Acute and Chronic Injuries to the Syndesmosis

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KEYWORDS

• Syndesmosis • Tibiofibular • Chronic syndesmosis • Syndesmotic • Disruption
• High ankle sprain

KEY POINTS

- Stable syndesmotic injuries do not require surgical stabilization and can be treated with protected weight bearing. Advanced imaging demonstrating an intact deltoid ligament with preservation of the interosseous ligament and posterior inferior tibiofibular ligament is associated with a stable injury.
- Unstable syndesmotic injuries require operative stabilization. The use of a suture button device may be appropriate in the setting of a length-stable fibula.
- Use of a suture button device in the setting of a Maisonneuve injury may not provide sufficient coronal and sagittal stability and should be used with caution in these cases.
- Anatomic reduction of the syndesmosis is critical to providing improved outcomes, and direct visualization should be considered in addition to obtaining a contralateral lateral radiograph to assess the reduction.
- Chronic syndesmotic diastasis requires restoration of the mortise and can be performed with graft reconstruction or arthrodesis. The use a graft has been successful in limited clinical series and may offer stability without limiting the motion of the fibula and theoretically may improve function and decrease the risk of ankle arthritis compared with syndesmotic fusion.

ANATOMY OF THE SYNDESMOSIS

Understanding of the anatomy of the normal syndesmosis is essential in both interpretation of diagnostic imaging and therapeutic management.

Distal Tibiofibular Joint

A syndesmosis is defined as a fibrous joint in which 2 adjacent bones are linked by a strong membrane or ligaments. The distal tibiofibular joint comprises the convex

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medial aspect of the distal fibula and the concave lateral aspect of the distal tibia, known as the incisura fibularis. Direct contact facets, which are very small and covered with articular cartilage, between the distal tibia and the fibula, are present in approximately three-quarters of patients.[1]

The size and shape of the incisura fibularis play an important role in ankle injury, and have been investigated using cadavers and computed tomography (CT). The anterior tibial tubercle is typically larger than the posterior tubercle and prevents forward translation of the distal fibula. In 97% of normal cases, the fibula is situated either anteriorly or centrally in the tibial incisura.[2] This posterior joint space width is significantly wider than the central and anterior joint spaces.[2] The axis of the distal tibiofibular joint was found to be, on average, 32° externally rotated in relation to the transmalleolar axis.[3]

Significant variance in this bony anatomy exists between individuals.[4] However, there is minimal difference between ankles of the same person, with tibiofibular intervals not varying by more than 2.3 mm and the rotation of the fibula not varying by more than 6.5°.[4] Because of significant anatomic variation between individuals, using a patient's contralateral ankle for comparison provides a precise definition of normal tibiofibular relationships.

Ligamentous Structures

The distal tibiofibular syndesmosis consists of 3 distinct ligaments that act to statically stabilize the distal tibiofibular joint.[5–7]

Anterior tibiofibular ligament

This multilayered ligament extends obliquely from the anterolateral tubercle of the distal tibia on average 5 mm above the articular surface to the longitudinal tubercle located on the anterior border of the lateral malleolus. The inferior fibers can be viewed arthroscopically as they cover the anterolateral corner of the ankle and anterolateral dome of the talus.

Posterior tibiofibular ligament

This ligament consists of a deep and superficial component. The superficial portion extends obliquely from the lateral malleolus to a broad attachment on the posterolateral tibia tubercle. The deep component is the transverse ligament, which is sometimes referred to as a separate ligament. This portion is thick and strong and originates from the round posterior fibular tubercle, inserting on the lower part of the posterior border of the tibial articular surface. This deep portion is more transverse and acts as a labrum, deepening the tibial articular surface.

Tibiofibular interosseous membrane and ligament

This membrane spans most of the length of the lower leg between the tibia and fibula. The ligament is a pyramidal thickening of the distal membrane that terminates just superior to the anterior tibiofibular ligament (AITFL) and posterior tibiofibular ligament (PITFL), helping stabilize the talocrural joint during loading.

Blood Supply

The vascular supply to the syndesmosis has been examined in a singular study. The posterior branch of the peroneal artery is the predominant blood supply to the posterior syndesmotic ligaments. The anterior branch of the peroneal artery, which is the predominant blood supply to the anterior ligaments, perforated the interosseous membrane on average 3 cm proximal to the ankle joint. Thus, this vascular supply would be at considerable risk of insult with a syndesmotic injury, which could explain why syndesmotic injuries are associated with slower healing rates than other ankle ligament injuries.[8]

BIOMECHANICS OF SYNDESMOSIS

The understanding of ankle biomechanics is critical to the formulation of rational treatment plans for syndesmotic pathology. Ankle motion requires rotation and translation of the fibula at the level of the syndesmosis.[9] Dorsiflexion of the ankle results in an average of 2.5° of external rotation of the fibula, whereas plantarflexion results in less than 1° of internal rotation.[9] In normal individuals, external rotation force causes external rotation, medial translation, and posterior displacement of the fibula through the syndesmosis.[10] The intact syndesmosis prevents lateral fibular translation during weight bearing, enabling the fibula to bear 10% to 17% of the weight-bearing load during gait.[11] In anatomic specimens, the relative importance of the individual syndesmotic ligaments to syndesmotic stability was found to be 42% for the transverse ligament and PITFL complex (33% and 9%, respectively), 35% for the AITFL, and 22% for the interosseous ligament.[12] Disruption of the syndesmotic complex disrupts the articular congruity and places increased weight-bearing forces to the tibiotalar articulation, resulting in a nonphysiologic increase in external rotation of the talus.[13] The talar shift results in decreased tibiotalar contact surface,[14,15] which may lead to secondary degeneration of the joint.

Injury Mechanisms

A variety of mechanisms individually or combined can cause syndesmosis injury. The patient often poorly recalls the mechanism, which is in contrast to the classic inversion ankle sprain. The most common mechanisms, individually and particularly in combination, are external rotation and hyperdorsiflexion.[16] Injuries to the syndesmotic complex can occur in isolation or with associated fractures. They can occur with any type of fracture but are most commonly associated with pronation-external rotation and supination-external rotational (SER) fractures and proximal fibular fractures (Maisonneuve injuries),[17,18] although the exact mechanism of these fractures have been called into question in recent years.[19]

ACUTE SYNDESMOTIC INJURIES

Epidemiology

Although injuries to the ankle are extremely common, injuries to the syndesmotic complex are uncommon, comprising 1% to 10% of all ankle sprains.[20–22] The incidence is poorly defined but has been reported to be 6445 syndesmotic injuries per year in the United States when using emergency room and inpatient data. This rate will most likely continue to increase, especially given the expanding utilization of MRI and a heightened awareness in sports medicine. The highest rate of injury was found in patients aged 18 to 34 years.[23] The injuries may occur more frequently in athletes, with 2 studies reporting that greater than 20% of acute ankle sprains in athletes demonstrate syndesmotic disruption.[22,24] Sports at a considerable risk involve immobilization of the ankle in a boot, such as skiing and hockey,[25–28] and in collision sports, such as football, wrestling, rugby, and lacrosse.[29–32]

Diagnosis

The diagnosis of syndesmotic injury is based on the mechanism of injury, manifesting symptomology, a thorough physical examination, and radiographic findings. Importance must be placed on each one of those facets to make the correct diagnosis.

Isolated Syndesmotic Injuries

Clinical evaluation

In the absence of fracture, patients with syndesmotic injuries typically complain of persistent pain on weight bearing or an unusually long period of recovery after the initial injury. The clinical history should include the mechanism of injury, delineation of any prior ankle injuries, and direct location of pain. Any history of an eversion mechanism should prompt the physician toward consideration of a syndesmotic injury.

Physical examination

Physical examination findings include tenderness and swelling over the anterolateral aspect of the syndesmosis.[33–36] This finding is distinctly different in quality from the contralateral lower extremity. The patient may have reduced passive dorsiflexion.[37] Tenderness of the deltoid ligament may also be noted. In patients with complaints of instability, physical examination may denote a normal anterior drawer and inversion stress test, increasing suspicion of a syndesmotic injury over a lateral ankle sprain. In addition, the proximal fibula can be palpated to assess for a Maisonneuve-type injury. The physical examination can be performed 5 days after injury without compromising diagnostic accuracy and causing less discomfort to the patient.[38,39]

Stress tests are also useful in the diagnosis of syndesmotic injuries. Pain, rather than fibular translation, should be the outcome measure of these tests, because very small amounts of displacement are actually conferred by the physical examination maneuvers.[40] The external rotation stress test can be performed either by sitting while placing the knee in 90° of flexion and applying an external rotatory force on the foot or standing with a single limb stance on the affected side and then rotating the body externally[41,42] (**Fig. 1**). This test causes the greatest amount of displacement of the fibula when biomechanically analyzed.[40] A positive test result occurs if pain if reproduced in the syndesmosis.[30,41] The squeeze test involves compressing the proximal fibula to the tibia above the level of the calf, which may separate the bones distally.[43] The test result is positive if pain is elicited in the distal tibiofibular joint[29] (**Fig. 2**). The crossed legged stress test entails crossing the injured leg over the non-injured legged in the seated position followed by applying a downward pressure to the knee of the injured leg.[44] The fibula translation test places an anterior-to-posterior force on the fibula, and the result is considered positive if this translation causes pain at the level of the syndesmosis.[42] Lastly, the stabilization test is performed by tightly taping circumferentially just proximal to the ankle joint to stabilize the syndesmosis. The test result is positive if the patient has less pain with activities such as standing, walking, and jumping after the taping.[45]

The reliability and accuracy of these specialty tests are limited, and these tests should be used in conjunction with further imaging and/or arthroscopy.[46,47] The external rotation stress and the squeeze test demonstrated high specificity, but low sensitivity, when using MRI to confirm the diagnosis.[48,49] Intrarater reliability was high for the squeeze, Cotton, dorsiflexion range of motion, and external rotation tests. Interrater reliability was good for the external rotation tests and fair-to-poor for other tests.[50,51] Thus, the physical examination should always be used in accordance with the clinical history, as the clinician cannot rely on a single test to make the diagnosis. If an injury is suspected, additional diagnostic tests should be considered before making a final diagnosis.

Initial radiographic evaluation

Plain radiographs Typically, anteroposterior (AP), lateral, and mortise views of the ankle are used to evaluate the integrity of the distal tibiofibular joint and to assess

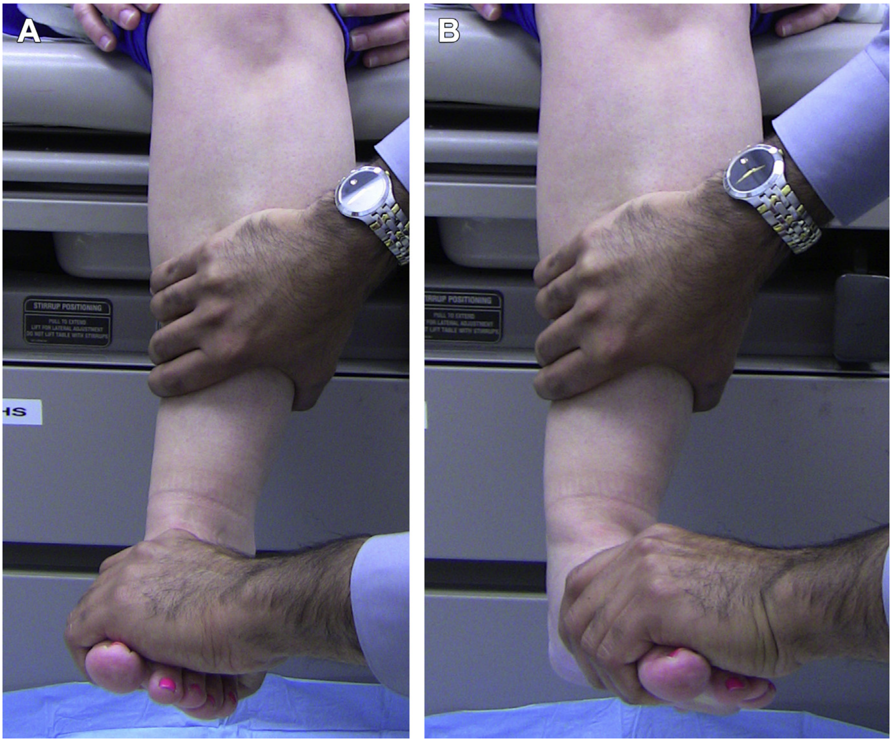

Fig. 1. External rotation stress test for evaluation of a syndesmotic injury. One hand is placed at the mid-calf to stabilize the leg. The foot is then grasped and taken from internal rotation (*A*) to maximum external rotation (*B*). Pain with external rotation indicates syndesmotic injury.

for fractures. Views of the proximal tibia and fibula are obtained if a Maisonneuve injury is suspected (**Fig. 3**). Occasionally, an avulsion fracture at the posterior tibial tubercle can be seen on the lateral view.[41]

When attempting to define abnormal radiographic relationships, it is important to try to describe the normal appearance. Harper and Keller[52] first described the normal relationships of the distal tibiofibular syndesmosis in 12 normal cadavers 1 cm proximal to the plafond. The tibiofibular clear space (TFCS) on the AP and mortise views should normally be less than 6 mm. The tibiofibular overlap (TFO) should normally be greater than 6 mm on the AP view and greater than 1 mm on the mortise view. The medial clear space (MCS) should be less than or equal to the superior joint space. Measurements on lateral radiographs to assess the syndesmosis have not been well defined. Croft and colleagues[53] showed with high reliability that 40% of the tibia was anterior to the fibula at 1 cm above plafond. However, the rotation of the limb can significantly influence each of these measurements[54] except for the TFCS on the AP view.[55]

Recent studies have found great variability in the radiographic measurements of normal patients.[54,56] A study in patients without known clinical or radiographic evidence of abnormality found that the mean TFCS was 4.6 mm on the AP view and 4.3 mm on the mortise view, whereas the mean TFO was 8.3 mm on the AP view and 3.5 mm on the mortise view. It was also demonstrated that a lack of overlap on the mortise view may represent a normal variant.[56] MRI studies have demonstrated that the TCFS and TFO did not correlate with syndesmotic injury, and MCS greater

Fig. 2. Squeeze test to assess for syndesmotic injury. Pain distally at the syndesmosis with medial/lateral compression at the mid-calf is suggestive of injury.

than 4 mm may correlate with disruption of deltoid and tibiofibular ligaments.[57,58] Thus, relying solely on these measurements may result in both failure to treat and overtreatment of patients. Therefore, because of the variability among different individuals, comparison views of the contralateral extremity and advanced imaging are an important diagnostic tool for confirmation of clinical suspicion of syndesmosis disruption.[56] Although plain weight bearing radiographs can show abnormalities, frank diastasis without fracture or applied stress is a rare occurrence.[54,55,59] External rotation stress or gravity stress views may be used to confirm latent diastasis.[13,60] Late disruption is best visualized on the lateral radiographs, with posterior displacement of the fibula.[13]

Computed tomography Owing to the questionable reliability of plain radiographic parameters and the difficulty in detecting subtle injuries, advanced imaging is frequently used. The recent literature has investigated the normal anatomic morphology as visualized on CT scan, focusing on the axial cuts.[35] CT is more sensitive than radiography for detecting mild diastasis.[61] Fibular malrotation is still difficult to assess, because there has been no standardized method for measurement.[62,63] Knops and colleagues[62] investigated multiple measurement methods for rotational malreduction and found 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 to be fairly reliable and

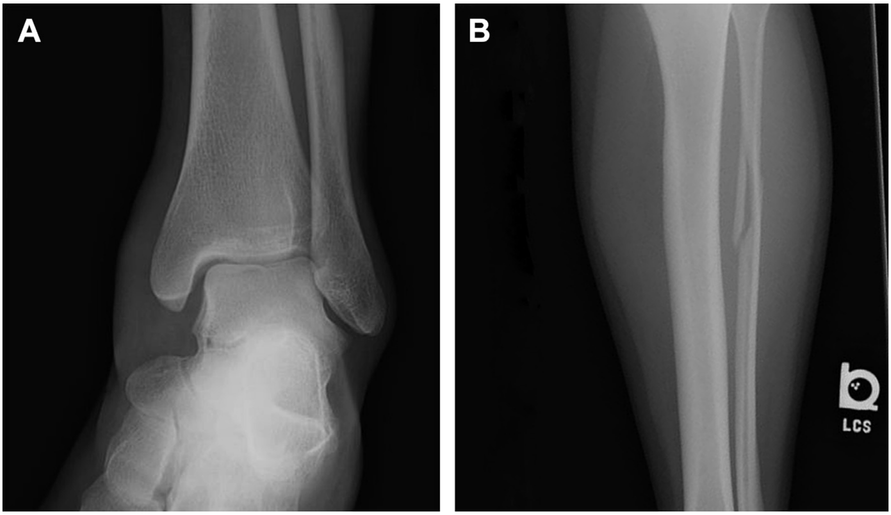

Fig. 3. Mortise ankle radiograph (*A*) does not demonstrate significant radiographic abnormality. A thorough examination noted pain within the proximal leg and a full length tib/fib radiograph demonstrates the presence of a proximal fibula fracture (*B*). This finding is highly suggestive of a Maisonneuve injury.

accurate. Just as with plain radiography, CT imaging has demonstrated variability in the anatomy of the syndesmosis between individuals.[64] Thus, bilateral imaging can be extremely useful.[65,66] Even after plain radiographs have demonstrated diastasis of the syndesmosis, CT scan can be a useful adjunct on the bony anatomy to guide surgical planning.

MRI In the setting of nondiagnostic radiographs, the use of MRI is superior to obtain the diagnosis of a syndesmotic injury, especially on the T1 and T2 axial images[67] (**Fig. 4**). MRI has excellent sensitivity, specificity, positive predictive value, negative predictive value, and accuracy at diagnosing syndesmotic disruption.[68] In a series of 78 patients, Han and colleagues[69] reported MRI to be 90% sensitive and 94.8% specific in diagnosing syndesmotic injury, using arthroscopic findings as a definitive diagnostic standard. In a similar study by Oae and colleagues,[70] MRI demonstrated 100% sensitivity and 94% specificity for AITFL disruption and 100% specificity and sensitivity for PITFL injury. MRI can be used to grade the injury and may be useful in predicting the time of disability, with involvement of the PITFL possibly signifying a more severe injury.[71] Although MRI is sensitive and specific for syndesmotic injuries using standard protocol at 3.0 T,[68] it is not predictive for instability because it is a static test.[49] In addition, injury to the tibiofibular syndesmosis has a significant association with several secondary findings on MRI, including anterior talofibular ligament injury and osteochondral lesions.[72,73]

Classification

Multiple classification systems have been described.[31,45,74] Most use clinical findings and plain radiographic interpretation, but no current classification uses anatomic location or MRI findings. There is a general agreement that there are 3 grades of injury (I–III). Grade I injuries have a stable syndesmosis with normal results on radiographs and may manifest with mild clinical symptoms and tenderness at the distal tibiofibular joint. Grade II indicates complete AITFL and interosseous ligament (IOL) disruption.

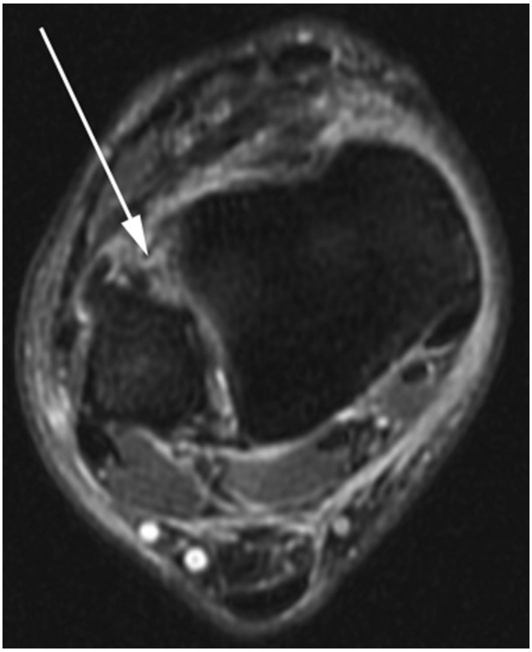

Fig. 4. Axial T2 fat-saturated image of a patient with a complete tear of the AITFL. Note the complete absence of the ligament in the anterior aspect of the tibiofibular joint space (*white arrow*).

Radiograph results are normal, and the provocative test results are positive. Unfortunately, there is no consensus regarding the stability of this injury pattern. The authors' preference for this injury depends on the status of the deltoid ligament. In the setting of an injury to the deltoid, stabilization of the syndesmosis is performed. If the deltoid ligament appears intact based on MRI, then conservative treatment in a controlled ankle motion (CAM) walker is initiated. Grade III injuries represent complete disruption of the AITFL, PITFL, IOL, and deltoid ligament. The distal tibiofibular joint is unstable and requires operative stabilization.

Syndesmotic Injuries with Associated Fractures

Fractures of the malleoli should increase clinical suspicion for syndesmotic injury. Although syndesmotic instability has been shown to occur more commonly in pronation-external rotational ankle fractures with high fibular fractures (36%–60%),[75,76] it also occurs in 17% to 45% of unstable SER ankle fractures with lower fibula fractures.[65,77–81] Multiple studies have attempted to predict syndesmotic disruption based on fracture pattern. Syndesmotic injury has been positively correlated with transverse fractures of the medial malleolus and bimalleolar fractures.[82] Choi and colleagues[83] found that in SER patterns, fracture height (distance between the lowest point of the fracture and the plafond) greater than 7 mm and MCS greater than 4.5 mm were significant preoperative factors associated with syndesmotic injury. The presence of a posterior malleolar fracture is the equivalent of a bony disruption of the PITFL (Fig. 5). Therefore, the authors advocate either direct fixation of the posterior malleolus or syndesmotic stabilization in this setting. Although not all patients do poorly without fixation, late posterolateral subluxation of the talus is extremely difficult to treat and should be avoided if possible. Fixation of the posterior malleolus in the

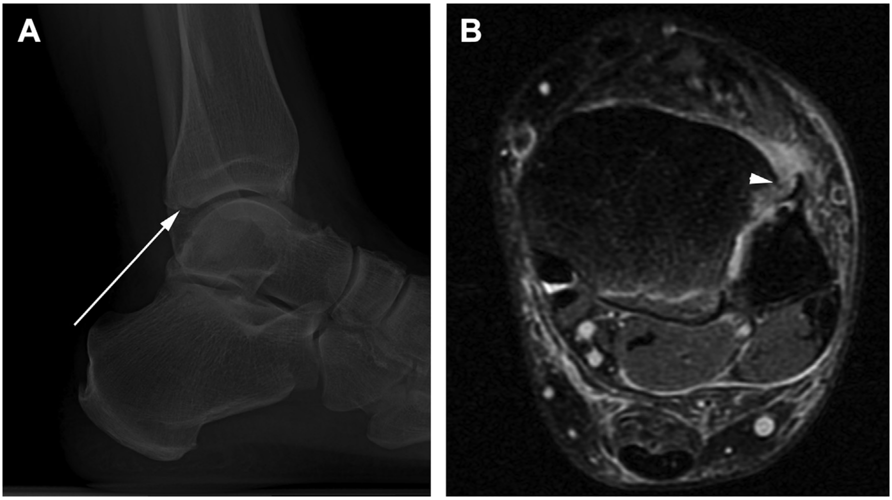

Fig. 5. Lateral radiograph (*A*) of a patient with a history of an ankle sprain with a subtle finding of a posterior malleolar fracture (*arrow*). MRI was performed to evaluate the syndesmosis with evidence of complete disruption of the AITFL (*arrowhead*) with fluid within the syndesmosis itself (*B*). Patient was appropriately treated with open reduction and internal fixation.

setting of a Weber B fibular fracture typically mitigates the need for additional syndesmotic fixation presuming all other bony fixation has been completed. However, in the setting of a Weber C fibular fracture, rotational stability to the fibula may not be restored with fixation of the posterior malleolus, and additional stabilization of the syndesmosis with either a screw or suture button device is considered.

Because plain radiographic findings are often inadequate for diagnosing syndesmotic disruptions in malleolar fractures and injuries can happen across all fracture patterns,[57,65,79] the diagnosis depends on thorough intraoperative assessment. This evaluation can be performed using an external rotation test or Cotton hook test under fluoroscopy.[84] In the external rotation stress, the tibia is stabilized and an external rotation force is applied to the medial aspect of the forefoot and lateral aspect of the hindfoot. Fluoroscopy is used to evaluate for MCS widening. The hook, or lateral stress, test uses a bone hook applied to the lateral malleolus to assess for greater than 2 mm of lateral movement of the lateral malleolus.[85] There is evidence to suggest that assessment of the fibula on the lateral radiograph may improve both the accuracy of the hook test[86] as well as the external rotation test.[13] The fibula demonstrates maximal motion in the sagittal plane with disruption of the syndemosis that is increased with concomitant deltoid disruption that lends more strength to the argument that anterior/posterior stress testing of the fibula is superior to isolated coronal plane stress testing. Pakarinen and colleagues[84] prospectively compared these 2 intraoperative tests with a standardized 7.5-Nm external rotation stress test as a reference. Although tests showed excellent interobserver agreement and specificity, both also had poor sensitivity. A prospective cohort study showed that widening with stress external rotation was significantly greater than with lateral fibular stress and appreciable on standard fluoroscopic views.[87] However, these results must be taken in the context of biomechanical evidence to suggest that the hook test with a 100 N force and visualization of widening of the TFCS is superior in differentiating syndesmotic disruption from isolated deltoid ligament injury in a Weber B ankle fracture model.[88,89] Thus, even if the external rotation stress may demonstrate significant widening, this may represent a deltoid ligament injury based on biomechanical data; this underlies the point that the clinician needs to use all available techniques to accurately diagnose a syndesmotic injury.

Lastly, as noted previously, due to individual anatomic differences, using a patient's contralateral ankle for comparison provides a precise definition of their normal tibiofibular relationships under stress examination.[66]

Role of Arthroscopy

The role of arthroscopy in the treatment of acute syndesmotic injuries is an ever-evolving field with little support in the literature. Its primary role at present is to diagnose syndesmotic instability and other intra-articular pathology.[72,90] Takao and colleagues[91] showed that in operative ankle fractures, arthroscopy confirmed 100% of cases of disruption that had been identified on preoperative plain radiographs and identified 12 additional patients with instability. A subsequent study revealed that compared with arthroscopy for diagnosis of syndesmosis disruption, MRI had 100% sensitivity and 93.1% specificity, showing 2 false-positive cases.[92]

CONSERVATIVE TREATMENT

There is limited quality literature available to help the clinician make a decision in terms of operative versus nonoperative treatment. Conditions with clinical evidence of syndesmotic injury without radiographic abnormality on static images and stress tests can be treated nonoperatively (grades I and II). MRI evidence of an intact deltoid ligament with isolated injury to the AITFL without involvement of the PITFL does not warrant surgical intervention in the opinion of the authors.

When an appropriate diagnosis is made, nonsurgical treatment of stable injury patterns has shown good results[30,31] and consists of a 3-phase approach.[93] The optimal rehabilitation program for these injuries is unknown, because there is no high-quality literature to direct the surgeon. A typical program includes a short period of non–weight bearing, followed by restoration of mobility, strength, and function and lastly advanced sports-specific training. An orthopedic device, most commonly a CAM walker, to limit external rotation is often used. The length of restricted weight bearing and advancement of activities depend on the clinical symptoms, injury severity, and the patient's functional presentation.[45] Rest, elevation, compression, anti-inflammatory medications, and appropriate use of therapeutic modalities such as electric stimulation and massage should be incorporated into the treatment regimen. After 4 to 6 weeks, transition to a lace-up ankle brace is initiated with more aggressive physical therapy as the patient can tolerate. The lace-up brace may be used for a further 6 weeks to minimize symptoms.

A systematic review evaluated 6 studies regarding conservative treatment of syndesmotic injuries.[25,29–31,36,41,94] These studies involved sprains without diastasis on radiographic examination. When compared with lateral ankle sprains, all studies showed prolonged recovery in the syndesmotic sprain group, with a resultant delayed return to play. Return to play is challenging, and is typically based on a functional testing evaluation and physical examination. One study in National Hockey League players showed a mean time to return to play of 45 days versus 1.4 days for lateral ankle sprains.[25] More severe injuries, as determined by MRI involvement of the IOL and PITFL, were positively correlated with increased numbers of missed games and practices.[71] The number of missed competitions also correlated with the interosseous tenderness length[30] and a squeeze test with positive results.[30,71] Although syndesmotic injury is most predictive of persistent symptoms in the athletic population,[95] with correct diagnosis, function is typically good after the initial recovery period.

In syndesmotic injuries associated with malleolar fractures, those with resultant incongruity of the ankle mortise require surgical treatment. Proper intraoperative assessment is paramount and was discussed in the prior section.

SURGICAL TREATMENT

Patients with persistent symptoms despite conservative treatment or with higher-grade injuries with tibiofibular diastasis benefit from operative treatment. Athletes with grade III injuries treated operatively demonstrated similar long-term outcomes when compared with nonsurgical patients.

Most syndesmotic injuries that occur with malleolar fractures require surgical stabilization. There is some debate as to whether syndesmotic fixation is always necessary in SER-type ankle fractures. As bony injuries heal anatomically, the ligamentous injuries may heal at their proper length after malleolar reduction. In 2 small prospective randomized studies of SER ankle fractures, there was no difference in functional outcomes scores or radiologic findings in stress-positive ankles with and without syndesmotic fixation at 1-[77] and 4-year[96] follow-up. In addition, the recent literature has investigated deltoid ligament repair instead of syndesmotic repair in bimalleolar equivalent ankle fractures and found comparable subjective, functional, and radiographic outcomes at mid-term follow up.[97]

However, to prevent potential chronic instability and late arthrosis, the syndesmosis disruption is typically addressed. In the settings of fibular fracture with deltoid disruption, anatomic reduction of the ankle mortise relies on the fibula to hold the talus in proper alignment. The presence of a syndesmotic injury prevents the fibula from facilitating proper alignment of the mortise, leading to recurrent talar translation. Thordarson and colleagues[98] have shown that a 50% increase in pressure in the lateral half of the tibiotalar joint occurs with only 2 mm of lateral talar translation.

Reduction Techniques

Once the decision has been made to proceed to address the syndesmotic injury surgically, the first step is reduction of the distal tibiofibular joint. When applicable, fibular length must be assessed and corrected appropriately to facilitate anatomic reduction of the syndesmosis.[99]

Clamp placement

The syndesmosis is most commonly reduced with use of reduction clamps to compress across the tibia and fibula (**Fig. 6**). If choosing to reduce the syndesmosis with a clamp application, it is important to consider clamp trajectory and force. A cadaveric study demonstrated small, but significant, overcompression and external rotation displacement of the fibula when clamps were placed at 15° and 30° of angulation in the axial plane, relative to the anatomic axis of the syndesmosis.[100] Another cadaveric study showed that placing a clamp in the neutral anatomic axis reduced the syndesmosis most accurately, although minimal overcompression was observed.[101] The authors use a clamp in some situations; however, they have used manual reduction and stabilization using the thumb to generate the reduction force. This is an emerging technique that may decrease the risk of malreduction associated with a clamp. Once the syndesmosis is felt to be reduced, a K-wire may be placed along the syndesmotic axis to stabilize the position of the fibula. The use of a clamp at this point allows further reduction of the syndesmosis in the coronal plane without risking sagittal malalignment.

Fig. 6. Intraoperative photograph demonstrating placement of a large reduction clamp to reduce the syndesmosis. The clamp should be placed at the level of the ankle joint with the foot held in neutral.

Assessment of reduction

Once a reduction is attempted, the next important step is the assessment of the reduction.

Assessment may be attempted indirectly via radiographic imaging. Unfortunately, the same inaccuracies in diagnosing injuries using plain radiographs in the preoperative setting exist when assessing the reduction in the operative setting. A cadaveric study suggested that a 30° external malrotation of the fibula may result when using TFCS, TFO, and posterior subluxation to assess reduction.[102]

Because of these difficulties, surgeons have attempted to compare the injured side with a normal contralateral extremity.[103,104] Although substantial variation in ankle anatomy exists between individuals, there is little variation between contralateral ankles of a single individual.[4] A cadaveric study using perfect lateral radiographs showed that anterior displacement and greater than 5 mm translation were accurately detected and that fluoroscopic comparisons to the normal ankle were helpful in determining reduction.[104] In a clinical study, Summers and colleagues[105] used uninjured contralateral ankle radiographs as a template for reduction and demonstrated anatomic reduction on intraoperative CT scan in 17 of 18 of patients.

Other investigators have suggested the use of intraoperative CT scan to improve the reduction.[106–108] Franke and colleagues[108] used this technology in a consecutive series and altered the surgical outcome in 32.7% of cases, improving reduction of the distal tibiofibular joint in 30.7% of the total cases. Other studies have shown that intraoperative CT reduced their posterior malreduction rate but not the anterior malreduction rate.[107] Thus, although intraoperative 3-dimensional imaging increases cost and exposes the patient to additional radiation, it provides an intraoperative assessment that can improve reduction.

The reduction can also be assessed directly via open reduction of the syndesmosis. Studies have demonstrated improved accuracy of the reduction with direct visualization of the incisura, although 15% to 16% still demonstrated incongruity on postoperative CT scan.[109,110] Direct repair of the deltoid ligament is Dr Kadakia's preference when treating syndesmotic injuries, which may improve the reduction of the fibula within the incisura fibularis. A combination of direct visualization of the syndemosis and incisura along with primary repair of the superficial component of the deltoid ligament may minimize the risk of iatrogenic malreduction.

Fixation Construct and Placement

Once a reduction is obtained and maintained, the syndesmosis must be stabilized. There are numerous studies evaluating the technical aspects of syndesmotic fixation. The next step is choosing an implant for fixation.

Screw composition, size, number, and cortices engaged

The traditional method, and the most common current practice,[111] is stainless steel screw fixation, although other screw compositions have demonstrated satisfactory results.[112,113] The composition of the screw has not been shown to differ in biomechanical testing nor does it significantly influence the radiographic or clinical outcomes; this is true in regards to bioabsorbable screws[114–116] and titanium screws.[117] Bioabsorbable screws may offer slightly increased range of motion[118] and obviate subsequent hardware removal but have a higher incidence of foreign body reactions.[118]

If choosing a stainless steel screw, fixation can be achieved with 3.5- or 4.5-mm screws. There is biomechanical evidence to suggest that the 4.5-mm screw provides more resistance to shear stress,[119] although other studies showed no biomechanical difference.[120,121] Once the screw size is selected, there has been no difference in radiographic or functional outcomes in tricortical and quadricortical screws.[117,122–125] Two screws or locking plate fixation provides stronger mechanical fixation,[13,126] without translating into improved clinical outcomes.[99,127,128] Multiple screws are typically considered in Maisonneuve injuries, in obese patients, or in severely osteoporotic bone to increase construct stability.[129] If screw fixation is chosen, the authors' preference is a 3.5-mm tricortical screw if the fibula is fixated.

Dynamic fixation

Dynamic fixation with suture-button fixation has been widely studied.[130–144] A hole is drilled through the fibula and tibia, and then a suture is passed through and secured on both ends via a metallic button. Systematic reviews of low levels of clinical evidence have demonstrated similar functional outcomes, with quicker return to work and less frequent need for implant removal. A single suture button device has demonstrated lack of sagittal stability compared with a screw and must be considered when choosing this implant. A prospective, randomized control trial demonstrated better clinical and radiographic outcomes with a dynamic device, with improved maintenance of reduction and lower reoperation rate.[131] Despite the increased cost of the implant, the decreased need for hardware removal may confer cost-effectiveness to this technique. Lastly, one can consider hybrid fixation with a screw and suture button construct for severe diastasis or large athletes.

Implant placement

Once a reduction is obtained and maintained and an implant is selected, the implant must be placed.

There is conflicting biomechanical evidence regarding placement of the implant relative to the tibiotalar joint. One study showed that a screw placed 2.0 cm above the tibiotalar joint resulted in less syndesmotic widening than a screw placed 3.5 cm above the joint,[145] whereas another showed that fixation 3 to 4 cm above the joint may have biomechanical advantages.[146] Clinical evidence has not demonstrated significantly different radiographic or clinical outcomes in transsyndesmotic or suprasyndesmotic fixation.[147] Screw placement more than 4.1 cm above the joint negatively influences patient outcomes, likely due to decreased stability at this level or by slight bending of the fibula on insertion, causing widening at the mortise.[148]

All evidence regarding orientation of the fixation is from cadaveric and anatomic studies. Anatomically, the fibula sits posteriorly in the tibia, and screws should therefore be directed 30° anteriorly.[149] This position corresponds to a line from the lateral cortical apex of the fibula to the anterior half of the medial malleolus.[150] Aberrant screw placement may cause malreduction.[100] Furthermore, the screw should be inserted parallel to the ankle joint in the coronal plane to prevent any proximal migration.

The sagittal position of the ankle while the implant is being placed has been debated. An older cadaveric study suggested that dorsiflexion of the ankle may be restricted if the ankle is not in a maximally dorsiflexed position during fixation.[151] However, more recent literature does not support this.[152,153] Thus, it is the surgeon's choice in determining the position of the ankle during fixation. However, in the setting of a posterior malleolar fracture, the authors do not recommend dorsiflexion to minimize iatrogenic posterior translation of the fibula.

Posterior Malleolar Fixation and Anterior Tibiofibular Ligament Reconstruction

There has been much interest in the role of the posterior malleolar fracture in regards to syndesmotic stability. Syndesmotic injuries are not infrequently associated with a fracture of the posterior malleolus. When there is a posterior malleolar fracture, the PITFL is reliably intact and attached to the posterolateral fragment.[154] Subsequently, malreduction of this component may result in malreduction of the syndesmosis with resultant posterolateral subluxation of the fibula. Fixation of this fragment alone confers increased stability to the syndesmosis[154] and equivalent functional outcomes in small series when compared with syndesmotic screw fixation.[155] This method of syndesmotic stabilization would also obviate removal of screw fixation from the syndesmosis and may allow for earlier weight bearing as a result of bony healing as opposed to ligamentous healing. In addition, there is some limited evidence that repair or reconstruction of the AITFL restores the stability, allows for early return to functional activities, and obviates syndesmotic screw fixation.[156]

Postoperative Protocol

Return to sports can be expected as early as 4 weeks after rigid fixation of an isolated fibula fracture and up to 8 to 10 weeks after stabilization of a bimalleolar equivalent fracture with deltoid repair. Syndesmosis fixation can take up to 4 to 6 months before successful return to sport.

Outcomes and Complications

Satisfactory outcomes can be expected with syndesmotic fixation, even in high-level athletes.[78,127,157,158] There exist a variety of factors that can influence a patient's surgical outcome. Failure to diagnose the syndesmotic injury has been found to be a common cause of reoperation.[159] Thus, it is important for the surgeon to have a high incidence of suspicion for injury and assess for disruption appropriately.

Injury factors

There is literature indicating that syndesmotic injuries associated with trimalleolar fractures have significantly lower outcomes than unimalleolar or bimalleolar fractures.[148,160] When compared with all operative ankle fractures not requiring syndesmotic fixation, those requiring stabilization had worse American Orthopedic Foot and Ankle Society (AOFAS) scores in function and pain and worse Short Musculoskeletal Functional Assessment (SMFA) scores at 12 months.[161] Litrenta and colleagues[162] found similar findings in SER-IV ankle fractures, with small clinical differences in SMFA and bother index but not in the AOFAS score. However, conflicting evidence was presented by Kortekangas and colleagues[163] in SER-IV ankle fractures, who showed no clinical or radiographic differences at 4- to 6-year follow-up in patients with syndesmotic injury compared with patients with a stable syndesmosis. This lack of significant difference was also seen by Kennedy and colleagues[164] in Weber C ankle fractures. Worse functional results have been demonstrated in ankle fractures that were dislocated on initial presentation.[165]

Patient factors

There is evidence demonstrating that increasing age negatively affects outcome.[148,160] Although diabetes mellitus and smoking did not show an effect on loss of syndesmosis reduction, obese patients were 12 times more likely to lose reduction than were patients with a normal body mass index[166] and had poorer functional outcomes.[123] Wukich and Kline[167] found that patients with complicated diabetes were 3.4 times more likely to have soft-tissue and bony complications than patients with uncomplicated diabetes, without considering specifically syndesmotic injuries.

Surgeon factors

As discussed previously, there have been no major differences in functional or radiographic outcomes between 1 and 2 screws, tricortical and quadricortical screws, or screws of varying compositions. The literature on dynamic fixation is evolving, with the recent high-level literature suggesting improved outcomes without the need for hardware removal.[131]

The most pertinent, technical aspect of surgical treatment is the accuracy of the reduction. This aspect has been shown to be the most important independent predictor of clinical outcomes and vital in avoiding posttraumatic arthrosis.[14,15,78,123,132,165] It involves first correctly diagnosing the injury, then establishing an anatomic reduction of the syndesmosis and the fibula if there is a fracture.[159] In a prospective evaluation with minimum 2-year follow-up, Sagi and colleagues[109] found that malreduced syndesmotic injuries had significantly worse functional outcome scores than those with anatomic reductions.

Malreduction Despite the focus on syndesmotic injuries and the importance placed on anatomic restoration, malreduction is still commonplace. The literature has shown syndesmotic malreductions to occur in as many as 25.5% to 52% of patients.[66,75,76,102,109,110] The malpositioning is often in the sagittal plane with anterior displacement and internal rotation.[108–110] Predictors of malreduction have been investigated, but no significant factors could be elucidated.[168]

Given the high rates of malreduction several strategies were noted for improving the accuracy of reduction, including recent evidence that accuracy in reduction can be improved using direct visualization of the reduction,[109,110] contralateral radiographs as a template,[103,105] and intraoperative CT scan.[106–108] In Maisonneuve injuries, a small series demonstrated improved syndesmotic reduction with open reduction and internal fixation of the proximal fibular fracture.[169] Despite all those techniques, there is still difficulty in obtaining and maintaining an anatomic reduction. Because of this, dynamic implants have been investigated in malreduced cadaveric models and have been shown to mitigate clamp-induced malreduction in the coronal and sagittal planes.[144]

By improving the reduction, the surgeon can hopefully maximize patient outcomes and minimize need for secondary interventions.

Hardware-related complications

The syndesmosis is a dynamic articulation, and screw insertion provides a static means of stabilization. This nonphysiologic intervention, theoretically, may result in some degree of functional incapacity and abnormal ankle motion.[170,171]

Syndesmotic screws are typically left in place 12 weeks to allow for ligamentous healing.[172,173] The authors prefer screw retention for 4.5 months to decrease the risk of syndesmotic failure after screw removal. Whether or not it is necessary to remove the intact screw remains a subject of debate. As patients increase their weight bearing, this causes increased shear stresses that can result in screw breakage.[161] If this screw breakage, or removal, occurs before ligamentous healing, it can result in loss of reduction.[158,174,175] One study found that 3.5-mm screws were more likely to break than 4.0- or 4.5-mm screws but without any increased loss of reduction.[176]

A survey demonstrated that 65% of respondents from the Orthopaedic Trauma Association and AOFAS routinely removed syndesmotic screws.[111] However, there is evidence to suggest that patients with retained syndesmotic screws have no functional or radiographic deficits when compared with those with screws removed[78,161,177–179] or with broken screws that are retained.[158,178–180] However, when comparing retained broken screws with retained intact screws, there are studies to suggest that screw removal, or hardware failure, may allow the distal tibiofibular joint to return to normal function and improve functional outcomes. Hamid and colleagues[178] showed that patients with retained broken screws had higher AOFAS scores than patients with intact screws or removed screws. Manjoo and colleagues[181] demonstrated similar results and also showed that there was no benefit in screw removal in patients with loose or fractured screws. Song and colleagues[182] used CT scans to find that 8 of 9 malreductions of the syndesmosis showed adequate reduction once the screw was removed.

It is important to thoroughly consider the literature, because complications can occur with screw removal, with Schepers and colleagues[174] demonstrating a 9.2% wound infection rate and 6.6% rate of recurrent diastasis. In conclusion, there is no high-quality evidence to support the absolute need for routine removal of the syndesmotic screw. Removal may be reserved for intact screws that cause hardware irritation or reduced range of motion after 4 to 6 months or have known malreduction of the syndesmosis.

Dynamic fixation of the syndesmosis has been reported to have cases of infection, skin irritation, and granulomatous tissue formation necessitating secondary intervention.[143] These complications may occur at a lower rate in the new generation of implants that do not have as large of a knot as the original implant, but this has yet to be shown in the literature.

Authors' approach to fixation

Given the lack of direct evidence to determine which mode of fixation is superior, the authors have developed a treatment algorithm based on sagittal stability.

The deltoid ligament is treated with open repair in all cases of preoperative incongruity of the mortise on nonstress radiographs. In the setting of stress-only widening of the mortise, the deltoid is not repaired as in these cases; the authors have noted that the deep component of the deltoid is torn without complete rupture of the superficial deltoid ligament. Repair of the deltoid is associated with improved reduction of the syndesmosis and decreases sagittal plane instability.

In the setting of a Weber B fracture without a posterior malleolar fracture, a suture button device is used to stabilize the syndesmosis given the minimal sagittal instability in these fractures as the IOM is typically intact.

In the setting of a Weber B fracture with a posterior malleolar fracture, the posterior malleolar fracture is reduced and stabilized if amenable to fixation. The authors are aggressive in fixation of all posterior malleolar fractures to directly restore the integrity of the PITFL without additional syndesmotic stabilization. However, if the posterior malleolus is reduced and not amenable to fixation, then rigid fixation with a screw is performed to ensure sagittal stability.

Weber C fractures typically involve greater soft-tissue injury relative to a Weber B fracture with sagittal stability compromised in most cases. Without the presence of a posterior malleolar fracture, a suture button device is used if the deltoid ligament is repaired. If the deltoid ligament is not repaired, sagittal instability is not minimized, and therefore, rigid fixation with a screw or 2 suture button devices is used. Given the cost of 2 suture button devices, the use of a screw is used in the authors' practice.

Weber C fractures with a posterior malleolar fracture are best treated with fixation of the posterior malleolus if possible to restore the anatomy of the incisura. Unlike a Weber B with a posterior malleolar fracture, disruption of the AITFL and IOL occurs in most cases. Therefore, a suture button device is used to restore rotational and coronal stability. If the posterior malleolus cannot be fixated, then rigid fixation is used as discussed earlier.

In the setting of a Maisonneuve injury, fixation of the fibula is difficult and may be associated with injury of the peroneal nerve and is not routinely advocated. In this setting, isolated use of suture button devices may not be provide sufficient sagittal or axial stability despite providing coronal stability and are therefore not used in isolation for this injury. However, given the improved reduction that has been noted with the use of a suture button device, a hybrid construct with a suture button device and a 3.5-mm tricortical screw over a 4-hole plate is used. Traction is placed on the fibula with a reduction clamp to help restore fibular length with temporary stabilization performed with a 0.062 K-wire. A 4-hole plate is chosen with the most distal hole at the level of the tibiotalar joint. The plate is fixed to the fibula using the proximal and distal screw holes. A large reduction clamp is placed with gentle compression to ensure fibular reduction in this setting. The suture button device is placed initially followed by placement of the transsyndesmotic screw (Fig. 7).

Routine hardware removal is no longer performed unless the patient is noted to be symptomatic.

CHRONIC SYNDESMOTIC INJURIES

Chronic syndesmotic injuries are defined as persistent widening of the tibiofibular joint 3 months after the initial injury[11] and may occur secondary to malreduction or missed diagnosis. Chronic diastasis of the distal tibiofibular joint is a cause of persistent pain and dysfunction after a rotational ankle injury. Widening and chronic instability of the distal tibiofibular syndesmosis has been shown to be associated with poor outcomes and the development of osteoarthritis.[93,109,183–187] The distal tibiofibular instability is treated with various reconstruction techniques, including tightening with advancement or transposition, autograft substitution, and arthrodesis. Most reconstructions include anatomic restoration of length and rotation of the fibula in addition to addressing the soft-tissue hypertrophy and its mechanical impaction in the ankle joint.

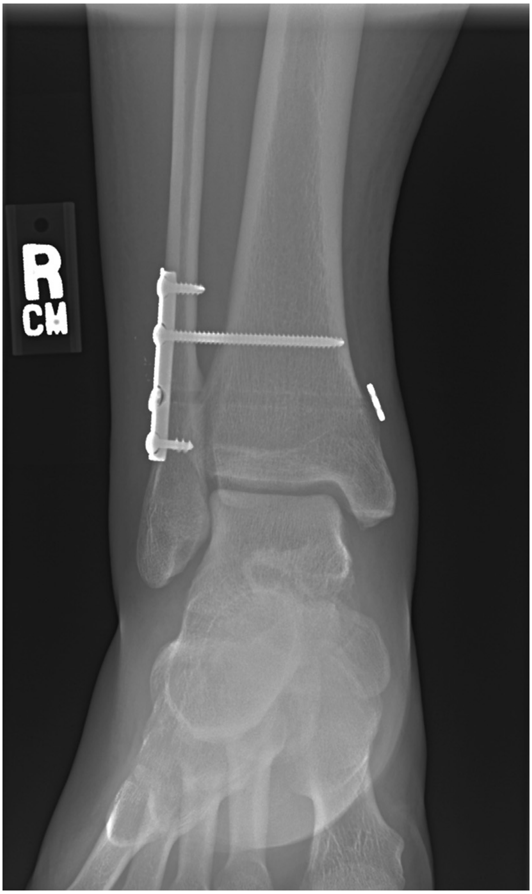

Fig. 7. Postoperative standing AP radiograph of a patient treated with Dr Kadakia's preferred method of a 4-hole plate with 1 syndesmotic screw and 1 suture button. Removal of the screw can be performed at 4.5 months without any concern for fracture of the fibula. Although rare, the complication can lead to significant disability if it occurs. At present, the author no longer performs routine removal of hardware.

DIAGNOSIS

Clinical Evaluation and Physical Examination

Similar methods are used for the diagnosis of chronic injuries to the syndesmosis. Again, the clinician must have a high index of suspicion for the injury and use numerous physical examination techniques and radiographic modalities to make an accurate diagnosis.

Radiographic Evaluation

Plain radiographs

Just as in acute syndesmotic injuries, plain radiography are the first step in imaging evaluation. In the setting of a chronic syndesmotic injury, many patients present with abnormal diastasis of the syndesmosis along with lateral talar translation and an increased MCS (Fig. 8). In this scenario, the increase in the forces on the lateral tibiotalar joint is greater than in either condition alone. In addition, instability may be

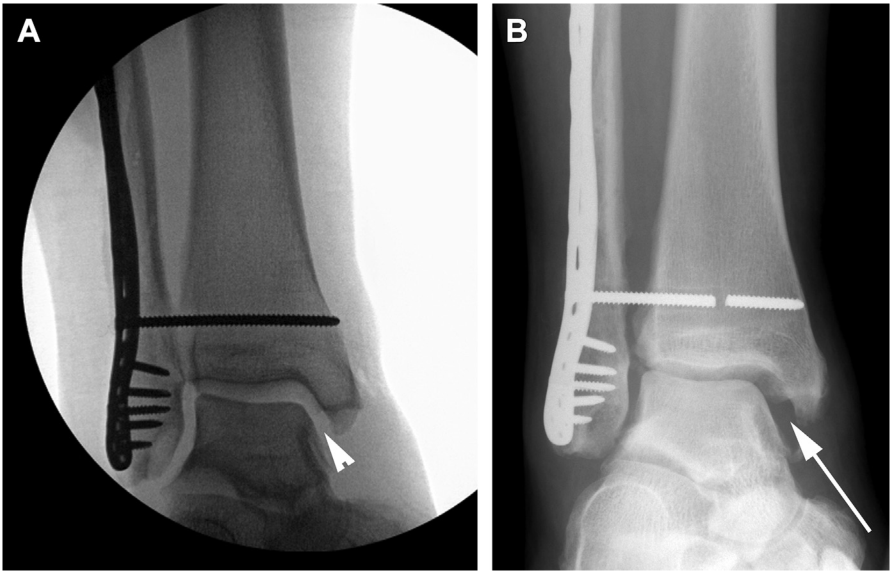

Fig. 8. Early failure of the syndesmotic fixation in a patient who had a concomitant fibular fracture. Appropriate intraoperative reduction and fixation was obtained (*A*) with reduction of the medial clear space (*arrowhead*). With failure of the syndesmosis in the postoperative period (*B*), the loss of syndesmotic stability results in lateral talar translation with an increased medial clear space (*arrow*).

evaluated by dynamic stress evaluation.[42,69,91,92] Instability is present if there is 2 mm or more of widening after an external rotatory stress is applied to the ankle in a neutral position.

CT scan is often more useful in a chronic setting when assessing for associated bony injury, fracture healing, and presence of arthritis. CT is used preoperatively to assess fibular length, degenerative changes within the syndesmosis or tibiotalar joint, presence and location of a synostosis, a malreduced posterior malleolar fracture, and presence of osteochondral lesions[188] (**Fig. 9**). Given anatomic variations, bilateral ankle CT scans are vital to allow the surgeon to compare angular measurements to detect latent diastasis.[189]

MRI may also be obtained to aid in diagnosis and assess for intra-articular pathology and is sensitive, specific, and accurate in the diagnosis of chronic syndesmotic injury.[69] A recent publication noted that, in the presence of positive physical examination findings, a high-intensity signal seen on coronal MRI that resembles the Greek letter λ was sensitive (75%) and specific (85%) for a latent syndesmotic injury with greater than 2 mm of diastasis as seen on arthroscopy.[49]

Arthroscopy

Ankle arthroscopy is a useful tool in the diagnosis of chronic disruption of the distal tibiofibular syndesmosis allowing direct visualization of the disrupted anatomy. Arthroscopic assessment allows for debridement of fibrous tissue interposed in the distal tibiofibular joint as well as concomitant osteochondral defects and synovitis (**Fig. 10**). In a prospective randomized trial of 20 patients, Han and colleagues[69] showed no statistical difference in AOFAS scores in patients treated with arthroscopic debridement with or without screw fixation. These findings were supported by a

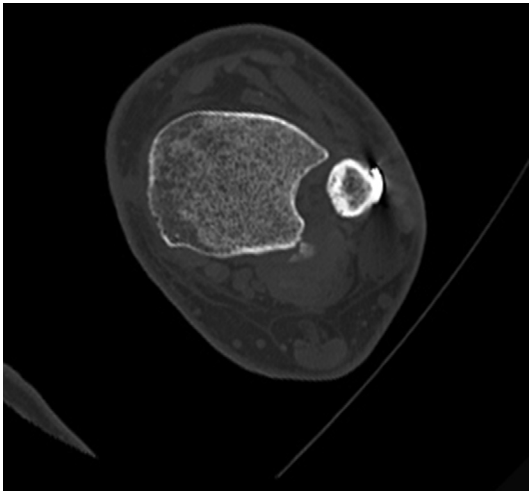

Fig. 9. CT scan of a patient demonstrating clear anterior and lateral malreduction of the fibula.

previous trial by Olgivie-Harris and Reed[42] suggesting that patients' symptoms were secondary to hypertrophied soft tissue within the joint and not instability. Arthroscopic debridement is best used in the setting of normal findings on radiographs without bony abnormality or as an adjunct to a reconstructive procedure. The authors use a suture button device in addition to arthroscopic debridement in these cases to maximize syndesmotic stability. Isolated arthroscopic debridement is contraindicated in the presence of frank diastasis, as the underlying deformity cannot be corrected with arthroscopy alone.

SURGICAL TREATMENT

Reconstruction

Reconstructive techniques depend on the integrity of the distal tibiofibular ligaments, with the goal of restoring the normal anatomy between the distal tibia and fibula in

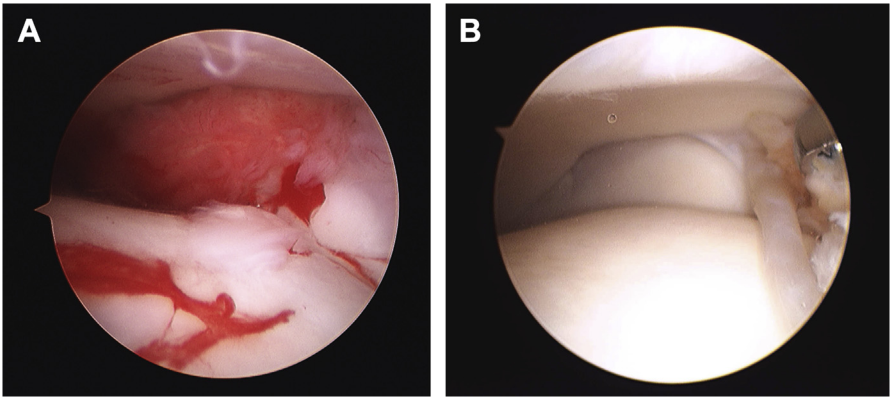

Fig. 10. Arthroscopic view of a patient with chronic syndesmotic instability with an associated osteochondral defect (*A*). Note the significant synovitis and hypertrophic tissue emanating from the syndesmosis. This image is in contrast to a normal appearance (*B*) of the syndesmosis in a patient who had intra-articular fibrous scar after a low ankle sprain.

addition to stabilizing the talus within the mortise. In the setting of a continuous AITFL, bone block advancement has been demonstrated to be a viable option. In a prospective study, Wagener and colleagues[190] osteotomized and mobilized the insertion of the AITFL with a 1 $\times$ 1-cm bone block. A gutter directed medial and proximal to the original insertion was then made in the tibia. After application of maximal compression to the mortise with a pelvic clamp, the bone block was advanced into the gutter and stabilized with screw fixation. The bone block was supplemented with a tetracortical syndesmotic screw. Follow-up demonstrated improved average AOFAS scores (75–92) in 12 patients treated greater than 2 years after initial injury with an average follow-up of 25 months.

When the AITFL is ruptured or attenuated, reconstructive surgery using local graft or free autogenous substitute may be used. Grass and colleagues[34] used a split peroneus longus tendon autograft with a tricortical transfixation screw in a series of 16 patients. At an average follow-up of 16 months, 15 of 16 patients reported pain relief and stated they would undergo the surgery again. Hamstring autograft is another alternative that has been performed with encouraging results.[33] This technique described by Morris and colleagues[33] anatomically reconstructed the AITFL and the interosseous ligament using 2 tunnels. The first tunnel was directed from slightly posterolateral to the fibula to slightly anterior in the tibia. The second tunnel was placed anterior to the fibula below the level of and parallel to the first tunnel. The graft was then passed medial to lateral through tunnel 1 and finally looped over the fibula into tunnel 2. The graft was secured medially and laterally with 15-mm interference screws. Visual analog pain scores improved from 73 preoperatively to 19 postoperatively. No preoperative AOFAS scores were recorded preoperatively; however, the average postoperative AOFAS score was 85.4. The graft used in this technique was 7 to 8 mm in diameter compared with the previously described peroneus graft, which was only 3.5 mm in diameter.

Lui[191] described a minimally invasive triligamentous reconstruction using 3 tunnels. The first tunnel connects the anterior and posterior tubercle of the distal tibia, followed by a second tunnel joining the fibular insertions of the AITFL and PITFL. The third and final tunnel is made over the lateral malleolus and directed posteromedially above and toward the tibial tunnel. The peroneus longus tendon is then harvested and passed through the posterior half of the tibial tunnel exiting the third fibular tunnel reconstructing the interosseous ligament. The opposite end of the graft is passed anteriorly through the fibular tunnel reconstructing the PITFL. Finally, the 2 ends are sutured to each other and inserted into the anterior half of the tibial tunnel to reconstruct the AITFL. No long-term follow-up or outcomes were recorded.

Moravek and Kadakia[188] used a double-limbed hamstring allograft reconstruction of the syndesmosis in 6 patients. In contrast to the previously described methods, this technique primarily reconstructs the IOL and is augmented with suture button fixation, which obviates a second procedure for hardware removal. The surgical algorithm is presented in **Box 1**. A single tunnel directed at a 30° angle (posterior to anterior) was drilled from the fibula to the anteromedial tibia. A semitendinosis allograft is first passed medial to lateral and fixed medially with a biotenodesis screw. The free end is then passed over the fibular bridge and fixed over the medial aspect of the tibia. Next, the remaining graft is finally sewn to itself over a medial tibia bone bridge and augmented with a fibular locking plate due to the high stress placed on the fibula during graft tensioning to prevent iatrogenic fracture (**Fig. 11**). Although this was not the initial technique used, following a late stress fracture, the technique was modified. A suture button device is additionally used to decrease the stress on the allograft during the initial phase of healing (**Figs. 12** and **13**). No long-term follow-up was available;

Box 1
Surgical algorithm for the treatment of chronic syndesmotic diastasis

1. Hardware removal of prior fibular and syndesmotic fixation if present
2. Debridement of the syndesmosis and/or excision of synostosis
3. Posterior malleolar osteotomy if preoperative CT indicates a malunion
4. Transection of the deltoid ligament or medial malleolar osteotomy if malunion is present
5. Debridement of medial ankle joint gutter
6. Oblique lengthening fibular osteotomy if a shortened fibula is present
7. Reduction of the syndesmosis with a large tong clamp
8. Suture button fixation proximal to the proposed graft site
9. Doubled allograft reconstruction of the syndesmosis
10. Removal of the reduction clamp with assessment of syndesmotic reduction and stability
11. Imbrication of the deltoid ligament or reduction and fixation of medial malleolar osteotomy

however, all patients reported they would undergo surgical intervention again. Before graft placement, the syndesmosis was debrided and fibular and posterior malleolar nonunions were corrected to facilitate an anatomic reduction of the mortise.

Arthrodesis

An alternative to syndesmotic reconstruction particularly in the setting of existing syndesmotic arthritis is arthrodesis. Arthrodesis has proven results that ensure long-term stability of the distal tibiofibular joint provided that successful union occurs. However, this eliminates the normal motion of the syndesmosis that may lead to abnormal load to the talar articular surface with resultant risk of long-term ankle arthrosis. Incorrect positioning in both the sagittal and coronal planes may result in further abnormal forces to the talar articular surface. Despite the theoretic concerns regarding the abnormal talar constraints with resultant risk of arthritis, there is some evidence to suggest the contrary.[11,192,193] Olson and colleagues[193] described debriding the distal tibiofibular joint and stabilizing the arthrodesis with two 3.5-mm cortical screws placed in a lag fashion through 4 cortices. At an average follow-up of 41 months, mean AOFAS scores

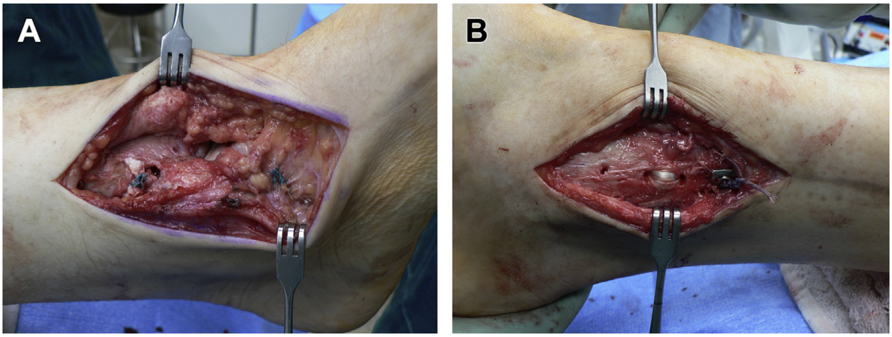

Fig. 11. Final appearance of the graft medially (*A*) and laterally (*B*).

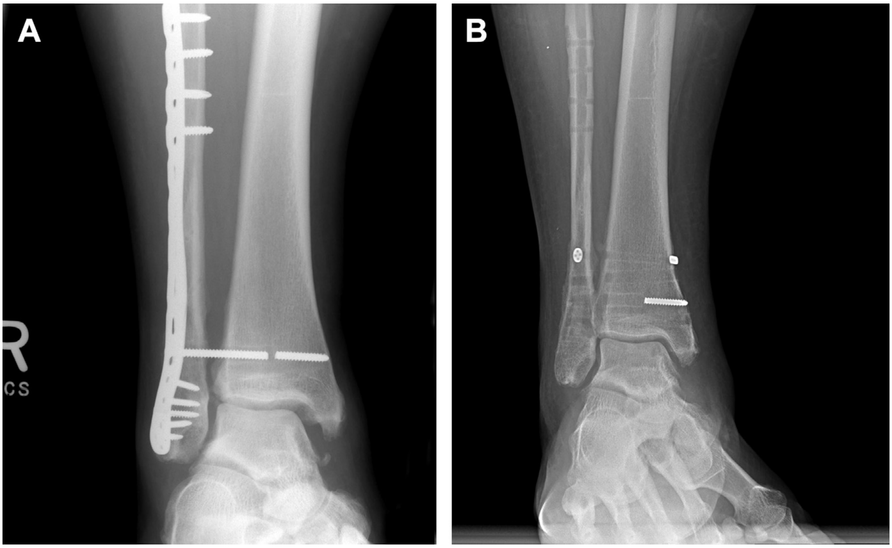

Fig. 12. Preoperative mortise (*A*) of a patient with failure of the syndesmotic fixation status post open reduction and internal fixation. The 6-month postoperative weight bearing radiograph (*B*) demonstrates stable reduction of the syndesmosis and medial clear space.

increased from 37 ± 15 to 87 ± 11. Again, all associated deformities were corrected such as fibular malunions and equinus contractures. The investigators noted an increase in the Kellgren and Moore grade of arthritis in 2 of the 10 patients, with 1 of the 2 patients having a normal ankle preoperatively. These results supported earlier findings by Pena and

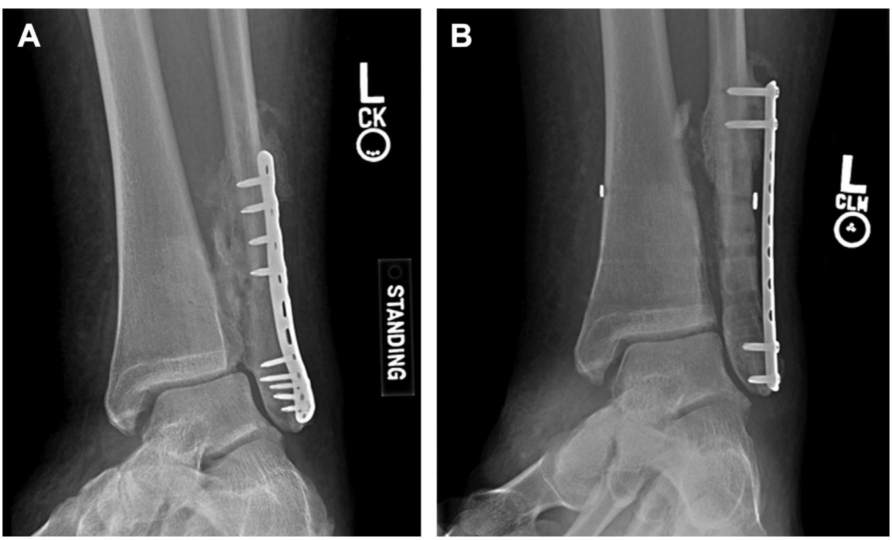

Fig. 13. Preoperative mortise (*A*) of a patient with an untreated syndesmotic injury who developed a significant synostosis. The 12-month postoperative radiograph (*B*) demonstrates excision of the synostosis with stable reduction of the syndesmosis and medial clear space.

Coetzee[192] who also recommended arthrodesis for patients with an injury older than 6 months, severe incongruity, or a recurrence of diastasis after removal of fixation. The authors thought this procedure should be reserved for low-demand patients (Fig. 14). Overcompression of the syndesmosis should be avoided, as this creates a nonanatomic mortise increasing the risk of tibiotalar arthritis.

Fig. 14. Preoperative radiographs (*A*) of a patient with persistent pain within the syndesmosis without clear evidence of tibiotalar arthritis. CT scan (*B*) reveals clear evidence of tibiofibular degenerative changes that precludes reconstruction. Postoperative radiographs (*C*) after syndesmotic fusion with allograft to maintain the appropriate relationship of the tibia and fibula.

C

Fig. 14. (*continued*)

SUMMARY

Injuries to the syndesmosis are a diagnostic and therapeutic challenge to the orthopedic surgeon. The lack of clear radiographic parameters on which to make surgical decisions places greater importance on the physical examination and advanced imaging. Lack of injury to the deltoid ligament and PITFL based on MRI imaging is a reliable determinant to consider nonoperative treatment. Injury to the deltoid ligament or disruption of the relationship of the tibia and fibula typically is treated with surgical reduction and fixation. Use of the contralateral lower extremity is the most reliable in determining the normal relationship of the tibia and fibula for the patient both preoperatively and intraoperatively. Sagittal instability is more critical than coronal instability and must be taken into account when considering reduction of fixation of the syndesmosis. Further studies will determine the need for primary repair of the deltoid ligament and fixation of the posterior malleolus in the setting of ankle fracture and syndesmotic injuries. As the understanding of the longer-term outcomes following injury to the syndesmosis advances, a logical algorithm to the treatment of these injuries should emerge.

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