STUDY OF MORPHOLOGICAL DISTRIBUTION OF ANKLE FRACTURES BASED ON THE NOVEL FOUR COLUMN FRACTURE CLASSIFICATION-A ONE YEAR HOSPITAL BASED CROSS-SECTIONAL STUDY.

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LIST OF ABBREVATIONS

L & H	Laugh and Hansen
D & W	Dennis and Weber
AO/ OTA	Arbeitsgemeinchaft fur Osteosynthesefragen/ Orthopedic Trauma Association
AP	Antero- posterior
AOFAS	American Orthopedic Foot and Ankle Society
PTTL	Posterior Tibiotalar ligament
TNL	Tibionavicular ligament
TCL	Tibiocalcaneal ligament
TFL	Talofibualr ligament
DF	dorsiflexion
PF	Planterflexion
FHL	Flexor Hallucis Longus
EDL	Extensor Digitorum Longus
EHL	Extensor Hallucis Longus
PA	Peroneal Artery
PTA	Posterior Tibial Artery
ATA	Anterior Tibial Artery
D-P	Deep Peroneal
ER	External Rotation
MM	Medial Malleolus
LCL	Lateral Collateral Ligament
TT	Tibial Tuberosity
MT	Metatarsal
T-F overlap	Tibiofibular
CT scan	Computed Tomography
3D	Three- dimensional
X	Mean
SD	Standard deviation
#	Fracture

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STUDY OF MORPHOLOGICAL DISTRIBUTION OF ANKLE FRACTURES BASED ON THE NOVEL FOUR COLUMN FRACTURE CLASSIFICATION-A ONE YEAR HOSPITAL BASED CROSS-SECTIONAL STUDY

ABSTRACT

Background: Ankle fractures manifest intricate morphological variations, necessitating meticulous classification for optimal management. This investigation sought to assess the morphological distribution of ankle fractures utilizing the innovative four-column classification system, while concurrently evaluating its efficacy in comparison to established classification methodologies.

Methodology: This hospital-based cross-sectional investigation was executed over a one-year period within a tertiary care environment. 33 adult individuals presenting with intra-articular distal tibial fractures were evaluated through three-dimensional computed tomography reconstruction. Fractures were systematically categorized into anterior, posterior, medial, and lateral columns. The distribution of fractures, their correlation with mechanisms of trauma, as well as associations with the Denis Weber and Lauge-Hansen classifications, were meticulously analyzed. Statistical relationships were examined to elucidate gender-based and injury-specific disparities.

Results: The lateral and medial columns emerged as the most frequently fractured due to their critical weight-bearing function, whereas the anterior column exhibited the least involvement. Multi-column fractures were prevalent, with 18.2% encompassing all four columns, underscoring the complexity inherent in high-energy trauma. Fractures of the posterior column demonstrated a significant association with supra-syndesmotic (Type C) fractures ($p = 0.007$), while lateral column fractures exhibited correlation with infra- and trans-syndesmotic fractures ($p < 0.001$).

Conclusion: The four-column classification system provides a more nuanced comprehension of ankle fracture morphology when juxtaposed with conventional systems. It adeptly encompasses multi-column injuries and their biomechanical ramifications, thereby facilitating informed clinical decision-making. This study underscores the necessity for an anatomically precise classification system to enhance fracture evaluation and treatment strategies.

Keywords: Ankle fractures, four-column classification, fracture morphology, 3D CT reconstruction, Denis Weber classification, Lauge-Hansen classification, trauma mechanisms, intra-articular fractures.

INTRODUCTION

With an incidence rate of 137 per 100,000 individuals annually, ankle fractures constitute approximately 10% of all skeletal fractures and represent the most prevalent fractures of the lower extremities, surpassed only by hip fractures.[1] The epidemiological distribution of these injuries exhibits a bimodal pattern, with the most pronounced incidence observed in younger males and older females, separated by a temporal span of approximately 50 years.[2] Typically resulting from low-energy mechanisms, the predominant cause of these fractures is self-inflicted falls, particularly twisting injuries, followed by injuries sustained during athletic activities and vehicular accidents.[1]

The distal tibia, fibula, and talus all articulate to form the ankle joint. Consequently, ankle fractures are classified when there exists a disruption in one or more of these bony structures, namely the tibia or fibula. These fractures can range from uncomplicated breaks to complex injuries that may involve multiple bones and associated ligaments. Ankle fractures are of various forms: bimalleolar fractures, which implicate both the lateral and medial malleoli, and trimalleolar bony break, which involve the lateral, posterior, and medial malleoli. In contrast, lateral malleolus fractures specifically affect, fibula, tibia, and the posterior aspect of tibia [3].

Ankle fractures are associated with swelling, bruising, and, in more severe cases, a deformity and significant swelling that can proceed to skin necrosis or compartment syndrome. The treatment plan is determined on the type and severity of the fracture. For stable fractures, non-surgical solutions such as casting or bracing are used; for unstable or displaced fractures, surgical options such as plate and screw fixation are necessary [4].

Pilon injuries were first labeled by French radiologist Destot, affect the joint weightbearing area of the lower tibia. The word "pilon" comes from the French word pestle, which resembles a chemist's pestle when contrasted to the distal tibial metaphysis. Later, the name "plafond," which means "ceiling" in French, came to refer to the lower tibial Articular surface as the ankle joint's roof. These injuries account for less than one percent of all lower limb fractures and are notorious for their complexity and difficulty in generating positive clinical outcomes [5]. Modern pilon fractures often originate from high-energy mechanisms, often involving considerable articular compaction and extensive soft tissue trauma due to vertical loads, in contrast to the comparatively low-energy rotational mechanisms initially examined by Rüedi and Allgöwer. [6]

Ankle fractures present a significant challenge to orthopaedic surgeons due to difficulties with anatomic restoration and stabilization . Ankle fractures generate severe soft tissue injury, which can lead to fixation failure and a variety of consequences. Operative decision making for ankle fractures is a significant problem for orthopaedic surgeons in general [8]. The clinical classification of ankle fractures dictates the fixing strategy and, ultimately, the result. Earlier classification systems focused primarily on the mechanism of harm, which did not provide a definitive operative concept.

The Four Column categorization is based on local anatomical features of two bones in the ankle [6]. This study seeks to determine the morphological distribution of ankle # based on the 4 column fracture categorization to better understand the mechanism of ankle fractures & facilitate surgical methods such as column fixation. The mechanism, fracture sites, morphological changes, and anatomical features of the fracture will also be better understood thanks to this study method's comprehensive explanation of the patterns and incidence of ankle fractures from the viewpoints of mechanisms and anatomical structures.

AIM OF THE STUDY

To study and assess the Morphological distribution of Ankle Fracture pattern according to novel four column classification.

REVIEW OF LITERATURE

Three popular ankle fracture classification systems—L & H, D&W, and AO were evaluated via intra- and interobserver reproducibility. Additionally, the effect of evaluators' training level on classification consistency was examined. A total of 30 ankle fracture patients were chosen, with radiographic images in (AP), lateral, and true AP views assessed by eleven assessors in various stages of specialist training. Each evaluator classified the fractures twice, at different time points. The results showed that intra-observer agreement was significant for all three classification systems. However, the Danis-Weber categorization had the best inter-observer agreement, ranging from mediocre to outstanding. Furthermore, the study discovered that the evaluators' level of experience had no significant detrimental effect on classification reproducibility, implying that even inexperienced practitioners could use these categorization systems reliably. Overall, the findings demonstrate the Danis-Weber classification's better reproducibility, reaffirming its clinical relevance as a consistent and accurate method for diagnosing ankle fractures. [45]

A newer system [4] the four-column classification was used for the first time, considering fractures in fibula and lateral reigion of distal tibia plafond to be lateral-column fractures. Nonetheless, in cases of comminuted pilon fractures, these parts were repaired and restored independently. A single column is a more reasonable way to think of the fibula. Consequently, the novel four-column theory offers trustworthy and efficient surgical prognoses for a varied range of fractures.

For ankle fractures, the Rüedi-Allgöwer and AO/OTA classifications are still commonly employed [8]. The Rüedi-Allgöwer classification, which is simple to remember and use to assess the result of ankle fractures, comprises three types depending oN the displacement of the articular area, metaphyseal, and damage extent of fractures. However, Rüedi-Allgöwer is only classified based on X-ray radiography; no other radiological examination is used, and only varieties that originated from axial force with the foot in a neutral position are included. This classification is far from directing the choice of incision and implant, and it cannot account for all forms of ankle fractures. The AO/OTA classification is rather deep and extensive. It is convenient to manage case data, but the AO/OTA classification is difficult to recall and has little relevance to local anatomical traits and damage causes. As a result, orthopaedic surgeons have less incentive to choose the most appropriate treatment.

The study examined intraobserver and interobserver agreement in an Asian population under both timed and untimed situations. Two independent observers used all three techniques to classify 80 consecutive patients with malleolar ankle fractures whose anteroposterior and lateral radiographs were taken between 2015 and 2016. Over the course of four weeks, the tests were conducted again, with one week separating each session under both time-constrained (25 seconds) and untimed settings. The findings showed that the Weber classification system outperformed the AO/OTA and Lauge-Hansen methods in terms of interobserver and intraobserver reliability, especially when time was of the essence. This implies that the Weber categorisation is easier to use, consistent throughout evaluators, and ideal for hectic clinical settings when making decisions quickly is essential. The study came to the inference that the weber system should be the recommended classification technique in situations demanding quick and precise fracture assessment because of its exceptional reliability. [46]

Treating tibial Pilon fractures with 4 column theory were assessed by Zhiyuan Lou and colleagues in "Outcomes of Tibial Pilon Fracture Fixation Based on Four-Column Theory," utilising a retrograde analysis. The posterior column was most commonly damaged, occurring in 125 out of 142 cases, and the fractures were classified as either conventional pilon fractures or pilon variations. To examine fracture patterns, the researchers used categories such the four-column classification, Rüedi-Allgöwer, and the OTA/AO system. In comparison to low-energy fractures, the results showed that high-energy pilon fractures, which were more common in younger male patients and frequently linked to die-punch or intercalary #, had bad outcomes. On comparing with low-energy #, results showed that high-energy pilon fractures, which were more common in younger male patients and frequently linked to die-punch/ intercalary fracture, had worse outcomes. In particular (87), the high-energy group's avg AOFAS score was substantially lower (82). Furthermore, worse outcomes and more severe damage classifications were linked to multiple-column fractures. The study came to the conclusion that the 4 column theory can be used to treat both normal PILON fractures and their variations in old people, and that it is important to identify different types of pilon fractures. [47]

Researchers used a retrospective analysis in the study "Evaluation of Ankle Fracture Classification Systems in 193 Trimalleolar Ankle Fractures," specifically focussing on the posterior malleolus, to assess the accuracy of several classification schemes for ankle fractures in the trimalleolar region. Patients treated between 2011 and 2020 were included in the study; all had computed tomography (CT) scans and pretreatment radiography. The AO/OTA method, which classifies fractures according to the placement of fibula # in relation to the syndesmosis (3 types), was one of its classification systems the researchers used to assess the fractures. The study discovered that the AO/OTA grouping system lacks specific information about the posterior malleolus, yet it is accurate in describing the general type of Tri-malleolar ankle fractures. This restriction raises the possibility that the AO/OTA system is unable to adequately represent the intricacy of fractures affecting the tibia's posterior aspect. The study also observed a direct fixation of posterior malleolus in further years of the monitoring period, indicating that surgical therapy is evolving. The authors came to the conclusion that, although the AO/OTA categorisation offers a broad framework for comprehending trimalleolar fractures, it should be enhanced with extra evaluations, especially with regard to the posterior malleolus, in order to properly guide treatment plans. [48]

The authors looked in detecting ankle fractures with (DCNNs) in radiography. Radiographs from 1,050 patients with verified ankle fractures and an equivalent number of healthy people were used in the study to train DCNNs. The study made use of two pretrained models, Inception V3 and ResNet50. Utilising lateral, mortise, and anterior three-view radiographs yielded better outcomes than single-view images, the study found. Specifically, the Inception V3 model achieved a sensitivity of 98.7% and a specificity of 98.6%, missing only one ankle fracture in the dataset. These findings suggest that DCNNs could be helpful tools for the prompt and precise diagnosis of ankle fractures, perhaps leading to better patient outcomes and better clinical judgement. [49]

HISTORICAL REVIEW

The first documentation of trauma in the vicinity of the ankle was done in 1769. He detailed an instance of fibular fracture occurring within a range of 2 to 3 inches from its distal end, accompanied by damage to the ligament medially with dislocating talus.[8] His focus was on bimalleolar fractures, distinct from Guillaume Dupuytren's exploration of tibiofibular syndesmosis injuries.

In 1828, **EARLE** provided an account to posterior margin of the end articular tibia.[9].

In 1839, he elucidated the significance of inner and outer foot movements in ankle traumas, differentiating between fractures resulting from force on the TALUS and that caused by avulsed ligaments. He was the first to identify the ripping of tibiofibular ligaments as a common accompanying factor to this kind of fracture and to record the proximal dislocation of the talus after distal Tibio-fibular separation.

In the year 1840, A French military officer delineated a pronation - external rotation pattern of ankle trauma and substantiated that its occurrence was contingent upon the integrity of the syndesmosis. This description included an ankle trauma involving an upper fibular break, which was differentiated from a straight impact on the fibula.[10]

In 1872, a surgeon delineated the occurrence of avulsion fractures along the anterior tibial margin through a simultaneous application of abduction and external rotation forces, facilitated by the ATFL.

In 1886, He described vertical ripped bony integrity of the AITFL that affected anteromedial part of fibula below.

ROCHE demonstrated in 1890 that vertical force was a necessary component in producing marginal fractures of the distal fibula, a condition that Astley Cooper had first reported.

In 1907, **Quenu** was the pioneer in publishing a report on distal Tibio-fibular diastasis in ankle fractures, emphasizing the significant implication of syndesmotic injury cracks of malleolus as a clear poor outcome indicator.[11]

Rammelt et al highlighted its critical nature of fixing syndesmotic disruption to preserve the typical dynamic ankle support.[12]

Destot designated the back chipping of the tibia as the 3rd malleoli.

Around the year 1912**, Cotton** brought to light the issue of # involving the post malleolus.[13]

Based on direction of deforming force, BROMMER et al. created a classifying system for ankle mortise trauma in 1916. [14]

Between 1948 and 1954, **Lauge-Hansen** developed a classification system that highlighted the aetiologic interconnection of consecutive events or stage.[15]

A simple classification system for lateral malleolar fractures was introduced by Rober & Weber, who concentrated on the degree of syndesmotic damage.[16][17]

Surgical Anatomy of Ankle

The ankle, comprises of 3 bones & ligaments that supports it. It has a concavo-convex shape to maintain the integrity, which offers useful stability.

The bones involved in the articulations of the ankle joint include:

a. Distal tibia with medial malleolus

b. Lateral malleolus

c. Talus Distal Tibia

The plafond extends medial to the medial malleolus, which articulates with the medial aspect of the talus and divides into anterior and posterior colliculus. It serves as an attachment site for the deltoid ligaments. The incisura is a groove of the tibia where distal fibula rests.

The lower of fibula, which extends approximately 1 cm posteriorly and distally, forms lateral malleolus. It inculcates 10° to 15° valgus inclination in the direction of the fibula shaft. When the syndesmosis is interrupted, the fibula shortens, rotates externally, and moves laterally. This significantly limits the area of contact between the talus and tibia, which may result in early arthritis.

FIGURE 1: SURGICAL ANATOMY OF ANKLE

The front part of the talus is 2.5 mm wider than the posterior, and its trapezoidal dome is in line with the tibial plafond. Thus, the talus fills the mortise entirely in dorsiflexion, yet it allows for some inversion and eversion in plantar flexion. It articulates with the corresponding malleoli.

The ankle joint's bones and the twelve ligaments that make up the intricate ligamentous system connected to this hinge joint are depicted in a schematic diagram.

a. Medial collateral or deltoid ligament complex

b. Lateral or fibular collateral ligament complex

c. Syndesmotic ligament complex

The Deltoid is a triangle band composed of superficial and deep fibre groups.

The upper part is composed of the PTTL, TNL, and TCL.

The ant tibiotalar ligaments, which provide force to the talus's lateral rotation and lateral translation, are located in the deep portion.

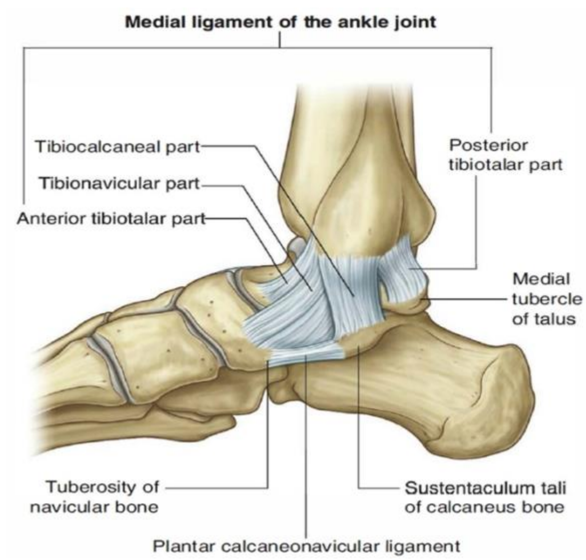


FIGURE 2: MEDIAL LIGAMENT COMPLEX OF ANKLE

The calcaneo navicular ligaments merge with the Tibio Navicular ligament as it extends forward inserting the navicular tubercle. Posterior colliculus is origin of Tibio Calcaneal ligament, which inserts into the sustentaculam tali.

The back of the talus, which is medially to flexor hallucis longus groove, is where the PTTL inserts after emerging from post colliculus. In contrast, the ANT colliculus gives rise to the anterior tibial ligament, which is connected to the anteromedial aspect of the talus. An assortment of ligaments can be seen to medial aspect of ankle joint.

The three-part lateral or fibular ligament, which supports the ankle laterally, is weaker than the medial ligament.

The ant, post TFL, and calcaneofibular ligament make up these components. Ankle sprains commonly cause damage to the ant TFL, the weakest of these ligaments, which stops the talus from anteriorly subluxing during plantar flexion.
A + talar tilt results from a rupture of the Calcaneo Fibular ligament, which stabilises the subtalar joint.

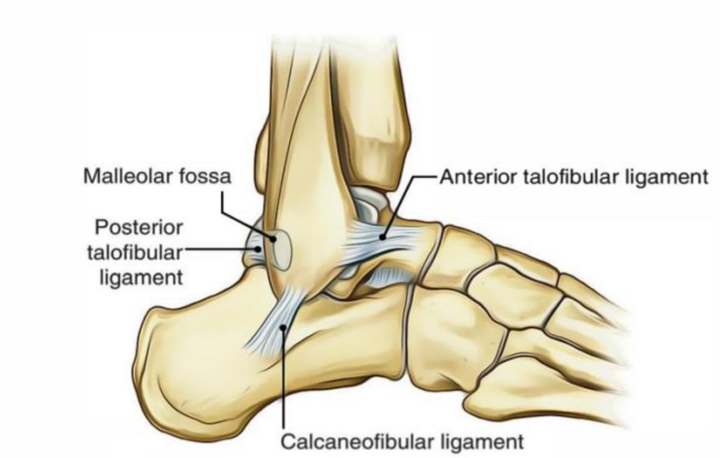


FIGURE 3: LATERAL LIGAMENT COMPLEX OF ANKLE

The degree of tibiofibular syndesmotic stability that these ligaments offered was evaluated by Ogilvie-Harris et al. [32]

1. Of the entire ligamentous structure, 35% constitutes anterior inferior tibiofibular ligament.
2. The post inferior TFL is responsible for a percentage of 10.
3. Of the total ligament composition, 35% is made up of the transverse ITFL
4. Twenty percent of the tibio-fibular ligament complex is made up of the interosseous ligament.

Sectioning particular ligaments caused noticeable increases in tibiofibular diastasis in a study by Xeno and others. In particular, tibiofibular diastasis increased by 2.3 mm due to anterior ligament sectioning, 2.2 mm due to interosseous ligament sectioning, and 2.8 mm due to posterior ligament sectioning. Sectioning every syndesmotic ligament resulted in a final diastasis of 7.3 mm [24]. During normal ankle motions, these configurations allow for minimal fibular mobility across multiple planes.

The tibiotalar contact area can be considerably decreased by 40% with a 1 mm lateral talar shift. A 2-3 mm lateral shift may be caused by syndesmotic disruptions from fibula fractures, particularly if the medial malleoli or deep deltoid ligament are unharmed. A larger lateral talar shift, however, suggests possible medial compromise. [33].

The groove that joins the distal tibia and fibula is known as the incisura fibularis, or peroneal groove. In 75% of cases, the incisura fibularis has a concave surface, although it can also be shallow, uneven, or slightly convex. Its depth can range from 1.0 to 7.5 mm. In the event of syndesmotic disturbances, some designs may make it more likely that the distal fibula may be reduced incorrectly into the groove. [34].

MUSCULATURE AROUND THE ANKLE

The musculature around the ankle is crucial for movement and stability. The primary muscles involved include:[51]

1.The calf is formed by the gastro-soleus, which are in charge of plantarflexion. Dorsiflexion is accomplished by the tibialis anterior, a muscle situated in front of the shin. Eversion, is accomplished by the peroneal muscles (PL & PB), running through the lower leg laterally.

2. The inner side contains the FHL and Flexor Digitorum-Longus muscles, which are in charge of flexing the digits.

3.The big toe and other toes are extended by the EHL & EDL muscles, are on the front of the leg, respectively.

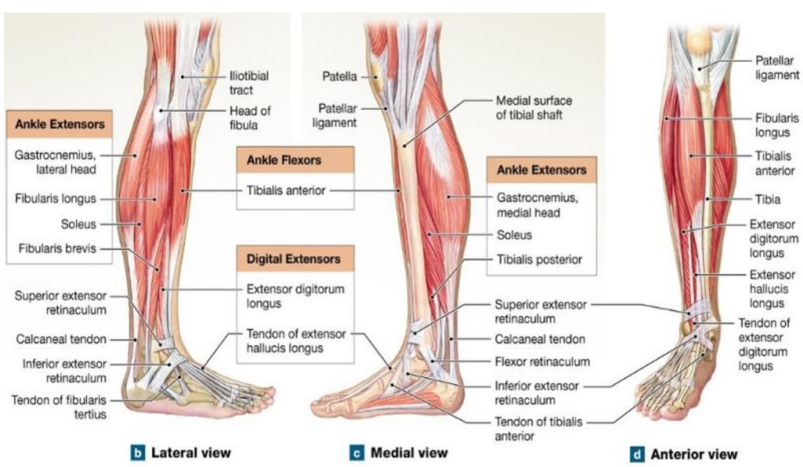


FIGURE 4: MUSCULATURE AROUND THE ANKLE

BLOOD SUPPLY OF THE ANKLE

The primary circulatory supply of the ankle and syndesmotic joints comes from a variety of sources, including the anterior tibial artery, the post tibial artery, and perforating branch of the peroneal artery. [35]

Specifically, the ant syndesmotic lig receives its main blood supply from the ant branch of the peroneal artery & ATA, while the post syndesmotic lig is fed by post branch of the PA. Moreover, the blood supply to the ant tibial tubercle & tibial plafond is facilitated by an anastomotic network between the perforating branch of the PA & ATA.[35]

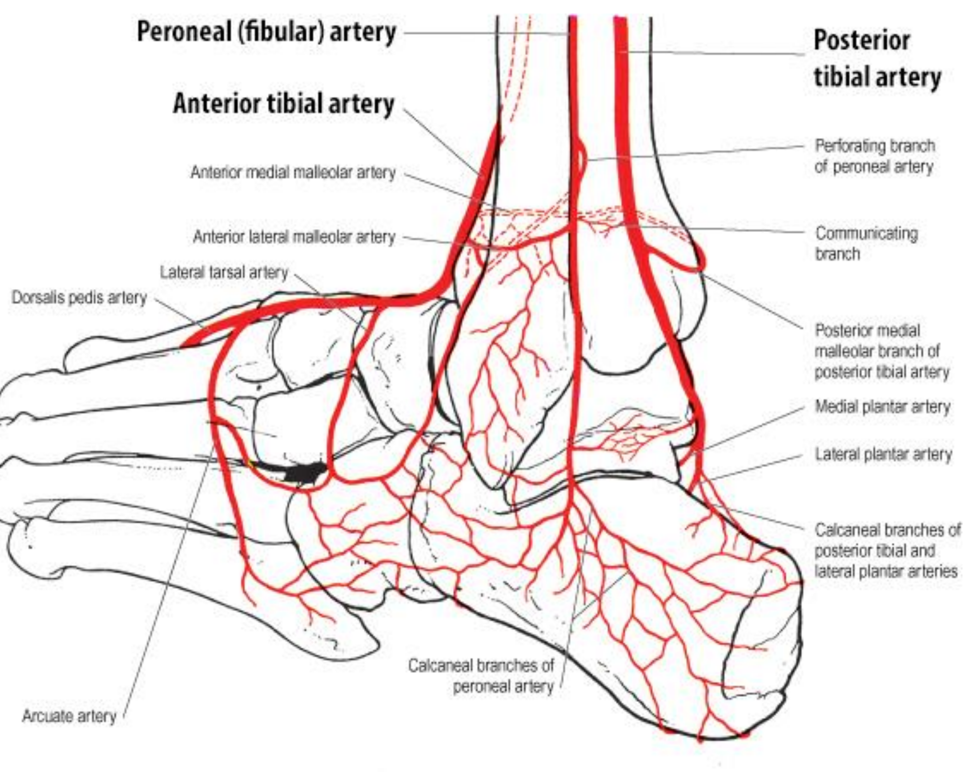


FIGURE 5: BLOOD SUPPLY AROUND THE ANKLE

NERVE SUPPLY AROUND THE ANKLE

The nerve supply surrounding the ankle is essential for both sensory and motor activities. The main nerves involved are as follows:

• TIBIAL Nerve: This nerve goes behind the medial malleolus and supplies the plantar part of foot.

• D-P Nerve: This nerve innervates the EDB and EHB after entering the foot anteriorly. Additionally, it gives the initial dorsal webspace feeling.

• FIBROUS/ SUPERFICIAL PERONEAL nerve innervates the dorsum of the foot and the lateral aspect of the lower leg.

The sensory nerve provides sensations to the lateral aspect of foot and ankle. Saphenous nerve provides feeling to the medial side of the foot.

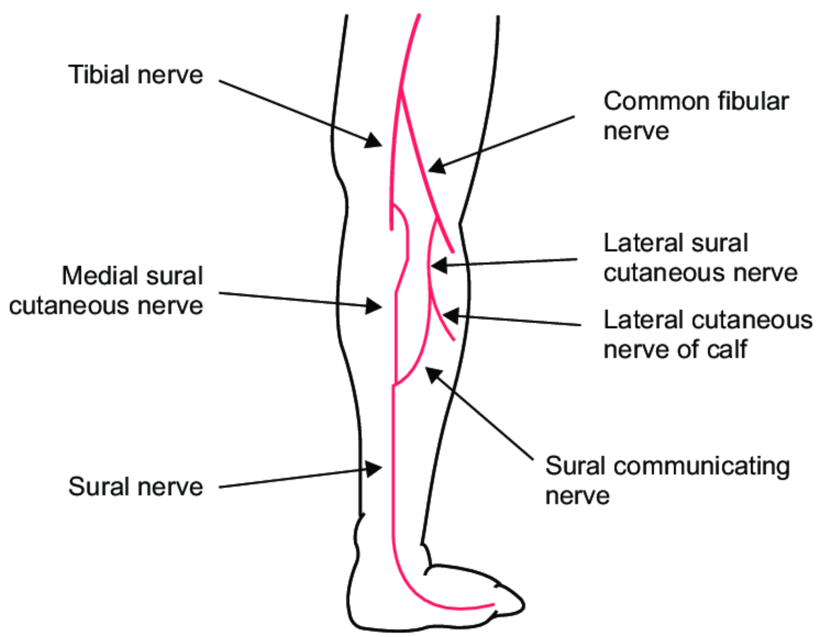


FIGURE 6: NERVE SUPPLY AROUND THE ANKLE

BIOMECHANICS OF ANKLE JOINT

Ankle joint's two primary motions are (DF) flexion (15˚-20˚) and PF (40˚-50˚). The aforementioned joint motions are thought to revolve around a single axis that is formed by the ends of the malleoli. This axis is thought to be the pivot of the ankle joint and is orientated 20˚-25˚ inferiorly, laterally, and posteriorly [36, 37].

As the joint shifts from PF to DF, the talus pronates, thereby separating the two malleoli and potentially damaging the syndesmotic ligaments. This causes the ankle mortise to enlarge by 1.5 mm. [38] The talus pseudo-rotates when moving within the ankle mortise because the lateral inclination of the talar dome is perpendicular to the pivot, unlike the medial aspect, which is inclined at 6˚. The ankle axis, which connects the two malleoli, has an external rotation of 20 degrees with regard to the knee axis. [39]

The distal tibia dynamically stabilises the distal fibula, allowing it to move in 3D during DF and PF at the ankle. The talus dorsiflexes, increasing the intermalleolar distance by 1.5 mm, and the fibula externally rotates by two degrees when the syndesmosis is intact. [40, 41] During normal locomotion, the distal fibula exhibits a distal translation of around 2.4 mm and modest anteroposterior movement of less than 0.4 mm. [42, 43]

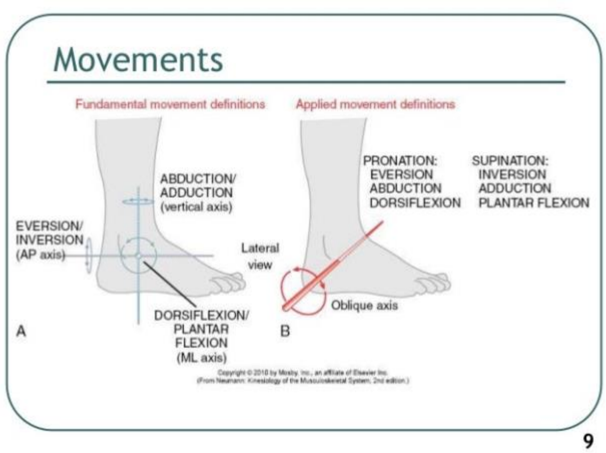


FIGURE 7: BIOMECHANICS OF ANKLE

Classification of Ankle Injuries

There are several categories for ankle injuries, including the

1. LH classification.

2. The categorisation of D-W

3 Classifying Edward and DeLee

4. The grading system for West Point ankle sprains

5. Classification by chronology

1.Lauge-Hansen Classification

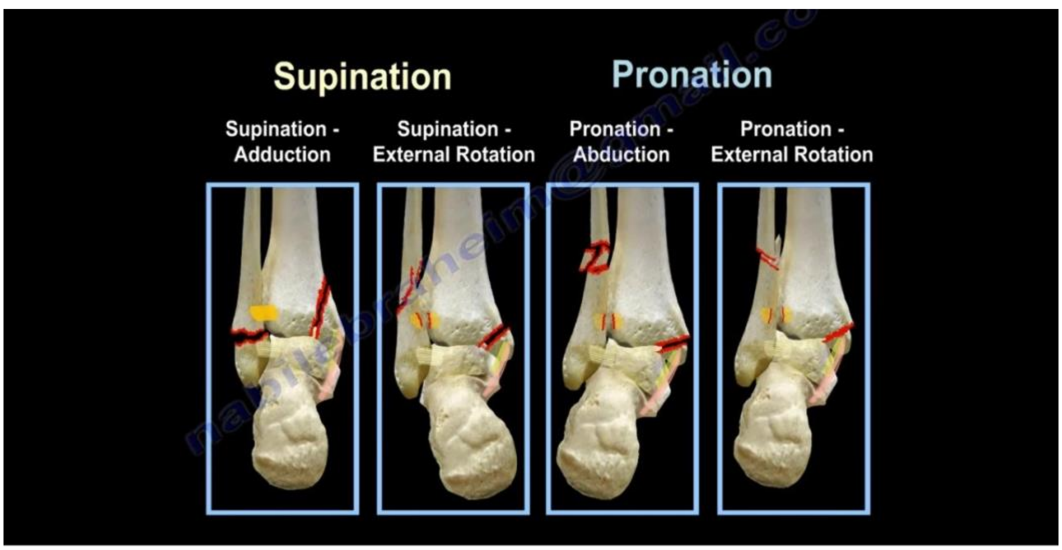


FIGURE 8: LAUGE HANSEN CLASSIFICATION

This framework identifies four primary patterns that are further subdivided into distinct phases by considering the orientation of the foot and the trajectory of the deforming force at the time of injury. The first phrase in this taxonomy denotes the foot's direction at the time of damage, while the second term denotes the force that caused the injury. [44]

The following are the four injury patterns:

Adduction is the type of supination.

One kind of ER is supination.

Abduction and external rotation are the two forms of pronation.

Supination-ER is the cause of 40–75% of malleolar fractures.

Avulsion fracture of the anterior syndesmosis (anterior tibioperoneal ligament) at the tibial or peroneal insertions, with or without its rupture, is stage I.

A spiroid fracture usually occurs in stage II of the fibula, which runs from the ant-inf zone to the post-sup zone.

Stage 3: a rupture of the post syndesmosis (posterior tibioperoneal ligament) or a # of the post malleolus.

Stage 4: transverse # brought on by an avulsion of the MM or a rupture of the deltoid ligament.

Ten to twenty percent of ankle # are sup-add forming. It is only kind that causes the talus to shift medially.
Stage I: a rupture of the LCL or a transverse ripped # of the fibula distal to joint.
Stage II: tibial malleolus fracture in a vertical direction.

Pronation-abduction accounts for between 5 and 20% of malleolar fractures.

In Stage one : a transverse # of the medial malleolus or a rupture of the deltoid ligament.

Second: a fracture brought on by a rupture of the syndesmosis or avulsion of its insertions.

Third stage: a transverse or short oblique # of end of the fibula at or above the syndesmosis, resulting in lateral comminution or a butterfly wing fragment.

In between 5% and 20% of cases, external pronation-rotation results in malleolar fractures. 1st: a medial malleolus transverse fracture or a rupture of the deltoid ligament. Two: avulsion of the ant syndesmosis (anterior tibioperoneal lig) insertions, either with # or not.

Distal fibula spiroid fracture at or above the syndesmosis connecting the anterosuperior and posteroinferior is stage III.

Fourth: either the posterior tibioperoneal ligament (posterior syndesmosis) ruptures or the posterolateral portion of the tibia avulsion fractures.

2. Dennis Weber Classification

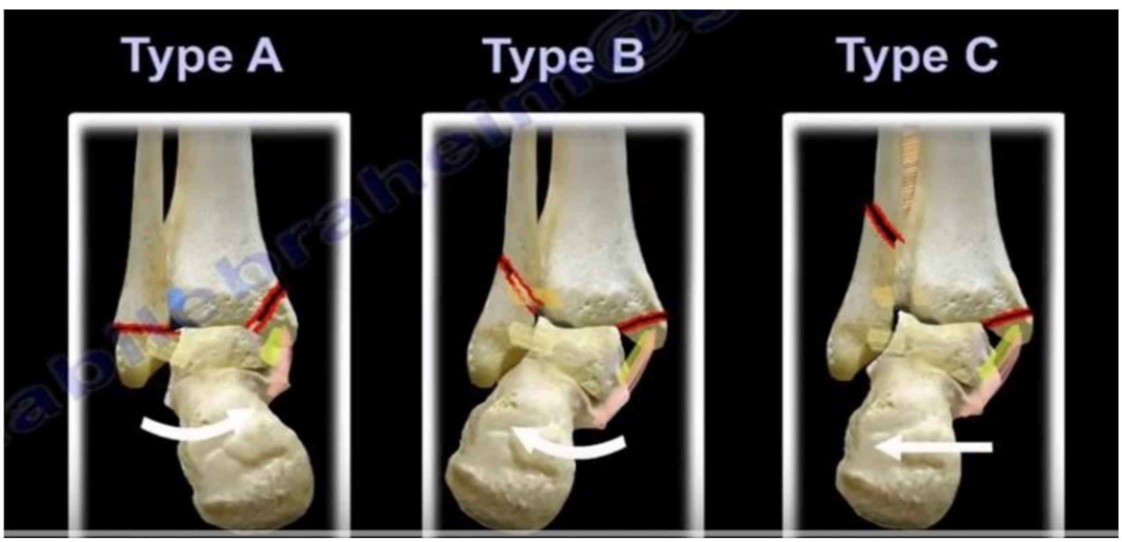


FIGURE 9: DENNIS WEBER CLASSIFICATION

Radiographic parameters serve as the primary foundation for the fibula fracture. According to the degree of fibula damage in respect to the syndesmosis, fractures are classified as infrasyndesmal (Weber A), transindesmal (Weber B), and suprasyndesmal (Weber C). However, this division cannot assess stability because it fails to consider the median component. as opposed to the different groupings listed within each category by the AO/OTA classification. Due to its ease of use and interobserver reliability, this category is currently the most popular. The closer you get, the more likely it is that the syndesmosis will rupture and become unstable. It is divided into three groups:

A: A fibula fracture beneath the horizontal articular surface of the tibia. Similar to the substitution-adduction method of Lauge-Hansen. A1 (isolated lateral malleolus fractures), A2 (related medial malleolus fractures), and A3 (trimalleolar fractures) are the three categories into which they are divided.

B: External rotation at or near the syndesmosis causes a spiroid or oblique fibula fracture. similar to the damage resulting from Lauge-Hansen supination-eversion. They can be further divided into three categories: associated medial and posterolateral injuries (B3), accompanied medial injuries (B2), and isolated lateral malleolus fractures (B1).

C: A rupture of the syndesmosis brought on by a fibula breakage above the syndesmosis is nearly invariably linked to a medial lesion. Maissonneuve is includes stage III of the Lauge-Hansen pronation-eversion fractures. Proximal fibula fractures (C3), multifragmentary fractures (C2), and single fibula fractures (C1) are the three categories into which they are divided. All of these are linked to medial (bony or ligamentous) injuries and/or posterior malleolus injuries.

3. Edward & LEE Classification

Based on radiological findings, Edward and De Lee classified syndesmotic injuries into latent and frank diastasis. Syndesmotic injuries are further classified as either traumatic or atraumatic (degenerative) based on their aetiology.

4. West Point Ankle Grading System

This technique has been identified by Gerber and associates as a means of differentiating between the three subsequent types of pure ligamentous syndesmotic injuries. ONE: There is no proof of instability or a half tear of the anterior tibiofibular ligament.

TWO: Mild signs of instability (tears in the interosseous and anterior ligaments)

THREE: Syndesmotic ligaments that are completely unstable or ruptured

5. Chronological Classification

There are three types of syndesmotic injuries based on the injury time interval.

Less than three weeks is considered acute; three weeks to three months is considered subacute; and more than three months is considered chronic.

FOUR COLUMN CLASSIFICATION OF ANKLE FRACTURES

A classification with four columns was suggested, which was based on the tibial and fibular plafonds' anatomical features. The intermalleolar line separates the anterior and posterior columns by joining the medial and lateral malleoli.

It is believed that the distal fibula is the lateral column and the medial part of the tibial plafond is the medial column.

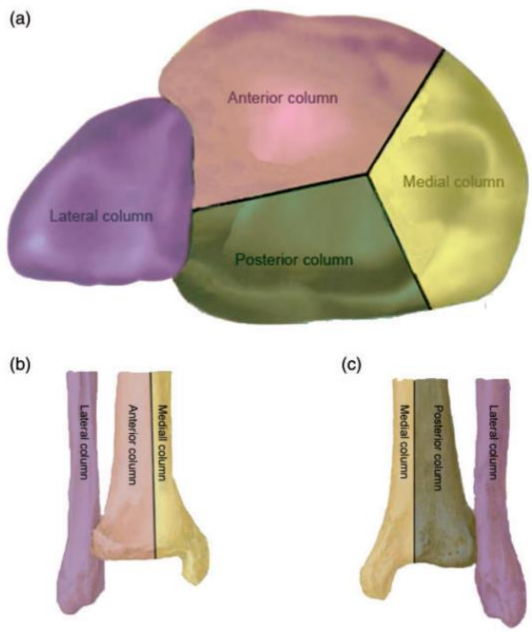


Figure 1. Schematic layout of four-column classification of tibial plafond. (a) Axial view of tibial plafond. (b) Anterior view of distal tibia. (c) Posterior view of distal tibia.

FIGURE 10: FOUR COLUMN CLASSIFICATION

The 4-column classification can be summarised as follows:

1. The lateral column's distal fibula

2. Posterior column being posterior part of intermalleolar line and distal tibial shaft

3. Anterior column: anterior part of the intermalleolar line and distal tibial shaft

4. The medial column consists of the medial portion of the tibial plafond and the distal tibial shaft.

Clinical Examinations for Syndesmotic Trauma

In order to support the diagnosis of syndesmotic injuries, the following diagnostics have been recommended. [52]

A squeeze test involves compression of the upper two parts of leg bones. Pain in ankle joint indicates a + test result. The complete fibula must be palpated in order to rule out a Maisonneuve fracture.

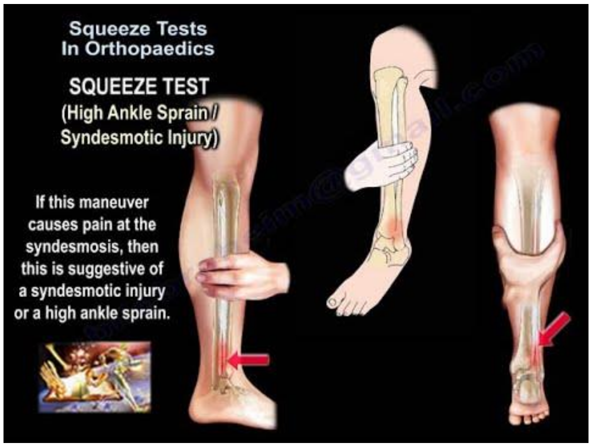


FIGURE 11: SQUEEZE TEST

A compression test- pain results from direct compression of the ant inf TFL, this is a sign of successful outcome.

FIGURE 12: COMPRESSION TEST

Kleiger external rotation stress test- When the ankle is in Df and the knee is 90-degree bent, a direct ER force is applied to foot above ankle as part of this test. Ankle joint pain indicates a favourable prognosis.

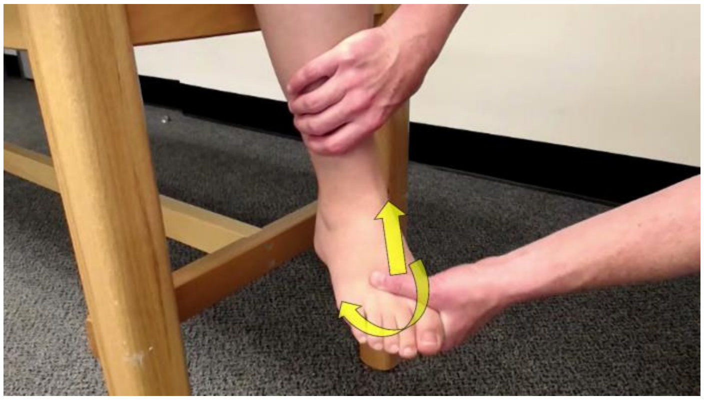


FIGURE 13: KLEIGER EXTERNAL ROTATION STRESS TEST

The movement of the talus from medial to lateral occurs in the **Cotton test**. When compared to the contralateral side, discomfort or greater talus translation are likely signs of deltoid ligament damage.

FIGURE 14: COTTON TEST

The fibula is translated more when antero posterior translation is attempted than when it is translated normally, according to the **Fibular translation test**. The tibia is kept still by the examiner.

FIGURE 15: FIBULAR TRANSLATION TEST

RADIOLOGY OF ANKLE

The AP, lateral, and 15-degree internal rotation (mortise) views are all part of the normal radiography examination of the ankle. [53]

FIGURE 16: RADIOLOGY OF ANKLE JOINT

Tibiofibular overlap, tibiofibular clear space, and medial or lateral tilt of the talus can all be evaluated by antero-posterior X-rays, which are obtained along the foot's long axis.

The talus dome be centred & parallel to the tibial pla-fond in the lateral X-ray. This picture might reveal post TT #, ER # of the fibula & AP shift # of the talus.

Place the foot on couch with the 5th toe MT in an IR of about 15 degrees to obtain the anteroposterior projection in the Mortise view. The talocrural angle, talar shift, t-F overlap, and medial clean space all be assessed with this angle.

FIGURE 17: ANKLE MORTISE VIEW (15˚ - 20˚ internal rotation view)

We can exactly examine the TF overlap and clear space thanks to the external rotation stress imaging. When evaluating ankle instability, stress radiographs can be helpful.

FIGURE 18: EXTERNAL ROTATION STRESS IMAGING

Stress radiographs are used to evaluate inside deltoid lig lesions engaged with ankle instability. These images aid in distinguishing Stage 2 sup-ER injuries from Stage four injuries.

Radiological Assessment of Reduction

1. Medial clear space

2. Tibiofibular overlap

3. Tibiofibular clear space

4. Talar tilt

5. Talar shift

6. Talocrural angle

7. Fibular length and displacement

1 Measurement of Medial clear space

The distance between the opposing articular surface of the talus and inner sides of medial and lat malleoli is known as clear space. Anteroposterior views provide a clearer view of the medial clean space, which is frequently uniformly wide throughout. Generally, less than 2 mm is okay.

Normal medial clear space

FIGURE 19: MEASUREMENT OF MEDIAL CLEAR SPACE

2 Tibiofibular Overlap

Tibiofibular overlap describes the bone overlap between the distal tibia's lateral border and the distal fibula's medial border. At least forty percent of the fibula’s breadth at level where syndesmosis is proven to be normal indicates a notable syndesmotic disruption; if it is < four mm, the overlap is expected to be > 5 mm.

FIGURE 20: TIBIOFIBULAR OVERLAP

3 Tibiofibular Clear Space

In 1907, Chaput coined the term "Ligne Claire" to describe tibifibular clean space.[48] The obvious gap shows the fibula's involvement in the peroneal groove. It must not exceed five millimetres in size. A distinct syndesmotic disruption is indicated by a tibiofibular clean space of greater than 5 mm.

FIGURE 21: TIBIOFIBULAR CLEAR SPACE

When syndesmotic disruption is overcorrected, the tibio-fibular clear space is < one millimetre, which limits the fibula's ability to move proximally, rotate externally, and move posteriorly during normal walking.

4 Assessment of Talar Shift

In AP view, a straight line across the middle of tibia should cross the centre of the talus. If it does not pass through the talus's centre, it is displaced laterally or medial. A clear medially Lateral talar displacement is indicated by a gap larger than 5 mm. A vertical line drawn across the middle of the tibia in lateral view should reach the highest point of the talus dome. Otherwise, either an anterior or posterior shift has taken place.

FIGURE 22: ASSESSMENT OF TALAR SHIFT

5. Assessment of Talar Tilt

FIGURE 23: ASSESSMENT OF TALAR TILT

The sup joint space on the med & lat joint borders can be measured to assess the talar inclination. It shows that the talar inclination is more than 2 mm. The angle created by the inter-malleolar line and the sup & inf surfaces of ankle can also be used to measure talar tilt.

Normal talar tilt | Abnormal talar tilt

FIGURE 24: NORMAL & ABNORMAL TALAR TILT

6. Assessment of Fibular Length and Displacement

By sketching a ball for the ankle, one can determine the fibular length. The fibula, which has a little spike, can be identified in MORTISE view by following the thick bone of tibia over the syndesmotic gap. A tibial subchondral bow is precisely where the spike points are located.

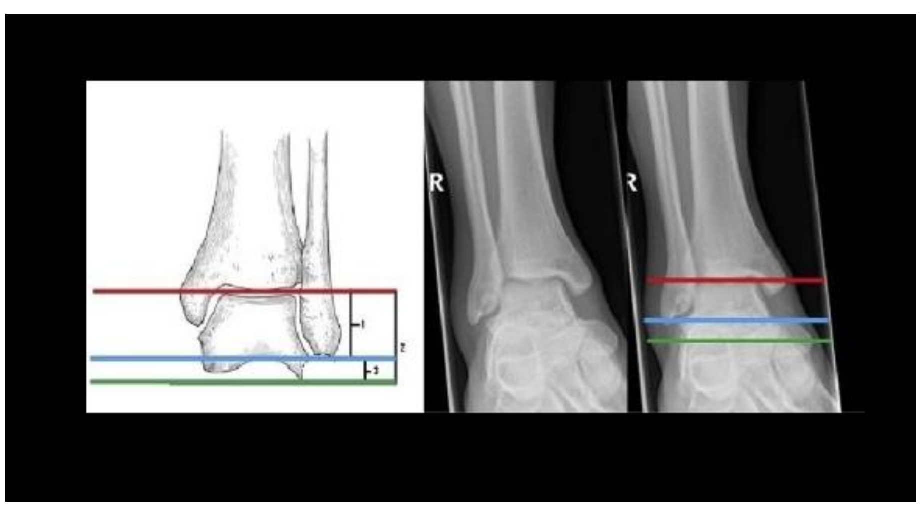


FIGURE 25: ASSESSMENT OF FIBULAR LENGTH & DISPLACEMENT

Fibular shortening breaks the ball sign. The dime sign, which joins the end tip to lateral process of talus, is an unbroken curve on an AP radiograph when the fibula is extended. When the fibula is mal reduced, there is no dime indication in the fracture.

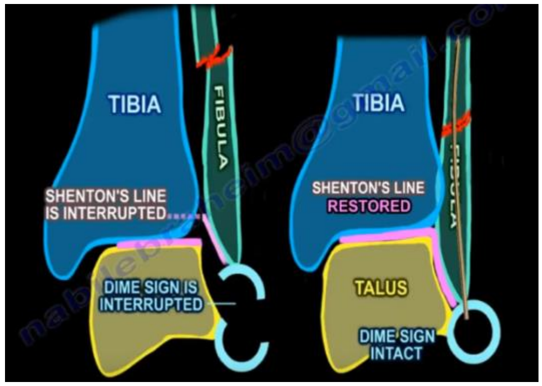


FIGURE 26: FIBULAR SHORTENING

7. Assessment of Talocrural Angle

An angle that exists between the tibial plafond and a line that is perpendicular to it is known as the talocrural angle. An $83^0 \pm 4^0$ range is typical. This angle ought to be between 2^0 and 3^0 degrees from the undamaged ankle.

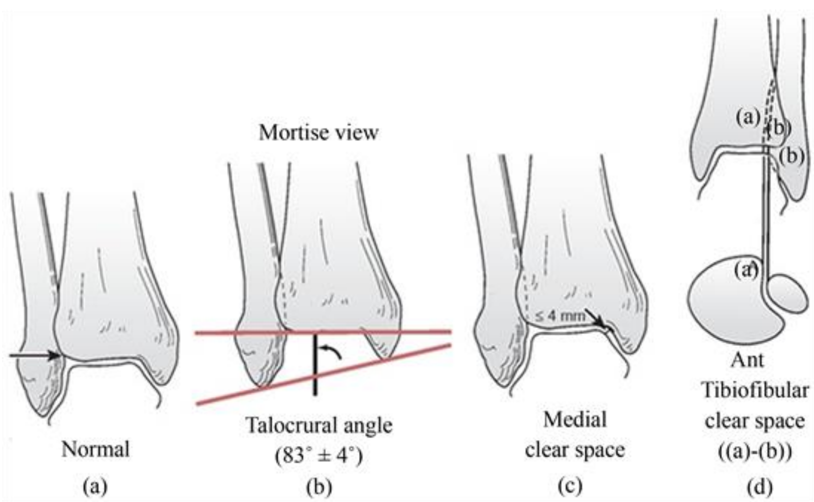


FIGURE 27: ASSESSMENT OF TALOCRURAL ANGLE

MATERIALS AND METHODS

Source of Data: All the patients admitted in Dr KLE's Prabhakar Kore Hospital diagnosed with ankle fractures involving articular surface of distal two bones and planned for treatment.

Study Design: CROSS-SECTIONAL STUDY

Study Period: ONE YEAR

Sample Size: Sample size formula:

Based on prevalence rate, the minimal sample size calculation is

$$n = \frac{z_{\alpha}^{2} P(1-P)}{d^{2}}$$

where d is the percentage probability difference in the prevalence and P is the prevalence rate. The significance level is associated with zα. zα = 1.96 at the 5% level of significance.

The percentage of concurrent ankle and distal one-third spiral tibial shaft fractures, which is 84%, is the parameter taken into account in the computation. The sample size is 33 with P = 84% and d = 15% of P = 12.6%.

Sampling technique: Random selection of patients was done who were admitted to Orthopaedic department of JNMC, who fit the the inclusion and exclusion criteria.

Inclusion Criteria:

1. Adult patients (18 to 70 years)
2. All distal end tibia fractures with intra articular extension requiring treatment.
3. Patients willing to be a part of the study
4. Patients requiring CT 3D RECON scan.

Exclusion Criteria:

1. Open fractures
2. Paediatric fractures
3. Distal end tibia fractures without intra articular extension.
4. Patients who are not willing to provide informed consent

Data collection procedure: : All patients coming to the Tertiary Care Hospital complaining with pain over the ankle following any trauma or injury to the ankle; and admitted under the orthopaedics department was examined and evaluated for ankle fractures. Patients' histories were obtained, and in order to rule out any additional clinical abnormalities, a comprehensive clinical examination and regular investigations were conducted. Patients were advised to get Plain CTscan of the ankle joint with 3D reconstruction. 3D CT video and reconstructed films was studied and fracture pattern, mechanism of injury, morphological features were recorded in an excel sheet and studied further. This recorded data was used to classify the Ankle fractures based on novel 4column classification.

Data Processing and Analysis/ Statistical analysis:

Frequency, percentage, X, and SD were the descriptive statistics to summarise the data that was gathered. Age was compared by gender, side affected, and four column fracture categorisation using the sample "t" test. Using the ratio test, disparities in proportions were compared. P values less than 0.05 were regarded as significant. The SPSS program (SPSS Inc.; Chicago, IL) version 29.0.10 was used to analyse the data.

RESULTS

The study comprehensively evaluated the morphological distribution of ankle fractures using the novel four-column classification system, revealing key insights into demographic patterns, fracture characteristics, and their associations with mechanisms of injury. Participants ranged from 14 to 76 years, with a mean age of 43.12 ± 16.79 years

Table 1: Descriptive Statistics for age

(n = 33)	Range	Mean	S.D.
Age (Years)	14 to 76	43.12	16.79

Table 2: Distribution of gender and side affected

		Frequency	%
Gender	Male	20	60.6
	Female	13	39.4
Side affected	Right	17	51.5
	Left	16	48.5

Among the 33 participants; the majority were males (60.6%); and the 39.4% were females. The majority of the cases were affected with right side (51.5%); and the left side affected cases includes 48.5%. [Table -2]

Table 3: Comparison of age according to gender

		Mean	S.D.	"t"	p value
Age (Years)	Male	45.10	15.94	0.84	0.410
	Female	40.08	18.26		

(“t” = Independent sample “t” test)

The mean age for males was 45.10 ± 15.94 years, while for females, it was 40.08 ± 18.26 years. The independent sample t-test revealed no statistically significant difference in age between genders (p = 0.410). [Table - 3]

Table 4: Comparison of age according to side affected

		Mean	S.D.	"t"	p value
Age (Years)	Right	40.06	14.55	-1.08	0.287
	Left	46.38	18.82		

(“t” = Independent sample “t” test)

Participants with right-side fractures had a mean age of 40.06 ± 14.55 years, compared to 46.38 ± 18.82 years for those with left-side fractures. The difference was not statistically significant (p = 0.287) [Table - 4]

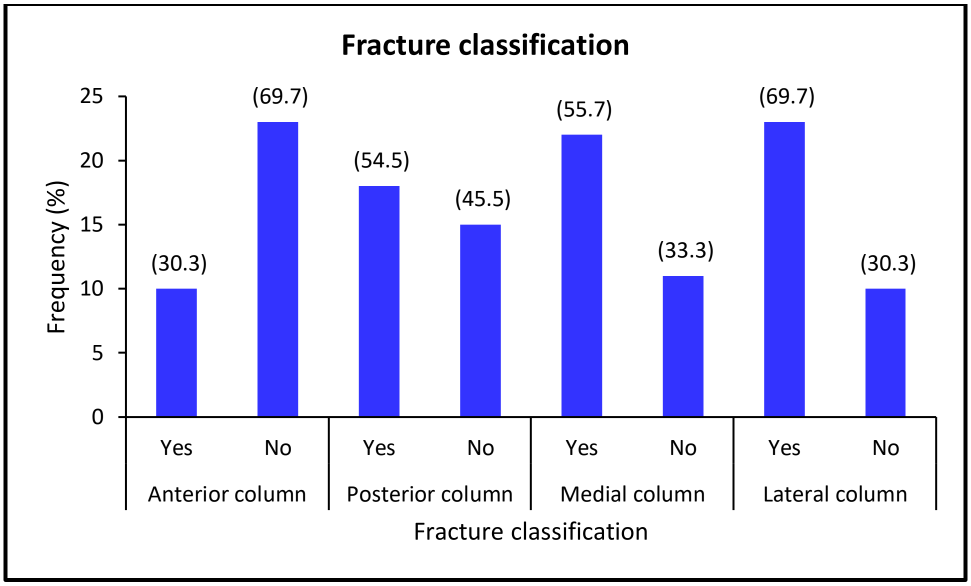
Table 5: Comparison of side affected according to gender

		Gender				Chi square	p value
		Male		Female			
		n	%	n	%		
Side affected	Right	12	60	5	38.5	1.463	0.226
	Left	8	40	8	61.5		

The Chi square test was used to compare side affected according to gender. There was no difference ($p > 0.05$) in side affected; between males and females. These results suggest that gender does not strongly influence the side of injury. [Table - 5]

Table 6: Four Column Fracture classification

Fracture classification	Yes		No	
	n	%	n	%
Anterior column	10	30.3	23	69.7
Posterior column	18	54.5	15	45.5
Medial column	22	66.7	11	33.3
Lateral column	23	69.7	10	30.3



GRAPH 1: FOUR COLUMN FRACTURE CLASSIFICATION

The lateral column was the most frequently involved (69.7%), followed by the medial (66.7%), posterior (54.5%), and anterior (30.3%) columns. This distribution aligns with the biomechanical vulnerabilities of the lateral and medial columns, which bear significant loads during ankle motion.[Table -6]

Table 7: Association between four column fracture classification and gender

Fracture classification		Gender				Likelihood ratio / Chi square#	p value
		Male		Female			
		n	%	n	%		
Anterior column	Yes	6	30	4	30.8	0.002	0.963
	No	14	70	9	69.2		
Posterior column	Yes	8	40	10	76.9	4.33#	0.037*
	No	12	60	3	23.1		
Medial column	Yes	12	60	10	76.9	1.044	0.307
	No	8	40	3	23.1		
Lateral column	Yes	11	55	12	92.3	5.909	0.015*
	No	9	45	1	7.7		

(* Significant, p<0.05)

The chi-square test or likelihood ratio revealed significant associations between gender and posterior ($p = 0.037$) and lateral ($p = 0.015$) column fractures, with females showing higher prevalence in these categories.[Table -7]

Table 8: Comparison of four column fracture classification according to age

Fracture classification		Mean	S.D.	"t"	p value
Anterior column	Yes	44.60	13.71	0.33	0.744
	No	42.48	18.22		
Posterior column	Yes	43.50	15.36	0.14	0.890
	No	42.67	18.92		
Medial column	Yes	42.05	18.29	-0.51	0.611
	No	45.27	13.87		
Lateral column	Yes	46.83	16.16	2.01	0.053
	No	34.60	15.76		

The Independent sample "t" test was used to compare age; according to fracture classification. There was no difference ($p > 0.05$) in the age according to fracture classification.

No significant age differences were observed in relation to any column fractures. [Table – 8]

Table 9: Association between four column fracture classification and side affected

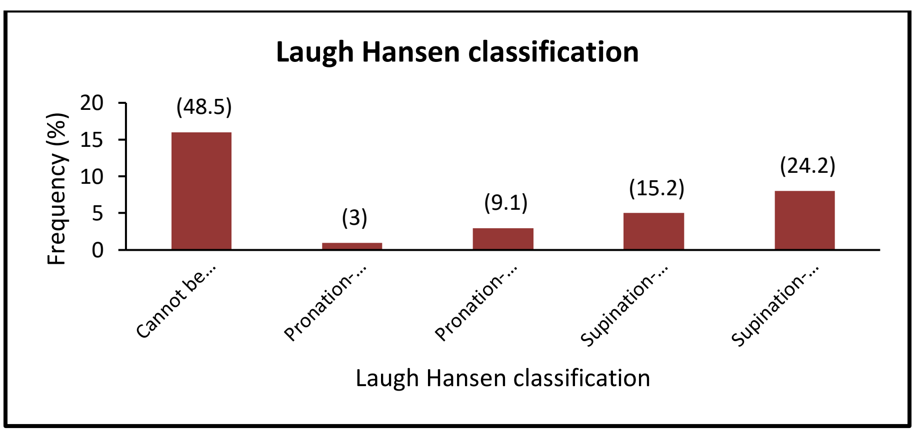
Fracture classification		Side affected				Likelihood ratio / Chi square#	p value
		Right		Left			
		n	%	n	%		
Anterior column	Yes	7	41	3	19	2.008	0.156
	No	10	59	13	81		
Posterior column	Yes	10	59	8	50	0.26#	0.611
	No	7	41	8	50		
Medial column	Yes	12	71	10	63	0.24#	0.622
	No	5	29	6	38		
Lateral column	Yes	10	59	13	81	2.008	0.156
	No	7	41	3	19		

The Chi square or Likelihood ratio test was used to find the association between the fracture classification and side affected. The fracture classifications were not associated ($p > 0.05$) with side affected. [Table – 9]

Table 10: Laugh Hansen classification

Laugh Hansen classification	Frequency	%
Cannot be classified	16	48.5
Pronation- Abduction	1	3
Pronation- External rotation	1	3
Pronation- External rotation	1	3
Pronation-External rotation	1	3
Supination-Adduction	1	3
Supination-Adduction	3	9.1
Supination-Adduction	1	3
Supination-External rotation	2	6.1
Supination-External rotation	1	3
Supination-External rotation	3	9.1
Supination-External rotation	1	3
Supination-External rotation	1	3

Table 10 classified fractures based on the Lauge-Hansen system, revealing that 48.5% of cases were unclassifiable. Among classifiable fractures, supination-external rotation was the most common mechanism (24.2%), followed by supination-adduction (15.2%). Other mechanisms, including pronation-external rotation and pronation-abduction, were rare.

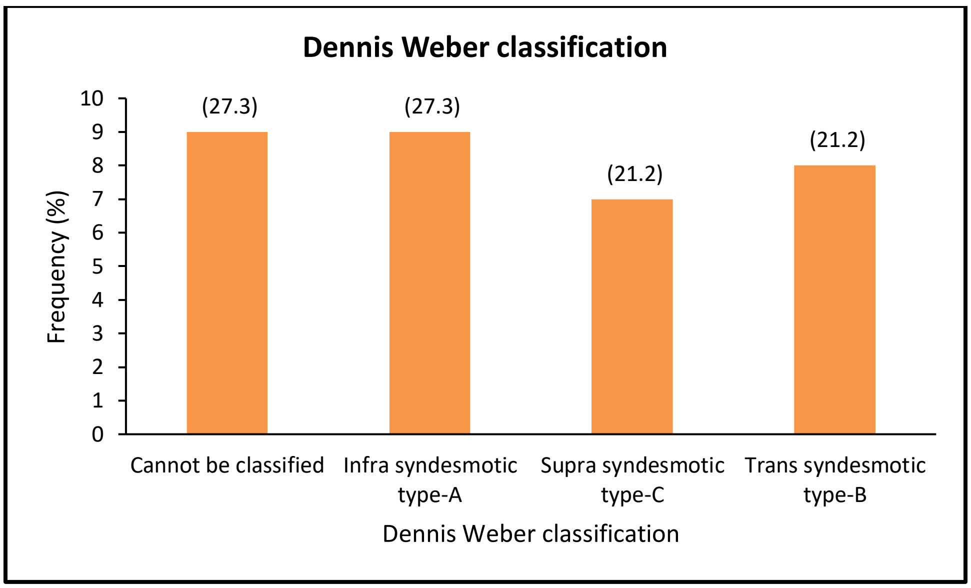


GRAPH 2: LAUGH HANSEN CLASSIFICATION

Table 11: Dennis Weber classification

Dennis Weber classification	Frequency	%
Cannot be classified	9	27.3
Infra syndesmotic type-A	9	27.3
Supra syndesmotic type-C	7	21.2
Trans syndesmotic type-B	8	24.2

The fractures were evenly distributed among infra-syndesmotic (Type A; 27.3%), trans-syndesmotic (Type B; 24.2%), and supra-syndesmotic (Type C; 21.2%) categories, with 27.3% unclassifiable.

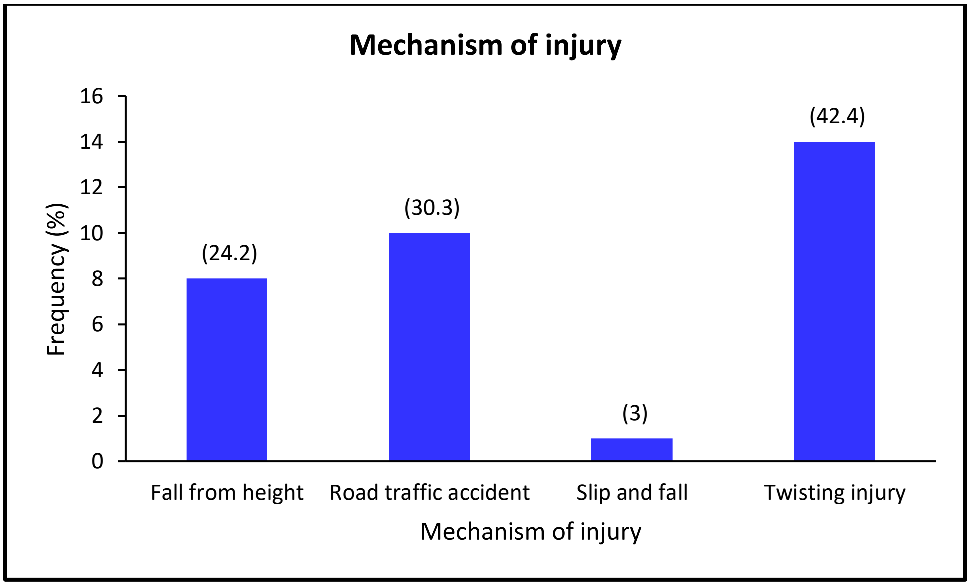


GRAPH 3: DENNIS WEBER CLASSIFICATION

Table 12: Mechanism of injury

Mechanism of injury	Frequency	%
Fall from height	8	24.2
Road traffic accident	10	30.3
Slip and fall	1	3
Twisting injury	14	42.4

Twisting injuries accounted for 42.4% of fractures, followed by road traffic accidents (30.3%) and falls from height (24.2%).



GRAPH 4: MECHANISM OF INJURY

Table 13: Comparison of Dennis Weber classification, and mechanism of injury according to gender

		Gender				Likelihood ratio	p value
		Male		Female			
		n	%	n	%		
Dennis Weber classification	Cannot be classified	8	40	1	7.7	7.049	0.070
	Infra syndesmotic Type-A	6	30	3	23.1		
	Supra syndesmotic Type-C	2	10	5	38.5		
	Trans syndesmotic type B	4	20	4	30.8		
Mechanism of injury	Fall from height	3	15	5	38.5	3.455	0.327
	Road traffic accident	6	30	4	30.8		
	Slip and fall	1	5	0	0		
	Twisting injury	10	50	4	30.8		

The Likelihood ratio test was used to compare Dennis Weber classification, and mechanism of injury according to gender. There was no difference ($p > 0.05$).

Table 14: Comparison of Dennis Weber classification, and mechanism of injury according to side affected

		Side affected				Likelihood ratio	p value
		Right		Left			
		n	%	n	%		
Dennis Weber classification	Cannot be classified	6	35.3	3	18.8	2.657	0.448
	Infra syndesmotic Type-A	3	17.6	6	37.5		
	Supra syndesmotic Type-C	3	17.6	4	25.0		
	Trans syndesmotic type B	5	29.4	3	18.8		
Mechanism of injury	Fall from height	5	29.4	3	18.8	2.148	0.542
	Road traffic accident	5	29.4	5	31.3		
	Slip and fall	1	5.9	0	0		
	Twisting injury	6	35.3	8	50.0		

No significant associations were observed between Denis Weber classifications or mechanisms of injury and the affected side.

Table 15: Comparison of Dennis Weber classification according to mechanism of injury

Dennis Weber classification	Mechanism of injury								Likelihood ratio	p value
	Fall from height		Road traffic accident		Slip and fall		Twisting injury			
	n	%	n	%	n	%	n	%		
Cannot be classified	1	12.5	4	40	0	0	4	28.6	15.26	0.084
Infra syndesmotic Type-A	1	12.5	2	20	0	0	6	42.9		
Supra syndesmotic Type-C	3	37.5	3	30	1	100	0	0.0		
Trans syndesmotic type B	3	37.5	1	10	0	0	4	28.6		

Table 15 showed showed trends linking specific fracture types according to Dennis Weber classification to injury mechanisms:falls from height were associated with supra- and trans-syndesmotic fractures, while twisting injuries often caused infra-syndesmotic fractures.

Table 16: Comparison of four column fracture classification according to Dennis Weber classification

Fracture classification		Dennis Weber classification								Likelihood ratio	p value
		Cannot be classified		Infra syndesmotic Type-A		Supra syndesmotic Type-C		Trans syndesmotic type B			
		n	%	n	%	n	%	n	%		
Anterior column	Yes	4	44.4	1	11.1	2	28.6	3	37.5	2.88	0.411
	No	5	55.6	8	88.9	5	71.4	5	62.5		
Posterior column	Yes	3	33.3	3	33.3	7	100	5	62.5	11.975	0.007*
	No	6	66.7	6	66.7	0	0	3	37.5		
Medial column	Yes	6	66.7	4	44.4	5	71.4	7	87.5	3.783	0.286
	No	3	33.3	5	55.6	2	28.6	1	12.5		
Lateral column	Yes	0	0	9	100	6	85.7	8	100	34.743	< 0.001*
	No	9	100	0	0	1	14.3	0	0		

(* Significant)

Table 16 analyzed the relationship between fracture patterns (anterior, posterior, medial, and lateral columns) and Denis Weber classifications. Significant associations were observed for posterior column fractures with supra-syndesmotic (Type C) fractures ($p = 0.007$) and for lateral column fractures with infra- and trans-syndesmotic (Type A and B) fractures ($p < 0.001$).

Table 17: Association between four column fracture classification and mechanism of injury

Fracture classification		Mechanism of injury								Likelihood ratio	p value
		Fall from height		Road traffic accident		Slip and fall		Twisting injury			
		n	%	n	%	n	%	n	%		
Anterior column	Yes	6	75	2	20	0	0	2	14.3	10.00	0.019*
	No	2	25	8	80	1	100	12	85.7		
Posterior column	Yes	8	100	7	70	1	100	2	14.3	21.77	< 0.001*
	No	0	0	3	30	0	0	12	85.7		
Medial column	Yes	7	87.5	7	70	1	100	7	50.0	4.36	0.225
	No	1	12.5	3	30	0	0	7	50.0		
Lateral column	Yes	7	87.5	6	60	0	0	10	71.4	4.25	0.236
	No	1	12.5	4	40	1	100	4	28.6		

(* Significant) The association between fracture classification and mechanism of injury. Significant associations were found: posterior column fractures were linked to twisting injuries ($p < 0.001$), and anterior column fractures were associated with falls from height ($p = 0.019$).

Table 18: Laugh Hansen classification

Laugh Hansen classification	Frequency	%
Cannot be classified	16	48.5
Pronation-abduction	1	3
Pronation-external rotation	3	9.1
Supination-adduction	5	15.2
Supination-external rotation	8	24.2

Table 18 classified fractures using the Lauge-Hansen system, showing that nearly half (48.5%) of the fractures were unclassifiable. Among classifiable fractures, supination-external rotation (24.2%) was the most frequent mechanism, followed by supination-adduction (15.2%)

Table 19: Comparison between four column fracture classification and Laugh Hansen classification

		Laugh Hansen classification										Likelihood ratio	p value
		Cannot be classified		Pronation-abduction		Pronation-external rotation		Supination-adduction		Supination-external rotation			
		n	%	n	%	n	%	n	%	n	%		
Anterior column	Yes	10	62.5	0	0	0	0	0	0	0	0	19.32	0.001 *
	No	6	37.5	1	100	3	100	5	100	8	100		
Posterior column	Yes	10	62.5	0	0	3	100	1	20	4	50	8.21	0.084
	No	6	37.5	1	100	0	0	4	80	4	50		
Medial column	Yes	12	75	1	100	3	100	4	80	2	25	10.01	0.040 *
	No	4	25	0	0	0	0	1	20	6	75		
Lateral column	Yes	7	43.8	1	100	2	66.7	5	100	8	100	14.74	0.005 *
	No	9	56.3	0	0	1	33.3	0	0	0	0		

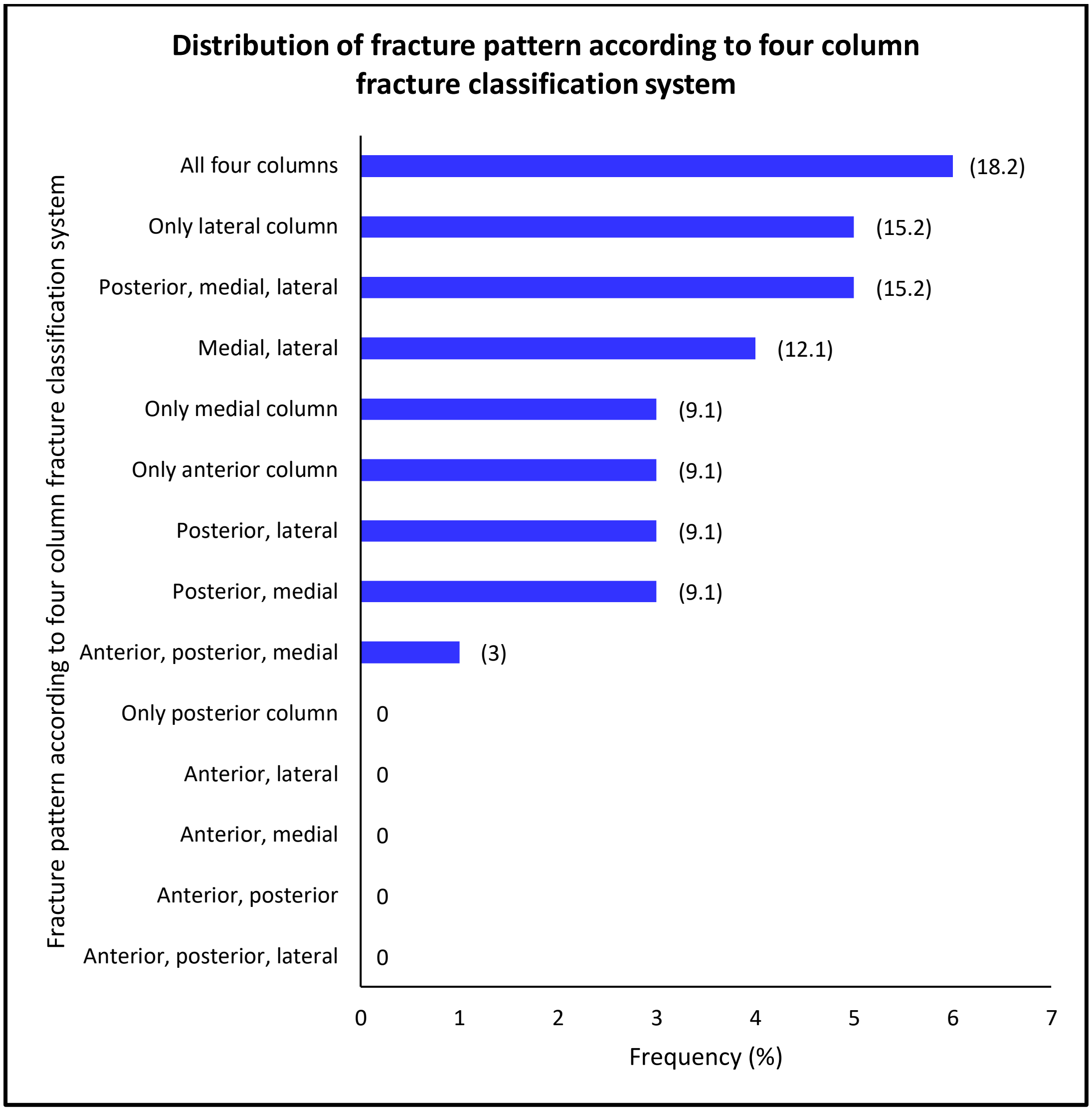
(* Significant)

This table analyzed the relationship between the four-column classification and Lauge-Hansen mechanisms. Significant associations were found: anterior column fractures were predominantly linked to unclassifiable injuries (p = 0.001), medial column fractures to supination-adduction injuries (p = 0.040), and lateral column fractures to supination-external rotation injuries (p = 0.005).

Table 20: Distribution of fracture pattern according to four column fracture classification system

	Frequency	%
All four columns	6	18.2
Anterior, posterior, medial	1	3.0
Anterior, posterior, lateral	0	0.0
Posterior, medial, lateral	5	15.2
Anterior, posterior	0	0
Anterior, medial	0	0
Anterior, lateral	0	0
Posterior, medial	3	9.1
Posterior, lateral	3	9.1
Medial, lateral	4	12.1
Only anterior column	3	9.1
Only posterior column	0	0
Only medial column	3	9.1
Only lateral column	5	15.2

The distribution of fracture patterns showed that 18.2% of cases involved all four columns, while the remaining patterns reflected varied multi-column or isolated column injuries. This distribution underscores the utility of the four-column system in capturing the complexity of ankle fractures, providing a detailed framework for clinical decision-making.[Table 20]



GRAPH 5: DISTRIBUTION OF FRACTURE PATTERN ACCORDING TO FOUR COLUMN FRACTURE CLASSIFICATION SYSTEM

DISCUSSION

Using the new four-column categorisation system, this study wanted to evaluate morphological distribution of ankle fractures during a one-year period in a tertiary care setting. Adult patients with distal tibial fractures displaying intra-articular extension were among them. An extensive evaluation of fracture patterns, classified into anterior, posterior, medial, and lateral columns, was made possible by the use of 3D CT reconstruction. Analysis of column-specific involvement and related damage processes was done on 33 individuals.

The results showed no much variation in ages of patients & that age distribution of ankle fractures was consistent between males and females. This suggests that factors like trauma mechanisms or activity levels are more likely to contribute to fracture risk than age.

The results also showed that the posterior and anterior columns were the next most frequently fractured, after the lateral and medial columns. The lateral and medial structures of these columns bear significant loads during weight-bearing and ankle movement, which is consistent with their biomechanical functions. The anterior column's structural placement and the surrounding tissues' protective support may be the reason for its comparatively reduced participation. Multi-column fractures were common, with 18.2% of cases including all four columns, highlighting the complexities of high-energy trauma encountered in intra-articular ankle fractures. In the Denis Weber classification, posterior column fractures were frequently associated with supra-syndesmotic (Type C) fractures, emphasising their close relationship with syndesmotic injuries that are critical for ankle stability. In contrast, anterior column fractures were primarily related with falls from height, indicating that axial compression played a substantial role in these injuries.

The male preponderance among the 33 participants—60.6% male and 39.4% female—is probably related to increased exposure to high-risk activities or occupational risks. This is consistent with a 2021 study in which the author discovered that men were more likely than women to sustain ankle fractures. [54] Significant correlations between gender and posterior ($p = 0.037$) and lateral ($p = 0.015$) column fractures were found by the tests; the occurrence of these fractures was higher in females. This might be explained by variations in bone density, biomechanics, or activity patterns between the sexes, such as the increased risk of fractures or rotational injuries in women due to osteoporosis. Females may be more susceptible to rotational injuries due to lower bone mineral density and ligament strength disparities. Twisting injuries were the most common mechanism (42.4%), followed by car accidents and falls from heights. According to one study, women are more likely to sustain foot and ankle injuries than males, with anatomical, hormonal, and biomechanical factors all playing a role. [55] These findings highlight the need of taking into account both demographic parameters and trauma mechanisms when examining fracture patterns.

Although there was no substantial difference between the two sides, the right side was somewhat more impacted than the left (51.5% versus 48.5%), suggesting that random trauma mechanisms rather than dominance may determine the side of injury. While road traffic accidents and falls from heights typically result in high-energy injuries with more intricate patterns, twisting injuries are often associated with low-energy trauma that causes rotational fractures. The afflicted side did not significantly correlate with Denis Weber classifications or mechanisms of injury. The idea that side dominance or anatomical variations between the right and left ankles are not reliable indicators of fracture patterns is supported by this study.

The Lauge-Hansen approach was unable to classify nearly half (48.5%) of the fractures, revealing its limits when dealing with complex or multi-column fractures. The most prevalent recognised pattern was supination-external rotation (24.2%). This finding emphasises the inadequacies of existing approaches for categorising all fracture patterns, particularly those involving high-energy causes. The fractures were evenly divided among three categories: infra-syndesmotic (Type one; 27.3%), trans-syndes (Type 2; 24.2%), & supra-syndesmotic (Type 3rd; 21.2%), with 27.3% unclassifiable. This uniform distribution reflects the wide range of damage mechanisms and fracture types seen. However, the large number of unclassifiable fractures highlights the need for a more thorough and anatomically orientated classification system.

The relationship between fracture patterns (anterior, posterior, medial, and lateral columns) and Denis Weber classifications showed significant associations for posterior column fractures with supra-syndesmotic (Type C) fractures ($p = 0.007$) and lateral column fractures with infra- and trans-syndesmotic (Type A and B) fractures ($p < 0.001$). These data suggest that Denis Weber classifications can only partially predict column-specific fracture patterns and struggle to account for multi-column involvement or complex injuries.

The four-column classification and Lauge-Hansen mechanisms showed significant associations: anterior column fractures were primarily linked to unclassifiable injuries ($p = 0.001$), medial column fractures to supination-adduction injuries ($p = 0.040$), and lateral column fractures to supination-external rotation injuries ($p = 0.005$). These findings show the anatomical uniqueness of the four-column system in relating fracture patterns to distinct causes, filling gaps left by L-H classification.

According to the distribution of fracture patterns, all four columns were implicated in 18.2% of cases, with the other patterns reflecting isolated or variable multi-column injuries. By offering a thorough framework for clinical decision-making, this distribution highlights the value of the four-column approach in expressing the complexity of ankle fractures.

The Lauge-Hansen approach, which is best suited for rotational injuries and cannot account for high-energy trauma involving numerous columns, was unable to classify nearly half of the fractures. According to a study, the Danis-Weber system exhibits good consistency than A-O & Lauge-Hansen classifications. [45] Likewise, although the Denis Weber classification aids in determining fibular involvement, it is devoid of the anatomical specificity required to adequately characterise multi-column fractures. The benefits of the four-column classification method, which offers a more thorough understanding of fracture morphology and its relationship to trauma causes, are highlighted by these drawbacks.

LIMITATIONS OF THE STUDY

Small Sample Size: The study included just 33 patients, which may have reduced the generalisability of the findings. A larger sample size is necessary for stronger statistical significance and validation of the results.

Single-Center Study: Because this study was only carried out in one tertiary care institution, its findings might not be universally applicable to other populations or healthcare environments.

Possibility of Observer Bias: When implementing a novel classification system without established protocols or training, observer bias may affect how fracture patterns are interpreted and classified.

STRENGTHS OF THE STUDY

In contrast to conventional techniques, the four-column categorization system used in this study offers a more thorough and anatomically focused framework for examining ankle fractures. This invention fills up the classification gaps for complicated multi-column injuries.

The study offers a thorough understanding of fracture patterns by breaking down the participation of the front, posterior, medial & lateral columns and their relationships to age, gender, and injury mechanisms.

The work greatly advances our knowledge of ankle fractures and opens the door to better classification and management techniques by utilising sophisticated imaging, addressing multi-column injuries, and exposing the shortcomings of conventional system

CONCLUSION

The Four-Column Classification is an innovative and effective method to the morphological classification of ankle fractures, providing a more complete and anatomically precise framework than existing classifications. This categorization, which divides the ankle structure into anterior, posterior, medial, and lateral columns, gives a complete assessment of fracture patterns, allowing for more precise diagnosis and treatment planning.

When compared to existing classification methods such as LAUGE Hansen, Danis-Weber & AO, the Four-Column Classification improves understanding of complex ankle fractures by including three-dimensional anatomical considerations. Studies have shown that it improves interobserver agreement and reproducibility, implying that it has the potential to standardise ankle fracture examinations across a range of clinical contexts.

Additionally, by classifying fractures according to their particular anatomical involvement, this classification system helps surgeons to customise treatment plans. This focused strategy helps patients recover more functionally, have fewer problems, and have better surgical results.

To sum up, the morphological classification of ankle fractures has advanced significantly with the Four-Column Classification. Its anatomically-driven, organised framework facilitates more effective and individualised treatment planning in addition to increasing diagnostic accuracy. Its usefulness in improving the management of ankle fractures will be further established by future studies and clinical validation.

SUMMARY OF THE STUDY

The purpose of this cross-sectional study was to assess the morphological distribution of ankle fractures over a one-year period in a tertiary care context using the novel four-column categorisation system. Thirty-three adults with distal tibial fractures displaying intra-articular extension were included in the investigation. Using 3D CT reconstruction, fractures were divided into anterior, posterior, medial, and lateral columns, enabling a thorough analysis of patterns and their connection to damage causes. The male preponderance among the participants—60.6% male and 39.4% female—probably reflects more exposure to high-risk activities or occupational risks. The most frequent mechanism of injury was twisting (42.4%), which was followed by falls from a height and traffic accidents. Although there was no discernible difference between the two sides, right-side injuries (51.5%) marginally outnumbered left-side injuries (48.5%), indicating that side dominance had little bearing on fracture patterns.

The results showed that the posterior and anterior columns were the next most commonly fractured, followed by the lateral and medial columns. This distribution is consistent with the biomechanical functions of these structures, which include significant loads being placed on the medial and lateral components during movement and weight bearing. . Due to the complexity of high-energy trauma, multi-column involvement was prevalent, occurring in 18.2% of cases involving all four columns. In the Denis Weber classification, posterior column fractures were often linked to supra-syndesmotic (Type C) fractures ($p = 0.007$), highlighting their connection to syndesmotic injuries that are essential for ankle stability. Infra- and trans-syndesmotic (Type A and B) fractures were linked to lateral column fractures ($p < 0.001$). While lateral column fractures were more frequently associated with twisting injuries, anterior column fractures were mostly associated with falls from height, suggesting axial compression as a key cause.

Females had a higher prevalence of posterior ($p = 0.037$) and lateral ($p = 0.015$) column fractures, according to gender-specific analysis. Given that women are more likely to have rotational injuries and osteoporosis-related injuries, this results might be the result of variations in bone density, ligament strength, and activity patterns. Due mainly to its emphasis on rotational injuries and incapacity to handle high-energy trauma involving several columns, the Lauge-Hansen method showed shortcomings, with 48.5% of fractures appearing to be unclassifiable. Medial column fractures were linked to supination-adduction injuries ($p = 0.040$), whereas lateral column fractures were linked to supination-external rotation injuries ($p = 0.005$). Supination-external rotation was the most frequently identified mechanism (24.2%). The Denis Weber classification lacked the anatomical complexity required to describe complex multi-column injuries, but it was able to anticipate fracture patterns specific to individual columns to a certain extent.

Overall, the study emphasizes the importance of the four-column classification method in providing a more complete understanding of ankle fracture morphology. It successfully connects column-specific patterns to injury mechanisms, filling gaps left by previous systems like Lauge-Hansen and Denis Weber. Almost half of the fractures could not be identified using traditional methods, emphasizing the importance of anatomically orientated classifications that better handle the complexity of intra-articular and high-energy fractures. This approach provides considerable clinical decision-making benefits by capturing the full anatomy and processes of multi-column ankle fractures.

FUTURE SCOPE OF THE STUDY

The study lays the groundwork for future research into the utility of the four-column system, including its prognostic value and ability to improve treatment outcomes, hence encouraging its widespread adoption and development.

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ANNEXURE I

INFORMED CONSENT FORM

KAHERs JNMC
BELAGAVI

"STUDY OF MORPHOLOGICAL DISTRIBUTION OF ANKLE FRACTURES BASED ON THE NOVEL FOUR COLUMN FRACTURE CLASSIFICATION-A ONE YEAR HOSPITAL BASED CROSS-SECTIONAL STUDY "

This informed consent form is for men and women who come to Dr Prabhakar Kore Hospital and Medical research Centre ,Belagavi and who are we are inviting to participate in the study" STUDY OF MORPHOLOGICAL DISTRIBUTION OF ANKLE FRACTURES BASEDON THE NOVEL FOUR COLUMN FRACTURE CLASSIFICATION"

Introduction: I, am conducting a cross sectional study on morphological distribution of ankle fractures based on the novel four column fracture classification. I am going to give u information and invite you to be a part of this research. There may be some words that you may not understand .Please contact me for more information as needed.

Ankle Fracture are a great challenge to orthopaedic surgeons because of difficulties in the anatomic reconstruction and fixation. High energy trauma including falls from heights or road traffic accidents may cause this kind of injury. Ankle fractures are related to significant soft tissue injury, which may cause failure of fixation and multiple complications. Operative decision making of ankle fractures are of great challenge to orthopaedic surgeons as a whole. The clinical classification of ankle fractures determines the fixation plan and ultimately the outcome. Earlier classification systems focus mainly on the mechanism of injury which does not give a definitive operative idea. The Four Column classification is based on local anatomical characteristics of distal tibia and fibula. This Study aims at determining the Morphological distribution of Ankle Fractures based on the four column fracture classification to understand the mechanism of ankle fractures and further aid the surgical procedures in the form of column fixation.

Explanation of procedure: All patients coming to the KLE's Dr Prabhakar Kore Hospital with complains of pain over the ankle following any trauma or injury to the ankle; and admitted under the orthopaedics department would be examined and evaluated for ankle fractures. Detailed history of patients will be taken and thorough clinical examination and routine investigations will be done to rule out any other clinical abnormality. A plan radiograph of the ankle in AP-lateral view will be taken. Patients with ankle fractures will be advised to get Plain CT scan of the ankle joint with 3D reconstruction. 3D CT video and reconstructed films would be studied and fracture pattern, mechanism of injury, morphological features would be recorded in an excel sheet and studied further. This recorded data would be used to classify the Ankle fractures based on novel 4 column classification

Withdrawal from participation in the study: Any patient not willing to continue with the study can withraw from the study at any given time. Participation in this study is completely voluntary. You will be free to decide whether to participate in this study or continue participation once enrolled. In case you decide to withdraw your participation, you are free to do so. However, please convey the decision to the principal investigator.

Possible benefits from participating in the study: The patient will not get any benefits by participating in this study. The data gathered will help population at large.

Possible risks from participating in the study: There are no risks involved in participating in this study. It is an observational study. No intervention will be carried out hence the study does not pose any risk.

Privacy and confidentiality: The information collected from you will be coded, to prevent any person to identify you. Your identity will never be revealed. The data collected from you will be kept confidential and only processed or aggregated data will be used for publication.

Financial incentives: You will not receive any payment or financial incentives for participating in this study. Cost of investigations done during the course of study will be paid by the Participant. (Strike out which is not applicable)

Authorization for publication of aggregated data: Results obtained after processing of the aggregated data will be published for scientific purpose and or presented to scientific groups.

However, your identity will never be revealed.

Legal rights: By signing this consent form, we are not waving any of your legal rights

CONSENT STATEMENT

I am making a voluntary decision to participate in the study “STUDY OF MORPHOLOGICAL DISTRIBUTION OF ANKLE FRACTURES BASED ON THE NOVEL FOUR COLUMN FRACTURE CLASSIFICATION-A ONE YEAR HOSPITAL BASED CROSS-SECTIONAL STUDY”. My signature below indicates that I have decided to participate and I have read the information provided above or the information provided above has been read to me in the language that I understand best. I was given the opportunity to ask questions and that they have been answered to my satisfaction.

Name of the participant:

Signature or left thumb impression of the participant:

Name of the witness:

Signature or left thumb impression of the witness:

Name of the investigator:

Signature of the investigator:

ANNEXURE- II

PROFORMA

Patient Name:

Date of Scan:

Age:

Sex:

Ip No:

1. **Classification according to 4 Column Classification (Column involved):**
    a) **Medial Column**
    b) **Anterior Column**
    c) **Posterior Column**
    d) **Lateral Column**

2. **Classification according to Laugh Hansen:**
3. **Classification according to Dennis Weber:**
4. **Mechanism of Injury:**
5. **Side involved**

Comments if any

KEY TO MASTER CHART

Serial No.	Age	Sex	IP No	Date	Side	Anterior columr	Posterior column	Medial columr	Lateral column	Laugh Hansen classification	Dennis Weber classification	Mechanism of injury	Comments
1	36	female	C45806	23-12-2023	Right	yes	yes	yes	yes	cannot be classified	Trans syndesmotic type B	Fall from height	
2	42	male	C117119959	16-05-2023	Right	no	no	no	yes	Supination-Adduction	Infra syndesmotic Type-A	Road traffic accident	
3	54	female	C12422050	23-07-2023	left	no	yes	yes	yes	Supination-Adduction	Infra syndesmotic Type-A	Road traffic accident	
4	50	male	12486815	29-07-2023	right	no	yes	no	yes	Supination-External rotation	Infra syndesmotic Type-A	Twisting injury	ligament integrity not known
5	64	female	1172794	24-02-2023	right	yes	yes	yes	yes	cannot be classified	Trans syndesmotic type B	Fall from height	
6	31	male	1173788	05-03-2023	left	yes	yes	yes	yes	cannot be classified	Infra syndesmotic Type-A	Fall from height	
7	55	male	7339530	08-02-2023	left	yes	yes	yes	yes	cannot be classified	Supra syndesmotic Type-C	Fall from height	
8	24	male	10016957	29-10-2023	right	no	yes	yes	no	Pronation- External rotation	Supra syndesmotic Type-C	Slip and fall	
9	68	male	10010189	28-09-2023	left	no	no	no	yes	Supination-External rotation	Infra syndesmotic Type-A	Twisting injury	
10	26	female	10060600	14-05-2024	left	no	no	no	yes	Supination-External rotation	Infra syndesmotic Type-A	Twisting injury	ligament integrity not known
11	43	male	10069082	17-07-2024	Right	yes	no	no	no	cannot be classified	cannot be classified	Road traffic accident	
12	54	male	10075199	13-07-2024	Right	no	no	no	yes	Supination-External rotation	Infra syndesmotic Type-A	Twisting injury	
13	56	female	10093165	26-09-2024	Right	yes	yes	yes	yes	cannot be classified	Supra syndesmotic Type-C	Road traffic accident	
14	76	male	10092073	23-09-2024	left	no	no	yes	yes	Supination-Adduction	Infra syndesmotic Type-A	Twisting injury	
15	20	female	C1159665	17-01-2024	left	no	yes	no	yes	cannot be classified	Supra syndesmotic Type-C	Fall from height	
16	20	female	C1159665	29-06-2024	Right	no	yes	yes	yes	Pronation- External rotation	Supra syndesmotic Type-C	Fall from height	
17	56	male	7204443	11-07-2024	left	no	no	no	yes	Supination-External rotation	Trans syndesmotic type B	Twisting injury	
18	37	male	7274633	17-07-2024	Right	no	yes	yes	no	cannot be classified	cannot be classified	Road traffic accident	
19	36	male	10033658	15-01-2024	left	yes	no	no	no	cannot be classified	cannot be classified	Twisting injury	
20	53	female	C46722	12-01-2023	left	no	yes	no	yes	Supination-External rotation	Supra syndesmotic Type-C	Road traffic accident	
21	17	male	3152371	17-04-2024	Right	no	no	yes	no	cannot be classified	cannot be classified	Twisting injury	ligament integrity not known
22	27	male	10084402	18-Aug	left	no	no	yes	no	cannot be classified	cannot be classified	Road traffic accident	ligament integrity not known
23	14	female	1007285	14-09-2023	left	no	no	yes	yes	Supination-Adduction	Infra syndesmotic Type-A	Twisting injury	
24	24	male	10112322	10-12-2024	Right	no	no	yes	no	cannot be classified	cannot be classified	Twisting injury	ligament integrity not known
25	55	male	10102705	11-04-2024	Right	yes	yes	yes	yes	cannot be classified	Trans syndesmotic type B	Fall from height	
26	45	female	10098616	16-10-2024	left	no	yes	yes	yes	Supination-External rotation	Trans syndesmotic type B	Twisting injury	
27	42	male	C1148840	30-10-2023	Right	no	no	yes	yes	Supination-Adduction	Trans syndesmotic type B	Twisting injury	
28	20	female	10110200	11-10-2024	Right	yes	yes	yes	no	cannot be classified	cannot be classified	Fall from height	
29	47	male	10101288	25-10-2023	Right	no	yes	yes	yes	Supination-External rotation	Trans syndesmotic type B	Road traffic accident	
30	68	male	10114598	19-12-2024	left	no	yes	yes	no	cannot be classified	cannot be classified	Road traffic accident	
31	48	female	10047001	14-03-2024	left	no	yes	yes	yes	Pronation-External rotation	Supra syndesmotic Type-C	Road traffic accident	
32	65	female	1202101	12-07-2023	left	no	no	yes	yes	Pronation- Abduction	Trans syndesmotic type B	Twisting injury	
33	50	male	1001089	03-09-2023	Right	yes	no	no	no	cannot be classified	cannot be classified	Twisting injury	ligament integrity not known