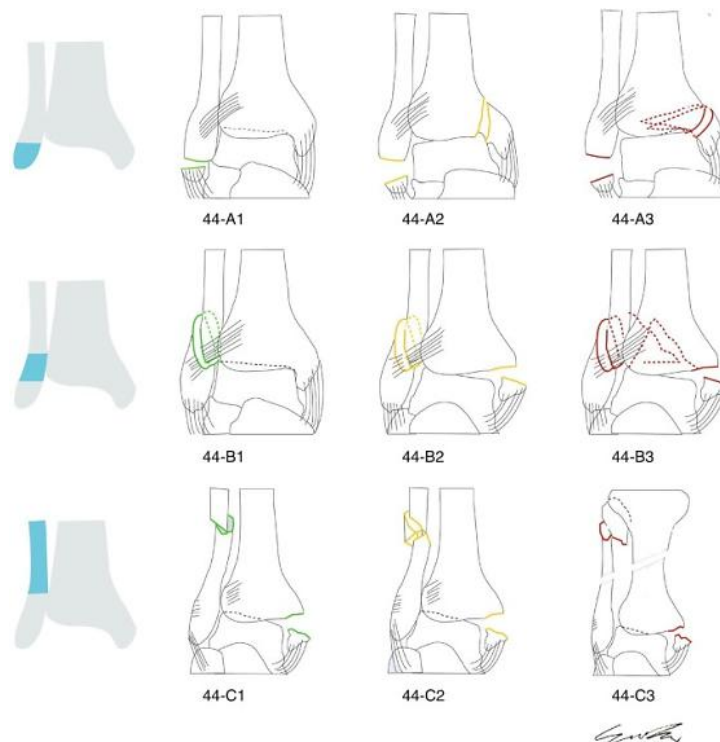


Figure (18): AO/OTA classification (Malleolar segment).⁽¹⁵⁾

44 = Distal tibia and fibula (Ankle region / Malleolar fractures). 44-A = Infra-syndesmotic. 44-B = Trans-syndesmotic. 44-C = Supra-syndesmotic.

Management of the Posterior Malleolus in Trimalleolar Ankle Fractures

Diagnosis

History

History taken from the patient with an ankle trauma should include the following:

Mechanism of injury: a road traffic accident (RTA) or a fall from height is usually associated with a more extensive soft tissue damaged even if closed.

Date of trauma: soft tissue bullae may develop if the limb is not adequately treated with anti-edematous measures in a timely manner.

Limb status before injury: an unrecovered previous injury, neuropathy, chronic vascular disease should be asked for and noted.

Medical illnesses such as diabetes mellitus or neuropathy.

Medications and individual habits such as smoking.

Physical Examination

Inspection of ankle deformity, swelling, skin abrasions, blisters and wounds.

Palpation of points of local tenderness to differentiate between a sprained ankle and fractured malleoli.

Distal circulation and capillary refill should be noted.

Neurological examination should be done, but usually difficult due to pain and edema.

Radiographic Evaluation

Plain Radiographs

Routine studies of ankle x-ray include anteroposterior (AP), mortise (10 to 20 degree internal rotation) and lateral view.

Measurements on Plain Radiographs

Tibiofibular overlap: On plain radiography there is an overlap between the lower ends of the tibia and fibula. Measuring the amount of overlap of both bones at one centimeter above the plafond provides the value of tibiofibular overlap. In the anteroposterior radiograph, it normally measures more than six millimeters. However, absence of overlap may exist as a normal variation. (Fig 19).



Figure (19): Plain ankle x-ray depicting the tibiofibular overlap.⁽¹⁶⁾

Tibiofibular clear space:

This is the measured distance between the medial border of the fibular malleolus and the lateral border of the posterior aspect of the tibial incisura one centimeter above the tibial plafond. In both the anteroposterior and mortise radiographs, this space normally measures less than six millimeter (Fig.20).



Figure (20): Plain ankle x-ray depicting the tibiofibular clear space.⁽¹⁷⁾

Medial clear space

This is the measured distance between the lateral border of the tibial malleolus and the medial border of the talus opposite to its dome. In the mortise radiograph, this space is normally equal to or smaller than the superior clear space between the plafond of the tibia and the dome of the talus (Fig.21).



Figure (21): Plain ankle x-ray depicting the medial, superior, and lateral clear spaces.⁽¹⁸⁾

Talar tilt

This is the measured angle between the two lines drawn parallel to the talar dome articular surface and the tibial plafond articular surface. In both the anteroposterior and mortise radiographs, the talar tilt should be less than 2° . (Fig.22).

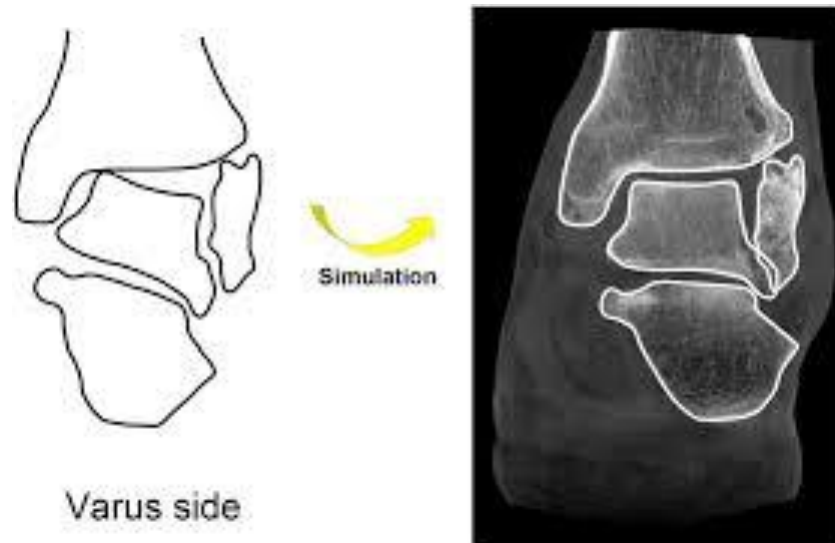


Figure (22): Diagram depicting the normal talar tilt (left) and abnormal talar tilt (right). .⁽¹⁹⁾

In the presence of distal tibiofibular syndesmotic injury, the tibiofibular overlap would be less 6 mm and the tibiofibular clear space greater than 6 mm in the anteroposterior radiograph as well as the medial clear space would be greater than the superior clear space, or greater than 4 mm in the mortise radiograph (Fig.23).



Figure (23): Plain ankle x-ray depicting a wide medial clear space, lost tibiofibular overlap, and a wide tibiofibular clear space.⁽¹⁸⁾

Talocrural angle:

Line between the two malleolus. The talocrural angle is the angle between this line and the tibial plafond (Figure 24).

A second talocrural angle exists and it is formed by a line between the two malleolus and a perpendicular line to tibial plafond. The normal value for this angle is $83 \pm 4^\circ$.

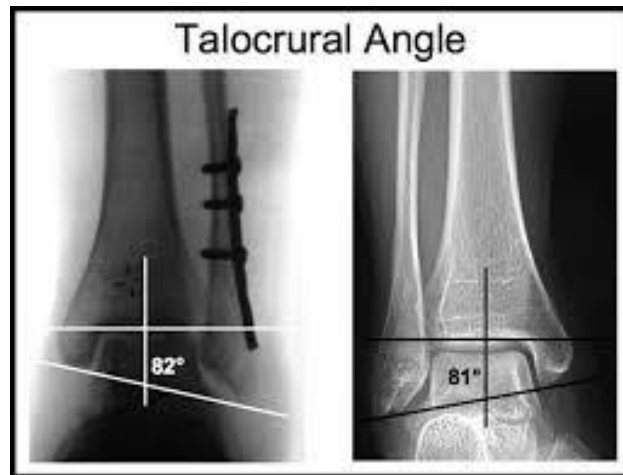


Figure (24): The talocrural angle.⁽¹⁾

Computed Tomography

True fragment size and geometry, as well as displacement of posterior malleolus can be nicely visualized and assessed with axial and sagittal planes, which can be combined with 3D reconstructions, CT is also helpful for exact fracture classification. The first classification using a CT scan was conducted by Haraguchi et al. using only axial images, they proposed three types of posterior malleolus fractures:

Type I: Posterolateral oblique

Type II: Medial extension

Type III: Small shell

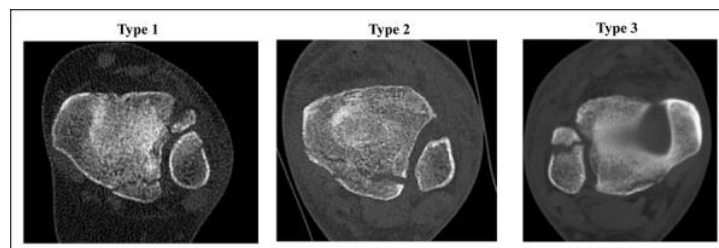


Figure (25): Haraguchi CT based classification of posterior malleolus.⁽²⁰⁾

In 2015, Bartoníček and Rammelt et al. proposed a new classification using axial, coronal, sagittal, and 3D reconstruction images. They categorized the fracture of the posterior malleolus into five types: (Figure 26) .

Type I: Extrainsisural fragment with an intact incisura

Type II: Posterolateral fragment involving the incisura

Type III: Posteromedial two-part fragment extended to the medial malleolus

Type IV: Large posterolateral triangular fragment

Type V: An irregular osteoporotic fracture not classifiable in the other types

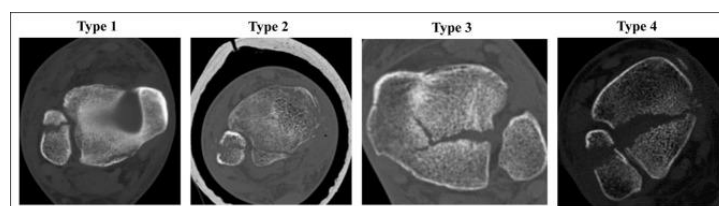


Figure (26): Bartoníček CT based classification of posterior malleolus.⁽²¹⁾

Finally, Mason et al. characterized the posterior malleolus into four categories: (Figure 27).

Type I: A small extra-articular posterior malleolar fragment

Type IIA: A posterolateral triangular fragment involving the incisura fibularis

Type IIB: A posterolateral and posteromedial fragment at a 45° angle to the primary fragment

Type III: A coronal plane fracture involving the entire posterior plafond

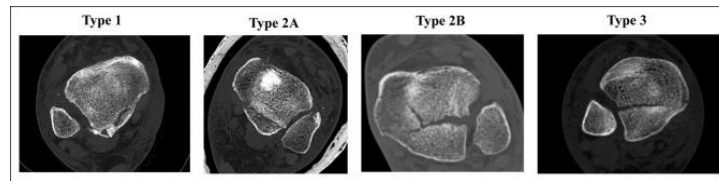


Figure (27): Mason CT based classification of posterior malleolus. .⁽²²⁾

Magnetic Resonance Imaging

MRI is rarely used for evaluation of soft tissue injury if suspected.

Treatment

Nonoperative Treatment

Isolated undisplaced posterior malleolar fractures with no articular step-off and stable ankle (fragment size less than 10 % of articular surface) can be managed conservatively with below knee plaster cast and non weight bearing for 6-8 weeks.

Although nonoperative treatment may provide good stability and full weight bearing is possible in stable fractures, it carries the risks of cast complications (e.g., pressure ulcer, nerve compression, risk of DVT), the risk of malunion, and a possible longer period of rehabilitation.

Conservative treatment entails the immobilization of the fractured ankle in a well molded below-knee plaster cast with the principle of 3-point fixation being applied. Weight bearing is not allowed for 6 weeks, and then permitted gradually the next 2 weeks.

Appropriate painkillers as well as anti-inflammatory medications are advised for the first 2 weeks, whereas anticoagulant medications should be prescribed during the whole period of non-weight bearing. After removal of the cast, rehabilitation and physiotherapy should ensue for 2-4 weeks.⁽²³⁾

Operative Treatment

Recently, it has been shown that open reduction and fixation of Posterior Malleolus is a superior quality of reduction compared to conservative treatment regardless of its size. Posterior Malleolus fragment is important for stability of talotibial articulation and syndesmosis.

Fixation of Posterior Malleolus fragment decreases need of trans-syndesmotic screws as posterior inferior tibiofibular ligament attached to it (most important part of syndesmosis).⁽²⁴⁾

Fixation of the posterior fragment remains a matter of debate. Recent studies have shown that a persistent step-off in the talotibial joint is the most important factor in the development of osteoarthritis and therefore the functional outcome. The disadvantages of the regularly performed indirect reduction by ligamentotaxis or percutaneous reduction followed by percutaneous screw fixation of the posterior fragment in an anteroposterior direction are that an anatomical reduction is more difficult to achieve because of the interposition of soft tissue or loose osseous fragments, it is hard to assess reduction satisfactorily using an image intensifier, and fixation of small or comminuted fragments is technically difficult. Therefore, we favor an open, anatomical reduction of the posterior malleolus using posterolateral approach.⁽²⁵⁾

Percutaneous Fixation

Indirect reduction of posterior fragment and fixation by lag screws from anterior to posterior using small partially serrated cancellous screws or cannulated screws.⁽²⁶⁾

Inserting percutaneous instrumentation such as pins or screws through safe zones reduces the risk of damage to neurovascular important structures (Fig.28).

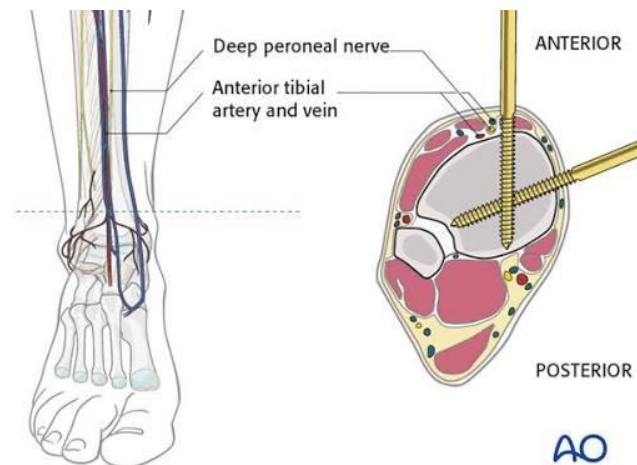


Figure (28): Safe zone of anteroposterior screw positioning.⁽²⁷⁾

Open Reduction and Internal Fixation

Surgical Approaches

Posterolateral Approach

The patient is placed prone. The posterolateral approach gives direct access to the Volkmann fragment. This approach also allows fixation of distal fibular fracture, with a plate and screws placed on the posterior surface of the fibula. Care should be taken for the sural nerve as it runs parallel to the lateral margin of the achilles tendon proximally (Fig.29).⁽²⁸⁾

Fixation Through the Posterolateral Approach

Lag Screws

Fixation of posterior malleolar fragment using 3.5 mm partially threaded cancellous screw or cannulated screw perpendicular to fracture line (Fig.30).

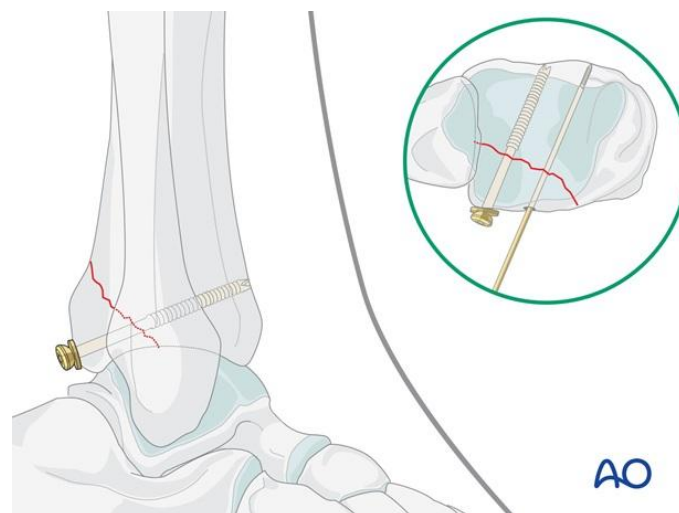


Figure (30): fixation of Volkmann fragment with lag screw.⁽²⁹⁾

Buttress Plate and Screws

A large fragment with long proximal extension can be fixed with lag screws and buttress plate (Fig.31).



Figure (31): ORIF of posterior fragment with buttress plate and screws.⁽³⁰⁾

Methods of fixation of lateral malleolus through posterolateral approach using plate and screws:

A one third tubular plate is fixed to the posterior surface of the fibula, however, screws could be omitted from the distal fragment providing an antiglide construct. However, distal fixation is utilized, bicortical screws can be used without the concern for intra-articular screw placement. Interfragmentary compression may also be obtained through placing a screw through a plate hole perpendicular to the fracture line utilizing the lag technique. Additionally, it has been proven that posterior plating is far superior biomechanically compared to lateral plating. Nevertheless, peroneal dissection, pain and irritation remain a prominent risk (Fig.32).⁽³¹⁾

Posteromedial Approach

The posteromedial exposure allows direct reduction of posterior and medial fracture fragments.

A posterior plate can be placed, effectively buttressing the posterior fragments.

A full thickness subcutaneous anteromedial flap can be created to allow exposure and fixation of the medial malleolus if necessary.

Multiple deep surgical intervals can be used dependent on the fracture configuration (Fig.32).

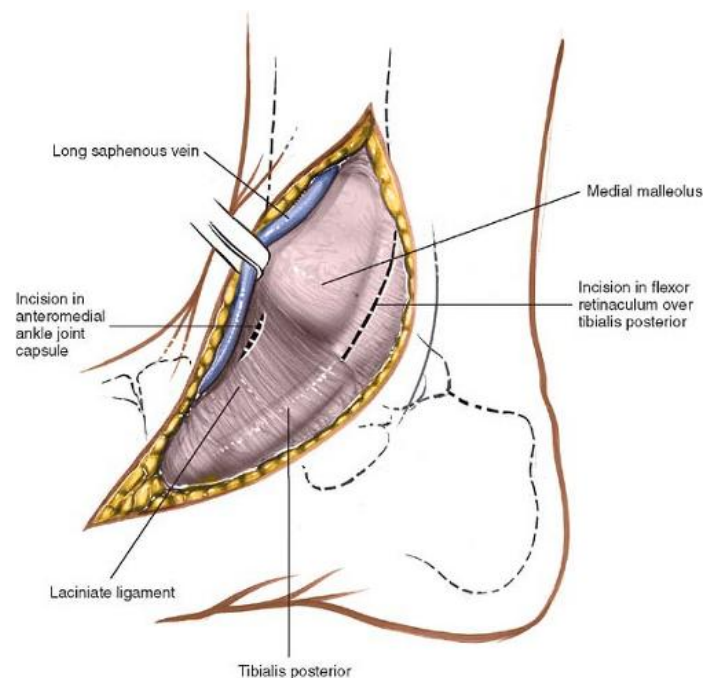


Figure (32): Posteromedial approach of ankle.⁽³²⁾

Complications

Wound Infection

This complication is more common with old age, diabetes, venous insufficiency and history of smoking.

Surgical debridement is done and broad-spectrum antibiotics are started then modified according to culture and sensitivity results.

It may require removal of implants if unstable, then revision of fixation after successful eradication of infection.⁽³³⁾

Malunion and Nonunion

Malunion results from the inability to attain or maintain the reduction of the fracture. Shortening of the fibula will lead to talar tilt, medial clear space widening and later arthritis.

Nonunion of the lateral malleolus is far less frequent than that of the medial malleolus. It can occur if the bone is extensively comminuted or devitalized or if the fixation is inadequate. CT is the gold standard study to diagnose nonunion.

Treatment consists of adequate open reduction internal fixation with bone grafting.⁽³⁴⁾

Painful Hardware

It is not uncommon due to good soft tissue coverage.

Persistent pain related to the implant may be treated by implant removal after radiographic evidence of union.⁽³⁵⁾

Nerve Injury

The sural nerve may be injured during the posterolateral approach to the fibula.

The superficial peroneal nerve crosses from the lateral to the anterior compartment about 7 cm from the tip of the fibula. It is more prone to injury with high fibular fractures. Nerve injury may lead to a painful neuroma.⁽³⁶⁾

Venous Thrombosis

Deep vein thrombosis can occur after ankle fractures and range from 3% to 21%.

Development of a postoperative deep vein thrombosis may be asymptomatic, may cause fatal pulmonary embolism and may be the source of a persistent calf and foot swelling.

The use of chemical prophylaxis helps to reduce the risk, especially in high-risk patients.⁽³⁷⁾

Compartment Syndrome

Although it is rare, it may occur related to high energy trauma.⁽³⁸⁾

Arthritis

Occurs usually several years after malreduction of the ankle mortise or persistent step off of posterior malleolus after union.⁽³⁹⁾

Complex Regional Pain Syndrome

It may be seen in all types of ankle injuries. It is characterized by pain out of proportion to the injury, cool and often erythematous or shiny skin, and atrophy of the bone and soft tissues.

Treatment is directed at the restoration of function and interruption of the pain cycle. lumbar sympathetic block or calcium channel agents have been reported to be successful.⁽⁴⁰⁾

Conclusion

The posterior malleolus is an important component of ankle stability and articular congruity. Evaluation includes clinical examination, plain radiographs, and computed tomography. Treatment may be nonoperative or operative according to fracture displacement, fragment size and morphology, articular step-off, and ankle

stability. Operative treatment includes percutaneous fixation and open reduction and internal fixation through posterolateral or posteromedial approaches. Complications should be recognized and appropriately managed.

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