Introduction

Ankle fractures are one of the most common types of fractures, making up roughly 9% of all musculoskeletal injuries\(^1\). With the exception of adult women over the age of 50-years-old, young adult athletes are disproportionately more likely to sustain ankle fractures than any other population\(^1\). A study by Clanton et al\(^2\) found that the ankle is the most common site of injury in 24 of 70 sports. For example, sports like basketball and soccer have been found to have a higher proportion of ankle injuries, with the risk of injury being 4-6 times greater during game play than training\(^2\). Additionally, with the Physical Activity Council\(^3\) reporting a rise in participation in fitness, team, and outdoor sports since 2014, it is no surprise that the incidence of ankle fractures is on the rise\(^3,4\).

Research indicates there is an increased risk for chronic complications and re-injury for all types of ankle injuries. For instance, Clanton et al\(^2\) reports basketball players are 5 times more likely to re-injure an ankle after a prior ankle injury. Additionally, the increase in severity of an ankle injury results in an increase in severity of consequences. In the Percival Pott classification system for ankle fractures, the most severe ankle injury is the trimalleolar ankle fracture\(^5\). This type of fracture involves the lateral malleolus, medial malleolus, and posterior malleolus, and accounts for 7% of all ankle fractures\(^5\). Most commonly seen in traumatic accidents or forceful sport injuries, trimalleolar ankle fractures are associated with worsened clinical outcomes\(^4\). For example, a retrospective study by Evers et al\(^4\) found patients with trimalleolar ankle fractures to have a 34% risk of developing post-traumatic arthritis. In order to fully understand the consequences of trimalleolar ankle fractures as they relate to treatment,
rehabilitation, and outcomes, one must first be oriented to the ankle anatomy and the tissues impacted by trimalleolar ankle fractures.

**Anatomy**

The ankle is a hinge joint, with the medial malleolus of the distal tibia and the lateral malleolus of the distal fibula forming a bony mortise that articulates with the body of the talus\(^5\). In addition, preventing posterior translation of the talus is the posterior malleolus, which is found at the posterior aspect of the distal tibia\(^5\). The ankle joint is further stabilized at the tibiotalar joint by the medial and lateral collateral ligaments and the syndesmotic ligamentous complex\(^6\).

The medial ligaments (Figure 1) are the anterior tibiotalar, tibionavicular, tibiocalcaneal, and posterior tibiotalar ligaments, together forming the durable deltoid ligament\(^6\). The relatively weaker, more susceptible lateral complex (Figure 2) is made up of the anterior talofibular, calcaneofibular, and posterior talofibular ligaments\(^6\). Finally, the syndesmotic ligamentous complex (Figure 3) assists in the formation of the deep articulating ankle mortise and is made up of the posterior and anterior inferior tibiofibular ligaments and the transverse ligaments of the interosseous membrane\(^6\).

Singh et al\(^5\) states that most passive stability in the ankle is provided by the medial and lateral ligaments, tibiofibular ligaments, tendons crossing the joint, capsular attachments, and bony contours, such as how the talus fits in the ankle mortise. Dynamic stability, which is particularly important during participation in sports, is provided by gravity, muscle actions like the soleus and gastrocnemius, and ground reaction forces\(^5\). In the case of ankle fractures, dynamic stability is most commonly challenged by supination and external rotation injuries, resulting in roughly 60-75% of ankle fractures\(^6\). A supination and external rotation force, particularly in traumatic events or sport-related injuries, is also the most common mechanism of
injury for trimalleolar ankle fractures. These rotational injuries not only result in fractures at the ankle, but also trigger ligamentous injuries that have significant impacts on post-fracture stability, as well as future ankle congruency and stability.

**Mechanism of Injury**

Strong anatomical knowledge of the ankle and its soft tissues attachments can help predict ligamentous structures at risk for injury when faced with excessive forces and range of motion extremes. Lauge-Hansen developed a classification system based on the premise that certain forces will create a predictable and repeatable injuries. Using cadaveric ankles, Lauge-Hansen was able to reproduce fracture patterns dependent on foot position and direction of forces. Studies have shown that the mechanisms of injury and fracture patterns proposed by Lauge-Hansen can in fact predict soft tissue injuries, thus supporting the use of the Lauge-Hansen Classification System to help diagnose occult ligamentous injuries and guide clinical decision making after fractures. Supporting this assumption, a large cohort study by Warner et al used comparisons between injury radiographs, pre-operative MRI, and intraoperative findings to confirm that the Lauge-Hansen system is an accurate predictor of ligamentous injuries. Based off this study’s findings, the Lauge-Hansen classification system is also useful for fracture reduction maneuvers and operative planning.

In the Lauge-Hansen classification, trimalleolar ankle fractures fall within stage 4—the most serious category of ankle injury. According the Sharp, the predicted series of the Lauge-Hansen classification system during a forced supination with external rotation injury starts with lateral malleolus failure and anterior inferior tibiofibular ligament rupture in stage 1. Damage to the transverse fibers of the syndesmosis can also be seen with stage 1 injuries. In stage 2, greater force results in a oblique fibular fracture at the syndesmosis. In stage 3, posterior
malleolar fracture occurs, and can be coupled by posterior-inferior tibiofibular ligament damage. Finally, if there is enough stress, stage 4 involves the medial malleolus, as well as either a transverse avulsion fracture of the deltoid ligament or complete deltoid ligament rupture. While a forced supination with external rotation injury is the most common mechanism for involvement at all 3 malleoli, including medial ligamentous damage, it should also be mentioned that forced pronation with external rotation can also result in bimalleolar ankle injuries. In such cases, medial and posterior malleolar fractures can be seen, while the lateral force in the fibula at the syndesmosis in this mechanism of injury may not be enough to result in a lateral malleolus fracture.

According to a study by Gardner et al, a significant number of trimalleolar ankle fractures have coexisting bony and ligamentous injuries. However, Warner et al references several studies that question the reliability and repeatability of the Lauge-Hansen system in predicting and detecting soft tissue injuries associated with ankle fractures. Therefore, appropriate and effective imaging is essential for confirming diagnosis and severity, detecting ligamentous damage, and planning for stabilization and post-operative rehabilitation. An article by Prasarn et al states that while standard ankle radiographs are commonly obtained for significant ankle injuries, these radiographs are not very sensitive for detecting posterior malleolus fractures (Figures 4 & 5). Additionally, standard radiographs sometimes fail to demonstrate the severity of fractures, fragment size, and soft tissue damage (Figure 6), which are all important factors for determining surgical intervention. As a result, most research recommends computed tomography (CT) for diagnostics and pre-operative planning, as CT scans can better detect posterior malleolus fractures, distinguish fragment size, and differentiate fracture type. Considering the instability resulting from bony injury and concomitant deltoid
ligament damage with trimalleolar ankle fractures, it is imperative to accurately determine the extent of soft tissue damage\textsuperscript{10}. Gardner et al\textsuperscript{8} supports MRI as the “gold standard” as it is proven to be extremely accurate in visualizing soft tissue injuries around the ankle. However, because MRI is not definitely proven for determining functional instability of an injured ankle, Gardner still recommends the use of the Lauge-Hansen classification system for clinical application, while concurrently utilizing radiographs and MRI when there are doubts about stability and soft tissue injuries\textsuperscript{8}.

**Surgical Intervention**

Isolated medial malleolar fractures do not typically require surgical intervention\textsuperscript{6}. With appropriate treatment, most patients see a return to a fully active lifestyle after a severe injury such as a medial malleolar fracture\textsuperscript{6}. For medial malleolus fractures involving injury to the deltoid ligament, non-operative management is typically reserved for patients with low functional demand or those who are unable to undergo surgery\textsuperscript{10}. In such cases, strong fixation and prolonged immobilization is employed. Additionally, patient physiologic age, comorbidities, level of physical demand, preference, and mechanism of injury are essential considering factors for surgical decision-making\textsuperscript{10}.

However, in the case of trimalleolar ankle fractures, surgical intervention to achieve stability of each malleoli is vital for positive long-term clinical outcomes\textsuperscript{6}. A study referenced by Kusnezov\textsuperscript{10} established one of the first objective criteria for operative intervention, concluding that the order of importance for restoration of stability was the lateral malleolus, medial malleolus, deltoid ligament, and syndesmosis. Trimalleolar fractures typically compromise all of these supporting structures and leave the ankle joint unstable, requiring open anatomic reduction with internal fixation (ORIF) to restore normal joint mechanics\textsuperscript{11,12}. 
According to the Sharp et al\textsuperscript{6} study of trimalleolar ankle fractures, indications for open reduction with internal fixation include talar dislocation greater than 1 mm, a disrupted syndesmosis, a posterior tibial fracture involving more than 25\% of the articular surface, or a medial malleolar fracture or deltoid tear along with instability in one of the other two malleoli\textsuperscript{6}. Many studies have confirmed that posterior malleolus fractures involving over 25\% of the articular surface can result in the increased incidence of post-traumatic osteoarthritis, worse functional outcomes, and decreased ankle stability\textsuperscript{12}. Therefore, anatomical reduction of the articular surfaces in an unstable ankle is necessary to achieve successful functional outcomes\textsuperscript{12}.

Prasarn et al\textsuperscript{9} agrees with the current recommendation of surgical fixation for posterior malleolar fractures greater than 25\% of the articular surface. In a case series of 15 patients, the results of ORIF treatment were compared to conservative cast treatment of trimalleolar ankle fractures\textsuperscript{9}. In 7 patients, surgeons performed an ORIF of the posterior malleolus, while treating the remaining patients with closed reduction and casting at the fractured malleoli\textsuperscript{9}. Results showed anatomic reduction and “good” to “excellent” results in 6 out of 7 patients in the ORIF treatment arm. However, no patients treated by closed means had anatomical reduction, and only 2 out of 8 had “good” to “excellent” results\textsuperscript{9}. These results support that ORIF of the posterior malleolus in trimalleolar fractures restores joint stability and anatomy of the syndesmotic complex better than alternative, conservative approaches\textsuperscript{9}. Additional research indicates that ORIF results in better reduction of the fibula, leading to improved mechanics and both short- and long-term outcomes\textsuperscript{9}. Finally, fixing the bone fragment through ORIF, rather than relying on ligamentous healing, certainly expedites return to normal activity. Ultimately, ORIF is the preferred treatment method in the setting of articular incongruity and posterior malleolus instability due to trimalleolar ankle fractures\textsuperscript{9}. Nevertheless, there are still mixed
opinions regarding the best surgical approach to achieve successful clinical outcomes after ORIF in trimalleolar ankle fractures⁹.

According to a study by Talbot et al¹¹, a posterolateral approach for open reduction and internal fixation of trimalleolar ankle fractures has several advantages. The most obvious advantage is that this surgical approach allows for direct inspection and reduction of the posterior fragment. As a result, there is a better chance for anatomical reduction of the articular surfaces of the posterior malleolus¹¹. Exemplifying the effectiveness of this approach, Huber et al¹³ found that anatomical reduction of the posterior malleolus occurred more frequently with direct reduction (83%) compared to indirect reduction through anteroposterior screws (27%)¹³. While a prone position can make ORIF of the medial malleolus more challenging, the medial malleolus is generally the easiest of the malleoli to reduce and fix, resulting in a favorable trade-off for having direct access to the posterior malleolus¹¹. Finally, the direct visualization provided by a posterolateral approach allows for the joint to be inspected for any osteochondral fragments, talar chondral defects, or impaction injuries¹¹.

In a study by Zhong et al¹², posteromedial and posterolateral fixation approaches were compared in 48 patients with trimalleolar ankle fractures. In all cases, the posterior malleolus was fixed using one or two screws, while a plate was used to fix the lateral malleolus, and two screws to fix the medial malleolus (Figure 7)¹². Results from this study showed there were no statistical differences between posteromedial and posterolateral approaches for posterior malleolar fractures in American Orthopedic Foot and Ankle Society scores, range of motion, and postoperative complications¹².

Regardless of approach, a final consideration for surgical management of trimalleolar fractures is the posterior malleolus fracture size. As previously mentioned, ORIF is traditionally
indicated for fragments affecting greater than 25% of the tibial articulating surface, while fractures smaller than 25% are generally not fixed due to the lack of perceived benefit\textsuperscript{12}. However, Zhong\textsuperscript{12} reports that anatomic reduction of posterior fragments should still be considered when only 10% or more of the articular surface is involved. In the Talbot et al study\textsuperscript{11} fixation of smaller fragments was found to facilitate rehabilitation by creating a more stable construct. Additionally, posterior malleolus fragments treated with closed reduction can result in subluxation of the talus, while ORIF prevents this from occurring by stabilizing the syndesmosis\textsuperscript{11}. Ultimately, the more stable and congruent the ankle joint is, the easier it will be to achieve early range of motion, suggesting a significant clinical impact of surgical fixation on smaller fragments in trimalleolar fractures.

While ORIF improves short- and long-term clinical outcomes and is favored over conservative treatment, there is still a risk of complications fractures, such as symptomatic nonunion or malunion, dynamic ankle instability, articular incongruity, and post-traumatic osteoarthritis\textsuperscript{10}. Additionally, trimalleolar ankle fractures are associated with poorer outcomes compared to unimalleolar ankle fractures, with one 3-year study of 107 patients confirming the number of malleoli involved in the fracture correlates with poorer functional outcomes\textsuperscript{14}. In a study assessing long-term results of ankle fractures with posterior malleolar fragments, De Vries et al\textsuperscript{15} found that inadequate reduction of ankle fractures leads to early osteoarthritis, resulting in pain and decreased function. A retrospective study by Heim et al\textsuperscript{16} bolsters De Vries findings. Assessing 45 patients with trimalleolar fractures who received fixation of the posterior fragment, Heim reports only 10% of patients exhibited severe arthritis 5 years post-operation\textsuperscript{16}. In all of these cases, patients experienced technical errors, supporting the theory that anatomically reduced and correctly stabilized posterior fragments do not typically lead to arthritis\textsuperscript{16}. 

A higher incidence of posterior instability of the talus is also seen with larger posterior malleolar fragment sizes that accompany trimalleolar fractures\textsuperscript{15}. Studies show that a change in articular loading and a decrease in contact area at the articular surface post-injury could explain why larger posterior malleolar fragments seem to have worsened outcomes\textsuperscript{15}. Furthermore, increased size of the posterior malleolar fragment can result in an anteromedial shift of contact stresses in the tibiotalar joint\textsuperscript{15}. This shift in stress concentration at the tibiotalar joint can lead to increased stress on cartilage that normally sees little loading, resulting in early and/or more severe osteoarthritis\textsuperscript{15}. Therefore, anatomical reposition and successful fixation of posterior fragments seems to be of great importance for long-term clinical outcomes\textsuperscript{15}.

Ultimately, the ability to return to normal physical activity and/or sport participation is dependent on many individual factors, as well as the success of the surgical reduction and fixation of the posterior malleolus. One study reports that after 1 year post-fixation of an unstable ankle fracture, only 25\% of patients will return to pre-injury level of sport participation, with no notable differences between fracture types\textsuperscript{14}. However, other studies have shown that return to normal function can be more likely, with positive predictors at 1 year including: younger age, male gender, no or mild systemic disease, and a less severe ankle fracture\textsuperscript{14}. Finally, studies show that even after achieving full return to sport after an ankle injury, the risk for re-injury is significantly greater than prior to the original injury. For example, a study by Clanton et al\textsuperscript{2} found the ankle injury recurrence rate to be as high as 73\%. Therefore, proper reduction and fixation, recovery, and rehabilitation are all essential for ensuring the best possible outcomes and avoiding premature return to activity.
Post-operative Rehabilitation

Most physicians advocate for a period of non-weight bearing followed by partial weight bearing after operative treatment of ankle fractures\(^1^7\). This is especially the case for concomitant ligamentous injuries (deltoid ligament or syndesmotic complex) with trimalleolar fractures\(^1^8\). A case study by Feigenbaum et al\(^1^9\) recommends the use of an initial protection phase with non-weight bearing to allow for proper fixation and soft-tissue healing. The patient can then be transitioned to toe-touch weight bearing after radiographs show soft callous healing, typically between 4 to 8 weeks depending on severity of injury\(^1^9\). During this phase, rehabilitative goals should focus on protecting the ankle, decreasing swelling, restoring range of motion, and avoiding further muscle weakness\(^1^9\). Functional progression is an important aspect of the rehabilitation protocol, as it is important to achieve full active range of motion and lower extremity strength as fast as possible\(^1^9\). This phase should also focus on improving aerobic conditioning, normalizing gait, improving balance and postural steadiness, and achieving pain-free mobility\(^1^9\). Most importantly, careful progression should be performed in this phase of rehabilitation in order to safely stress the ligamentous complexes without causing damage\(^1^9\).

Finally, rehabilitation should focus on return to normal activities, and in the case of athletes, sport-specific activities. Achieving this process can take as little as 4 months, or as long as 1 year, again depending on severity, operative treatment, and incidence of complications.

Early rehabilitation and decreased non-weight bearing restrictions is a growing alternative to the traditionally conservative rehabilitation protocol used. The aim of operative treatment for trimalleolar fractures is early functional post-operative treatment in order to start the rehabilitation process as soon as possible\(^1^8\). Additionally, with internal fixation, the ankle joint is provided increased ability to withstand early weight bearing and ankle motion, therefore...
making rehabilitation only a few days following surgery feasible and safe\textsuperscript{19}. Studies have shown quicker improvements in return to activities of daily living and work for subjects that underwent early functional exercise and weight bearing following internal fixation of the ankle\textsuperscript{19}. In a systematic review by Lin et al\textsuperscript{20}, thirty studies investigated rehabilitation interventions during the immobilized period after surgical fixation of ankle fractures. One study used a removable immobilizer to promote early rehabilitation by initiating exercises during the immobilization period after surgical fixation\textsuperscript{20}. In this study, subjects reported reduced pain and demonstrated improved ankle range of motion compared to immobilized subjects\textsuperscript{20}. However, when considering this method, it is important to educate the patient so that they can safely adhere to the exercises, while also carefully removing and applying the immobilizer\textsuperscript{20}.

Another alternative for achieving early rehabilitation while maintaining precautions is through the use of an active controlled motion device. A study by Hendrik et al\textsuperscript{18} found that an active controlled motion device could be used even when the ankle is immobilized with a boot during the non-weight bearing phase of rehabilitation. As a result, the active control motion device decreased proprioceptive deficits by allowing training to start with minimal delay, within days of the operation, rather than waiting for 6-weeks\textsuperscript{18}. By allowing for safe neuromuscular training early on, the active controlled motion device improved post-operative range of motion and functional outcomes at 6 and 12 weeks, and resulted in earlier return to work by 4 weeks compared to a control group\textsuperscript{18}.

Finally, post-operative rehabilitation should include assessment and interventions that address function. Once the patient is appropriate and safe to progress, physical performance tests and subjective measures should be utilized to determine readiness for return to sport or normal activity levels prior to injury\textsuperscript{2}. Range of motion and strength assessments should be regularly
performed throughout the rehabilitation process in order to measure progress and set goals. One range of motion test that can assess readiness for return to normal activity and sport participation is the dorsiflexion lunge test\(^2\). Sufficient dorsiflexion range of motion is required for normal gait mechanics and activities of daily living such as climbing stairs and rising from a squatting position\(^2\). Additionally, patients that lack adequate dorsiflexion are at an increased risk for re-injury. In the dorsiflexion lunge test, the patient will place their foot perpendicular to a wall and lunge the knee toward the wall\(^2\). The foot is then moved farther away from the wall until the maximum range of dorsiflexion is achieved without the heel lifted off the floor\(^2\). The distance from the foot to the wall is measured, with less than 9-10 cm considered “restricted,” while a tibial shaft angle of less than 35°-38° is also considered restricted\(^2\).

Balance and proprioception are also important factors to consider for return to sport or to determine a patient’s readiness for discharge. Loss of proprioception resulting from ligamentous damage after a trimalleolar ankle fracture is a risk factor for re-injury\(^2\). According to Hendrik\(^1\),\(^8\), proprioceptive training of ankle fractures using balance boards or balance circles is effective for patients who are full weight-bearing. Additionally, the star excursion balance test is an effective measure of unilateral balance and dynamic neuromuscular control\(^2\). This test requires the patient to stand in unilateral support on their involved leg while reaching maximally outside their base of support in varying directions with the contralateral leg, forming an 8-point star shape\(^2\). Therapists can measure patient progress on this test, while also addressing areas for improvement prior to discharge.

Strength and agility must also be considered for athletes in order to ensure safe and appropriate return to sport. The agility T-test assesses movement in multiple directions using a T-shaped course with “arms” measured a distance of 10 yards in each direction\(^2\). The athlete
must sprint from the base of the longitudinal arm to the center of the horizontal arm, then facing forward, sidestep to one end of the horizontal arm to the other end, without crossing feet\(^2\). To finish, the athlete sidesteps back to the center of the horizontal arm and runs backward down the longitudinal limb to the starting point. This test has a high reliability, with typical times for athletic adults ranging from 9 to 13.5 seconds\(^2\). Additionally, athletes that demonstrate deficits in strength are more prone to lower extremity injuries, and athletes with muscle strength imbalances are especially at increased risk of ankle injuries\(^2\). A simple test for athletes measuring strength is the sargent jump test. This test also evaluates speed, energy, dexterity and estimates power jumps\(^2\). For this test, the athlete squats and jumps upward into full extension, reaching above as high as they can. The distance jumped is then measured and can be compared to previous attempts using the efficiency index calculation (weight x height of jump / athlete height), which is a reliable estimation of explosive power\(^2\).

Finally, subjective measures should be used to determine an athlete’s readiness to return to sport. According to Clanton\(^2\), between 5% and 19% of athletes experience psychological distress following an injury. Additionally, rehabilitation following injury can be adversely affected by loss of confidence, fear, and anxiety, delaying return to sport\(^2\). Athletes who demonstrate apprehension, fear, or anxiety are also at an increased risk for re-injury\(^2\). Therefore, scoring systems such as the Trait Sport Confidence Inventory, State Sport Confidence Inventory, and the Injury-Psychological Readiness to Return to Sport Scale should be used to formally assess psychological factors that may negatively impact return to sport outcomes\(^2\). Additionally, for non-athletes returning to normal activity level, scales like the Fear Avoidance Belief Questionnaire could prove useful for measuring readiness for community and ADL participation.
Conclusion

While trimalleolar ankle fractures are associated with worsened outcomes and lengthy recovery times, research indicates positive functional outcomes and return to prior level of activity are achievable. Research shows successful ORIF, in addition to surgically addressing defected syndesmotic and ligamentous structures, can reduce the risk of post-operative osteoarthritis, especially in the participation of early and progressively monitored rehabilitation. Additionally, several controllable factors such as opting for surgical fixation of posterior malleolus fragments of any size, decreased time spent in non-weight bearing s/p fixation, and responsible activity modification can all play important roles in the functional outcomes of patients recovering from trimalleolar fractures.
Appendix A: Anatomy of the Ankle

Figure 1: Medial Ligaments making up the Deltoid Ligament Complex.\(^5\)

Figure 2: Lateral Ligaments, anterior talo-fibular, posterior talo-fibular, and calcaneo-fibular ligaments. Also seen in this figure is the ankle mortise around the talus, formed by the distal fibula and tibia, and secured by the syndesmotic ligamentous complex (Figure 3).\(^5\)
Figure 3: The posterior and anterior inferior tibiofibular ligaments and the posterior talofibular ligament, making up the Syndesmotic Ligament Complex.
Appendix B: Trimalleolar Fracture Radiographs

Figure 4: A frontal plane radiograph of a trimalleolar ankle fracture. The green arrows indicate the posterior malleolus fracture.\(^6\)

Figure 5: The posterior malleolus fracture is much easier to see from the lateral radiograph view.\(^6\)
Figure 6: Radiograph demonstrating the importance of obtaining MRI imaging for determining extent of ligamentous damage. The green areas point to the only indication of ligamentous damage—soft tissue swelling and joint gapping at the medial malleoli.¹⁶

Figure 7: A radiograph of a surgically fixed trimalleolar fracture⁹
References:


