

We are IntechOpen, the world's leading publisher of Open Access books Built by scientists, for scientists

6,900

Open access books available

186,000

International authors and editors

200M

Downloads

Our authors are among the

154

Countries delivered to

TOP 1%

most cited scientists

12.2%

Contributors from top 500 universities



WEB OF SCIENCE™

Selection of our books indexed in the Book Citation Index
in Web of Science™ Core Collection (BKCI)

Interested in publishing with us?
Contact book.department@intechopen.com

Numbers displayed above are based on latest data collected.
For more information visit www.intechopen.com



Syndesmotic Injuries in Athletes

Jeffrey R. Thormeyer, James P. Leonard
and Mark Hutchinson

*Department of Orthopaedic Surgery, University of Illinois, Chicago,
USA*

1. Introduction

Ankle injuries are the most common presenting injury in the athletic population, with the ankle sprain accounting for 10% to 30% of all single-sport injuries [1-4]. Lateral ankle sprains make up a majority of these injuries, and the literature describes a high degree of success with quick return to play afterward. Injuries to the syndesmotic ligaments occur far less frequently, with reported values between 1% and 18% of all ankle sprains [5-8]. However, the incidence of these “high ankle sprains” has been increasing recently due to an increase in the knowledge and understanding of the clinical diagnosis, biomechanics, and cause of syndesmotic injuries. More recent reports have the incidence ranging from 17% to 74% of all ankle injuries in young athletes [9-11]. Despite the improved awareness for this injury, there still exists a paucity of information on optimal conservative and operative management. In a recent survey, health care providers caring for professional athletes identified syndesmotic injuries as the most difficult foot and ankle injury to treat [12]. Athletes have shown a delayed return to play, higher incidence of chronic pain, and significant long-term disability compared to lateral ankle sprains [8, 13, 14]. A study from the United States Military Academy found that involvement of the syndesmosis was the most predictive factor of chronic ankle dysfunction six months after an injury [14]. This review will describe the anatomy of the biomechanics of the distal tibiofibular ligament, followed by an assessment of the clinical evaluation and diagnosis of syndesmotic ligament injuries. Finally, the indications and treatment options for both nonoperative and operative intervention will be discussed and evaluated with a current review of the literature.

2. Anatomy

A syndesmosis is defined as a fibrous joint in which two adjacent bones are linked by a strong membrane or ligaments [15]. The distal tibiofibular joint is a syndesmotic joint between the tibia and fibula, linked by four ligaments: the anterior inferior tibiofibular ligament (AITFL), the interosseous ligament (IOL), the posterior inferior tibiofibular ligament (PITFL), and the inferior transverse ligament (ITL). The distal tibiofibular joint employs both its bony and ligamentous structure for stability (FIGURE 1).

The architecture of the bony components of the syndesmosis provide significant stability to this joint. The fibula sits in a groove created by bifurcation of the lateral ridge of the tibia into the anterior and posterior margins of the tibia, approximately 6-8cm above the level of

the talocrural joint [16]. The anterior margin ends in the anterolateral aspect of the tibial plafond called the anterior tubercle, or Chaput's tubercle. The posterior margin ends in the posterolateral aspect of the tibial plafond called the posterior tubercle, or Volkmann's tubercle. The apex of this fibular notch is the incisura tibialis, which has a depth that varies from concave (60-75%) to shallow (25-40%) [17, 18]. Its depth varies from 1.0 to 7.5mm [19, 20] and is a little less in women than in men [21]. A shallow notch may predispose to recurrent ankle sprains or syndesmotomic injury with fracture-dislocation [15]

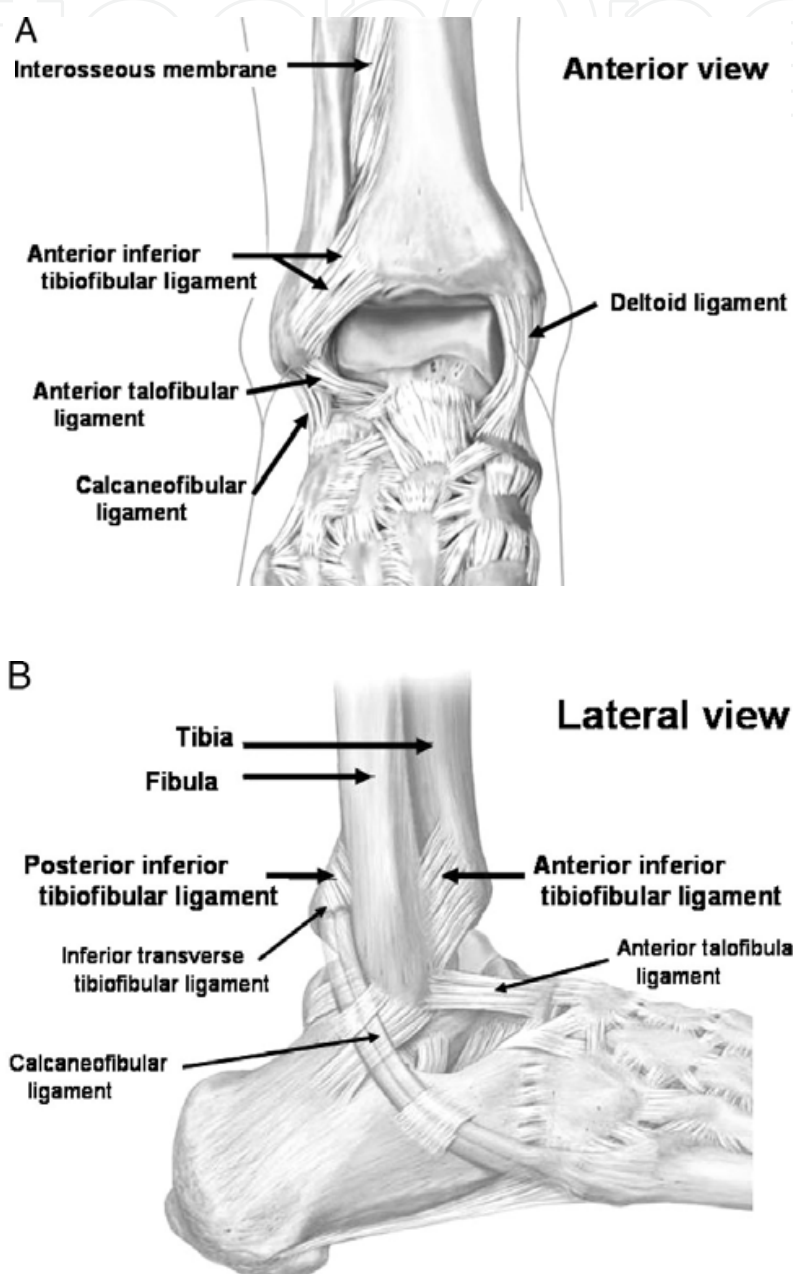


Fig. 1. Anatomy of syndesmosis, A) anterior; B) lateral. AITFL = anterior tibiofibular ligament; IOL = interosseous ligament; PITFL = posterior tibiofibular ligament; ITL = inferior tibiofibular ligament. (Reprinted from Browner B, Jupiter J, Levine A, Trafton P. *Skeletal Trauma: Fractures, Dislocations, Ligamentous Injuries*, 3rd edition. Philadelphia: Saunders, 2002; p. 2307Y74. Copyright * 2002 Saunders.

The bony architecture of the fibula mirrors that of the fibular notch. The medial aspect of the fibula forms a convex structure that complements that of the tibia, with an anterior and posterior margin, as well as a ridge that bifurcates that margins and aligns itself with the incisura tibialis.

The AITFL originates from the anterior tibial tubercle and runs distally and laterally in an oblique fashion to insert onto the anteromedial distal fibula. This ligament has a width of approximately 18mm, length between 20 and 30mm, and a thickness of 2 to 4 mm. It is the most commonly sprained ligament in syndesmotic injuries and is always disrupted with joint space widening or frank diastasis [15]. It is often multifascicular, and its most inferior fascicle has been described as a discrete structure called the accessory AITF ligament. The fibers can be seen during ankle arthroscopy and have been reported to be a source of impingement [22]. The PITFL originates on the posterior aspect of the fibula and runs horizontally to Volkmann's tubercle (FIGURE 5). This ligament has an approximate width of 18mm and a thickness of 6mm and is the strongest component of the syndesmosis. Because of its extensive breadth of attachment coupled with elasticity, the PITFL is able to withstand greater forces without failure than the AITFL and reaches maximal tension during dorsiflexion [23, 24]. The inferior transverse ligament is deep and inferior to the PITFL, extending over to the posterior aspect of the medial malleolus. The inferior transverse ligament is often difficult to distinguish from the PITFL as it runs just distally in the same plane. It forms the most distal aspect of the articulation. A portion of this ligament lies below the posterior tibial margin preventing posterior translation of the talus and deepening the ankle mortise to increase joint stability by functioning as a labrum. The interosseous ligament spans the space between the lateral tibia and medial fibula and is confluent with the proximal interosseous membrane. It is the main restraint to proximal migration of the talus between the tibia and the fibula [25] (FIGURES 2 and 3).



Fig. 2. The anatomy of the ankle syndesmosis in anterior, posterior, lateral positions; anterior inferior tibiofibular ligament (AITFL), interosseous ligament (IOL), posterior inferior tibiofibular ligament (PITFL), inferior transverse ligament (ITL). Copyright: Mark Hutchinson, University of Illinois

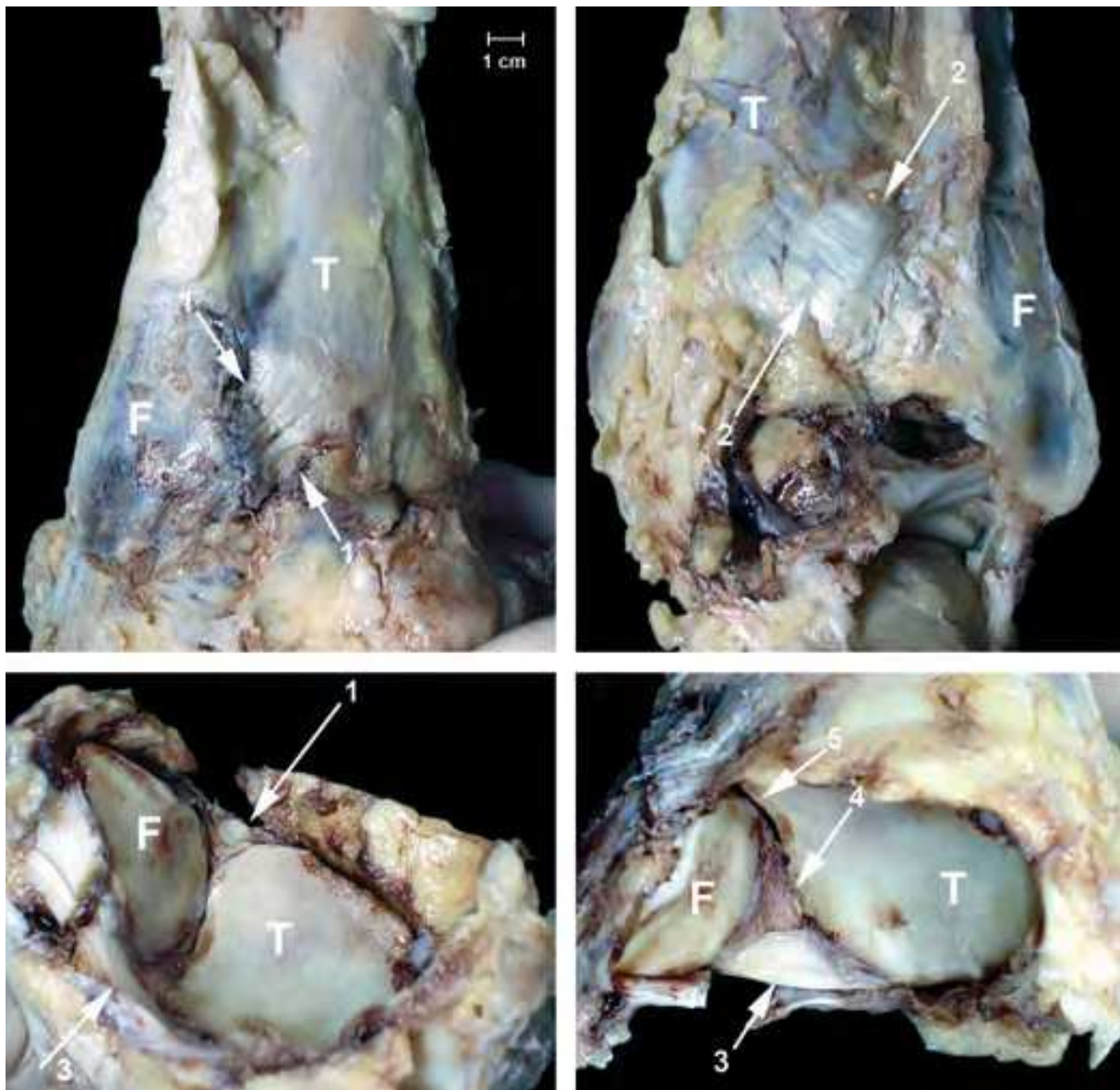


Fig. 3. Exposure of syndesmotic ligaments in a dissected right ankle (male, 92 years). (A) The trapezoid multifascicular anterior tibiofibular ligament (AITFL) (1) runs obliquely upwards from the anterior fibular tubercle towards the anterior tibial tubercle. (B) The band-like posterior tibiofibular ligament (PITFL) (2) runs obliquely upwards from the posterior fibular tubercle towards the posterior tibial tubercle. (C) View from below after removal of the talus shows the curved and horizontally running transverse ligament (3) and the inferior margin of the AITFL. In (D) fat (4) from the synovial fold is visible in the tibial incisure between the transverse ligament and the small contact area between the tibia and fibula (5). F, fibula; T, tibia. Picture courtesy of:

Title: Anatomy of the distal tibiofibular syndesmosis in adults: a pictorial essay with a multimodality approach

Author: John J. Hermans, Annechien Beumer, Ton A. W. De Jong, Gert-Jan Kleinrensink

Publication: Journal of Anatomy

Publisher: John Wiley and Sons

Date: Dec 1, 2010

3. Biomechanics

The ankle joint undergoes extreme loading which places stresses upon the bones, ligaments and dynamic stabilizers. Failure or injury to any of these components can lead to instability and pain. As a weight-bearing joint, the ankle can experience a multitude of different forces, reaching up to 6 times body weight at times [23]. The syndesmotic ligamentous complex maintains the integrity of the ankle mortise necessary to perform its hinge and glide movements. In simple terms, the ligaments stabilize the syndesmosis by preventing lateral displacement of the fibula. If any or all of the structures fail and the lateral malleolus displaces laterally, the talus usually follows. When the syndesmosis is disrupted, the normal gliding and rotational motion of the talar dome within the distal part of the tibia is altered. In addition to maintaining the integrity between the tibia and fibula, the syndesmosis complex resists axial, rotational, and translational forces. The deep portion of the deltoid ligament also contributes to the stability of the syndesmosis and must be evaluated after injury [26].

Normal motion exists between the distal fibula and tibia. The fibula can move medially, laterally, proximally, and distally in small increments. It also has a rotational component in relation to the tibia. The ankle joint undergoes triplanar motion from plantarflexion to dorsiflexion [27]. The movements require the talus and malleoli to remain in intimate contact. The superior portion of the talus is wider anterior vs. posterior, often described as a trapezoid. In dorsiflexion, the wider portion of the talus is set between both malleoli, providing maximum stability. The reverse process happens with plantarflexion. The syndesmotic ligaments provide such strong stabilization to the articulation that the fibula only rotates externally about 2 degrees, and the intermalleolar distance widens only about 1mm when the ankle joint is brought from full plantar flexion to full dorsiflexion [28]. The talus rotates an average of 5 degrees with dorsiflexion. The fibula moves approximately 2-4 mm distally with weight bearing. Mechanical disruption of the syndesmosis may result in increased compressive stresses seen by the tibia, increased likelihood of lateral subluxation of the distal fibula, and incongruence of the ankle joint articulation [29]. The relative joint position of the talus under the tibial plafond and dynamic joint motion would be altered with resulting abnormalities in contact pressures and a medium for development of degenerative joint disease.

Radiostereometric analysis of normal ankles by Beumer et al [30] showed that with an external rotation moment of 7.5N-m applied to the foot, the fibula externally rotated between 2-5 degrees, translated medially between 0 and 2.5mm, and moved posterior between 1 and 3.1mm. The extremes of motion are seen in the stance phase of gait. Oglivie-Harris et al. performed a biomechanical study to determine the relative contribution of each of these ligaments during 2 mm of lateral displacement of the fibula [31]. Their results showed the AITFL contributed 35% of the restraining force, the inferior transverse ligament contributed 33%, the intraosseous ligament contributed 22%, and the PITFL contributed 9%. They proposed that injury to two of the ligaments may lead to instability. Another study used cadaver specimens to determine the effects of sequential sectioning of the syndesmotic ligaments to resistance of an external rotation force. The distal tibiofibular diastasis was 2.3mm after sectioning of AITFL, 5.5mm with the additional sectioning of distal 8cm of the intraosseous ligament, and 7.3mm after division of the PITFL [29]. Sectioning of all 3 ligaments allowed for close to 5 degrees of pathologic external rotation at ankle joint. The AITFL has been found to prevent excess fibular movement and rotation of the talus and

maximum tension is achieved in plantar flexion. The posterior ligaments are able to withstand greater forces without failure than the AITFL and reach maximum tension during dorsiflexion [23]. The posterior structures combination of strength and elasticity make them the last structures to tear in an injury [24]. The IOL is the shortest but primary bond between tibia and fibula [32]. The IOL restrains posterolateral bowing of the fibula and transmits a small portion of the weight bearing load to the fibula [33]. It is thought to behave as a spring, allowing for slight separation of tibia and fibula during dorsiflexion [34]. Normal axial loading within the leg segment during walking involves a transfer of between 6% to 15% of the compressive axial load from the tibia to the fibula through the distal interosseous ligament and membrane [27].

4. Mechanism of injury

Athletes may present with a variety of mechanisms for injury. The exact mechanisms are not known for certain and despite the fact that researchers have been unable to duplicate the lesions of a syndesmotic sprain, most syndesmotic injuries are caused by external rotation [29, 35, 36]. Any measure that widens the mortise may damage the syndesmosis. Most proposed mechanisms of injury were based on the observations of clinicians who have interviewed patients with these injuries. The mechanism of external rotation is supported by multiple biomechanical studies that demonstrate increased external rotation of the talus and fibula upon sequential sectioning of the ligaments involved [37]. With this external rotation moment, the fibula separates from the tibia, causing initially a disruption of the AITFL. Commonly, the medial deltoid ligament is also injured. Nussbaum produced a study of 60 athletes with syndesmotic sprains without diastasis [38]. 55% of the injuries occurred when an athlete collided with another with a planted foot in external rotation; after the contact, the player fell forward, dorsiflexing the ankle and further externally rotating the foot. 37% caught their toe and twisted their ankle without receiving contact. No significant correlation existed between the mechanism of injury and the severity of injury. External rotation of the talus also occurs, with possible injury to the deltoid ligament medially. The severity of the force and the duration are determining factors on how far the injury extends; sometimes the proximal extent of the fibular injury component results in a fracture.

Clinicians should be aware of other possible mechanisms of injury. Others have reported on syndesmotic injuries that were due to hyperdorsiflexion, inversion, and plantarflexion [39-42]. Brosky reported that when maximal tension is achieved with external rotation, either dorsiflexion or plantarflexion may result in damage [43]. Other more recent cadaveric studies have looked at whether syndesmotic injuries can cause result from and cause multidirectional instability [44].

Mechanisms during individual sporting activities have been described. Fritschy noted that despite the protection offered by the rigid ski boot, syndesmotic injuries were common among elite skiers because of extremely rapid turns and sudden forceful external rotation of the foot. The external rotation forces acting on the individual ski are caused by a relatively long moment arm [45]. Skiers typically catch the inner edge of the ski which causes forceful external rotation of the foot. Football players often encounter 2 possible scenarios involving contact for high ankle sprains. One involves a direct blow to the lateral leg with a planted foot causing internal rotation of the leg relative to the foot. The other scenario involves a blow to the lateral knee with the foot planted in external rotation relative to the body being

internally rotated [9]. (FIGURE 4) Other injuries include falls, twisting weight-bearing injuries, and motor vehicle accidents. Athletes often are incapable of providing an exact mechanism; but they often recognize that the injury is not consistent with a typical ankle sprain.



Fig. 4. The mechanism of syndesmotic injury typically seen in sports such as (a) soccer and (b) football is a direct or indirect external rotation force placed on the foot relative to leg and trunk. Figures copyright is owned by Jeffrey R. Thormeyer. Artist: Matthew Mendoza

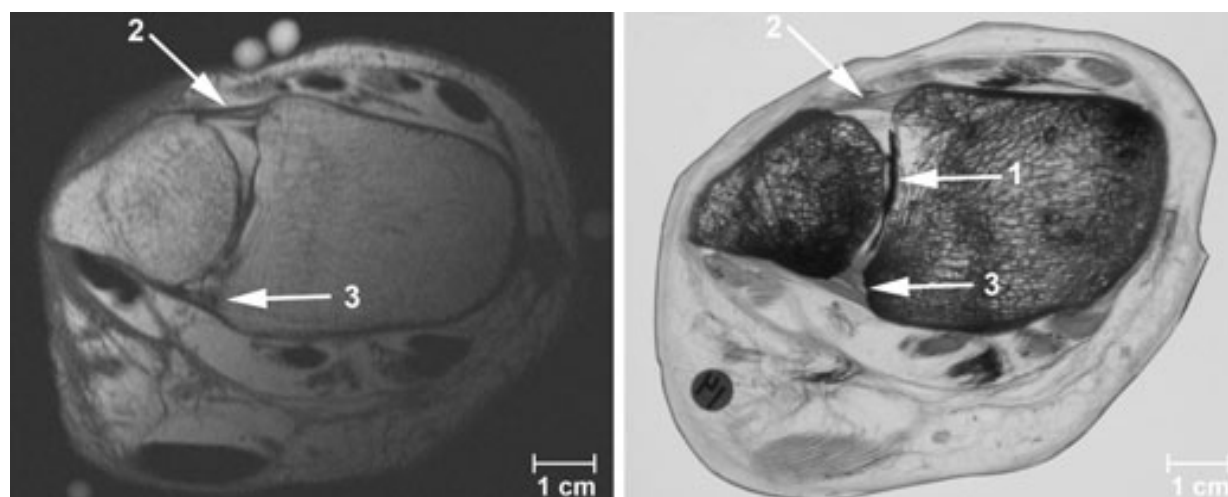


Fig. 5. Correlation between MR image (left) and plastinated slice (right) at the same level through the tibiofibular syndesmosis (female, 84 years). The intra-articularly injected green dye is visible in the tibiofibular recess (1), which extends between the anterior (2) and posterior (3) tibiofibular ligament. As the MR image is obtained without intra-articular contrast, the recess is not visible here. The incisura fibularis is shallow with an irregular contour.

Picture courtesy of :

Title: Anatomy of the distal tibiofibular syndesmosis in adults: a pictorial essay with a multimodality approach

Author: John J. Hermans, Annechien Beumer, Ton A. W. De Jong, Gert-Jan Kleinrensink

Publication: Journal of Anatomy

Publisher: John Wiley and Sons

Date: Dec 1, 2010

5. Epidemiology

Isolated ankle syndesmosis injuries are not very common disruptions. They are seen more often in conjunction with deltoid ligament injury and fractures in the malleoli. The real prevalence of ankle syndesmosis injuries is likely underestimated because many are missed or are not treated in a timely fashion. Hopkinson and colleagues suggested that ankle syndesmosis injuries account for 1% of all ankle injuries in the United States military. This was a study of cadets at West Point, who must participate in a contact sport, and showed 15 syndesmotomic injuries out of a total of 1344 total ankle sprains [39]. Fallat and colleagues followed all ankle injuries that presented at a local emergency department and a primary care clinic prospectively for 33 months. The diagnosis of a high ankle sprain was made on physical examination alone. Of 639 patients who had 547 soft tissue injuries and 92 ankle fractures, the prevalence of syndesmosis injuries was 5% [46].

In populations of high-level sports participation or high impact activities, the incidence has shown to be higher [10, 47]. In ice hockey and skiing syndesmotomic sprains are occurring more frequently than lateral ankle sprains most likely due to the rigid nature of the footwear as observed by Fritschy in world class skiers [45]. Boytim and colleagues reported a prevalence of 18% for syndesmosis injuries in a prospective study of 98 ankle injuries, and close to 40% of ankle sprains in an American professional football team [9]. Vincelle and

colleagues showed that close to a 1/3 of Canadian football players had calcification of the syndesmosis, documenting evidence of old, chronic, syndesmotic injuries [48]. A retrospective study by Wright et al showed syndesmotic sprains accounting for 74% of ankle sprains in two professional hockey teams over 10 years [11]. A study using arthrography demonstrated high incidences (50% direct and 36% indirect signs of syndesmotic injury) [49]. In a retrospective study using MR to assess injuries to the ankle in 90 severe sprains, Brown et al. found a syndesmotic injury in almost 2/3 (24% acute; 38% chronic) [50].

Syndesmosis injuries are increasing in incidence in the athletic population, and in collision sports such as football, hockey, and rugby. They account for an increasingly significant proportion of ankle sprains. For athletes, the increase in risk stems from the intensity of play, twisting and cutting demands, as well as risk of contact and collision. Risk factors were identified in a study performed with data over 4 years looking at injuries sustained by cadets at the United States Military Academy. Syndesmotic and medial ankle sprains accounted for about 12% of ankle sprains in this young, athletic population. Important risk factors noted included male sex, higher level of competition, and exposure to selected sports such as football, team handball, basketball and soccer [51]. Using all available data, the incidence of high ankle sprains in the general athletic population is increasing as a percentage of all ankle sprains and is higher with more intense sporting activities.

Despite syndesmotic injuries being less common, they are often more difficult to diagnose than lateral or medial ankle sprains and recovery from the injury can be very protracted. Common complications of syndesmotic sprains are heterotopic ossification or frank synostosis, prolonged dysfunction of the ankle, and diastasis. Taylor and colleagues reported the findings on 50 syndesmosis injuries in 44 football players [52]. Reported that Hopkinson [39] reported that 90% of syndesmotic injuries showed HO (although asymptomatic), while Boytim [9] demonstrated a 75% rate. McMaster and Scranton found radiographic evidence of synostosis in seven patients who had persistent pain 3 to 11 months after a high ankle sprain [53]. Veltri et al. reported 2 cases of symptomatic synostosis in 2 football players [54]. A different study conducted by Bassett et al [52] reported that 50% of players who sustained syndesmotic injuries had evidence of HO and that their recovery period was on average 11 additional days as compared to those without HO. In a survey of NFL head athletic trainers, the mean return to play time was 30 days with a range of 5-56 days [55]. Boytim et al reported that football players with a high ankle sprain averaged 6.3 missed or limited practices (range 2-21) and averaged 1.4 missed games (range 0-5) as compared to 1.1 missed or limited practices and 0.04 games missed for lateral ankle sprains [9]. Difficulties in ankle function become apparent as soon as the athlete returns to high demand activities such as cutting, twisting, turning, jumping or pushing off. A study revealed that an ankle syndesmotic sprain requires a recovery period almost twice as long as that of a severe lateral ankle sprain [39]. Furthermore, residual chronic pain is more common than in an isolated lateral ankle sprain [38, 56]. Failure to reduce or stabilize a syndesmotic injury and the associated lateral talar translation may cause abnormal joint mechanics, diastasis, and degenerative changes. Accordingly, early recognition and treatment of high ankle sprains is paramount for a normal non-antalgic gait and return to sport.

6. Clinical evaluation

As with all injuries, a thorough history and physical exam are mandatory. Paramount within the history is relevant information concerning mechanism of injury and prior ankle

injuries or instability. It is important to detail the time interval between injury and evaluation. A simple classification system into acute (<3 weeks), subacute (3 weeks to 3 months), or chronic (> 3 months) is useful. Because many ankle injuries can appear similar on initial presentation, an understanding of the mechanism of injury is crucial. A grade III lateral ankle sprain (non-surgical) from an inversion type injury can look similar to an unstable syndesmotic injury (surgical). Differential diagnoses begins with mechanism of action, location of injury, type of sport, position of limb, direction of forces, and magnitude and velocity of injury. Elapsed time from injury allows correlation with amount and timing of swelling. Severity of injury can be correlated with ability to bear weight. Athletes complain of generalized pain with weight-bearing or push off during gait if they are able to bear weight. A heel-raise gait pattern may be observed to avoid excessive ankle dorsiflexion and to avoid pain during pushoff [43]. In chronic situations, the athlete may complain of stiffness and feelings of instability, especially on rough or uneven terrain [57]. Patients with chronic injuries may show prolonged recovery as compared to those with ordinary lateral ankle sprains [56].

Inspection may reveal edema and ecchymoses about the lateral aspect of the ankle. Palpation is necessary for differentiation. Palpation is necessary as the patient will often have well-localized anterolateral pain located over the anterior syndesmosis of the ankle. The pain and swelling in acute syndesmotic injuries are often more precisely localized than in patients with the common inversion lateral ankle sprain. Careful palpation over the anterior talofibular and calcaneofibular ligaments should reveal minimal if any tenderness. The degree of swelling tends not to be as substantial as with lateral inversion injuries. Note any tenderness along the interosseous membrane and the length of the tenderness. Nussbaum et al found that days lost from competition could be predicted by measuring the distance over which the interosseous membrane was tender to palpation [38]. There may be tenderness about the medial aspect of the ankle if they injury involved an abduction component. Fites et al. recommend that if swelling about the joint between tibia and fibula occurs less than 24 hours after injury, consider it a syndesmotic injury until proven otherwise [58]. The deep deltoid ligament and posterior syndesmotic ligaments are structures deep within the ankle and difficult to palpate independently. Each may be ruptured without isolated palpable tenderness. Because of the uncertainty with presentation, repeat clinical exams are often necessary to delineate between stable and occult unstable injuries. A missed, unstable injury that is undertreated can lead to a poor result. Range of motion is often limited in both directions of sagittal plane motion with an empty or painful end feel at terminal dorsiflexion [55]. If the athlete is unable to bear weight, the Ottawa fracture rules should be applied to determine the need for radiographs before provocative stress tests are performed [59].

To evaluate syndesmotic injuries, numerous clinical exam tests have been described. However, the accuracy, prognostic potential, ability to detect severity of injury, or capability to correlate with the degree of instability present have not been well established [55]. A number of exam tests have been developed that include the external rotation test, the Cotton test, the fibular-translation test, the squeeze test, and the crossed-leg test [60].

The squeeze test is performed by compressing the tibia and fibula at midcalf level [61]. Pain in the area of AITFL is a positive test and may herald a syndesmotic injury (FIGURE 6). Teitz et al confirmed that compression of the two bones proximal to the midpoint of the calf

caused separation at the origin and insertion of the AITFL [62]. Reliability remains in question with reported low positive predictive value as well as poor intra-examiner reliability [63, 64]. Studies have indicated that a positive test is correlated with a prolonged recovery time or presence of heterotopic ossification [39, 52].



Fig. 6. The squeeze test. The tibia and fibula are compressed at the level of the mid-calf. Pain at the ankle joint indicates a positive test. The examiner should palpate the fibula along its entire length. Copyright: Mark Hutchinson, University of Illinois

The external rotation test is performed with the patient sitting facing the examiner with hips and knees at 90 degrees. The leg is stabilized and an external rotation force is applied to the ankle with the foot in dorsiflexion (FIGURE 7). The largest displacement of the syndesmosis and creation of tension within the ligamentous structures occurs here as the broadest portion of the talus is present in this position. Reproduction of pain in the syndesmotic area is a positive test. Medial sided pain points toward a deltoid ligament injury. Alonso [63] reported a high degree of inter-tester agreement, low rate of false positives and a protracted recovery if coupled with palpatory tenderness and a positive squeeze test.



Fig. 7. The external rotation test. With the knee bent to 90- and keeping the leg steady, an external force is applied to the ankle. Pain at the ankle indicates a positive test. Copyright: Mark Hutchinson, University of Illinois

The fibular-translation test is performed by applying an anterior and posterior drawer force to the fibula with the tibia stabilized. Increased translation as compared to contralateral side accompanied by pain defines the test as positive. This test has shown poor correlation to syndesmotic injury both in cadaveric sectioning studies as well as clinically [55].

The Cotton or shuck test is done by attempted translation of the talus within the mortise in a lateral direction. The distal lower extremity is held steady with one hand while the plantar heel is grasped with the other hand and the heel is moved side to side. Increased translation or pain may be indicative of a syndesmotic injury along with a concomitant deltoid injury. A high degree of false positives secondary to subjective interpretation has been shown. Excessive translation is more often seen with the most severe injuries [65, 66].

The crossed-leg test is a more recently described test. The patient rests the midtibia of his affected extremity on the knee of the other extremity, in a figure 4 type position. The patient then applies a downward force on the medial side of the knee. The test is positive if pain is felt in the syndesmotic region. The authors reported 7 of 9 patients with radiographic abnormalities tested positive with this maneuver [67].

The heel thump test was described as a test to target ligamentous injury in the absence of a fracture. The patient rests with leg dangling over edge of table or chair with the foot in gravity induced equinus. The examiner delivers a firm thump to the heel in line with the long axis of tibia with the intention of delivering talus into the mortise. A positive test is aggravation of pain above the ankle briefly. The utility of this test may lie in the ability to

examine the structures when swelling precludes palpation or ligamentous stressing [68]. However, the test is not specific as it has been described as a method for identifying tibial stress fractures also [69].

Stability of the ankle joint may be further examined by asking the patient to perform some active maneuvers including performing a toe raise, walking and jumping. Spaulding found in gait analysis that syndesmotic injury decreased the ability to effectively push off the toes while walking [70]. The above mentioned actions should be painful or prevent normal motion if a syndesmotic injury is present. Improvement with these measures by tightly taping the ankle just above joint is an adjunctive test described by Williams and Amendola [71] to further confirm suspicion. Additionally, functional ability may be assessed by having the athlete perform a single leg hop. Disability was defined by Nussbaum as an inability to hop 10 times without significant pain [38]. Nussbaum concluded that 4 parameters may help determine severity of the syndesmosis injury: AITFL tenderness, the length of tenderness along the interosseous membrane, a positive external rotation test, and functional disability. This study reported 55 out of 60 patients had a positive external rotation test which also required longer rehab and return to play time. They also found that return to play time could be correlated directly with the tenderness length with a 95% confidence interval.

Although the presence of positives with any of these tests should generate suspicion to a syndesmotic injury, there are no good studies demonstrating that one test is reliably predictable as to the severity of the injury. Beumer and colleagues performed a biomechanical evaluation of 5 special tests (squeeze, fibula translation, Cotton, external rotation, and anterior drawer) to determine the degree of distal tibiofibular displacement induced by each test in intact cadaveric ankles and after sectioning of the anterior talofibular ligament, the posterior talofibular ligament, and the deltoid ligament [60]. The average increase in displacement after sectioning of all ligaments was only approximately 1 mm. This study showed that the degree of distal displacement between tibia and fibula exhibited with specific exam maneuvers combined with creation of syndesmotic specific ligament injuries failed to show that any of the tests can be used to predict extent of injury.

7. Imaging

Evaluation of the syndesmosis should include three views (AP, lateral, mortise) of the ankle as well as orthogonal views of the entire tibia and fibula especially if any tenderness along the proximal leg exists. A mortise view taken with the patient positioned in unilateral weight bearing is the most accurate way to assess instability radiographically but many patients with mortise instability may not be able to tolerate unilateral standing due to pain [72]. Bilateral weight-bearing or non-weight bearing radiographs can be considered instead. Weight bearing films provide physiologic stress to unveil occult unstable injuries. CT scans and MRI scans may be of value in more subtle cases. Radiographs are evaluated for the relationship of the tibia and fibula as well as for fractures along the entire lengths of the bones. Disruption of the normal relationship between distal tibia and fibula is often representative of a syndesmotic injury. Radiographic evaluation with full length views of the leg is needed to evaluate pronation or external rotation injuries resulting in a Maisonneuve type fracture. The more proximal the fibular fracture, the greater risk for syndesmotic injury and resulting instability. Beumer et al [30] studied motion of the distal fibular before and after syndesmotic injuries on cadavers. The fibula tended to externally rotate after disruption but this was difficult to see on plain radiographs. Posterior

translation on the lateral view was described as a secondary pathology. Radiographic parameters have been developed to help identify syndesmotic injuries: increased tibiofibular clear space decreased tibiofibular overlap, and medial clear space widening.

Tibiofibular clear space is defined as the distance between the medial border of the fibula and the lateral border of the posterior tibia as it extends into the incisura fibularis. This distance is measured at 1 cm proximal to the tibial plafond and should be less than 6mm in both the AP and mortise projections. This measurement provides the most reliable indicator of injury to syndesmosis [73]. Tibiofibular overlap is the overlap of the lateral malleolus and the anterior tibial tubercle. This is also measured 1 cm above the plafond. The overlap should be greater than 6mm in the AP view, and greater than 1 mm in the mortise view. Medial clear space is defined by the distance between the lateral border of the medial malleolus and the medial talus at the level of the talar dome (FIGURE 8). With the ankle in neutral, the clear space should be less than or equal to the space between talar dome and tibial plafond. A widening of the medial clear space correlates with a concomitant deltoid ligament injury [61]. Avulsion fractures may occur and aid in identification; calcification above syndesmosis or at tibial attachment of PITFL may also aid in diagnosis.

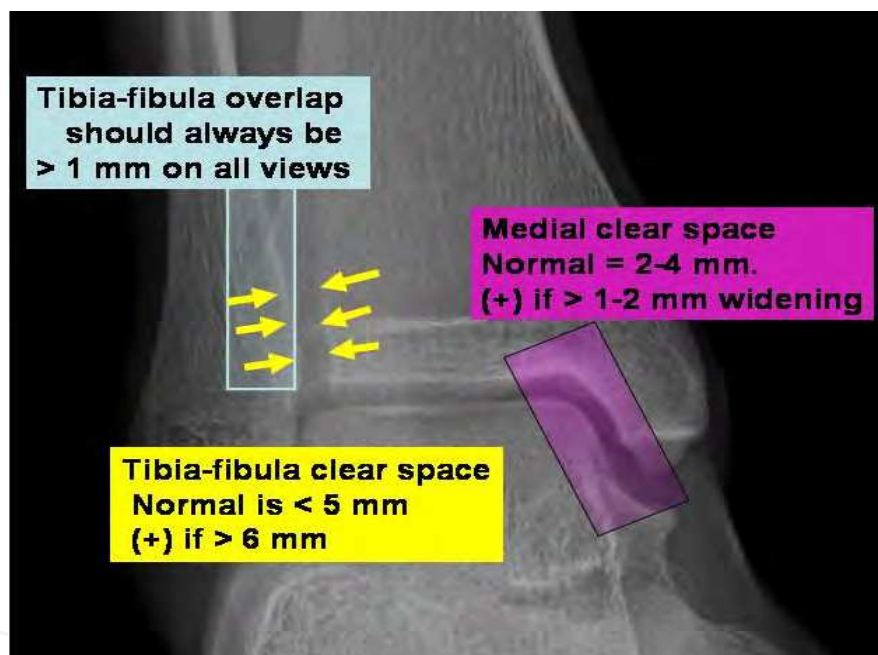


Fig. 8. Diastasis of the tibiofibular clear space greater than 6 mm is considered one of the most reliable indicators of syndesmotic injury. There should be at least 1 mm of tibiofibular overlap on all views. The medial clear space of greater than 4 mm or greater than 2 mm difference compared with the opposite side is indicative of instability. Copyright: Mark Hutchinson, University of Illinois

Reliability of evaluation of syndesmotic injuries by measuring diastasis of the tibia-fibula interval and tibia-fibula overlap on standard radiographs has been questioned. There is considerable variation in the size and depth of the notch which can make radiographic interpretation of separation difficult [74]. Absolute values of distances do not take into account anatomic differences in size or with gender. To account for these, Ostrum et al. introduced the concepts of measurements based on ratios [75]. They concluded that there was an injury to the syndesmosis if the ratio of the tibiofibular overlap: fibular width was

greater than 24%; ratio of tibiofibular clear space: total fibular width less than 44%. In addition to gender differences, rotation effects measurement of tibiofibular overlap. Pneumáticos et al [76] demonstrated that overlap changed with rotation but the clear space remained same during rotation from degrees of external rotation to 25 degrees of internal rotation. They concluded that the tibiofibular clear space is the most reliable parameter for measuring widening on plain radiographs. Takao et al. published results of ankle arthroscopy in tibiofibular syndesmotic rupture [77]. Evaluating 38 patients who had Weber B ankle fractures, they identified disruption on AP and mortise radiography in 42% and 55% respectively. During arthroscopy, the diagnosis actually increased to 87% [78]

Some authors have suggested stress radiographs to aid in identification; stress radiography with an external rotation force placed on the foot is a useful imaging approach (FIGURE 10). It may require local anesthesia to obtain these views. Alternatively, a gravity stress view may be obtained by performing an AP radiograph with the leg horizontal and without support under the foot/ankle. The resultant displacements are then compared to the uninjured side. Lateral views may allow for easier interpretation to assess possible posterior and lateral displacement of the fibula [29]. However, studies evaluating translation after rotation forces applied show that after sectioning of ligaments, distance is negligible and stress views cannot be reliably used for predictive purposes because of the high false negative rate.

CT scans are more sensitive than plain radiography in detecting syndesmotic injuries based on diastasis. Ebrahiem et al noted that CT is more effective at picking out 2-mm and 3-mm diastasis [79]. Avulsion fracture may occur on either the anterior or posterior aspect of the tibia and have been noted to occur in up to 50% of syndesmotic injuries. CT imaging utilized in this case can pick up avulsion fractures without evidence of diastasis [80].

MRI can be used for diagnosis and has shown to effectively display the components of the syndesmotic complex with high interobserver agreement [81]. A study by Takao et al. revealed 100% specificity and 93% sensitivity of injury of AITFL and 100% specificity and sensitivity for PITFL as compared to arthroscopy in acute studies [82]. While useful for confirmation, it is unclear if MRI imaging has shown to alter treatment plans or prognosis. MRI allows for the grading of ligamentous injuries. Grade 1 injuries represent stretching of the ligament without fiber disruption. The ligament is intact on MR imaging but often has edema present adjacent to the ligament and within overlying soft tissues. Grade II injuries represent partial tearing of the ligament. MR images demonstrate thickening of the ligament with partial fiber disruption and associated edema within the ligament and overlying soft tissues. Grade III injuries represent discontinuity of the ligament. MR images demonstrate this along with extensive edema. The normal AITFL is dark on all MR sequences and has an oblique course. This structure may have normal fenestrations and accessory fascicles [83]. MR imaging findings of acute injuries include abnormal T2 signal with thickening, waviness, or disruption of the AITFL and interosseous membrane, usually with fluid extending superiorly within the distal tibiofibular joint. MR imaging findings of more chronic injuries include thickening, attenuation or disruption without associated edema. Associated injuries also are common with these injuries and are picked up by MR imaging. Brown et al looked at associated injuries in 59 patients with acute and chronic injuries. AITFL injuries were present in 74%; bone contusions in 24%, osteochondral lesions in 28%, joint incongruence in 33%, and osteoarthritis in 10% [50].

Recent interest has been garnered for the use of ultrasound with its inherent advantages as a method of diagnosis. Ultrasound can be performed in the office setup in both real time and dynamic modes. It is inexpensive, fast and does not have radiation exposure (FIGURE 9). Mei-Dan et al conducted ultrasound evaluations on athletes with syndesmotic injuries and compared them to athletes who sustained lateral ankle sprains as well as a control group without injury. The results were encouraging for accurately diagnosing a syndesmotic injury in cases of latent high grade syndesmotic sprains. Exams within two weeks of injury increased the ability of ultrasound to detect injury [84]. Milz et al compared US examination and MRI studies for lateral ligament injuries and syndesmotic injuries. The study showed a sensitivity of 66% and specificity for AITFL of 91% [85].

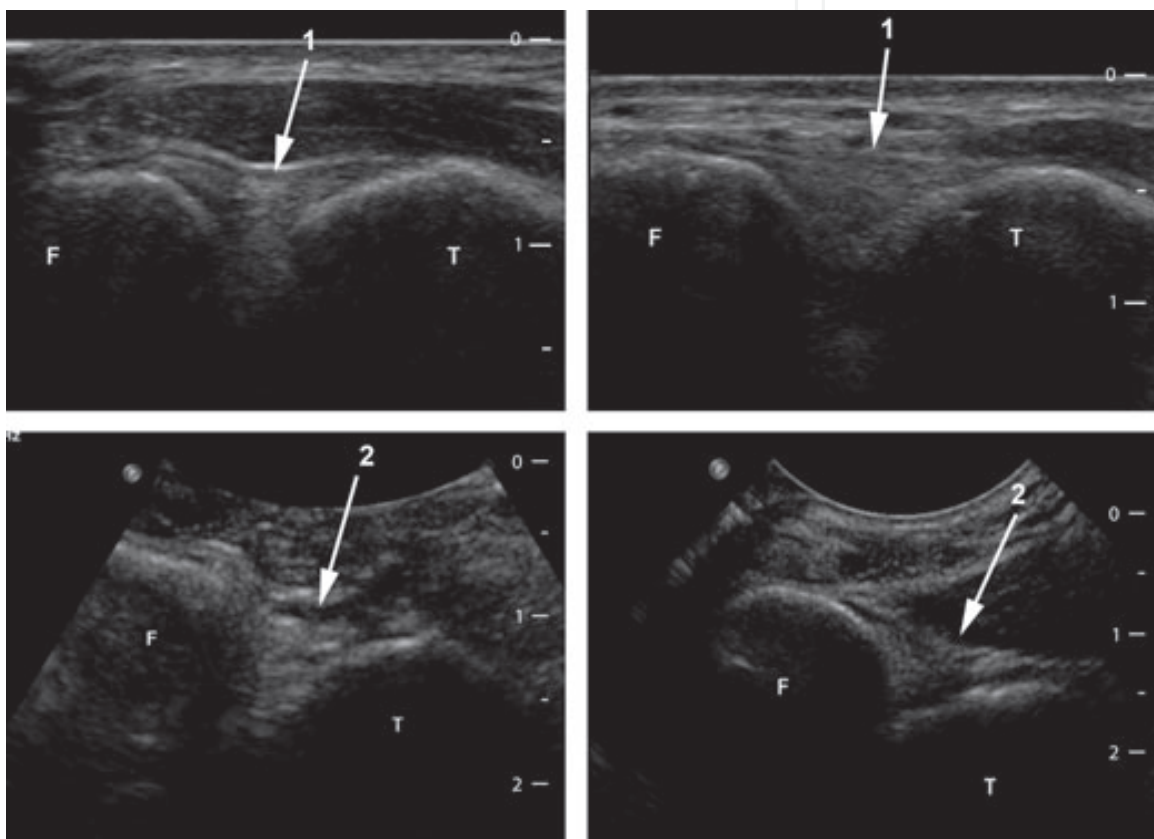


Fig. 9. Ultrasound images of anterior (1) (A,B) and posterior (2) (C,D) tibiofibular ligament (female, 20 years). F, fibula; T, tibia. In plantar flexion the ATIFL is slack (A). In dorsiflexion the talus pushes the tibia and fibula outwards, with stretching of the anterior tibiofibular ligament as a result (B). The same mechanism applies for the PTIFL. In plantar flexion the ligament is slack with a resulting increase in echogenicity (C). In dorsiflexion the fibres are stretched and are more longitudinally aligned (D). F, fibula; T, tibia

Title: Anatomy of the distal tibiofibular syndesmosis in adults: a pictorial essay with a multimodality approach

Author: John J. Hermans, Annechien Beumer, Ton A. W. De Jong, Gert-Jan Kleinrensink

Publication: Journal of Anatomy

Publisher: John Wiley and Sons

Date: Dec 1, 2010



Fig. 10. Mortise radiographs of subject 1, 1 day after injury. (A), at rest, there is a suggestion of widening of the syndesmosis without widening of the medial clear space. (B), with external rotation stress, there is obvious widening of the medial clear space and distal syndesmosis

Source: American Journal of Sports Medicine

Aggressive Surgical Treatment and Early Return to Sports in Athletes With Grade III Syndesmosis Sprains

1. Dean C. Taylor, MD, COL (Ret)^{†,*},
2. Joachim J. Tenuta, MD, MC, COL[‡],
3. John M. Uhorchak, MD, COL (Ret)[§], and
4. Robert A. Arciero, MD, COL (Ret) ||
5. Am J Sports Med November 2007 vol. 35 no. 11 1833-1838

8. Classification

There are two classification systems for syndesmotic injuries. The West Point Ankle Grading system provided by Gerber and colleagues is more applicable to athletes [10] and is based on amount of edema, tenderness, ability to bear weight, stress testing, and abnormal radiographic parameters. It distinguishes the following categories of pure ligamentous syndesmotic injuries: grade I—no evidence of instability (partial tear of the AITFL; grade II—no or slight evidence of instability (tear of the AITFL, partial tear of the IOL); and grade III—definite instability (complete tear of the syndesmotic ligaments). A grade II injury poses a particular diagnostic challenge because the extent of injury and its occult instability often

requires provocative measures to recognize. Underestimating or undertreating the injury can have devastating consequences.

The other classification system is based on whether diastasis is acute or latent. Based on radiographic findings, Edwards and DeLee [86] classified traumatic syndesmotic sprains into latent diastasis (seen on stress radiographs only) and frank diastasis, which is obvious on plain radiographs.

Because the existing classification systems do not offer a clear therapeutic algorithm, clinical and radiographic examination should focus on detecting and documenting the amount of latent and frank diastasis, as well as documenting the time course of injury. Traumatic injuries can be catergorized into acute, subacute, and chronic. Acute injuries, identified within three weeks of injury, are divided into sprains without diastasis, sprains with latent diastasis, and sprains with frank diastasis based on clinical examination, routine radiographs, stress radiographs, and futher imaging studies. Injuries to the syndesmosis of longer than 3 weeks’ duration are considered subacute. Syndesmotic injuries more than 3 months old are considered chronic. The latter two entities can be further subdivided based on variables such as presence of arthritic changes, and presence or absence of a synostosis.

9. Management

(TABLE 1) Treatment intervention is based on the severity of the syndesmotic injury. Grade 1 injuries are treated with non-surgical management. Symptomatic treatment includes a period of rest, ice, and immobilization for comfort and assistance with rehabilitation. For mild injuries in athletes, casting is generally not required and may impede course of therapy because of risk of disuse atrophy and stiffness. Patients often utilize crutches only 1 to 2 weeks for comfort in a controlled ankle motion walker boot. This immobilization allows

	Grade I	Grade II	Grade III
Clinical	Stable exam Good end point	Mid laxity Soft but positive end point	Unstable exam No end point Gross instability
X-rays	Stable on stress radiographs	0-1 mm laxity on stress x-rays	Unstable stress radiographs
Treatment	Rest, ice Bracing and crutches for comfort Functional brace at 2-4 wk Return to play when no symptoms appear on functional testing	Consider surgery; Cast immobilization may be 6-8 wk Return to play may be delayed for 6-8 wk until able to pass functional testing Take another x-ray at 2-3 wk to ensure no displacement Then treat the same as Grade I injury	Followed by functional bracing After surgery, follow same return to play as Grade II

Table 1.

athlete early mobilization but protects against external rotation. The athlete is then switched to a functional brace usually between weeks 2 and 4. Exercises are initiated during this transition. They include gradual increases in range of motion and stretching with eventual balance and bicycle program additions. Of note, patients need repeat examinations and radiographs every 1 to 2 weeks during this initial period to determine continued stability [87].

Nussbaum et al [38] and Williams et al [71] have described a 3-phase approach to rehabilitation. The acute phase aims at protecting the joint and decrease pain and swelling through immobilization and pain control. The subacute phase includes an increase in exercise intensity with goals of restoration of strength and basic functional motion. This includes cardiovascular conditioning. The final stage has its goal of returning the patient back to sport participation with strengthening, neuromuscular training, and sport-specific exercises. Determining the timing of return to sports is difficult and is based on examination as well as ability to perform sport specific tasks.

Grade II and III injuries are inherently unstable. The consensus concerning Grade III injuries is that operative fixation is necessary to maintain anatomic reduction of the mortise. The optimum treatment plan for Grade II injuries is less clear [88]. Nonoperative treatment for this injury includes initial splinting and protection from rotation as well as strict non-weight bearing status. Once swelling has retreated and the syndesmosis remains reduced on exam, the patient is transitioned to a short leg cast for 6 to 8 weeks. The athlete is then transitioned to progressive weight bearing in a walking cast, and then eventually to a soft ankle brace. If conservative approach is undertaken, again, serial evaluations are needed to ensure maintenance of reduction. Rehabilitation should focus on range of motion, balance, proprioception, strength, and return to play exercises specific to his/her sport [32]. Some investigators have suggested more aggressive treatment in athletes, including arthroscopic debridement and percutaneous screw fixation; however, this approach has not yet been substantiated by biomechanical or clinical data ([89] Early anatomic reduction and fixation ensures that the ligaments are in an optimal position for healing. Early fixation avoids the potential of a subtle missed diagnosis or for a delayed slip while attempting cast immobilization.

10. Operative treatment

10.1 Indications

The goal of surgical stabilization is to restore and maintain the normal tibiofibular relationship to allow appropriate healing of the ligamentous structures of the syndesmosis. Therefore, any sign of instability, either frank diastasis on radiograph or diastasis on stress radiographs, direct treatment towards syndesmotic fixation. However, these clear indications for surgical intervention represent a small percentage of the population. Taylor et al [90] noted that only 0.25% of ankle injuries and 1.7% of syndesmotic sprains are Grade III injuries with unstable radiographs. In addition, stress radiographs have been shown to be unreliable [91, 92] on biomechanical studies with a high false negative rate [32].

Chronic sprains with recalcitrant pain and functional instability are another indication for surgical fixation of the syndesmosis. Often times, these patients present with chronic ankle pain of an unknown etiology requiring an ankle arthroscopy to make the appropriate diagnosis [93, 94]. Thus, arthroscopic evidence of syndesmotic instability is another indication for surgical intervention. However, this modality is mostly used for chronic ankle pain, as it is unrealistic to perform an ankle arthroscopy on every ankle injury without radiographic signs of instability.

The challenge becomes identifying those patients with injuries that will result in prolonged recovery, recurrent symptoms, or chronic pain and instability despite normal radiographs. Amendola et al [95] performed a systematic review of syndesmotic sprains, and was only able to find six prospective studies investigating isolated syndesmotic sprains without radiographic widening or associated fracture in athletes. The average amount of time lost due to injury between studies was from 10 days to 52 days, but the range of missed time was from 0 days to 137 days. Surgical intervention was required in only two of these studies, with Wright et al [13] reporting 1 out of 14 cases and Hopkinson et al [5] reporting 1 out of 15 cases. Recurrent or prolonged symptoms were not recorded in all the studies, but Hopkinson et al [5] noted no recurrences, Nussbaum et al [96] documented a 6% recurrence and Taylor et al [97] a 43% recurrence of ankle instability. Because of the small size, varied follow-up and heterogeneous outcome measures of these studies no conclusion could be made regarding risk factors or prognostic signs regarding prolonged symptoms, recurrent symptoms, or surgical intervention.

11. Surgical implants

There are a multitude of different implants employed for syndesmotic fixation. Metal screws are the most common hardware utilized, however recently the development of bioabsorbable screws and suture-button fixation has been analyzed as alternatives. Each mode of fixation has its own advantages and disadvantages, and several biomechanical studies are available in the literature evaluating each implant, as well as comparing different methods of fixation.



Fig. 11. Proper orientation of syndesmotic screws. Copyright: Mark Hutchinson, University of Illinois

There are multiple different methods to choose from when using a metal syndesmotic screw, such as composition of the screw, size of the screw and number of cortices of fixation (FIGURE 11). Several biomechanical studies have evaluated these parameters, and for the most part no difference in strength of fixation was found. Beumer et al [98] evaluated the difference between stainless steel and titanium screws, and found no difference in strength of fixation. The same study also noted no difference between three and four cortical fixation. No biomechanical advantage was found using a 4.5-mm screw over a 3.5-mm screw in tricortical fixation of the syndesmosis [99]. However, with quadricortical fixation the 4.5-mm screw did show improved resistance to shear stresses during axially loading compared to a 3.5-mm screw [100].

Syndesmotic fixation of the tibiofibular joint prevents its normal physiologic movement that occurs during normal weight bearing and ankle range of motion. Needleman et al [101] demonstrated that quadricortical fixation with a 4.5-mm screw decreases tibiotalar external rotation, and may result in fatigue fracture of the screw [102]. Three cortical fixation may decrease the rigidity of fixation and increase physiologic motion, but may also lead to hardware loosening [103]. Other complications associated with the metal screw include inferior tibiofibular synostosis [104] and osteolysis around the implant [102].

To avoid the hardware complications associated with metal screws, bioabsorbable screws have been proposed as an alternative mode of fixation. The goal of the bioabsorbable implant is to temporarily hold the tibiofibular joint in place while the syndesmosis heals, but over time hydrolyze and degrade to the point of failure after weight bearing as started to allow for normal physiologic motion of the ankle. Two cadaveric, biomechanical studies compared the load to failure and stiffness of fixation between a stainless steel screw and a polylactide bioabsorbable screw of the same size [105, 106]. Both studies found no difference in syndesmotic fixation between the metal and bioabsorbable screw group. Two randomized, clinic trials evaluating bioabsorbable and metallic screws found no loss of reduction in either group, with no different in subjective and objective outcomes between the two groups [107, 108]. In fact, patients were more likely to return to their previous level of activity when treated with a bioabsorbable screw rather than a metal screw [108].

The material of these bioabsorbable screws has caused concern regarding possible biologic reactions with the body. Several studies have reported osteolysis [109], foreign-body reaction [110, 111], late inflammatory reaction [112] and osteoarthritis due to polymer debris entering the joint [113] with use of bioabsorbable screws. However, these studies were either case reports, or involved treatment of ankle fractures or talar neck fractures. In the previous four studies comparing metal and bioabsorbable screws, there was no osteolysis or inflammatory reaction recorded.

Another alternative to screw fixation is the suture button. This method resists tibiofibular diastasis while allowing for some movement at the distal tibiofibular joint (FIGURE 12). Proponents of this technique believe that it is simple, safe and effective when compared to the syndesmotic screw [114, 115]. Several biomechanical studies have been published recently comparing this technique to metal syndesmotic screws. These studies were in agreement that the metal screw has on average increase strength to failure compared to the suture button, but that the suture button has more consistent strength [114, 116, 117]. Failure of the suture button occurs through the button, whereas failure of the screw is relative to

cortical thickness. Forsythe et al [118] found the suture-button was not as strong, with increased diastasis compared to a metal screw. However, the studies did not agree on the amount of motion that suture-button allowed. Klitzman et al [119] noted in their biomechanical analysis that suture-button fixation allowed more physiologic motion of the fibula in the sagittal plane when compared to tricortical screw fixation. On the other hand, Sojin et al [117] denied observing a difference in fibular motion during cyclic loading for the suture-button and syndesmotic screw. They described ankle motion for both constructs as being similar, and stated that neither was normal.

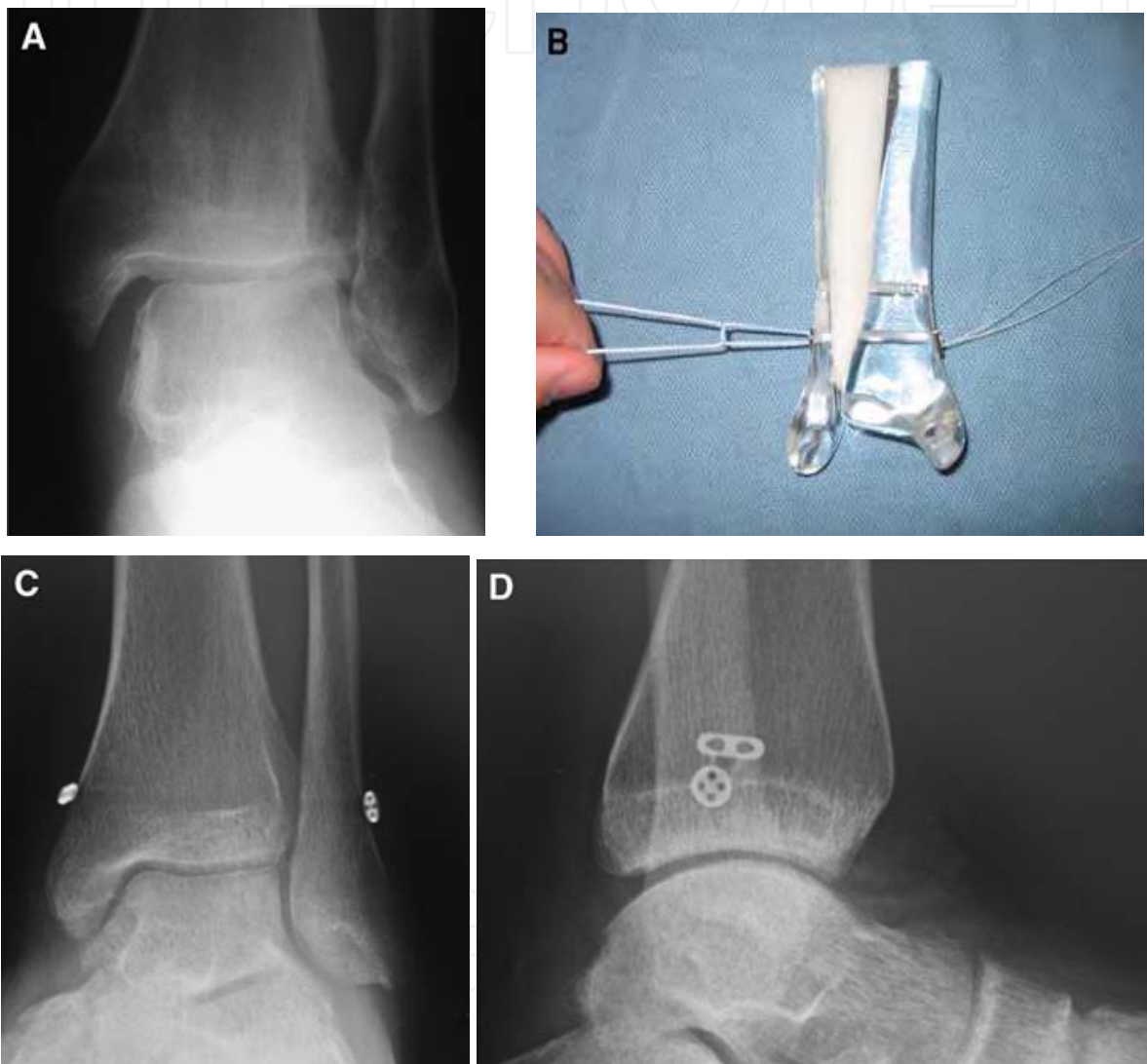


Fig. 12. (A) Anteroposterior (AP) view of a widened syndesmosis. (B) TightRope system for syndesmosis fixation.(C, D) AP and lateral weight-bearing radiographs 6 months after a TightRope fixation of a syndesmosis disruption

Title: Ankle Syndesmosis Injuries
Author: Fernando A. Peña,J. Chris Coetzee
Publication: Foot and Ankle Clinics
Publisher: Elsevier
Date: March 2006

12. Surgical intervention

The AO technique for syndesmotic fixation recommends that diastasis screws be placed parallel and 2cm to 3cm above the ankle joint angled 20° to 30° anteromedially to match the anatomic relationship of fibula and tibia axially [120] (Figure 14). Two different cadaveric studies evaluated the level of placement of fixation, yielding conflicting data. McBryde et al examined syndesmotic fixation at 2 cm and 3.5 cm above the tibial plafond, and found 2cm above the tibial plafond gave improved syndesmotic fixation. Miller et al [121] found improved holding strength and decreased displaced with fixation at 5cm above the tibial plafond compared to 2cm regardless of using tricortical metal screws or suture button. The AO technique also warns about placing screws within 2cm of the tibial plafond for fear of inferior tibiofibular synostosis, although Kukreti et al [104] did not find a significant difference in synostosis when placed within 2cm of the ankle joint and between 2 – 5cm from the joint. Therefore, no conclusions can be made regarding the appropriate height of diastasis fixation.

No recommendations have been made between tricortical and quadricortical fixation. As previously discussed, there is no biomechanical difference between three cortical and four cortical fixation [98]. A prospective, randomized trial comparing two tricortical screws with one quadricortical screw showed improved subjective outcomes at three months for tricortical fixation [122]. By one year, the outcomes were not statistically different. Ankle motion between the two groups was equivalent at all time periods. All quadricortical screws were routinely removed at two months, while tricortical screws were removed in two patients because of discomfort.

The AO technique recommends one screw for syndesmotic fixation, with an additional screw being used with concurrent multiple fractures of the fibula [120]. Biomechanical studies have shown two screws increase the fixation strength of the tibiofibular joint [123], but there are no clinical studies comparing one-screw versus two-screw fixation. Another biomechanical study evaluated single versus double suture-button fixations[124]. The second suture-button added very little strength to the construct, which was still significantly less than an intact syndesmosis. However, this study did show that an “anatomic” suture-button fixation provided significantly improved strength compared to the original technique that was equivalent to the intact syndesmosis. This technique provides fixation at the posterior cortex of the fibula to the anterolateral edge of the tibia (FIGURE 13).

Traditional, syndesmotic fixation has been performed with the ankle in maximum dorsiflexion [101, 125]. This maneuver accounts for the narrower posterior talus engaging in the mortise during plantarflexion, which theoretically could cause overtightening of the mortise and prevent dorsiflexion when the wider anterior talus attempt to engage into the mortise. Lately, recent studies have shown that fixation in any amount of ankle flexion results in equivalent range of motion [126, 127].

13. Postoperative management

Most biomechanical studies evaluated in this review report fixation of the tibiofibular syndesmosis does not restore the strength or diastasis of the normal syndesmosis during normal weight bearing conditions. The only study that published data suggesting full strength and resistance to diastasis with loading is Teramoto et al [124] with use of their “anatomic suture-button” technique. However, their study also showed metal screw fixation that was stronger than the intact syndesmosis, which is contradictory to every other study regarding syndesmotic metal screw fixation. Because normal weight bearing results in

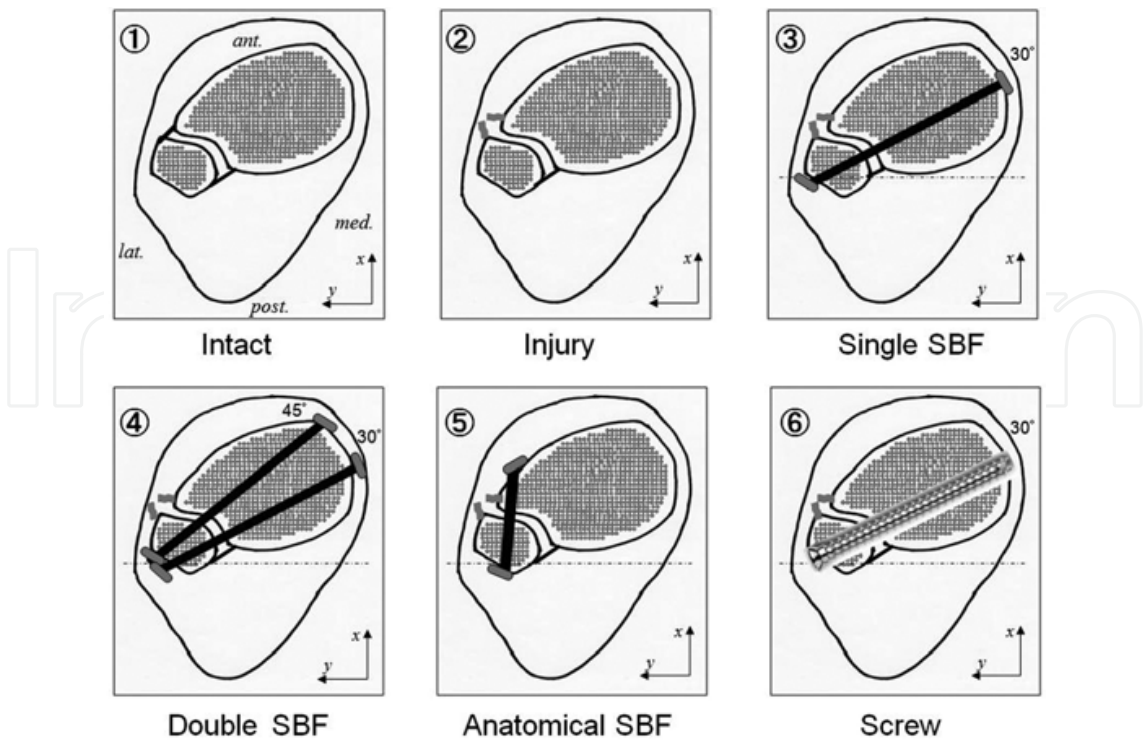


Fig. 13. Axial View of Different Fixation Devices for Ankle Syndesmosis. (1) Intact syndesmosis (2) Injured syndesmosis (3) Single Suture Button Fixation (4) Double Suture Button Fixation (5) Anatomic Suture Button Fixation (6) Screw Fixation
Reference: Figure 13 is from Teramoto A et al. Comparison of Different Fixation Methods of the Suture-Button Implant for Tibiofibular Syndesmosis Injuries. AJSM October 2011.

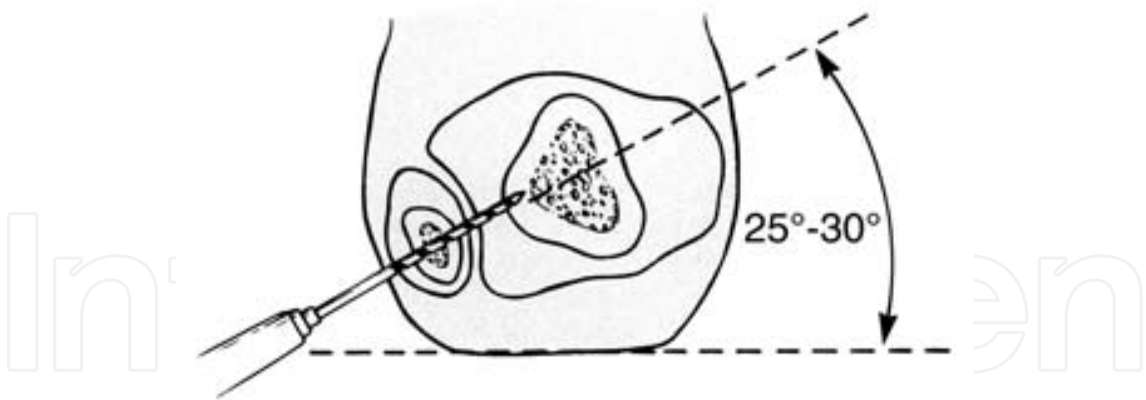


Fig. 14. Is from Browner BD, Jupiter JB, Levine AM, Trafton PG (eds). Skeletal Trauma ed 3. Philadelphia PA, WB Saunders, 2003, vol 2, p 2309.

increased diastasis regardless of surgical technique or implant, non-weight bearing is recommended for the first six weeks to allow the syndesmotic ligaments to heal. Weight bearing is then slowly progressed as tolerated.

Another controversy specific to metal screws is their removal postoperatively. As described previously, metal screws are at risk to loosen with tricortical fixation or break with quadricortical fixation. Other complications, such as symptomatic hardware, osteolysis and synostosis, are also possible postoperatively. Bell et al [102] retrospectively reviewed

patients with syndesmotic screws, and compared those that had the screw removed versus those in which the screw was maintained. There was no statistical significance between the two groups in ankle scores, range of motion or functional outcome. The only difference was a higher incidence of osteolysis and screw breakage in the retained screw group. Manjoo et al retrospectively divided patients into two groups: patients with intact screws and patients with fractured, loosened or removed screws. An intact syndesmotic screw was associated with worse function scores compared to loose, fractured or removed screws. No difference was noted in functional outcomes between patients with loose, fractured or removed screws. Intact syndesmotic metal screws are routinely removed as early as 8-12 weeks postoperatively [25, 128], but should not postpone weight bearing or limit rehabilitation. De Souza et al [129] did not show any adverse clinical outcomes to patients that began weight bearing prior to screw removal.

Rehabilitation can progress to functional activities when the patient demonstrates the ability to perform activities of daily living, ambulate on uneven/soft surfaces, and ascend/descend stairs without difficulty. Patients may return to sports participation when they demonstrate the ability to perform aggressive sports-specific tasks like running, jumping, kicking, and cutting/pivoting at competition/practice speed without noteworthy symptoms during or after participation. The expected time frame to return is around 12 to 14 weeks.

14. Outcomes

The literature has many outcome studies evaluating syndesmosis fixation in patients with concurrent ankle fractures. Most of these studies are retrospective case series. They show the most important predictor of functional outcome is accurate reduction of the syndesmosis [130-132]. A cadaveric study showed that 1mm of lateral talar displacement is associated with a 42% decrease in tibiotalar contact area [133].

Fewer studies have evaluated surgical fixation of pure syndesmotic injuries, and most of these studies are retrospective case series. There is a paucity of published data comparing the clinical results of different methods of surgical fixation. Edwards and DeLee [134] and Taylor et al [90] both published their case series of six patients with isolated, unstable ankle syndesmotic injuries that were treated with syndesmotic screw fixation. Edwards and DeLee reported 4 excellent and 2 good results, but no other information regarding functional outcome and return to sports. Taylor et al treated six intercollegiate athletes, and using aggressive rehabilitation was able to get the athletes to return to full activity in 41 days on average.

Degroot et al [135] followed 24 patients with suture button repair for syndesmotic injuries for an average of 20 months. Syndesmotic parameters returned to normal after surgery and remained normal throughout the followup period. However, one in four patients required removal of the suture endobutton device due to local irritation or lack of motion. Osteolysis of bone with subsidence of the device was noted in four patients, and three patients developed heterotopic ossification. This is somewhat surprising as the main advantage of suture button devices was the lack of hardware problems seen with metal screws. This study illustrates the point that clinical studies need to be performed to fully investigate outcomes of these devices. Although there is a significant amount of biomechanical data available, without good clinical evidence true recommendations regarding the best implant and technique for syndesmotic fixation will remain in question.

15. Conclusion

Controversy surrounds almost every aspect of syndesmosis injuries from diagnosis to treatment to return of play. More research will help in defining these areas more clearly as the awareness has increased recently. Isolated injury to the syndesmosis is associated with chronic pain, prolonged recovery, recurrent sprains, and the heterotopic ossification. The delay in fixation that can occur with either a delayed or missed diagnosis with resultant instability takes the athlete out of the crucial period of ligamentous healing where the response to surgery is often decreased. Optimizing outcomes from these complex injuries requires early recognition through awareness of mechanism of injury, a detailed physical exam, and appropriate imaging to assess for subtle changes. Successful treatment depends on early identification and timely intervention; anatomic reduction is required of any treatment modality. While the injury is difficult one, appropriate management can return the athlete to preinjury levels of participation, although their return will likely be delayed compared to lateral ankle sprains.

16. Acknowledgment

The authors would like to recognize the participation and dedication of Dr. Brandon Hill, Madigan Army Medical Center, to this project.

17. References

- [1] Waterman, B.R., et al., *Epidemiology of ankle sprain at the United States Military Academy*. The American journal of sports medicine, 2010. 38(4): p. 797-803.
- [2] Waterman, B.R., et al., *The epidemiology of ankle sprains in the United States*. The Journal of bone and joint surgery. American volume, 2010. 92(13): p. 2279-84.
- [3] Hootman, J.M., R. Dick, and J. Agel, Epidemiology of collegiate injuries for 15 sports: summary and recommendations for injury prevention initiatives. Journal of athletic training, 2007. 42(2): p. 311-9.
- [4] Fong, D.T., et al., A systematic review on ankle injury and ankle sprain in sports. Sports Med, 2007. 37(1): p. 73-94.
- [5] Hopkinson, W.J., et al., *Syndesmosis sprains of the ankle*. Foot & ankle, 1990. 10(6): p. 325-30.
- [6] Cedell, C.A., *Ankle lesions*. Acta orthopaedica Scandinavica, 1975. 46(3): p. 425-45.
- [7] Fallat, L., D.J. Grimm, and J.A. Saracco, *Sprained ankle syndrome: prevalence and analysis of 639 acute injuries*. The Journal of foot and ankle surgery : official publication of the American College of Foot and Ankle Surgeons, 1998. 37(4): p. 280-5.
- [8] Boytim, M.J., D.A. Fischer, and L. Neumann, *Syndesmotic ankle sprains*. The American journal of sports medicine, 1991. 19(3): p. 294-8.
- [9] Boytim, M.J., D.A. Fischer, and L. Neumann, *Syndesmotic ankle sprains*. Am J Sports Med, 1991. 19(3): p. 294-8.
- [10] Gerber, J.P., et al., Persistent disability associated with ankle sprains: a prospective examination of an athletic population. Foot Ankle Int, 1998. 19(10): p. 653-60.

- [11] Wright, R.W., et al., *Ankle syndesmosis sprains in national hockey league players*. Am J Sports Med, 2004. 32(8): p. 1941-5.
- [12] Clanton, T.O. and P. Paul, *Syndesmosis injuries in athletes*. Foot Ankle Clin, 2002. 7(3): p. 529-49.
- [13] Wright, R.W., et al., *Ankle syndesmosis sprains in national hockey league players*. The American journal of sports medicine, 2004. 32(8): p. 1941-5.
- [14] Gerber, J.P., et al., *Persistent disability associated with ankle sprains: a prospective examination of an athletic population*. Foot & ankle international / American Orthopaedic Foot and Ankle Society [and] Swiss Foot and Ankle Society, 1998. 19(10): p. 653-60.
- [15] Hermans, J.J., et al., *Anatomy of the distal tibiofibular syndesmosis in adults: a pictorial essay with a multimodality approach*. J Anat, 2010. 217(6): p. 633-45.
- [16] Kelikian, H. and A.S. Kelikian, *Disorders of the Ankle*. 1985: Saunders. 893.
- [17] Elgafy, H., et al., *Computed tomography of normal distal tibiofibular syndesmosis*. Skeletal Radiol, 2010. 39(6): p. 559-64.
- [18] Hocker, K. and A. Pachucki, [The fibular incisure of the tibia. The cross-sectional position of the fibula in distal syndesmosis]. Der Unfallchirurg, 1989. 92(8): p. 401-6.
- [19] Sora, M.C., et al., *Evaluation of the ankle syndesmosis: a plastination slices study*. Clin Anat, 2004. 17(6): p. 513-7.
- [20] Grass, R., [Injuries of the inferior tibiofibular syndesmosis]. Der Unfallchirurg, 2000. 103(7): p. 519.
- [21] Yildirim, H., et al., *Evaluation of the fibular incisura of the tibia with magnetic resonance imaging*. Foot & ankle international / American Orthopaedic Foot and Ankle Society [and] Swiss Foot and Ankle Society, 2003. 24(5): p. 387-91.
- [22] Bassett, F.H., 3rd, et al., *Talar impingement by the anteroinferior tibiofibular ligament. A cause of chronic pain in the ankle after inversion sprain*. J Bone Joint Surg Am, 1990. 72(1): p. 55-9.
- [23] Rammelt, S., H. Zwipp, and R. Grass, *Injuries to the distal tibiofibular syndesmosis: an evidence-based approach to acute and chronic lesions*. Foot Ankle Clin, 2008. 13(4): p. 611-33, vii-viii.
- [24] Kelikian, H. and A.S. Kelikian, *Disorders of the ankle*. 1985, Philadelphia: Saunders. vi, 893 p.
- [25] Williams, G.N., M.H. Jones, and A. Amendola, *Syndesmotic ankle sprains in athletes*. The American journal of sports medicine, 2007. 35(7): p. 1197-207.
- [26] Jones, M.H. and A. Amendola, *Syndesmosis Sprains of the Ankle: A Systematic Review*. Clinical Orthopaedics and Related Research, 2007. 455: p. 173-175 10.1097/BLO.0b013e31802eb471.
- [27] Espinosa, N., J.P. Smerek, and M.S. Myerson, *Acute and chronic syndesmosis injuries: pathomechanisms, diagnosis and management*. Foot Ankle Clin, 2006. 11(3): p. 639-57.
- [28] Sarsam, I.M. and S.P. Hughes, *The role of the anterior tibio-fibular ligament in talar rotation: an anatomical study*. Injury, 1988. 19(2): p. 62-4.

- [29] Xenos, J.S., et al., The tibiofibular syndesmosis. Evaluation of the ligamentous structures, methods of fixation, and radiographic assessment. *J Bone Joint Surg Am*, 1995. 77(6): p. 847-56.
- [30] Beumer, A., et al., Kinematics of the distal tibiofibular syndesmosis: radiostereometry in 11 normal ankles. *Acta Orthop Scand*, 2003. 74(3): p. 337-43.
- [31] Ogilvie-Harris, D.J., S.C. Reed, and T.P. Hedman, *Disruption of the ankle syndesmosis: biomechanical study of the ligamentous restraints*. *Arthroscopy*, 1994. 10(5): p. 558-60.
- [32] Press, C.M., A. Gupta, and M.R. Hutchinson, *Management of ankle syndesmosis injuries in the athlete*. *Curr Sports Med Rep*, 2009. 8(5): p. 228-33.
- [33] Evans, J.M. and W.G. Schucany, *Radiological evaluation of a high ankle sprain*. *Proc (Bayl Univ Med Cent)*, 2006. 19(4): p. 402-5.
- [34] Norkus, S.A. and R.T. Floyd, *The anatomy and mechanisms of syndesmotic ankle sprains*. *J Athl Train*, 2001. 36(1): p. 68-73.
- [35] Amendola, A., Controversies in diagnosis and management of syndesmosis injuries of the ankle. *Foot Ankle*, 1992. 13(1): p. 44-50.
- [36] Lin, C.F., M.L. Gross, and P. Weinhold, Ankle syndesmosis injuries: anatomy, biomechanics, mechanism of injury, and clinical guidelines for diagnosis and intervention. *J Orthop Sports Phys Ther*, 2006. 36(6): p. 372-84.
- [37] Close, J.R., Some applications of the functional anatomy of the ankle joint. *J Bone Joint Surg Am*, 1956. 38-A(4): p. 761-81.
- [38] Nussbaum, E.D., et al., Prospective evaluation of syndesmotic ankle sprains without diastasis. *Am J Sports Med*, 2001. 29(1): p. 31-5.
- [39] Hopkinson, W.J., et al., *Syndesmosis sprains of the ankle*. *Foot Ankle*, 1990. 10(6): p. 325-30.
- [40] Orthner, E., R. Weinstabl, and R. Schabus, [Experimental study for clarification of the pathogenic mechanism in traumatic peroneal tendon dislocation]. *Unfallchirurg*, 1989. 92(11): p. 547-53.
- [41] Pankovich, A.M., Fractures of the fibula at the distal tibiofibular syndesmosis. *Clin Orthop Relat Res*, 1979(143): p. 138-47.
- [42] Frick, H., [The isolated tear of the tibio-fibular syndesmosis-mechanism, clinical observations, diagnosis and therapy (author's transl)]. *Unfallheilkunde*, 1978. 81(8): p. 542-5.
- [43] Brosky, T., et al., The ankle ligaments: consideration of syndesmotic injury and implications for rehabilitation. *J Orthop Sports Phys Ther*, 1995. 21(4): p. 197-205.
- [44] Teramoto, A., et al., Three-dimensional analysis of ankle instability after tibiofibular syndesmosis injuries: a biomechanical experimental study. *Am J Sports Med*, 2008. 36(2): p. 348-52.
- [45] Fritschy, D., *An unusual ankle injury in top skiers*. *Am J Sports Med*, 1989. 17(2): p. 282-5; discussion 285-6.
- [46] Fallat, L., D.J. Grimm, and J.A. Saracco, *Sprained ankle syndrome: prevalence and analysis of 639 acute injuries*. *J Foot Ankle Surg*, 1998. 37(4): p. 280-5.
- [47] Crim, J.R., Winter sports injuries. The 2002 Winter Olympics experience and a review of the literature. *Magn Reson Imaging Clin N Am*, 2003. 11(2): p. 311-21.

- [48] Vincelette, P., C.A. Laurin, and H.P. Levesque, *The footballer's ankle and foot*. Can Med Assoc J, 1972. 107(9): p. 872-4 passim.
- [49] Weissman, J.A. and A.K. Lazis, [The radiological features of the distal tibio-fibular syndesmosis (author's transl)]. Rofo, 1980. 133(1): p. 46-51.
- [50] Brown, K.W., et al., MRI findings associated with distal tibiofibular syndesmosis injury. AJR Am J Roentgenol, 2004. 182(1): p. 131-6.
- [51] Waterman, B.R., et al., *The epidemiology of ankle sprains in the United States*. J Bone Joint Surg Am, 2010. 92(13): p. 2279-84.
- [52] Taylor, D.C., D.L. Englehardt, and F.H. Bassett, 3rd, *Syndesmosis sprains of the ankle. The influence of heterotopic ossification*. Am J Sports Med, 1992. 20(2): p. 146-50.
- [53] McMaster, J.H. and P.E. Scranton, Jr., *Tibiofibular synostosis: a cause of ankle disability*. Clin Orthop Relat Res, 1975(111): p. 172-4.
- [54] Veltri, D.M., et al., Symptomatic ossification of the tibiofibular syndesmosis in professional football players: a sequela of the syndesmotic ankle sprain. Foot Ankle Int, 1995. 16(5): p. 285-90.
- [55] Mulligan, E.P., *Evaluation and management of ankle syndesmosis injuries*. Phys Ther Sport, 2011. 12(2): p. 57-69.
- [56] Katznelson, A., E. Lin, and J. Militiano, *Ruptures of the ligaments about the tibio-fibular syndesmosis*. Injury, 1983. 15(3): p. 170-2.
- [57] Grass, R., et al., [Injuries of the inferior tibiofibular syndesmosis]. Unfallchirurg, 2000. 103(7): p. 520-32.
- [58] Fites, B., et al., *Latent syndesmosis injuries in athletes*. Orthopedics, 2006. 29(2): p. 124-7.
- [59] Stiell, I.G., et al., *Implementation of the Ottawa ankle rules*. JAMA, 1994. 271(11): p. 827-32.
- [60] Beumer, A., et al., A biomechanical evaluation of clinical stress tests for syndesmotic ankle instability. Foot Ankle Int, 2003. 24(4): p. 358-63.
- [61] Zalavras, C. and D. Thordarson, *Ankle syndesmotic injury*. J Am Acad Orthop Surg, 2007. 15(6): p. 330-9.
- [62] Teitz, C.C. and R.M. Harrington, A biochemical analysis of the squeeze test for sprains of the syndesmotic ligaments of the ankle. Foot Ankle Int, 1998. 19(7): p. 489-92.
- [63] Alonso, A., L. Khoury, and R. Adams, Clinical tests for ankle syndesmosis injury: reliability and prediction of return to function. J Orthop Sports Phys Ther, 1998. 27(4): p. 276-84.
- [64] Beumer, A., et al., Radiographic measurement of the distal tibiofibular syndesmosis has limited use. Clin Orthop Relat Res, 2004(423): p. 227-34.
- [65] Beumer, A., et al., A biomechanical evaluation of the tibiofibular and tibiotalar ligaments of the ankle. Foot Ankle Int, 2003. 24(5): p. 426-9.
- [66] Beumer, A., B.A. Swierstra, and P.G. Mulder, Clinical diagnosis of syndesmotic ankle instability: evaluation of stress tests behind the curtains. Acta Orthop Scand, 2002. 73(6): p. 667-9.
- [67] Kiter, E. and M. Bozkurt, The crossed-leg test for examination of ankle syndesmosis injuries. Foot Ankle Int, 2005. 26(2): p. 187-8.

- [68] Lindenfeld, T. and S. Parikh, *Clinical tip: heel-thump test for syndesmotic ankle sprain*. Foot Ankle Int, 2005. 26(5): p. 406-8.
- [69] Starkey, C., Injuries and Illnesses in the National Basketball Association: A 10-Year Perspective. J Athl Train, 2000. 35(2): p. 161-167.
- [70] Spaulding, S.J., Monitoring recovery following syndesmosis sprain: a case report. Foot Ankle Int, 1995. 16(10): p. 655-60.
- [71] Williams, G.N., M.H. Jones, and A. Amendola, *Syndesmotic ankle sprains in athletes*. Am J Sports Med, 2007. 35(7): p. 1197-207.
- [72] Smith, A.H. and B.R. Bach, Jr., *High ankle sprains: minimizing the frustration of a prolonged recovery*. Phys Sportsmed, 2004. 32(12): p. 39-43.
- [73] Harper, M.C., An anatomic and radiographic investigation of the tibiofibular clear space. Foot Ankle, 1993. 14(8): p. 455-8.
- [74] Bonnin, J.G., *Injuries to the ankle*. 1970, Darien, Conn.: Hafner Pub. Co. xvi, 412 p.
- [75] Ostrum, R.F., P. De Meo, and R. Subramanian, A critical analysis of the anterior-posterior radiographic anatomy of the ankle syndesmosis. Foot Ankle Int, 1995. 16(3): p. 128-31.
- [76] Pneumaticos, S.G., et al., The effects of rotation on radiographic evaluation of the tibiofibular syndesmosis. Foot Ankle Int, 2002. 23(2): p. 107-11.
- [77] Takao, M., et al., Arthroscopic and magnetic resonance image appearance and reconstruction of the anterior talofibular ligament in cases of apparent functional ankle instability. Am J Sports Med, 2008. 36(8): p. 1542-7.
- [78] Takao, M., et al., Arthroscopic diagnosis of tibiofibular syndesmosis disruption. Arthroscopy, 2001. 17(8): p. 836-43.
- [79] Ebraheim, N.A., et al., Anatomical evaluation and clinical importance of the tibiofibular syndesmosis ligaments. Surg Radiol Anat, 2006. 28(2): p. 142-9.
- [80] Sclafani, S.J., Ligamentous injury of the lower tibiofibular syndesmosis: radiographic evidence. Radiology, 1985. 156(1): p. 21-7.
- [81] Jones, M.H. and A. Amendola, *Syndesmosis sprains of the ankle: a systematic review*. Clin Orthop Relat Res, 2007. 455: p. 173-5.
- [82] Takao, M., et al., Diagnosis of a tear of the tibiofibular syndesmosis. The role of arthroscopy of the ankle. J Bone Joint Surg Br, 2003. 85(3): p. 324-9.
- [83] DeLee, J., D. Drez, and M.D. Miller, *DeLee & Drez's orthopaedic sports medicine : principles and practice*. 3rd ed. 2010, Philadelphia: Saunders/Elsevier. 2 v. (xxv, 2219, lv p.).
- [84] Mei-Dan, O., et al., A dynamic ultrasound examination for the diagnosis of ankle syndesmotic injury in professional athletes: a preliminary study. Am J Sports Med, 2009. 37(5): p. 1009-16.
- [85] Milz, P., et al., Lateral ankle ligaments and tibiofibular syndesmosis. 13-MHz high-frequency sonography and MRI compared in 20 patients. Acta Orthop Scand, 1998. 69(1): p. 51-5.
- [86] Edwards, G.S., Jr. and J.C. DeLee, *Ankle diastasis without fracture*. Foot Ankle, 1984. 4(6): p. 305-12.
- [87] Porter, D.A., Evaluation and treatment of ankle syndesmosis injuries. Instr Course Lect, 2009. 58: p. 575-81.

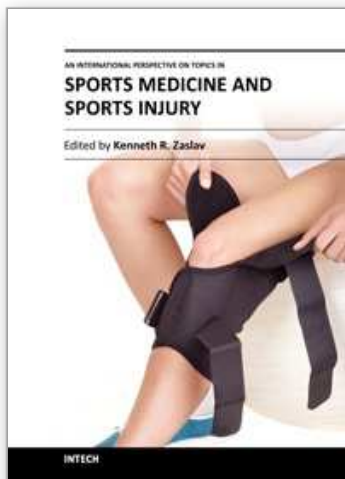
- [88] Jenkinson, R.J., et al., Intraoperative diagnosis of syndesmosis injuries in external rotation ankle fractures. *J Orthop Trauma*, 2005. 19(9): p. 604-9.
- [89] Jelinek, J.A. and D.A. Porter, Management of unstable ankle fractures and syndesmosis injuries in athletes. *Foot Ankle Clin*, 2009. 14(2): p. 277-98.
- [90] Taylor, D.C., et al., Aggressive surgical treatment and early return to sports in athletes with grade III syndesmosis sprains. *The American journal of sports medicine*, 2007. 35(11): p. 1833-8.
- [91] Beumer, A., et al., Kinematics of the distal tibiofibular syndesmosis: radiostereometry in 11 normal ankles. *Acta orthopaedica Scandinavica*, 2003. 74(3): p. 337-43.
- [92] Beumer, A., et al., External rotation stress imaging in syndesmotic injuries of the ankle: comparison of lateral radiography and radiostereometry in a cadaveric model. *Acta orthopaedica Scandinavica*, 2003. 74(2): p. 201-5.
- [93] Schafer, D. and B. Hintermann, *Arthroscopic assessment of the chronic unstable ankle joint*. *Knee Surg Sports Traumatol Arthrosc*, 1996. 4(1): p. 48-52.
- [94] Takao, M., et al., *Arthroscopic diagnosis of tibiofibular syndesmosis disruption*. *Arthroscopy : the journal of arthroscopic & related surgery : official publication of the Arthroscopy Association of North America and the International Arthroscopy Association*, 2001. 17(8): p. 836-43.
- [95] Amendola, A., G. Williams, and D. Foster, Evidence-based approach to treatment of acute traumatic syndesmosis (high ankle) sprains. *Sports Med Arthrosc*, 2006. 14(4): p. 232-6.
- [96] Nussbaum, E.D., et al., *Prospective evaluation of syndesmotic ankle sprains without diastasis*. *The American journal of sports medicine*, 2001. 29(1): p. 31-5.
- [97] Taylor, D.C., D.L. Englehardt, and F.H. Bassett, 3rd, *Syndesmosis sprains of the ankle. The influence of heterotopic ossification*. *The American journal of sports medicine*, 1992. 20(2): p. 146-50.
- [98] Beumer, A., et al., Screw fixation of the syndesmosis: a cadaver model comparing stainless steel and titanium screws and three and four cortical fixation. *Injury*, 2005. 36(1): p. 60-4.
- [99] Thompson, M.C. and D.S. Gesink, *Biomechanical comparison of syndesmosis fixation with 3.5- and 4.5-millimeter stainless steel screws*. *Foot & ankle international / American Orthopaedic Foot and Ankle Society [and] Swiss Foot and Ankle Society*, 2000. 21(9): p. 736-41.
- [100] Hansen, M., et al., *Syndesmosis fixation: analysis of shear stress via axial load on 3.5-mm and 4.5-mm quadricortical syndesmotic screws*. *The Journal of foot and ankle surgery : official publication of the American College of Foot and Ankle Surgeons*, 2006. 45(2): p. 65-9.
- [101] Needleman, R.L., D.A. Skrade, and J.B. Stiehl, *Effect of the syndesmotic screw on ankle motion*. *Foot & ankle*, 1989. 10(1): p. 17-24.
- [102] Bell, D.P. and M.K. Wong, Syndesmotic screw fixation in Weber C ankle injuries--should the screw be removed before weight bearing? *Injury*, 2006. 37(9): p. 891-8.

- [103] Heim, D., U. Heim, and P. Regazzoni, [Malleolar fractures with ankle joint instability--experience with the positioning screw]. *Unfallchirurgie*, 1993. 19(5): p. 307-12.
- [104] Kukreti, S., A. Faraj, and J.N. Miles, Does position of syndesmotomic screw affect functional and radiological outcome in ankle fractures? *Injury*, 2005. 36(9): p. 1121-4.
- [105] Thordarson, D.B., et al., *Biomechanical evaluation of polylactide absorbable screws used for syndesmosis injury repair*. *Foot & ankle international / American Orthopaedic Foot and Ankle Society [and] Swiss Foot and Ankle Society*, 1997. 18(10): p. 622-7.
- [106] Cox, S., et al., Distal tibiofibular syndesmosis fixation: a cadaveric, simulated fracture stabilization study comparing bioabsorbable and metallic single screw fixation. *The Journal of foot and ankle surgery : official publication of the American College of Foot and Ankle Surgeons*, 2005. 44(2): p. 144-51.
- [107] Thordarson, D.B., et al., Bioabsorbable versus stainless steel screw fixation of the syndesmosis in pronation-lateral rotation ankle fractures: a prospective randomized trial. *Foot & ankle international / American Orthopaedic Foot and Ankle Society [and] Swiss Foot and Ankle Society*, 2001. 22(4): p. 335-8.
- [108] Kaukonen, J.P., et al., Fixation of syndesmotomic ruptures in 38 patients with a malleolar fracture: a randomized study comparing a metallic and a bioabsorbable screw. *Journal of orthopaedic trauma*, 2005. 19(6): p. 392-5.
- [109] Bostman, O.M. and H.K. Pihlajamaki, *Late foreign-body reaction to an intraosseous bioabsorbable polylactic acid screw. A case report*. *The Journal of bone and joint surgery. American volume*, 1998. 80(12): p. 1791-4.
- [110] Hovis, W.D. and R.W. Bucholz, *Polyglycolide bioabsorbable screws in the treatment of ankle fractures*. *Foot & ankle international / American Orthopaedic Foot and Ankle Society [and] Swiss Foot and Ankle Society*, 1997. 18(3): p. 128-31.
- [111] Partio, E.K., et al., Self-reinforced absorbable screws in the fixation of displaced ankle fractures: a prospective clinical study of 152 patients. *Journal of orthopaedic trauma*, 1992. 6(2): p. 209-15.
- [112] Yoshino, N., et al., *Delayed aseptic swelling after fixation of talar neck fracture with a biodegradable poly-L-lactide rod: case reports*. *Foot & ankle international / American Orthopaedic Foot and Ankle Society [and] Swiss Foot and Ankle Society*, 1998. 19(9): p. 634-7.
- [113] Bostman, O.M., Osteoarthritis of the ankle after foreign-body reaction to absorbable pins and screws: a three- to nine-year follow-up study. *J Bone Joint Surg Br*, 1998. 80(2): p. 333-8.
- [114] Thornes, B., et al., *Suture-endobutton fixation of ankle tibio-fibular diastasis: a cadaver study*. *Foot & ankle international / American Orthopaedic Foot and Ankle Society [and] Swiss Foot and Ankle Society*, 2003. 24(2): p. 142-6.
- [115] Thornes, B., et al., *Suture-button syndesmosis fixation: accelerated rehabilitation and improved outcomes*. *Clinical orthopaedics and related research*, 2005(431): p. 207-12.
- [116] Seitz, W.H., Jr., et al., *Repair of the tibiofibular syndesmosis with a flexible implant*. *Journal of orthopaedic trauma*, 1991. 5(1): p. 78-82.

- [117] Soin, S.P., et al., *Suture-button versus screw fixation in a syndesmosis rupture model: a biomechanical comparison*. Foot & ankle international / American Orthopaedic Foot and Ankle Society [and] Swiss Foot and Ankle Society, 2009. 30(4): p. 346-52.
- [118] Forsythe, K., et al., *Comparison of a novel FiberWire-button construct versus metallic screw fixation in a syndesmotic injury model*. Foot & ankle international / American Orthopaedic Foot and Ankle Society [and] Swiss Foot and Ankle Society, 2008. 29(1): p. 49-54.
- [119] Klitzman, R., et al., *Suture-button versus screw fixation of the syndesmosis: a biomechanical analysis*. Foot & ankle international / American Orthopaedic Foot and Ankle Society [and] Swiss Foot and Ankle Society, 2010. 31(1): p. 69-75.
- [120] Hahn, D. and C. Colton, *Malleolar Fractures*. AO Principles of Fracture Management, ed. T. Ruedi and W. Murphy. Vol. 2. 2000, New York: Thieme.
- [121] Miller, R.S., P.S. Weinhold, and L.E. Dahners, Comparison of tricortical screw fixation versus a modified suture construct for fixation of ankle syndesmosis injury: a biomechanical study. *Journal of orthopaedic trauma*, 1999. 13(1): p. 39-42.
- [122] Hoiness, P. and K. Stromsoe, Tricortical versus quadricortical syndesmosis fixation in ankle fractures: a prospective, randomized study comparing two methods of syndesmosis fixation. *Journal of orthopaedic trauma*, 2004. 18(6): p. 331-7.
- [123] Xenos, J.S., et al., The tibiofibular syndesmosis. Evaluation of the ligamentous structures, methods of fixation, and radiographic assessment. *The Journal of bone and joint surgery. American volume*, 1995. 77(6): p. 847-56.
- [124] Teramoto, A., et al., Comparison of Different Fixation Methods of the Suture-Button Implant for Tibiofibular Syndesmosis Injuries. *The American journal of sports medicine*, 2011.
- [125] Barnett, C.H. and J.R. Napier, The axis of rotation at the ankle joint in man; its influence upon the form of the talus and the mobility of the fibula. *J Anat*, 1952. 86(1): p. 1-9.
- [126] Tornetta, P., 3rd, et al., *Overtightening of the ankle syndesmosis: is it really possible?* The Journal of bone and joint surgery. American volume, 2001. 83-A(4): p. 489-92.
- [127] Bragonzoni, L., et al., The distal tibiofibular syndesmosis during passive foot flexion. RSA-based study on intact, ligament injured and screw fixed cadaver specimens. *Archives of orthopaedic and trauma surgery*, 2006. 126(5): p. 304-8.
- [128] Zalavras, C. and D. Thordarson, *Ankle syndesmotic injury*. The Journal of the American Academy of Orthopaedic Surgeons, 2007. 15(6): p. 330-9.
- [129] de Souza, L.J., R.B. Gustilo, and T.J. Meyer, *Results of operative treatment of displaced external rotation-abduction fractures of the ankle*. The Journal of bone and joint surgery. American volume, 1985. 67(7): p. 1066-74.
- [130] Chissell, H.R. and J. Jones, The influence of a diastasis screw on the outcome of Weber type-C ankle fractures. *J Bone Joint Surg Br*, 1995. 77(3): p. 435-8.
- [131] Leeds, H.C. and M.G. Ehrlich, *Instability of the distal tibiofibular syndesmosis after bimalleolar and trimalleolar ankle fractures*. The Journal of bone and joint surgery. American volume, 1984. 66(4): p. 490-503.

- [132] Weening, B. and M. Bhandari, Predictors of functional outcome following transsyndesmotic screw fixation of ankle fractures. *Journal of orthopaedic trauma*, 2005. 19(2): p. 102-8.
- [133] Ramsey, P.L. and W. Hamilton, *Changes in tibiotalar area of contact caused by lateral talar shift*. *The Journal of bone and joint surgery. American volume*, 1976. 58(3): p. 356-7.
- [134] Edwards, G.S., Jr. and J.C. DeLee, *Ankle diastasis without fracture*. *Foot & ankle*, 1984. 4(6): p. 305-12.
- [135] Degroot, H., A.A. Al-Omari, and S.A. El Ghazaly, *Outcomes of suture button repair of the distal tibiofibular syndesmosis*. *Foot & ankle international / American Orthopaedic Foot and Ankle Society [and] Swiss Foot and Ankle Society*, 2011. 32(3): p. 250-6.

IntechOpen



An International Perspective on Topics in Sports Medicine and Sports Injury

Edited by Dr. Kenneth R. Zaslav

ISBN 978-953-51-0005-8

Hard cover, 534 pages

Publisher InTech

Published online 17, February, 2012

Published in print edition February, 2012

For the past two decades, Sports Medicine has been a burgeoning science in the USA and Western Europe. Great strides have been made in understanding the basic physiology of exercise, energy consumption and the mechanisms of sports injury. Additionally, through advances in minimally invasive surgical treatment and physical rehabilitation, athletes have been returning to sports quicker and at higher levels after injury. This book contains new information from basic scientists on the physiology of exercise and sports performance, updates on medical diseases treated in athletes and excellent summaries of treatment options for common sports-related injuries to the skeletal system.

How to reference

In order to correctly reference this scholarly work, feel free to copy and paste the following:

Jeffrey R. Thormeyer, James P. Leonard and Mark Hutchinson (2012). Syndesmotomic Injuries in Athletes, An International Perspective on Topics in Sports Medicine and Sports Injury, Dr. Kenneth R. Zaslav (Ed.), ISBN: 978-953-51-0005-8, InTech, Available from: <http://www.intechopen.com/books/an-international-perspective-on-topics-in-sports-medicine-and-sports-injury/syndesmotomic-injuries-in-athletes>

INTECH
open science | open minds

InTech Europe

University Campus STeP Ri
Slavka Krautzeka 83/A
51000 Rijeka, Croatia
Phone: +385 (51) 770 447
Fax: +385 (51) 686 166
www.intechopen.com

InTech China

Unit 405, Office Block, Hotel Equatorial Shanghai
No.65, Yan An Road (West), Shanghai, 200040, China
中国上海市延安西路65号上海国际贵都大饭店办公楼405单元
Phone: +86-21-62489820
Fax: +86-21-62489821

© 2012 The Author(s). Licensee IntechOpen. This is an open access article distributed under the terms of the [Creative Commons Attribution 3.0 License](https://creativecommons.org/licenses/by/3.0/), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

IntechOpen

IntechOpen