Abstract

Malleolar ankle fractures associated with syndesmotic injuries are common. Diagnosis of the syndesmotic injury can be difficult and often requires intraoperative fluoroscopic stress testing. Accurate reduction and stable fixation of the syndesmosis are critical to maximize patient outcomes. Recent literature has demonstrated that the unstable syndesmosis is particularly prone to iatrogenic malreduction. Multiple types of malreduction can occur, including translational, rotational, and overcompression. Knowledge of the technical details regarding intraoperative reduction methods and reduction assessment can minimize the risk of syndesmotic malreduction and improve patient outcomes.

The syndesmosis is a complex of ligaments that joins the distal fibula to the distal tibia at the level of the ankle joint. Four main ligaments contribute to the syndesmotic complex: the anterior-inferior tibiofibular ligament (AITFL), the posterior-inferior tibiofibular ligament (PITFL), the transverse ligament, and the interosseous ligament. The AITFL is situated obliquely between the anterolateral tibial (Chaput) tubercle and the anteromedial distal fibula. The PITFL is situated obliquely between the anterolateral tibial (Chaput) tubercle and the anteromedial distal fibula. The PITFL connects the posterolateral tibial (Volkmann) tubercle to the postero-medial distal fibula. The transverse ligament represents a deep, thickened zone of the distal-most portion of the PITFL and functions like a labrum, deepening and stabilizing the tibiotalar joint. The PITFL and associated transverse ligament provide nearly half of the overall syndesmotic strength. The interosseous ligament is the distal aspect of the tibiofibular interosseous membrane and joins the tibia to the fibula several centimeters above the articular surface. A concavity of variable depth and shape known as the incisura fibularis is located at the posterolateral aspect of the distal tibia. The distal fibula fits into this structure, which provides a small amount of bony support to this articulation. However, without the ligamentous stability provided by the syndesmosis, the articulation is rendered unstable to physiologic stresses.

In the normal ankle, the stabilizing ligaments of the syndesmosis provide a small amount of elasticity, allowing physiologic motion at the distal tibiofibular joint. With ankle dorsiflexion, the wider anterior talar body rotates into the mortise, requiring posterolateral and proximal translation of the fibula, as well as external rotation. Overall fibular displacement is normally approximately 1 to 2 mm through the entire ankle range of motion. The position of the fibula within the incisura and its relative stability are critical for maintenance of ankle mortise congruity and normal distribution.
of tibiotalar cartilage forces, minimizing the risk of posttraumatic arthrosis. Because multiple individual structures contribute to distal tibiofibular joint stability, pathological instability presents along a spectrum, depending on the number and severity of structures injured.

An untreated syndesmotic injury can adversely affect functional outcomes. Additionally, applying unstable fixation to a reduced syndesmosis or stable fixation to a malreduced syndesmosis can lead to poor function. Weening and Bhandari evaluated 51 syndesmotic injuries treated with screw fixation and 16% had syndesmotic malreduction on radiography. At an average of 18 months, syndesmotic malreduction was the only significant predictor of functional outcome. In a study of 68 patients with syndesmotic injuries, Sagi et al evaluated outcomes at a minimum of 2 years using functional outcome questionnaires and bilateral CT scans. The authors found that 27 syndesmoses (39%) were malreduced, and these patients had significantly worse outcomes than did those who had an anatomic reduction. Both of these studies demonstrate that accurate reduction of the syndesmosis after injury is a critical goal of surgical management and a major factor in the resulting outcome. Egol et al examined outcomes in patients with unstable ankle fractures treated with syndesmotic stabilization. The authors found that patients with ankle fractures and a syndesmotic injury had worse outcomes at 12 months postoperatively than did those without syndesmotic injury. Whether impaired function was caused by the intact syndesmotic screw, higher injury severity, or syndesmotic malreduction is unclear.

Recent studies have demonstrated that the rate of syndesmotic malreduction is extremely high. One report demonstrated a 52% malreduction rate on unilateral CT scans. The intraoperative use of three-dimensional CT to assess reduction was recommended by Franke et al, who found a lower rate of malreduction (25.5%) on unilateral scans. However, Davidovitch et al compared the accuracy of reductions with standard fluoroscopy or intraoperative three-dimensional CT in 36 patients and reported similar and relatively high malreduction rates with both modalities (30% and 38%, respectively).

**Preoperative Assessment**

Accurate preoperative diagnosis of a syndesmotic injury is important when the associated malleolar injuries alone do not mandate surgical intervention. Much work has been done to determine the best indications for surgical management, and care must be taken when interpreting this body of work to distinguish between indicators of deltoid incompetence concomitant with a distal fibula fracture and actual disruption of the syndesmosis complex.

Several signs found on physical examination are potential indicators of syndesmotic injury, including deltoid ligament tenderness, anterior syndesmotic ligament tenderness, a positive squeeze test (ie, manual compression of the tibia and fibula above the level of the joint), and pain with dorsiflexion and external rotation. A recent study compared the accuracy of physical examination with MRI findings for diagnosis of isolated ligamentous syndesmotic injury; the squeeze test was shown to be the most specific test (88%), and anterior syndesmotic ligament tenderness was the most sensitive (92%). However, these tests and others that have been proposed (eg, ability to hop on the injured leg) may not be practical in the setting of a malleolar ankle fracture.

Plain radiographs of the ankle and tibia should be evaluated for the presence of an ankle fracture, a proximal fibula fracture, and disruption of the normal relationship between the distal tibia and distal fibula. Three radiographic findings have been identified as indicators of syndesmotic injury: increased tibiofibular clear space, decreased tibiofibular overlap, and increased medial clear space. Tibiofibular clear space is the distance between the medial border of the fibula and the lateral border of the posterior tibia at the incisura. At 1 cm above the joint, the tibiofibular clear space should be <6 mm on both the AP and mortise radiographic views. Tibiofibular overlap is the radiographic projection of overlap of the lateral malleolus and the anterior tibial tubercle at 1 cm above the joint. On the AP view, the overlap should be >6 mm and, on a true mortise view, it should be >1 mm. On the mortise view, the medial clear space is the distance between the lateral border of the medial malleolus and the medial border of the talus, with the ankle at 90° of flexion. The medial clear space should be less than or equal to 6 mm.
to the superior clear space between the talar dome and the tibial plafond.\textsuperscript{12}

The evaluation and interpretation of these values has been the source of much investigation to determine if these numbers are reliable and useful for making decisions on surgical indications. Pneumaticos et al\textsuperscript{13} showed that the tibiofibular clear space does not change significantly with rotation of the ankle and should be viewed as more reliable than other plain radiographic parameters (eg, the tibiofibular clear space). However, Beumer et al\textsuperscript{14} demonstrated that plain radiographic views were unlikely to be replicated accurately between multiple radiographs, making interpretation of findings based on these views unreliable. The authors concluded that the usefulness of plain radiography for the diagnosis of syndesmotic injury was limited. Occasionally, preoperative stress radiographs are useful, however, in the presence of unstable malleolar fractures, specifically stressing the syndesmosis is not possible.

Other studies have shown that CT may demonstrate tibiofibular diastasis that is not evident on plain radiography.\textsuperscript{15,16} However, CT has poorer soft-tissue resolution than MRI, is a static examination, and may not demonstrate instability if diastasis is not present. Oae et al\textsuperscript{17} used preoperative MRI and ankle arthroscopy to assess 58 patients with distal fibula fracture or ankle sprain. MRI had a sensitivity of 100% and a specificity of 93% for diagnosis of ATFL rupture, with ankle arthroscopy considered the standard of care. Nielson et al\textsuperscript{18} examined ankle fractures with MRI and found that the classically described plain radiographic measurements did not correlate with demonstrated soft-tissue injuries seen on MRI. Although CT cannot demonstrate instability and may lead to underdiagnosis of clinically significant injuries, MRI demonstrates even the slightest evidence of soft-tissue injury, some of which may not correlate with clinical instability. Therefore, the clinical significance of these diagnostic tools in the management of syndesmotic injury remains unclear. Although preoperative evaluation of syndesmotic injury can be useful overall, the lack of accuracy of preoperative methods highlights the importance of intraoperative stress testing to determine the stability of the syndesmosis in all surgical ankle fractures.

**Intraoperative Injury Assessment**

Syndesmotic stability should be assessed intraoperatively in patients with ankle fracture. Although there are injury patterns that should heighten concern for instability, few patterns have no risk. According to the Lauge-Hansen classification system, pronation external rotation, supination external rotation, and pronation abduction fractures hold the highest risk of syndesmotic injury. The supination adduction pattern is the only type with minimal risk of instability. Based on the Danis-Weber classification system, type B and C fibular fractures have the highest risk of syndesmotic instability, and type A fibular fractures pose minimal risk (note the correlation between the two systems, with the type A fibular fracture pattern seen in the supination adduction fracture pattern). However, many ankle fracture patterns do not conform perfectly to the Lauge-Hansen system. Similarly, severe capsular and ligamentous injuries, which destabilize the syndesmosis, can be present even in Danis-Weber type A fibular fractures. Because missed syndesmotic injuries are associated with inferior results and the current classification systems are imperfect in predicting syndesmotic instability, it is logical to conclude that the syndesmosis should be evaluated intraoperatively in every patient with an ankle fracture.

The timing of intraoperative syndesmotic evaluation is critical. The tibial Chapat and fibular Wagstaffe fragments (ie, anterior avulsion from the fibula) provide attachment points for the ATFL. The tibial and posterior fibular tibial provide attachment points for the PITFL. In addition to these points of stability, pathologic talor motion is unlikely to occur if the deltoid ligament is intact or has been functionally restored. Because these osseous fragments contribute to syndesmotic stability, and syndesmotic reduction and stabilization maneuvers have been associated with complications, the intraoperative evaluation of syndesmotic stability should occur after all other points of instability have been addressed. Assessment of syndesmotic stability before stabilization of the lateral malleolus, medial malleolus, and posterior malleolus (assuming the decision has been made to treat these points of instability) is not effective for assessing the competence of the syndesmotic ligaments.

Manual stress testing and arthroscopy have been used for accurate intraoperative identification of a syndesmotic injury. Prior to dynamic testing, static radiographic parameters should be revisited, as described earlier. It should be noted that, on radiography, the syndesmosis may have a nonpathologic appearance because of the variability of the incisura contour (eg, flat or cupped)\textsuperscript{19} (Figure 1). Specifically, a tibiofibular overlap of 0 mm, which has traditionally been considered to be indicative of an injured syndesmosis, may be a normal finding in a patient with a flat incisura; however, it may represent pathology in a patient with a cupped incisura. If the contralateral ankle is uninjured, comparison radiographic views should be obtained; comparison of the injured and
uninjured ankles is more effective than comparing the injured ankle with standards based on the general population. These views can be obtained with fluoroscopy at the beginning of the surgical procedure, using standard ankle and C-arm positioning. In addition to determining whether an injury is present, these images aid in the assessment of intraoperative reduction. The lateral projection is critical for this evaluation.

When syndesmotic asymmetry exists on static imaging, stress views are typically not required; however, if doubt exists, diagnoses can be clarified with stress views. Standard intraoperative stress mechanisms include an external rotation stress test of the dorsiflexed ankle or direct translation of the fibula via a clamp or hook (modified Cotton test, Figure 2). Consistency is challenging with regard to the magnitude of force generated intraoperatively for translation of the fibula. The amount of instability (millimeters of displacement during the stress test) that can be recognized on radiography has been questioned. The degree of instability on stress testing that warrants stabilization is unclear.

Based on the literature on syndesmotic imaging, there are several reasonable, albeit imperfect, recommendations for identifying instability. First, preoperative plain radiographic assessment alone is inadequate. Unrecognized instability can be elucidated intraoperatively with stress testing. Second, the position of the ankle should be standardized during testing, and the tibiofibular clear space on the AP view reveals the least amount of variability attributable to rotation. Third, population norms for tibiofibular clear space and overlap can be deceiving based on the two primary types of incisura morphology. Comparison views of the uninjured contralateral ankle should clarify the patient norm more effectively than a population average. Fourth, the absolute increase in tibiofibular clear space is greater for the same injury pattern when using a laterally directed translational force with a hook than with an external rotation stress test. This larger absolute increase should be easier to detect intraoperatively with the modified Cotton test. Fifth, the coronal plane is not the only plane that should be assessed. Sagittal plane translational stress, as demonstrated on the lateral view, has been shown to be an effective measure for assessment of instability.

Although intraoperative manual stress testing provides the advantages of simplicity and efficiency, arthroscopic evaluation of the syndesmosis provides other advantages, including direct visualization of ligaments. First, direct visualization of the AITFL and PITFL ligaments provides clearer evidence of injury to these ligaments than an indirect evaluation of their stability through stress testing. Second, associated injuries, such as loose bodies and osteochondral defects, may be more completely diagnosed arthroscopically. Third, arthroscopy aids the clinician in defining the different patterns of syndesmotic displacement and assessment of reduction. Disadvantages include the potential for cutaneous nerve injury, overtreatment based on anatomic findings that do not correlate with pathologic instability, and

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Figure 1

Axial CT scans of the ankle demonstrating flat (A) and cupped (B) incisura morphology.

Figure 2

AP radiograph of the ankle after fibular fixation demonstrating a syndesmotic injury. Translation of the fibula (ie, Cotton test) produces demonstrable widening of the medial clear space (*) and syndesmotic space (#).
the increased setup time and logistical complexity of intraoperative fluoroscopy and arthroscopy equipment in the same surgical field.

** Syndesmotic Reduction and Assessment **

Following the intraoperative determination or confirmation of a syndesmotic disruption, reduction must be achieved. There are several syndesmotic reduction techniques. An indirect reduction involves the application of a clamp between the distal fibula and tibia without direct visualization of the syndesmotic relationship. Alternatively, a direct reduction can be performed by visualizing and palpating the anterior syndesmotic reduction.30

When planning the reduction, it is important to consider the variables that can lead to malreduction of the syndesmosis. These variables fall into several categories, including length (typically fibular shortening), rotation (either internal or external rotation), sagittal plane translation, or overcompression of the syndesmosis (Figure 3).

If an associated fibular fracture is present, the surgeon should strongly consider anatomic fibular reduction to accurately reduce the length and rotation of the fibula relative to the tibia. Additionally, if the fibula is anatomically reduced, the sagittal plane reduction can be more accurately accomplished and assessed. A fibular malreduction will likely translate into a syndesmotic malreduction regardless of the reduction method used. Although anatomic restoration of the fibula does not guarantee an accurate syndesmotic reduction, the length will be correct, provided the proximal tibiofibular joint is intact. The rotation and translation can then be more easily addressed.

When the fibular fracture is not directly reduced, intraoperative assessment of fibular length is largely based on fluoroscopy. Contralateral ankle radiographs are invaluable. The relationship between the fibula and the talus on the mortise view should demonstrate symmetry between the lateral talus and the medial fibula. Furthermore, restoration of the Shenton line at the ankle (ie, the confluence of the cortical line between the medial distal fibula and lateral distal tibia) produces a qualitative assessment of the fibular length.21

Intraoperative fluoroscopic assessment of the rotation of the fibula relative to the tibia is difficult. In a cadaver study, Marmor et al31 found that the typical radiographic indices used to judge syndesmotic reduction could not detect rotational abnormalities of as much as 30\(^\circ\) in external rotation. However, internal rotational deformities of the fibula could be detected with as little as 10\(^\circ\) of malreduction. The authors hypothesized that, with internal rotation, the fibula impinges at the talus distally, leading to a detectable decrease in the tibiofibular overlap and a detectable increase in the tibiofibular clear space. Conversely, with external rotation of the fibula, there is a decrease in the tibiofibular clear space and a slight increase in the tibiofibular overlap. This may be of clinical relevance given the common association between external rotation ankle injuries and syndesmotic disruptions.

Syndesmotic reduction most commonly involves placing a clamp between the fibula and the tibia. However, the clamp vector and location and the applied force need to be considered. Given that the estimated frequency of syndesmotic malreduction is as high as 50%,8 the need for technical accuracy during this portion of the procedure cannot be overemphasized. The clamp position is critical and should be applied at the level of the syndesmosis; proximal or distal clamp positions can introduce a coronal plane deformity in the fibula. Additionally, the location of the clamp on both the fibula and the tibia will determine the force vector for compression. In a recent cadaveric study,32 a clamp applied from the lateral malleolar ridge of the fibula to the center of the AP width of the tibia resulted in the most consistent and accurate reduction of the syndesmosis.
Translating the tibial clamp tine 10 mm anteriorly resulted in anterior fibular translation and abutment of the anterior incisura. With a posteriorly directed clamp vector, fibular displacement was posterior and increased with progressive levels of syndesmotic destabilization. Miller et al\(^1\) applied a clamp to one of three locations on the medial tibia over a 30° arc. Fibular external rotation and anterior fibular displacement were observed. The results of these two studies suggest that the clamp orientation can have significant effects on translational malreduction. Additionally, as noted, the internal contour of the incisura is variable, ranging from relatively flat to more cupped\(^1\) (Figure 1). Flat incisurae do not contain the fibula well and are likely more prone to translational malreductions.

The influence of foot position on reduction is currently unknown. In a study by Tornetta et al\(^3\), no loss of maximum ankle dorsiflexion was observed despite placement of lag screws across the syndesmosis with the foot in plantar flexion. The authors concluded that foot position does not have a clinical effect with regard to passive ankle dorsiflexion. However, no ligament injury was created in this model, and CT scans were not used for evaluation. More recently, several studies have suggested that overcompression of the syndesmosis is possible.\(^3\) In one study, all cadaver specimens had overcompression of the syndesmosis (by an average of 0.9 mm, based on CT measurements).\(^3\) In another cadaver study, Miller et al\(^3\) similarly demonstrated significant overcompression almost universally. The optimal force that should be applied with a clamp to reduce the syndesmosis is currently unknown, but overcompression is possible (Figures 3 and 4). Thus, consideration should be given to confirming the reduction (with direct visualization, fluoroscopy, or both) rather than clamping more vigorously in clinical instances where the reduction of the syndesmosis does not occur easily. Clinical data correlating syndesmotic overcompression to functional outcomes are currently unavailable.

Fluoroscopy is typically used for intraoperative assessment of the reduction of the syndesmosis. However, the use of other intraoperative imaging studies has been evaluated. Intraoperative three-dimensional CT has been used as an adjunct to improve the accuracy of syndesmotic reduction, with conflicting results reported. In a study of 251 consecutive ankle fractures with syndesmotic injuries, intraoperative three-dimensional CT altered the surgical outcome in 33% of ankles.\(^9\) The most common malposition was anterior displacement and internal rotation of the fibula. In contrast, a study that compared the accuracy of reduction assessment with intraoperative three-dimensional CT or standard fluoroscopic imaging at two trauma centers found that the addition of three-dimensional CT imaging did not decrease the malreduction rate.\(^10\)

Summers et al\(^2\) recently introduced a new method for intraoperative evaluation of the syndesmotic reduction using fluoroscopy. Given the frequency of malreduction in the sagittal plane, a careful analysis of the lateral view was felt to be an important component of intraoperative assessment. The authors recommended obtaining intraoperative mortise and perfect lateral fluoroscopic views of the talar dome of the uninjured ankle before fixation of the injured extremity. The mortise view was used to evaluate fibular length and rotation. The lateral view of the talar dome was used to assess the anterior to posterior relationship of the fibula and the tibia. On the posterior view, the distance from the point at which the posterior border of the fibula crosses the posterior tibial articular surface to the tip of the posterior malleolus was measured and used to compare the injured and uninjured ankles (Figure 5). This method led to highly accurate reductions confirmed by intraoperative three-dimensional CT scans. Alternatively, an anterior ratio can be
determined on the lateral view, which may be particularly useful in the setting of a posterior malleolus fracture.\textsuperscript{35}

The incidence of an associated posterior malleolus fracture as a component of an unstable ankle injury with an associated syndesmotic disruption has been reported in 36% of cases.\textsuperscript{30} These injury patterns may be particularly prone to malreduction because the tibial incisura is often involved (Figure 6). Reduction of the posterior malleolus reconstructs the tibial incisura and reestablishes the relationship between the fibula and theibia by effectively repairing the PITFL attachments.\textsuperscript{30} Interestingly, either internal rotation or anterior translation of the fibula was observed to be the most common malreduction. This led the authors to recommend anatomic reconstruction of the posterior malleolus in ankles that have an associated syndesmotic injury and a posterior malleolus fracture. In a study of 15 patients with posterior malleolar fractures, Gardner et al\textsuperscript{36} reported that the PITFL remained attached to the fractured posterior malleolus in all patients, and that fixation of the posterior malleolus led to restoration of 70% of native syndesmotic strength versus 40% with a syndesmotic screw.

Postoperative Reduction Assessment

Much of the focus on scrutinizing postoperative syndesmotic reduction began with a 2006 study that reported that 13 of 25 ankle fractures (52%) with syndesmotic fixation demonstrated malreduction of the fibula within the incisura.\textsuperscript{8} Furthermore, this article demonstrated that postoperative plain radiography had only a 31% sensitivity and 83% specificity for detecting malreduction compared with that of CT. These findings highlighted that accurate postoperative assessment could only be made with CT; subsequently, there has been further examination of the parameters measured on CT for syndesmotic assessment.

Nault et al\textsuperscript{37} showed reasonable consistency in CT measurements among the normal population and good interobserver reliability. They noted that the mean ratio of anterior tibiofibular distance to posterior tibiofibular distance was 0.54 (greater distance posteriorly) and, at the midpoint of the incisura, the mean width of the distal tibiofibular joint was 2.8 mm. Mendelsohn et al\textsuperscript{38} also showed the fibula to be closest to the tibia anteriorly and progressively further away more
posterior in the incisura. In a study of 107 CT scans of normal ankles, Lepojärvi et al\textsuperscript{39} noted that the fibula either sits centrally or anterior in the incisura in 97% of uninjured ankles, such that posterior translation of the fibula seen on CT should raise the index of suspicion for malreduction. Interestingly, a recent study by Song et al\textsuperscript{40} demonstrated that 8 of 9 syndesmotic malreductions (89%) spontaneously reduced following screw removal at 3 months postoperatively.

Although population norms may be used for ankle measurements, some investigators have advocated matching CT measurements of the injured ankle to those of the contralateral ankle. Mukhopadhyay et al\textsuperscript{41} examined anatomic variation in a small series of patients with normal ankles or injured ankles treated with syndesmotic fixation. The authors found that there was enough variation between all measurement parameters that caution must be exercised in concluding that the upper limit of side-to-side variation is 2 mm. However, Dikos et al\textsuperscript{42} examined the bilateral ankle CT scans of 30 normal volunteers and found that they had good symmetry side to side. The authors also reported excellent intraobserver and interobserver reliability, and the mean variance in anterior tibiofibular space was only 0.8 mm, with a calculated maximum variance of 2.3 mm side to side. The authors concluded that the contralateral ankle was a reliable standard for comparison. Finally, Knops et al\textsuperscript{43} looked specifically at how to determine rotational malreduction on CT, comparing the accuracy and reliability of four methods of measurement. The authors determined that the best method to assess rotation was the angle between the tangent of the anterior tibial surface and the bisection of the vertical midline of the fibula at the level of the incisura.

**Summary**

The use of a clamp to reduce the syndesmosis frequently leads to inaccurate reduction. Avoiding malrotation, overcompression, and sagittal plane translation can be difficult. The anatomic reconstruction of the fibula (in length and rotation) and reconstruction of the incisura (if either the anterolateral distal tibia or posterior malleolus is fractured) should be prioritized. Following restoration of lateral malleolar length and articulation with a stable syndesmotic incisura, ankle mortise relationships can be restored with the application of a clamp. Syndesmotic reduction is highly sensitive to clamp and screw positioning. A clamp angle of zero leads to the least amount of fibular rotation,\textsuperscript{33} but substantial posterior translation and all clamp vectors can lead to overcompression. Intraoperatively, assessment of direct reduction or meticulous fluoroscopic comparison of the injured and contralateral ankles can be helpful to determine the accuracy of the reduction. Restoring the fibula to an anatomic position within the incisura has repeatedly correlated with functional outcomes.

**References**

References printed in **bold** type are those published within the past 5 years.

Technical Considerations in the Treatment of Syndesmotic Injuries Associated With Ankle Fractures


