

Ankle Syndesmosis Injuries: Anatomy, Biomechanics, Mechanism of Injury, and Clinical Guidelines for Diagnosis and Intervention

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Syndesmosis injuries are rare, but very debilitating and frequently misdiagnosed. The purpose of this clinical commentary is to review the mechanisms of syndesmosis injuries, clinical examination methods, diagnosis, and management of the injuries. Cadaveric studies of the syndesmosis and deltoid ligaments are also reviewed for further understanding of stress transmission and the roles of different structures in stabilizing the distal syndesmosis. External rotation and excessive dorsiflexion of the foot on the leg have been reported as the most common mechanisms of injury. The injury is most often incurred by individuals who participate in skiing, football, soccer, and other sport activities played on turf. The external rotation and squeeze tests are reliable tests to detect this injury. The ability of imaging studies to assist in an accurate diagnosis may depend on the severity of the injury. The results of cadaveric studies indicate the importance of the deltoid ligament in maintaining stability of the distal tibiofibular syndesmosis and the congruency of the ankle mortise. Intervention programs with early rigid immobilization and pain relief strategies, followed by strengthening and balance training are recommended. Heel lift and posterior splint intervention can be used to avoid separation of the distal syndesmosis induced by excessive dorsiflexion of the ankle joint. Application of a rigid external device should be used with caution to prevent medial-lateral compression of the leg superior to the ankle mortise, thereby inducing separation of the distal syndesmosis articulation. Surgical intervention is an option when a complete tear of the syndesmosis ligaments is present or when fractures are observed. *J Orthop Sports Phys Ther* 2006;36(6):372-384. doi:10.2519/jospt.2006.2195

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The ankle is commonly injured in the athletic population. The high ankle sprain, or syndesmosis sprain, occurs less frequently than the lateral ankle sprain. The syndesmosis sprain is also a less-understood form of ankle sprain injury in comparison with the lateral ankle sprain. Syndesmosis injuries involve disruption of the ligamentous structures between the distal fibula and tibia, just proximal to the ankle joint.

Previous reports indicate that between 1% and 18% of all ankle sprains involve injury to the syndesmosis.^{17,20,24} Fallat et al¹⁷ conducted a prospective study over a 33-month period and reported that 4.85% of 639 ankle sprains were syndesmosis injuries. Hopkinson et al²⁴ reviewed clinical records and radiography images for 1344 ankle sprains that were incurred by military cadets over a 41-month period. Only 1.11% were diagnosed as having incomplete syndesmosis injuries. Gerber et al²⁰ conducted a prospective observational study in the United States Military Academy and reported that 17% of 96 ankle sprains were syndesmosis sprains. This injury is often more difficult to diagnose than lateral or medial ankle sprain injuries, and recovery from the injury can be very protracted and frustrating for both the injured individual and medical personnel who are involved in the treatment of the injury. Several authors^{9,22,49,56} have reported that syndesmosis injuries usually result in more time loss from athletic participation and longer treatment times compared to other ankle sprain injuries. Data from a 41-month retrospective study at the United States Military Academy in-

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dicate that the average recovery time for patients with incomplete injuries to the ankle syndesmosis was 55 days, almost twice the recovery time compared with patients with third-degree lateral ankle sprains.²⁴

The purpose of this paper is to provide a clear understanding of the ligamentous structures involved in this injury, and to describe the mechanism of injury. We will also review imaging and clinical assessments that would enable detection of the injury, discuss the clinical implications of cadaveric studies, and describe current guidelines for treatment of the injury.

ANATOMY AND FUNCTION

The distal syndesmotic articulation between the tibia and fibula is comprised of 3 major ligaments: the anterior inferior tibiofibular ligament (AITFL), the posterior inferior tibiofibular ligament (PITFL), and the interosseous ligament (Figure 1).^{9,19,24,26,59} These ligaments provide such strong stabilization to the articulation that the fibula only rotates externally up to 2° relative to the tibia, and the ankle mortise widens only about 1 mm as the intact ankle joint moves from full plantar flexion to full dorsiflexion.⁴² A fourth ligament, the inferior transverse tibiofibular ligament is located posterior to the talus, covers the superior part of the talus, and is sometimes considered as a separate component from the PITFL.^{26,35,43,52} These ligaments stabilize the ankle mortise by providing strong opposition of the fibula to the fibular notch of the tibia, and by providing strong dynamic support to the ankle mortise.³⁵ Of the 4 syndesmotic ligaments, the AITFL and PITFL are considered the primary stabilizers of the distal tibiofibular articulation.^{39,49}

The PITFL has an extensive breadth to its attachment on the fibula and constrains excessive external rotation of the foot on the leg and excessive distal fibular motion on the tibia.²⁶ The role of the AITFL is similar to the PITFL, constraining excessive distal fibular motion relative to the tibia and excessive external rotation of the foot on the leg.⁴² Injury to the AITFL is usually accompanied by a tear of the interosseous ligament.²⁶ The AITFL is weaker than the PITFL,⁵ but data from Sarsam and Hughes⁴² support that the AITFL acts as a primary constraint to excessive fibular motion relative to the tibia and talar external rotation within the ankle mortise.

The interosseous ligament is a thickened portion of the distal interosseous membrane and is considered one of the primary stabilizers of the distal tibiofibular articulation. The interosseous ligament also acts as a buffer to axial tibial loading as it transfers a portion of the weight-bearing load from the tibia to the fibula.⁶¹ Normal axial loading within the leg segment during walking involves a transfer of 6% to 15% of the axial compressive load from the tibia to the fibula through the distal interosseous ligament and mem-

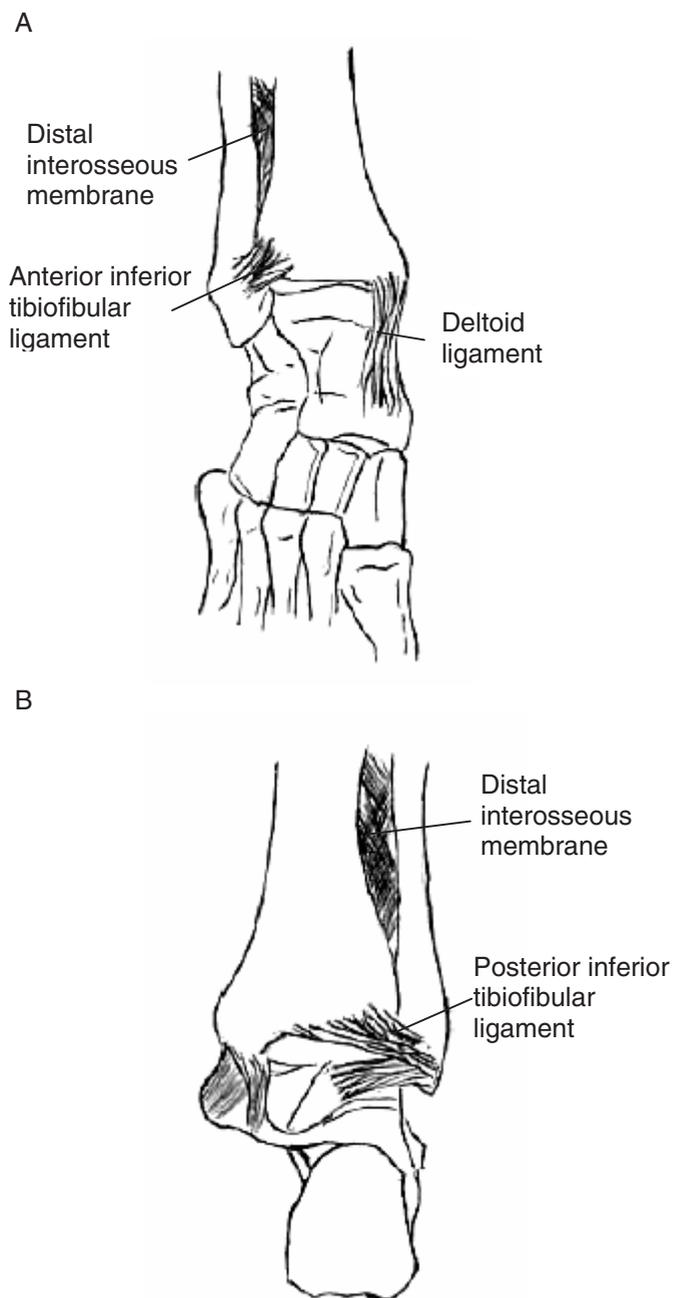


FIGURE 1. (A) Anterior view of the distal syndesmosis. (B) Posterior view of the distal syndesmosis.

brane.^{21,42} Mechanical disruption of the interosseous ligament and membrane may result in increased compressive stress within the tibia, increased likelihood of lateral dislocation of the distal fibula, and incongruence of the ankle joint articulating surfaces.⁵⁹ Dynamic ankle joint motion and relative joint position of the talus within the mortise would be altered under these circumstances, resulting in abnormal distribution of contact pressure and the possible development of joint arthritis.

Another important aspect of ankle joint anatomy involves the greater width of the anterior portion of the talar dome, an anatomic feature that can contrib-

ute to separation of the distal tibiofibular articulation during extreme dorsiflexion.^{12,25,30} The talus tends to act more forcefully as a wedge within the ankle mortise in extremes of dorsiflexion. Extreme dorsiflexion, therefore, may be involved in the mechanism of injury to the ligamentous structures that stabilize the distal tibia and fibula. Forceful passive dorsiflexion may also then add to the ability to detect syndesmosis injury during clinical examination and during imaging studies. Extreme dorsiflexion may also be a position that should be limited to promote tissue healing of injured syndesmotomous ligamentous structures.

MECHANISM OF INJURY

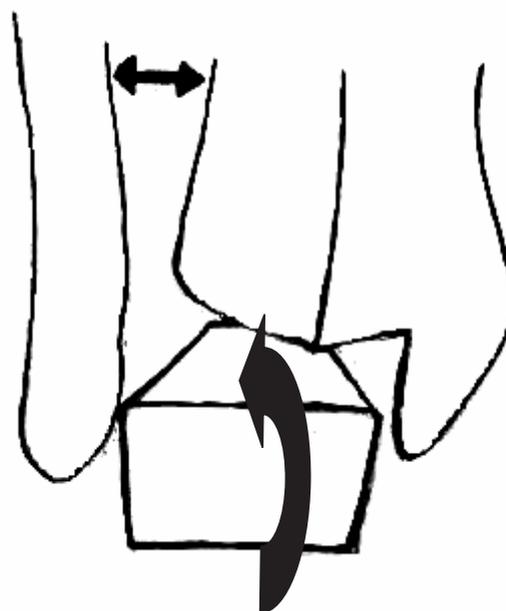
The mechanism of injury for syndesmotomous ankle sprains can be confusing because of the different anatomic structures involved and the manner in which these structures develop excessive stress in the 3 planes of motion.^{26,43} Most proposed mechanisms of injury are based on the observations of clinicians who have interviewed patients with these injuries.^{9,10,22,24,26,43} The 3 proposed mechanisms of injury for the syndesmotomous injury include external rotation of the foot,^{9,22,24,26,43} eversion of the talus within the ankle mortise,^{22,43} and excessive dorsiflexion.^{9,24,43} Mechanisms of injury to the syndesmosis are quite different from the typical lateral ankle sprain in which the foot and ankle are plantar flexed and inverted. Forceful external rotation of the foot results in widening of the ankle mortise as the talus is driven into external rotation within the mortise (Figure 2B).¹⁹ Forceful eversion of the talus also effects widening of the mortise.^{22,43} Forceful dorsiflexion tends to widen the ankle mortise as the wider anterior aspect of the talar dome enters the joint space (Figure 2A).¹⁹ In all cases, the distal fibula is pushed laterally away from its articulation with the distal tibia. Chronic instability of the syndesmosis may then result in increased shear stress and altered contact pressure patterns that might predispose the individual to degenerative articular cartilage changes in the ankle joint.⁴⁰ Ankle diastasis, with many subtypes, including lateral subluxation of the talus, posterior rotatory displacement of the fibula and talus, and complete diastasis with superior subluxation of the talus, could result from more severe injury to the syndesmosis.¹⁶

Individuals who participate in skiing, football, soccer, and other turf sports that involve planting of the foot and cutting may have the greatest risk for ankle syndesmotomous sprains.^{9,19} Even though the skier's foot and ankle might receive some protection from the rigid shell of the ski boot, Fritschy¹⁹ has noted that syndesmosis injuries have been observed frequently in elite professional skiers. Contributing factors to this injury among elite skiers may be the extremely rapid turns and sudden forceful external rotation of the

foot, perhaps caused by the relatively long moment arm of external rotation forces acting on the individual's ski.

Football players may encounter 2 possible injury scenarios for ankle syndesmotomous injuries. One involves a direct blow to the lateral leg, causing internal rotation of the leg, while the foot remains fixed on the ground in relative external rotation.⁹ The second injury scenario involves a blow to the lateral knee, with the foot planted in external rotation and the body rotated internally.⁹ Both situations force a

A



B



FIGURE 2. (A) The wider anterior portion of the talar dome forces the distal tibiofibular syndesmosis apart when the talus is subjected to a forceful dorsiflexion load. (B) The talus forces the distal tibiofibular syndesmosis apart when the talus is subjected to a forceful external rotation load.

widening of the ankle mortise and rupture of the ligamentous structures responsible for stabilizing the distal syndesmoti c articulation. Injury mechanisms other than those incurred during sporting activities include falls, twisting weight-bearing injuries, and motor vehicle accidents.^{13,57}

Several mechanisms of injury, therefore, are possible for the distal syndesmoti c sprain. Assessment of these possible mechanisms for syndesmoti c injuries should be explored during interviews with patients and considered in conjunction with the patient's chief complaints, clinical exam results, and diagnostic imaging results.

CADAVER STUDIES

Cadaver studies have provided valuable information to assist our understanding of syndesmoti c injuries and the clinical implications that might guide treatment of these injuries. Skraba and Greenwald⁴⁴ used strain gauges in their cadaveric study to detail how the interosseous membrane plays an important role in transferring axial load from the tibia to the fibula during weight bearing. Thomas et al⁵² also explored the role of the interosseous membrane during axial loading of cadaveric specimens. Their data indicate that the interosseous membrane stabilizes the fibula relative to the tibia and constrains posterolateral bending of the fibula.

Ogilvie-Harris et al⁴⁰ investigated the relative contribution of the 4 syndesmoti c ligaments to the stability of the ankle mortise by imposing up to 2 mm of lateral displacement of the fibula on the tibia. The investigators varied the order of sectioning of the syndesmoti c ligaments. Results from this study indicated that an average of 87 N of laterally directed force was needed to cause 2 mm of diastasis, and the interosseous membrane alone did not have a significant role in maintaining syndesmosis stability. The results also indicated that the AITFL and PITFL together provided approximately 77% of the stability to the syndesmosis under the experimental loading conditions. Injuries to the AITFL and PITFL, therefore, may cause appreciable instability of the syndesmosis.

Boden et al⁸ applied a foot external rotation load by imposing a 440-N force through a footplate, with the foot prepositioned in pronation and the tibia positioned in 15° to 20° of initial internal rotation. Testing was conducted under a variety of conditions that simulated soft tissue and fracture injuries, and surgical repairs in the anatomic region. Results indicated that cadavers with intact deltoid ligaments, repairs of medial malleolar fractures, or internal fixation of the distal fibula had greater ankle mortise stability when external rotation loads were imposed on the foot. Additionally, no significant widening of the mortise occurred even with isolated sectioning of the interosseous membrane up to 15 cm proximal to

the ankle joint. The study results also indicated no need for additional syndesmoti c fixation if the deltoid ligament was intact or if a rigid internal fixation device (eg, screw) was applied through the medial and lateral malleoli, because both can provide significant stability of the syndesmosis.

Studies by Michelson and Waldman³⁴ and Boden et al⁸ also support the importance of the deltoid ligament in stabilizing the distal tibiofibular articulation. Michelson and Waldman³⁴ modeled external rotation injury loads to the syndesmosis under various conditions involving sectioning of the interosseous ligament, transection of the superficial and deep portions of the deltoid ligament, and fibular osteotomy. Results indicated that isolated sectioning of the interosseous ligament had no significant effect on stability of the ankle mortise. Sectioning of the superficial and deep portions of the deltoid ligament, however, resulted in increased external rotation of the foot when the ankle was positioned in plantar flexion. The ankle mortise demonstrated significant instability in dorsiflexion when the superficial and deep deltoid ligaments had been sectioned and with a fractured fibula. Michelson and Waldman³⁴ propose that surgical syndesmoti c stabilization is needed only with injury to the deltoid ligament and if a fracture of the lateral fibula cannot be repaired. These authors³⁴ also emphasize the importance of the deltoid ligament in constraining talar movement within the mortise and providing stability to the distal tibiofibular articulation.

Pereira et al⁴⁰ investigated tibiotalar contact area, mean pressure distribution, and central shift of the ankle mortise by examining the effects of syndesmosis fixation, mortise widening of 2 mm and 4 mm, and transection of the deep deltoid ligament in an unconstrained cadaveric ankle model. Central shift was defined as medial-lateral displacement of the center of contact area on the articular surface of the talus. Each specimen was loaded with an axial load of 500 N imposed on the tibia with the ankle in 10° dorsiflexion, neutral, and 20° plantar flexion to represent selected ankle joint positions during normal walking gait. Fixation with tibiofibular screws positioned at levels 3 and 7 cm above the tip of the lateral malleolus, followed by transection of the syndesmoti c ligament and interosseous membrane, resulted in decreased tibiofibular contact area. The authors suggested that this decreased contact area could result in distal syndesmoti c instability. No statistical differences were found in the contact area and central shift with sequential widening of 2 and 4 mm of the syndesmosis. Their data also indicated significant decreases in tibiofibular contact area after syndesmosis fixation with the ankle joint in 10° dorsiflexion and 20° plantar flexion, when compared with the control condition. Pereira et al⁴⁰ concluded, therefore, that syndesmoti c fixation may have an

adverse effect on contact area of the ankle joint and may increase contact stress during weight bearing and walking.

Other investigators have also examined syndesmotic loading with different screw sizes, or different superior/inferior location of screw fixation with an external rotation load imposed on the foot and the foot prepositioned in pronation. Thompson and Gesink⁵³ assessed screw fixation 2 cm above the ankle joint with screws that were 3.5 mm and 4.5 mm in diameter, following the sectioning of syndesmotic ligaments. Screw fixation significantly decreased widening of the mortise and increased torsional stiffness, with screw diameter having no significant effects on the results. McBryde et al³³ attempted to determine the optimal level for syndesmotic screw fixation. They applied 3.5 mm screws 3.5 cm and 2 cm above the tibiotalar joint. Screw fixation 2 cm above the distal tibiofibular joint resulted in less mortise widening when compared with screw fixation at the 3.5 cm level. The results of McBryde et al³³ and Thompson and Gesink⁵² suggest that fixation at 2 cm above the tibiotalar joint is an effective surgical option.

Finally, Teitz and Harrington⁵¹ used fresh cadavers to examine the effects of the squeeze test and sectioning of the syndesmotic ligaments on ankle mortise widening. The order of ligamentous sectioning was 50% sectioning of the AITFL, AITFL sectioned completely, interosseous membrane sectioned, PITFL sectioned, deltoid ligament sectioned, anterior talofibular ligament sectioned, and calcaneofibular ligament sectioned. Medial-lateral compression of the leg was imposed manually (190 N) and mechanically (180 N) to simulate the squeeze test at a level just above the midleg. No significant difference in ankle mortise widening was noted between the manual and mechanical compression conditions. Ankle mortise widening occurred when a medial-lateral compressive force was applied to the mid leg and sequential sectioning of ligamentous structures significantly increased mortise widening. The authors⁵¹ also suggested that pain on clinical exam during the squeeze test might result from tension being imposed on the remaining intact fibers of the syndesmosis' ligamentous structures.

In summary, the results of cadaveric studies generally indicate that separation and widening of the syndesmosis occurs with application of an external rotation load with the foot positioned in pronation. Investigators have used the pronated foot position for these studies to simulate the dorsiflexion, eversion, and external rotation mechanisms of injury described earlier in this paper. Separation and widening of the syndesmosis, however, may or may not be affected by disruption of the interosseous ligament. The significance of the deltoid ligament, interosseous ligament, and interosseous membrane in stabilizing the distal syndesmosis is supported by some of these cadaveric

studies. Slight separation of the syndesmosis decreases congruency of the talocrural joint during extreme ankle dorsiflexion. The resulting incongruent joint motion can lead to degenerative changes in the ankle joint.⁴⁰ Screw fixation 2 cm proximal to the ankle joint can increase stability of the ankle joint and decrease widening of the syndesmosis. The potential adverse effects of screw application are to produce an abnormal constraint of the mortise, perhaps resulting in secondary problems such as insufficient range of motion and incongruent joint motion during walking and weight bearing. Clinicians should consider all of these possible factors while performing a physical examination and designing an intervention strategy.

CLINICAL ASSESSMENT

General Presentation

An accurate report of the injury by the patient or an observer of the injury is important for clinicians to complete a thorough initial examination.³⁵ Although a syndesmotic ankle sprain may have various mechanisms of injury, external rotation of the foot is most often reported by patients. Typical symptoms following syndesmotic injury are pain localized to the AITFL, tenderness with palpation of the AITFL, pain with active or passive external rotation of the foot, and pain with active or passive forced dorsiflexion. Pain may also extend proximally, indicating possible injury to either the interosseous membrane or a more severe injury.^{18,45} A normal heel-toe walking gait pattern may be replaced by a heel-raise gait pattern. The heel-raise gait pattern is used to avoid excessive ankle dorsiflexion and to avoid pain during push-off.^{10,18} An antalgic gait with a short duration of stance phase on the injured foot may also be observed. Severe swelling is not usually present for this injury and the absence of significant swelling may lead to inaccurate diagnosis of the syndesmotic injury when, in fact, a severe injury has occurred.^{9,18} Several authors have suggested that isolated syndesmotic ligamentous injury is rare, and is usually accompanied by a lesion of the deltoid ligament and fibular fracture.^{4,6,61}

Deltoid Ligament Involvement

Because injury of the deltoid ligament may accompany syndesmotic injuries, a differential diagnosis is needed to evaluate the involvement of the deltoid ligament and to develop a more effective rehabilitation program for patients. The mechanism of injury for the deltoid ligament is similar to syndesmotic injuries, involving external rotation of the foot or eversion of the talus within the ankle mortise. Significant swelling, tenderness, and ecchymosis over the medial ankle, and more than 4 mm of radiological

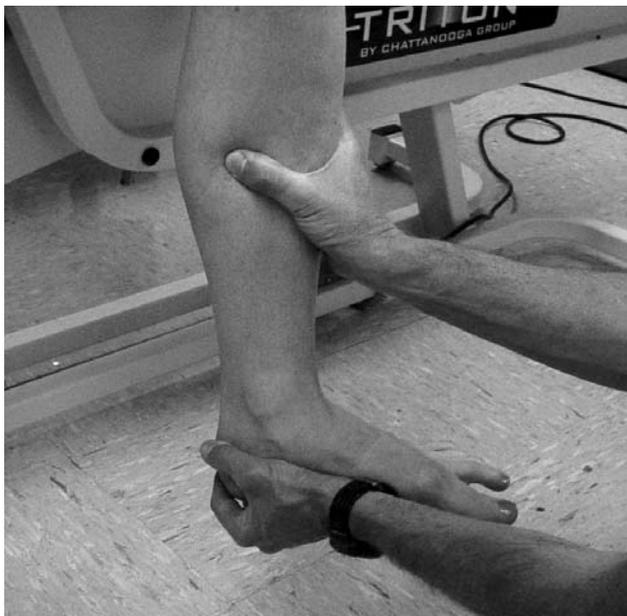


FIGURE 3. The external rotation stress test. The examiner stabilizes the leg with 1 hand and applies an external rotation load to the foot, with the ankle in neutral dorsiflexion/plantar flexion.



FIGURE 4. The squeeze test imposed on the distal leg. The examiner cups both hands around the distal tibia and fibula and imposes compression in a progressively more forceful manner. The test is repeated at progressively more proximal locations. Pain experienced at the distal tibiofibular syndesmosis is a positive test result.

widening of the syndesmosis may indicate involvement of the deltoid ligament.¹³ Pain localized to the medial ankle while a valgus stress is imposed on the rearfoot may also indicate deltoid ligament injury.^{31,54} A partial tear of the deltoid ligament occurs

often with medial ankle injuries, while a complete tear is rare and is usually associated with ankle fractures.

Injury to the deltoid ligament with injury to syndesmotoc ligaments usually results in very significant ankle mortise instability. A more effective support to the injured tissues is needed and an aggressive conservative intervention should be avoided to prevent other injuries. A radiograph may be helpful to rule out ankle fracture. Radiographs that demonstrate more than 1-mm widening of the syndesmosis may indicate that syndesmotoc screw fixation is necessary.³⁵

Special Tests

Clinical tests for syndesmotoc injury include the external rotation stress test (Kleiger test),^{3,9,47} the squeeze test,^{24,47,49,51} the point test,^{3,43} the dorsiflexion maneuver,^{3,50} and the one-legged hop test.³⁶ The external rotation stress test^{3,9,47} (Figure 3) is performed with the patient sitting at the edge of the examination table. The examiner stabilizes the proximal leg with 1 hand, while the other hand applies an external rotation load to the foot with the ankle positioned in neutral dorsiflexion/plantar flexion. The external rotation load imposed on the foot rotates the talus externally and promotes lateral displacement of the fibula and increased separation of the distal syndesmosis. Pain experienced at the anterolateral aspect of the distal tibiofibular syndesmosis is a positive sign for syndesmosis injury. Pain on the medial side of the injured ankle during the external-rotation stress test, with the ankle positioned in plantar flexion, may indicate involvement of the deltoid ligament.

The squeeze test^{24,47,49,51} (Figure 4) is used to promote separation of the distal tibiofibular syndesmosis by gently squeezing the tibia and fibula proximal to the ankle joint. The patient sits at the edge of the examination table. The examiner cups both hands around the distal fibula and tibia and compresses the leg, followed by application of the same load at successively more proximal locations until pain is noticed at the distal tibiofibular syndesmosis. The purpose of the sequentially more proximal squeezing is to avoid unexpected and intense pain at the injured syndesmosis. The presence of pain at the distal tibiofibular syndesmosis indicates disruption of the distal syndesmosis ligaments.

The point test,^{3,43} also referenced as the palpation test (Figure 5), is used to impose pressure on the anterior distal tibiofibular syndesmosis. The patient can be positioned supine or sitting. The examiner applies pressure directly over the anterior aspect of the distal tibiofibular syndesmosis. Pressure is applied gradually and a positive test involves a report of pain by the patient.

The dorsiflexion maneuver^{50,56} (Figure 6) is performed to force the wider anterior portion of the talar dome into the ankle mortise, thereby inducing separation of the distal fibula and tibia. The patient sits at the edge of the examination table and the examiner stabilizes the patient's leg with 1 hand, while the examiner's other hand passively moves the foot into dorsiflexion. Pain experienced at the distal tibiofibular syndesmosis is a positive test result.

The one-legged hop test³⁶ is performed by having the patient stand on the injured leg and hop continuously. Nussbaum et al³⁶ reported that patients with syndesmosis injuries could not complete 10 repetitions of unilateral hopping without significant pain, suggesting that this test may assist clinicians in their assessment of this injury during an initial examination and on follow-up examination. We suggest that the one-legged hop test should be used with caution, because performing this test may impose further separation of the distal tibiofibular syndesmosis. Perhaps the one-legged hop test should be used only if the previously described special tests are negative.

Alonso et al³ have described a variation of the dorsiflexion maneuver. They describe the dorsiflexion compression test, which involves patients moving their ankle joints into extreme dorsiflexion in bilateral weight bearing. Patients are asked to note the pain they experience in this position and the position of the tibia is noted with an inclinometer. The patient then assumes an upright position and the examiner applies medial-lateral compression with 2 hands on the malleoli of the injured leg. The examiner maintains the medial-lateral compression as the patient is asked to move into dorsiflexion again and to report if end-range pain has changed compared with the previous movement. A positive test result is either a reduction in end-range pain or an increase in dorsiflexion range of motion.

Alonso et al³ reported data that indicate that the external rotation stress test is more reliable than the squeeze test and the dorsiflexion-compression test. Interrater reliability was 0.75 for the external rotation stress test, 0.5 for the squeeze test, and 0.36 for the palpation test and the dorsiflexion-compression test. Alonso et al³ also reported that patients took significantly longer time to return to competition if they had combined positive results for the external rotation stress test and the dorsiflexion-compression test. Nussbaum et al³⁶ and Hopkinson et al²⁴ have reported that the squeeze test is also a reliable and useful screening tool in determining the duration of recovery from syndesmotic sprains. Patients in their studies who demonstrated a positive squeeze test had protracted recovery times. A positive squeeze test also has been correlated with delayed return to activity and heterotopic ossification at the distal tibiofibular syndesmosis.⁴⁹ Scranton⁴³ has suggested that the squeeze test should be used to determine involve-

ment of the syndesmosis, but that this test may not reveal the severity of the injury. Scranton⁴³ suggests that the external rotation stress test can be administered once pain and apprehension are apparent, and that a more forceful external rotation stress test should be performed under anesthesia with roentgenography to assess ankle mortise widening. Nussbaum et al³⁶ suggest that the external rotation stress test, with the foot passively dorsiflexed, and the squeeze test are helpful in examining the severity of injury. Nussbaum et al³⁶ also demonstrated that days lost



FIGURE 5. The point test. The examiner applies pressure in a progressively more forceful manner directly over the anterior aspect of the distal tibiofibular syndesmosis. Pain with palpation suggests the presence of an injury.



FIGURE 6. The dorsiflexion maneuver. The examiner stabilizes the leg with 1 hand and passively moves the foot toward dorsiflexion with the other hand to impose possible widening of the mortise. A positive test result is a report of pain that is localized to the distal tibiofibular syndesmosis.

from competition could be predicted by measuring the distance over which the anterior interosseous membrane was tender to palpation.

Two new clinical tests, the crossed-leg test²⁹ and the heel thump test,³¹ have been proposed to assess the presence of syndesmotic injuries. Reliability and validity data for these 2 tests, however, are not yet available. The crossed-leg test²⁹ mimics the squeeze test and attempts to induce separation of the distal syndesmosis. The patient sits in a chair, with the injured leg resting across the knee of the uninjured leg (Figure 7). The resting point should be at approximately mid calf. The patient then applies a gentle force on the medial aspect of the knee of the test leg. Pain experienced in the area of the distal syndesmosis suggests the presence of injury. This test may not be useful for patients with knee or hip pathology because it may be difficult for them to assume the test position.

The heel thump test³¹ is performed to force the talus into the mortise in an attempt to impose separation of the distal syndesmosis. The patient sits at the edge of the examination table with the ankle resting in plantar flexion (Figure 8). The examiner holds the patient's leg with 1 hand and with the other hand applies a gentle but firm thump on the heel with their fist. This force is applied at the center of the heel and in line with the long axis of the tibia. Pain experienced at the distal tibiofibular syndesmosis suggests the presence of injury. Although the heel thump test has been recommended to help differentiate between a syndesmotic sprain and a lateral ankle sprain, this test may not be specific for a syndesmotic sprain because this test has also been recommended to assess the possible presence of tibial stress fractures.⁴⁷



FIGURE 7. The crossed-leg test. The patient sits in a chair, with the injured leg resting across the knee of the uninjured leg. The resting point should be at approximately mid calf. The patient then applies a gentle force on the medial knee of the injured leg. Pain experienced in the distal syndesmotic area suggests the presence of injury.



FIGURE 8. The heel thump test. The examiner holds the patient's leg with one hand and with the other hand applies a gentle but firm thump on the heel with the fist. This force is applied at the center of the heel and in line with the long axis of the tibia. Pain experienced at the distal tibiofibular syndesmosis suggests the presence of injury.

Imaging Studies

Radiological studies may help confirm results from a clinical examination. Standard radiography with a true anteroposterior (AP) view and a mortise view can be used to evaluate the tibiofibular clear space and tibiofibular overlap.²³ Tibiofibular clear space is the distance between the lateral border of the posterior tibial prominence and the medial border of the fibula (Figure 9). Tibiofibular clear space in the AP and mortise views should be less than 6 mm with an intact syndesmosis. Tibiofibular overlap is the maximal overlap between the medial border of the distal end of the fibula and the lateral border of the anterior distal tibial prominence. Normal tibiofibular overlap for the AP view is more than 6 mm or more than 42% of the fibular width.^{23,27} Normal tibiofibular overlap for the mortise view (Figure 9) should be more than 1 mm.^{23,27} All measurements of tibiofibular clear space and tibiofibular overlap are made 1 cm above the tibia plafond.

A mortise view taken with the patient positioned in unilateral weight bearing is the most accurate way to assess syndesmotic instability radiographically,⁴⁵ but many patients with mortise instability may not be able to tolerate unilateral standing due to pain.⁴³ Bilateral

weight-bearing or non-weight-bearing radiographic acquisition, therefore, can be considered instead. Stress radiography with a lateral view, while an external rotation stress is imposed to the foot, is a useful imaging approach to assess possible posterior and lateral displacement of the fibula.^{47,58,59} Xenos et al⁵⁹ assessed cadaveric specimens and reported that this method of lateral stress radiography had a stronger correlation with actual measurements of the anatomical diastasis ($r = 0.81$) than the correlation between mortise radiograph imaging with an external rotation stress being imposed ($r = 0.41$). Imaging of the suspected injured diastasis should be compared with imaging of the contralateral intact ankle to assess the presence and severity of the involvement.

Beumer et al⁷ have described another imaging technique for assessing syndesmotic sprains. Radiostereometric analysis (RSA) enables an analysis of 3-dimensional motions of body segments. Beumer et al⁷ reported that RSA imaging with an external rotation stress imposed on the foot had better sensitivity than plain lateral-view radiography in examining lateral translation and external rotation movements of the fibula relative to the tibia. Traditional radiology, however, still has an important role in early recognition of syndesmosis injuries.

Computerized tomography (CT), magnetic resonance imaging (MRI), or arthroscopy may be necessary if patients have persistent symptoms following syndesmosis injury or a clinical diagnosis is still

uncertain.^{14,15,38,48,58} Ebraheim et al^{14,15} have demonstrated that a CT scan is a more accurate and sensitive method for detecting syndesmotic injuries when compared to plain film radiography. A CT scan is particularly sensitive for minor or partial ruptures and to assess diastasis. Scranton⁴³ has proposed that CT has less value for soft tissue injuries because only bony details can be identified. Vogl et al⁵⁵ and Oae et al³⁷ have demonstrated that distal tibiofibular syndesmosis injuries can be visualized with high sensitivity and specificity using MRI. MRI analysis of the syndesmotic injury also has a significant association with secondary findings, such as anterior talofibular ligamentous injury, osteochondral lesions, bone bruise (acute syndesmosis injury), and distal tibiofibular joint incongruity.¹¹ These secondary findings usually are associated with longer recovery times and poorer rehabilitation results. Clinicians, therefore, should be aware of the presence of these secondary findings to design appropriate intervention programs and to formulate realistic recovery times for the patient.

Arthroscopy allows clear visualization of the injured site and an accurate diagnosis of any tibiofibular syndesmosis disruption.^{38,48} Movements between the tibia and fibula can be measured using a probe that is introduced from a medial portal. Normal widening of the diastasis should be approximately 1 mm. An arthroscopic study by Ogilvie-Harris et al³⁸ consistently found scarring around the PITFL, disruption of the interosseous ligament, and chondral damage to the posterolateral portion of the tibial plafond in patients with syndesmotic injuries. Takao et al⁴⁸ reported 100% accuracy in identifying patients with syndesmotic injury using arthroscopy, when compared to AP radiography (48%) and mortise radiography (64%), which provides further support for arthroscopy as an accurate diagnostic tool.

Clinical Intervention

Conservative treatment is usually recommended for patients with syndesmotic sprains in the absence of fracture (Table). Rest, ice, compression, and elevation (RICE) are still the basic initial postinjury strategies. A rehabilitation program should be designed to hasten tissue healing and prevent further injury to the distal tibiofibular syndesmosis and the surrounding tissues. Immediate non-weight bearing with crutches or a walker is imperative to prevent further talar and fibular rotation, as well as further disruption of the syndesmotic soft tissues. A posterior splint can be applied with the ankle positioned in neutral dorsiflexion/plantar flexion to provide mechanical stability to the distal tibiofibular syndesmosis.³⁶ Stability can also be obtained using ankle stirrups, molded thermoplastic ankle stirrups, supportive taping, and semirigid ankle braces.⁴⁶ External supports can also be used to avoid unexpected relative movements of

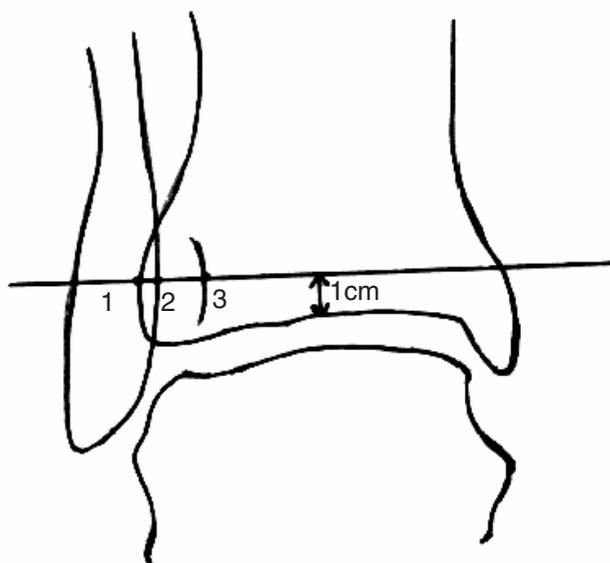


FIGURE 9. The tibiofibular clear space (mortise view) is the distance between the lateral border of the posterior tibial prominence (point 3) and the medial border of the distal fibula (point 2). The tibiofibular overlap is the maximal distance between the lateral border of the anterior border of the distal tibial prominence (point 1) and the medial border of the distal fibula (point 2). All these measures are made 1 cm above the tibia plafond.

TABLE. Summary of conservative treatment for syndesmotic injuries.*

Phase/Criteria	Description of Intervention
Phase I	<ul style="list-style-type: none"> • Pain and swelling control: rest, ice, compression, and elevation (RICE), electrical stimulation, toe curl, ankle pump, cryotherapy • Temporary stabilization (ie, short-leg cast, splint, brace, heel lift) • Non-weight bearing with crutches
Phase II	<ul style="list-style-type: none"> • Pain and swelling subside • Partial weight bearing with assistive device <ul style="list-style-type: none"> • Patient can ambulate partial weight bearing without pain • Low-level balance training: bilateral standing activity or standing on a balance pad or several layers of towels • Lower-level strengthening using Theraband
Phase III	<ul style="list-style-type: none"> • Patient can ambulate full weight bearing without pain, possibly still needing protection from heel lift or ankle brace <ul style="list-style-type: none"> • Unilateral balance training • Progress from double heel raises to single-heel raises • Treadmill walking or overground walking • Progress to fast walking
Phase IV	<ul style="list-style-type: none"> • Able to perform heel raises in unilateral stance <ul style="list-style-type: none"> • Fast pain-free walking without heel lift • Jog-to-run progression • Shuttle run and cutting maneuver • Sport-specific training

* The timeline for progression of an individual patient is dependent on the severity of the injury and the ability of the patient to meet the criteria listed in the table for progression to each phase. Hopkinson et al⁴¹ have reported a mean recovery time of 55 days.

the distal tibia and fibula. A heel lift can be used to decrease dorsiflexion during mid stance once weight bearing is initiated, thereby minimizing separation of the distal tibiofibular articulation by preventing the wider anterior aspect of the talar dome from entering the ankle mortise. External braces should be used with caution, because the transverse compressive application of straps on the leg (eg, Velcro straps) could squeeze the proximal tibia and fibula, thereby inducing the same separation of the distal tibiofibular syndesmosis that is observed during a positive squeeze test.

Electrical stimulation and cryotherapy can be used for the management of pain and inflammation. Rehabilitation exercises, such as ankle pumps and toe curls, can be used to maintain normal range of motion. These exercises should be performed through a pain-free active range of motion¹⁰ and may improve local circulation and decrease swelling.

Once protection has been obtained and pain subsides, an exercise program that includes light to moderate strength training, stretching, and balance training can be instituted, if these activities can be performed in a pain-free manner.^{10,36} Balance training can be initiated with the patient standing on a balance pad or several layers of towels, as long as weight bearing is tolerated without pain. More advanced interventions can begin once pain and swelling are no longer present and the tissue-healing process is almost complete. Unsupported, single-leg weight-bearing strengthening exercises, one-leg toe raises, and balance training can be incorporated into the intervention plan. Jogging, running, cutting maneuver, shuttle running, and jumping and other sports-specific training can be added to the rehabilitation program according to the individual's activity level and rehabilitation progress, as long as these activities can be performed in a pain-free manner.

In general, syndesmotic injuries can be treated with conservative intervention if no obvious and severe tear to ligaments exists and no bone fracture is present (Figure 10). With more severe injuries, surgical interventions are generally required for anatomic reduction of the syndesmosis and to restore stability to the ankle mortise. Wuest⁵⁸ has proposed that syndesmotic screw fixation should be used only if persistent lateral displacement of the fibula or significant widening of the mortise is observed, and if lateral radiography is positive with an external rotation stress being imposed on the foot. Based on cadaveric studies, syndesmotic screw fixation may be needed only if the deltoid ligament is torn or with malleolar fractures.^{8,58} Miller et al³⁵ treated patients with lateral talus subluxation greater than 1 mm by reduction combined with a 4.5-mm, single syndesmosis screw rather than with cast immobilization. Miller et al³⁵ propose that surgical repair assures reduction of the injury and stability of the ankle mortise. They also suggest that radiography should be acquired following surgical reduction to insure a complete reduction of the ankle mortise. Ogilvie-Harris et al³⁸ have described the benefits of using arthroscopic surgery to resect the torn portions of the interosseous ligament and chondral fractures. These arthroscopic procedures significantly improved pain, swelling, stiffness, stability, gait, and activity levels in their patient series. In addition, an external rotation stress test performed after the arthroscopic procedures consistently indicated negative test results (ie, absence of pain). Scranton⁴³ also proposed the use of arthroscopy to assist observation of the reduction using screws and to determine if any tissues were abnormally interposed within the mortise, thereby blocking successful reduction of the mortise.

Kennedy et al²⁷ compared the effectiveness of 2 different surgical treatments for patients who were diagnosed with distal fibular fracture and disruption

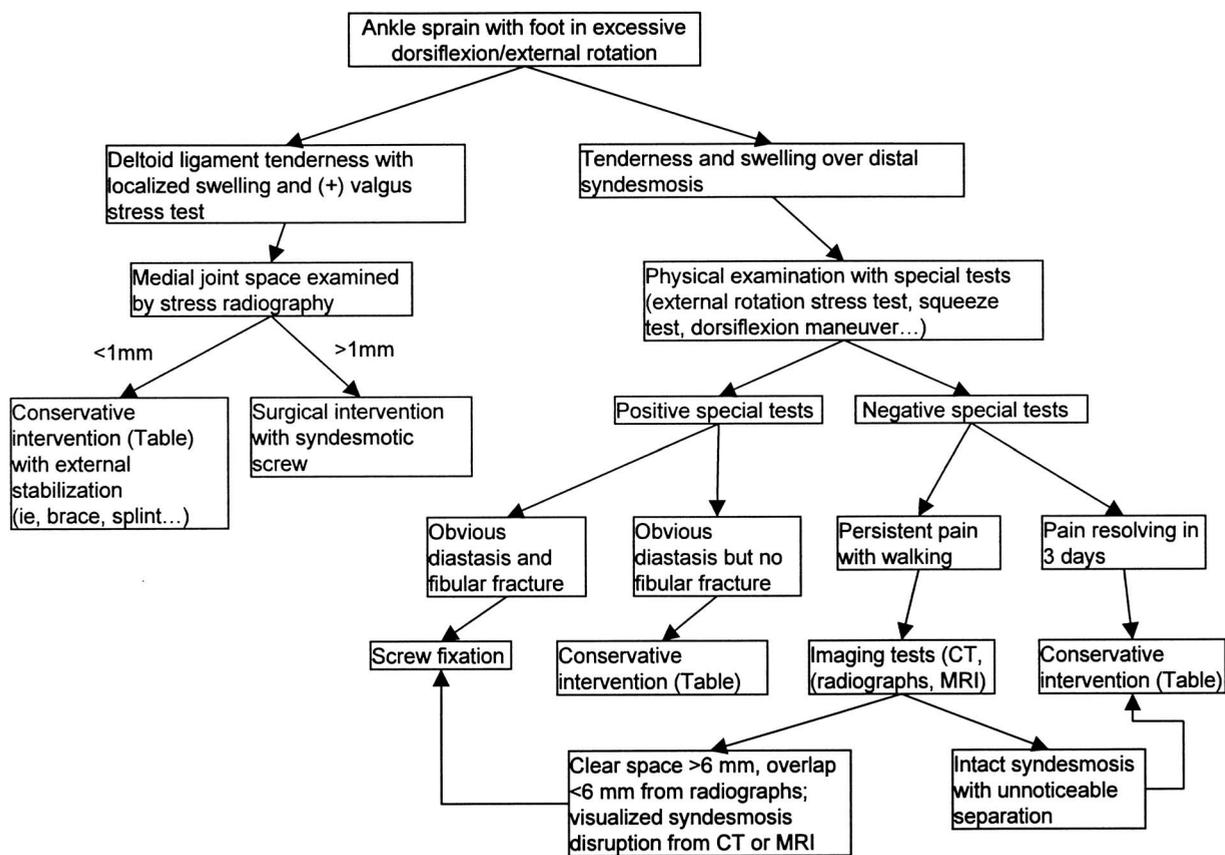


FIGURE 10. Flow chart for diagnosis and management of syndesmotic injuries.

of the distal tibiofibular ligament complex. One group was treated with an internal fixation procedure that was not described and the second group was treated with the same procedure and stabilization using a syndesmotic screw. The 2 groups did not demonstrate significant differences with regard to pain, stiffness, swelling, and the ability to return to work. Kennedy et al²⁷ concluded that there was no advantage to using syndesmotic screws in addition to their internal fixation method for these patients. Yamaguchi et al⁶⁰ treated a similar series of 21 patients and reported that syndesmotic screw fixation was necessary only if the fibular fracture was more than 4.5 cm proximal to the tibiotalar joint line and if deltoid ligament tears were present. Internal fixation of the fracture was sufficient without any placement of a syndesmotic screw if the fibular fracture was within 4.5 cm of the tibiotalar joint line, even in the presence of deltoid ligament disruption.

Screw fixation is a common surgical intervention to treat syndesmosis instability; however, the size and location of screw application are still in controversy. Screws greater than 4.5 mm in diameter may induce fibular fracture.⁴ Albers et al² suggest that syndesmotic screws should be applied approximately 2 cm above the plafond to avoid direct placement into the ligament complex, a recommendation that is consistent with results from cadaver studies by

McBryde et al³³ and Thompson and Gesink.⁵³ If screw fixation is left in place, a potential adverse consequence is that ankle mortise motion may be altered, possibly influencing joint congruency and the development of ankle joint arthritis.^{40,41} The decision to use syndesmotic screw fixation may be dictated by the presence of deltoid ligament disruption and the location of fibular fracture above the tibiotalar joint line.⁶⁰

Non-weight bearing is usually recommended for 6 to 8 weeks following surgical screw fixation for ankle syndesmosis injuries.⁴³ Wuest⁵⁸ proposes that immediate touch-down weight bearing is permissible postoperatively, but full weight bearing should be restricted until removal of the syndesmotic screw. One to 2 weeks of full weight bearing with the protection of a boot walker has been recommended following 6 to 8 weeks of non-weight-bearing status.⁴³

Another possible sequela following syndesmotic injury is anterior impingement syndrome of the talocrural joint. This is a common cause of chronic ankle pain. Several factors have been proposed as contributors to anterior impingement following syndesmotic ankle sprains. Fibrous connective tissues may form after an ankle sprain⁶ and a wider and longer distal fascicle of the AITFL¹ could limit talar movement, particularly during ankle dorsiflexion. Ankle arthroscopy, partial synovectomy, and scar tis-

sue debridement are recommended if chronic anterior ankle pain persists more than 6 months following injury and intense anterior ankle pain is observed during ankle dorsiflexion.

Surgical intervention is also recommended when heterotopic ossification is noted. Several authors have reported that heterotopic ossification may develop within the interosseous membrane following syndesmotic injury.^{24,28,49} Excision of heterotopic bone formation may be necessary if persistent pain is experienced following syndesmotic injury.

SUMMARY

Syndesmosis injury is rare, but is frequently misdiagnosed. The most common mechanism of injury involves external rotation and excessive dorsiflexion of the foot relative to the leg. An accurate and thorough physical examination is imperative to enable a correct diagnosis. An accurate diagnosis is imperative to design an appropriate intervention and to promote a timely return to the patient's previous activity level. Imaging studies may be necessary for some patients, depending on the severity of the injury and whether results from the clinical examination are unclear. A radiographic AP view, mortise view, and stress view of the mortise may be helpful in diagnosing the nature and severity of syndesmotic injuries. Results from cadaver studies indicate the importance of the deltoid ligament in maintaining stability of the distal tibiofibular syndesmosis and congruency of the mortise. Early rigid immobilization to protect the mortise and pain relief strategies are strongly recommended after injury. Subsequently, advanced strength and balance training can be included to recover normal muscle function, range of motion, and stability, as tolerated, based on pain and objective examination. Surgical intervention can be used to assist with complete reduction for severe tears to syndesmotic soft tissues, or for impingement syndrome or the excision of heterotopic bone.

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