Syndesmosis Injuries

6

Pieter D'Hooghe

6.1 Introduction

Syndesmotic injuries, or high ankle sprains, comprise 10% of all ankle sprains [1]. These injuries are frequently sustained during athletic competition, particularly soccer [1, 2]. However, as imaging studies suggest that up to 20% of acute ankle sprains involve the syndesmosis, the prevalence of syndesmotic injuries may be underestimated [3, 4]. Syndesmotic injuries often require twice as long to return to sport as compared to isolated lateral ligament sprains and can lead to prolonged pain and disability [5–8]. Further, the most common cause of chronic ankle dysfunction 6 months from an ankle trauma is related to syndesmotic injuries [7]. Recurrent and undiagnosed ankle instability is known to ensue and eventually lead to premature ankle arthritis [9]. Therefore, a timely diagnosis of unstable syndesmotic injuries is essential. A rapid pivoting and forced ankle dorsiflexion of the ankle with a forceful external rotation and pronation of the foot is the most common mechanism of a high ankle sprain [10]. Planovalgus foot alignment, high competitive sports level, and male gender are potential risk factors [9, 11, 12]. As the talus rotates in the mortise, the fibula rotates externally and moves posteriorly and laterally. This mechanism then separates the distal tibia and fibula and sequentially tears the AITFL, deep deltoid ligament (or causes a malleolar fracture), the inferior oblique ligament (IOL), and finally the posterior inferior talo-fibular ligament (PITFL) [10, 13]. When there is a combined syndesmotic injury with a deltoid ligament disruption, talar instability occurs [14].

Less commonly, the injury may occur in forced dorsiflexion without rotation since the anterior part of the talus is wider than the posterior part. The magnitude and duration of force application appear to be predictive factors of lesion severity [9]. Syndesmotic injuries are classified in three grades, ranging from a partially torn AITFL to a complete disruption of all ligaments with mortise widening [15].

Stress radiographs and magnetic resonance imaging (MRI) can be helpful in the diagnosis of these injuries, but currently there is no best evidence-based test available that can identify syndesmotic instability (especially in grade II lesions). This is particularly relevant in the athletic population, where appropriate management is crucial for the player to return to the team [3]. There is a consensus to use arthroscopy in the evaluation of syndesmotic stability in doubtful cases, but there is no validated surgical protocol available (except expert opinion) to identify syndesmotic stability under direct visualization with arthroscopy [16].

P. D'Hooghe (✉)
Department of Orthopaedic Surgery,
Aspetar Orthopaedic and Sports Medicine Hospital,
Doha, Qatar
e-mail: Pieter.Dhooghe@aspetar.com

G. L. Canata et al. (eds.), *Sports Injuries of the Foot and Ankle*,
https://doi.org/10.1007/978-3-662-58704-1_6

6.2 Anatomy

A syndesmosis is defined as a fibrous joint in which two adjacent bones are linked by a strong membrane or ligaments [17, 18]. 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 (Fig. 6.1).

The architecture of the bony components of the syndesmosis provides 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 6–8 cm above the level of the talocrural joint [17, 19]. 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, 20, 21]. Its depth varies from 1.0 to 7.5 mm [17, 22, 23] and is a little less in women than in men [17, 24].

A shallow notch may predispose to recurrent ankle sprains or syndesmotic injury with fracture dislocation [18]. 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 (Figs. 6.1 and 6.2). This ligament has a width of approximately 18 mm, length between 20 and 30 mm, and a thickness of 2–4 mm. It is the most commonly sprained ligament in syndesmotic injuries and is always disrupted with joint space widening or frank diastasis [17, 18].

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 [17, 25]. The PITFL originates on the posterior aspect of the fibula and runs horizontally to Volkmann's tubercle. This ligament has an approximate width of 18 mm and a thickness of 6 mm 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 [17, 19, 26].

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 (Fig. 6.2). 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 [9, 17] (Fig. 6.2).

6.3 Epidemiology

Syndesmosis or "high ankle" sprains are reported to occur in 1–18% of patients with an ankle sprain [27, 28]. However, this is probably an underestimate, as 20% of athletes with an acute ankle sprain have evidence of syndesmotic injury on MRI [28].

This variation can be explained by the fact that some sports have extrinsic risk factors asso-

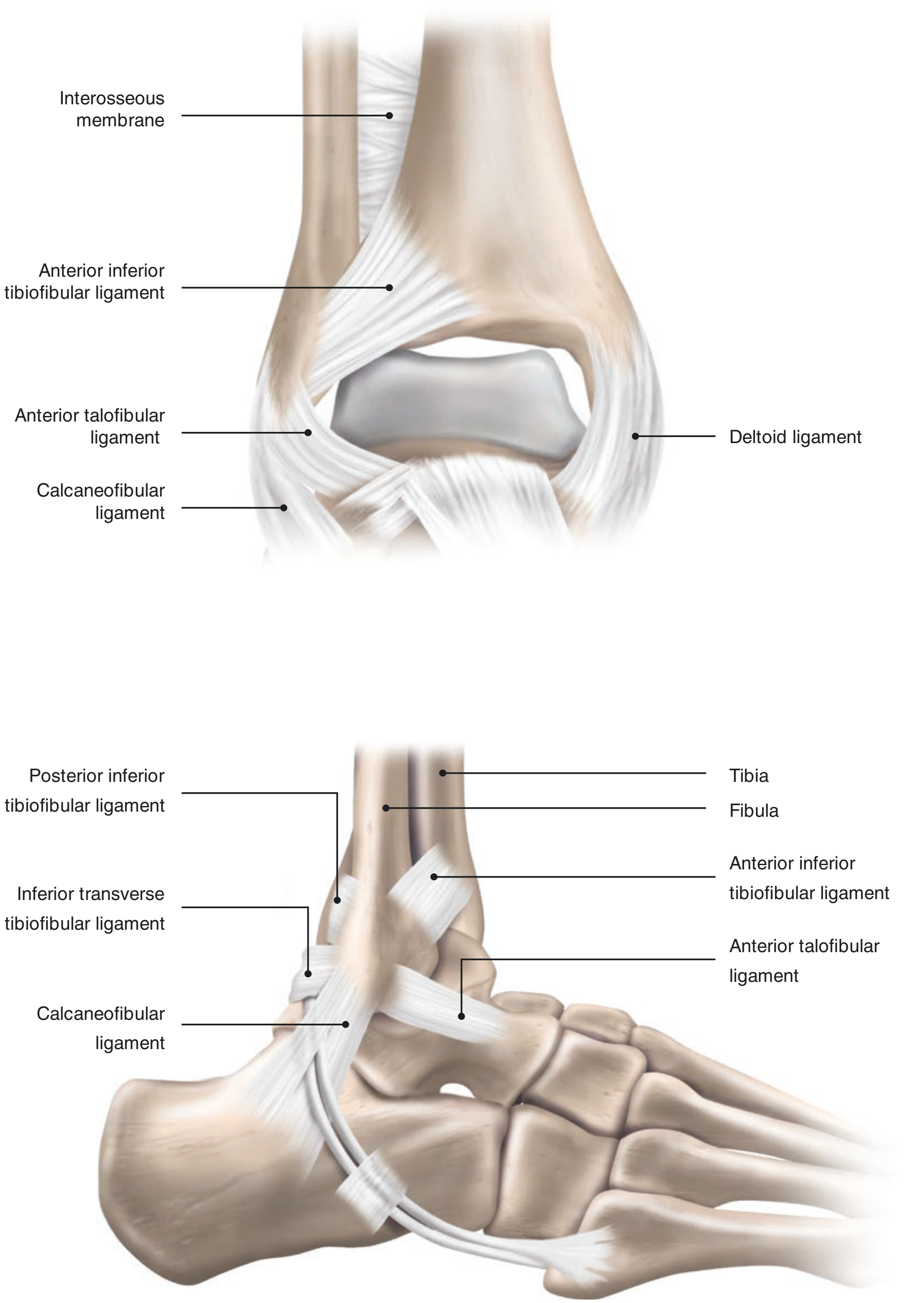

Fig. 6.1 Antero-posterior and lateral view of the ankle ligamentous complex

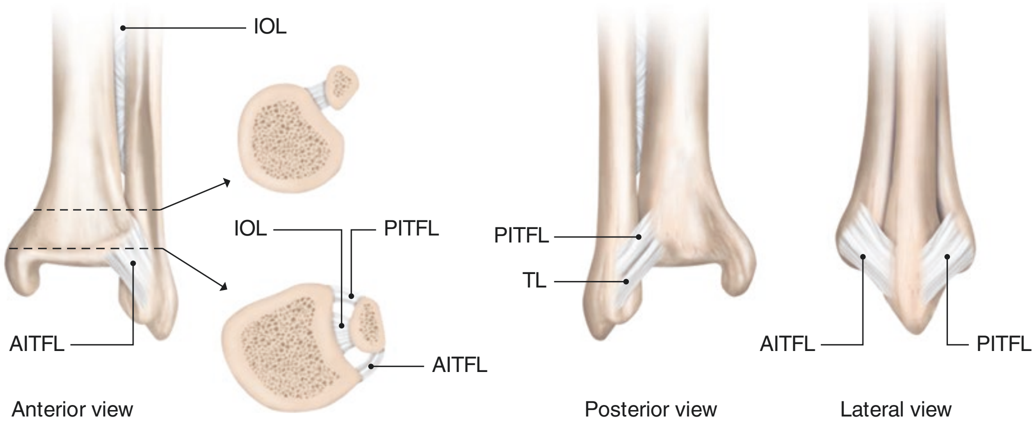

Fig. 6.2 Detailed antero-posterior and lateral view of the ankle syndesmosis ligaments

ciated with syndesmosis injury. Skiers and ice hockey players wear boots causing rigid immobilization of the ankle leading to high-torque external rotation of the foot [28–31] and American football is often played on artificial turf instead of natural surfaces [28, 32–35]. Another plausible explanation is that an isolated syndesmotic injury can be frequently misdiagnosed as an ankle sprain [28].

A recent epidemiological overview on isolated syndesmosis injuries in elite football indicated a significant increase in the incidence of these injuries with an average return to play time following injury that exceeded 5 weeks. Also, no change in injury burden was found over 15 consecutive football seasons. This was primarily linked to the more aggressive playing style during matchplay [28].

Male gender, elite performance, and a planovalgus alignment are risk factors for syndesmosis injury in athletes [36, 37]. Syndesmosis injuries can occur with an ankle sprain only, with fractures or as a combination of both. In fact, 23% of ankle fractures are reported to have combined syndesmosis injuries [36, 37].

The associated fractures are commonly either of the fibula or of the posterior and medial malleoli. Syndesmosis injury should be increasingly suspected if there is an associated fracture of the proximal fibula (Maisonneuve fracture, Fig. 6.3) and they are associated with prolonged pain, disability, and an unpredictable time away from sports [27, 37].

Fig. 6.3 Antero-posterior X-ray image of a Maisonneuve fracture

6.4 Mechanism of Injury

The general mechanism of injury for syndesmosis ankle sprains is a forceful external rotation of the foot and ankle with the ankle in dorsiflexion and the foot pronated [27, 38]. While the talus rotates in the mortise, the fibula rotates externally and moves posteriorly and laterally, separating the distal tibia and fibula.

This will sequentially cause tears of the anterior inferior tibiofibular ligament (AITFL), the deep deltoid ligament, or might alternatively cause a malleolar fracture. This shall be in turn followed by a tear of the interosseous ligament (IOL) and finally the posterior inferior tibiofibular ligament (PITFL) [27, 38, 39].

Severity of syndesmosis injury varies, ranging from a partially torn AITFL to a complete disruption of all ligaments with mortise widening. It has been shown that combined deltoid and syndesmosis injury will critically compromise talar stability [14, 27]. The magnitude of force and its duration will determine the extension of syndesmosis and interosseous injury proximally [9] and this may eventually lead to a Maisonneuve fracture (Fig. 6.3). Another injury mechanism for syndesmosis ankle sprains is hyper-dorsiflexion.

Forced dorsiflexion of the ankle causes the wider anterior talus to act as a wedge that can cause injury to the syndesmosis ligaments [27].

6.5 Clinical Evaluation

Athletes frequently present with an inability to bear weight, anterolateral pain between the distal tibia and fibula, medial ankle pain, ankle effusion, and pain during gait push off [40, 41]. However, anterolateral pain is not specific, as up to 40% of patients with an ATFL tear describe pain over the AITFL. Clinically it has been suggested that the more proximal the patient's pain, the more significant the injury [40, 41].

Several clinical tests can be used in the evaluation of a syndesmotic injury. The external rotation test and the squeeze test are the most commonly described tests, but the Cotton test, the fibular translation test, the heel thump test, the dorsiflexion compression test, and the cross-legged test can also be used [15, 27]. The combination of tenderness on palpation over the ATFL, a positive fibular translation test, and positive Cotton test is considered highly clinically suspicious [16, 27].

Although the squeeze test has been shown to be highly sensitive, there is no one "gold standard" for the clinical diagnosis of syndesmotic instability [27, 42]. In case of clinical suspicion, advanced imaging, such as MRI, is warranted.

It has been shown that there is a significant correlation between how far this tenderness radiates proximally in the leg and the severity of the injury and, consequently, the time to return to sports [27, 37].

Patients with high ankle sprains may complain of the inability to bear weight, swelling, pain during the push-off phase of gait, and pain anteriorly between distal tibia and fibula, as well as posteromedially at the level of the ankle joint [15, 27]. Ankle ROM will often be limited, with pain felt more at terminal dorsiflexion [27, 42]. Numerous special tests are used to detect syndesmosis injuries. However, a recent systematic review on eight different tests reported a low diagnostic accuracy of these tests [43]. The squeeze test was the only test with a clinical significance [43].

Diagnosing an athlete with a syndesmotic injury can however still be difficult.

The pain is often diffuse and difficult to differentiate from a lateral ankle sprain. Additionally, as previously noted, there can be overlap in injury patterns. This can further cloud the diagnosis and potentially lead to missed syndesmotic injuries.

However, a thorough history might uncover a mechanism that would increase the treating physician's suspicion. A thorough physical examination includes visual inspection for swelling, palpation for tenderness, and evaluation of the proximal extent of the tenderness.

The latter physical examination finding, known as "syndesmosis tenderness length" (the most proximal site of tenderness measured from the distal tip of the fibula), has been shown to correlate with the time to return to sports [40, 44].

The typical location of tenderness in a syndesmotic injury is at the anterolateral and/or posteromedial joint line.

All current clinical syndesmosis tests have been shown to be difficult to interpret with a low predictive value in the presence of a painful or swollen ankle [45]. Although the squeeze test has most clinical significance in recent literature [15, 27, 43], the external rotation test has been shown to be most sensitive with the lowest false positive rate [40, 46]. This is performed with the ankle in neutral or slight dorsiflexion and the heel in neutral or varus position, with subsequent external rotation of the foot relative to the tibia to the point of resistance and pain.

Additionally, a stress radiograph can be obtained to evaluate for medial clear space (MCS) or tibiotalar widening [40, 47].

6.6 Imaging

Plain radiographs should still always be obtained when there is concern for syndesmotic injury. The tibiofibular clear space, defined as the distance between the medial border of the fibula and the lateral border of the posterior tibia, is one of the most reliable indicators of syndesmotic disruption [41]. This distance is measured at 1 cm proximal to the tibial plafond and should not exceed 6 mm in both the AP and mortise views [41].

In the case of a suspected syndesmotic injury, radiographs must be carefully scrutinized. Signs of syndesmotic injury include avulsion fractures of the anterior tubercle of the tibia (Tillaux-Chaput fragment, Fig. 6.4a–d), anterior fibula (Wagstaffe le Fort fragment), and posterior malleolus (Volkmann fragment).

Radiographs should be evaluated for the tibiofibular clear space (TFCS) (normal = mean 4.4 ± 0.8 mm on antero-posterior view and 3.9 ± 0.9 mm on mortise view, respectively), the tibiofibular overlap (normal = mean 8.8 ± 2.4 mm on antero-posterior view and 4.6 ± 2.1 mm on mortise view, respectively), and for any increased MCS (normal <5 mm) [48]. However, it has been shown that tibiofibular overlap and TFCS do not correlate with syndesmotic injury seen on magnetic resonance imaging (MRI) [49]. Additionally, MCS

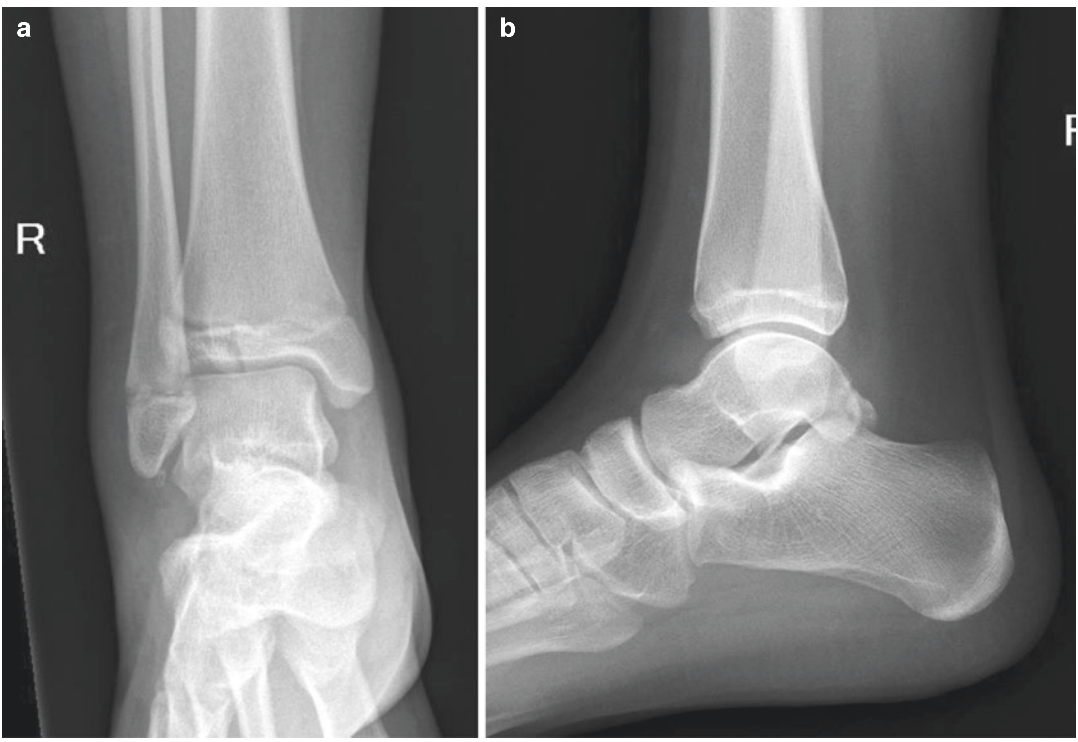

Fig. 6.4 (**a**–**d**) Avulsion fracture of the antero-lateral tubercle (**a**, **b**) of the tibia (Tillaux-Chaput) and after mini-open fixation fracture treatment (**c**, **d**)

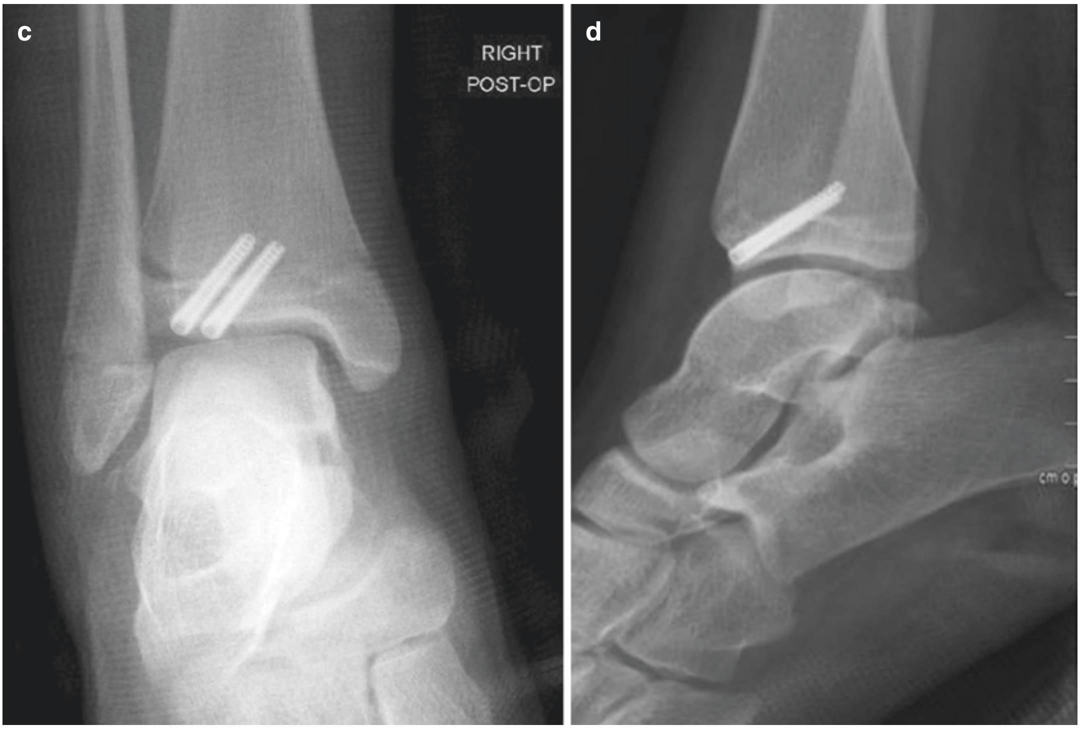

Fig. 6.4 (continued)

measurements have been shown to have poor accuracy and precision even among experienced providers. In a recent cadaver study, three specimens were evaluated with a known amount of displacement (6, 4, and 1.7 mm). Measurement errors ranged from 16% at 5° of internal rotation to 36% at 15° of external rotation for the specimen with 6 mm of known MCS widening but were even greater ranging from 3% at neutral to 100% at 5° external rotation for the intact specimen with 1.7 mm of MCS [40]. Although the sensitivity and specificity of detecting a syndesmotic injury on MRI has been shown to be up to 100%, determining the severity of that injury and the need for surgery is not straightforward and often only when frank diastasis is seen on radiography is the final determination for operative intervention made [41, 50–52]

Stress radiographs are no longer routinely recommended in the routine evaluation of syndesmotic instability since biomechanical studies have not shown significant advantage over plain radiographs [53, 54].

If an injury could potentially be managed nonoperatively, then stress radiographs can however be helpful in assessing the integrity of the syndesmosis and of the deltoid ligament. Still, there is no standardized technique or amount of force applied and the quality of the test can be significantly limited by the patient's pain [40, 41]. One recent study found that gravity stress radiographs (with the foot suspended via a bump under the calf allowing gravity to pull the foot in external rotation) resulted in equivalent MCS widening to manual stress radiographs [41]. Conversely, if there is an operative fracture, then stress radiographs can be postponed until surgery.

Computed tomography (CT) scanning can be helpful in identifying minor diastasis and small avulsion fractures [55]. Although its value still needs further evaluation, promising new diagnostic types of bilateral standing CT scan stress view are useful [56]. Magnetic resonance imaging (MRI) can identify most ligamentous syndesmotic injuries and combined injuries [53]. MRI shows a sensitivity of 100% and a specificity of 93% for AITFL injuries (positive likelihood ratio of 14, Fig. 6.5) and a sensitivity and specificity of 100% for PITFL injuries (infinite positive likelihood

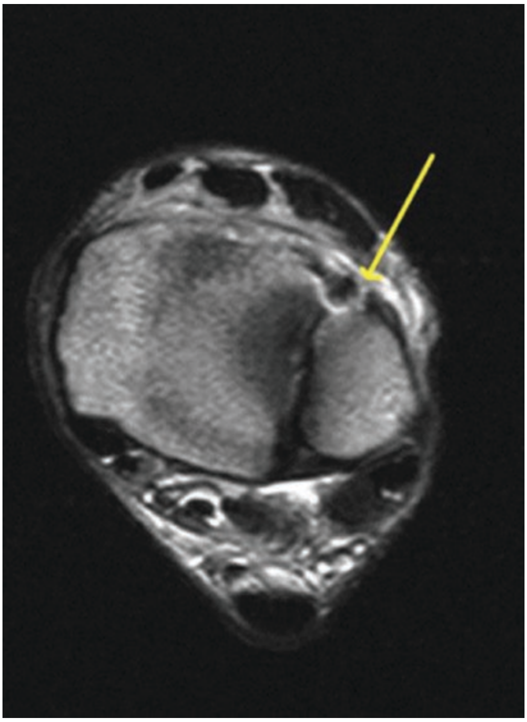

Fig. 6.5 Axial MRI image of an AITFL rupture in an elite football player

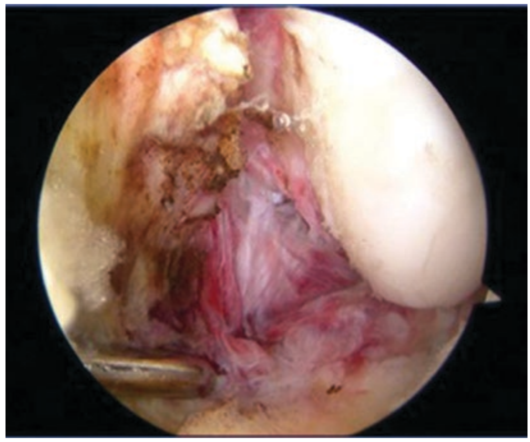

Fig. 6.6 Arthroscopic view of a grade III syndesmosis injury

ratio) [57] and has a high degree of interobserver reliability [49]. Ultrasonography is a fast and inexpensive tool to evaluate distal tibiofibular stability and does not expose the athlete to radiation. Further, it enables a dynamic assessment of the ligamentous injury, which is useful in cases of subtle instability. Patients with an acute AITFL rupture (confirmed on MRI) show a 100% sensitivity and specificity on dynamic ultrasound evaluation [58]. The disadvantages are that ultrasonography cannot detect associated injuries and is proven to be investigator dependent [41, 53].

6.7 Classification and Treatment

6.7.1 Classification of Syndesmotic Injuries

Syndesmotic injuries are divided into three grades. Grade I represents an AITFL sprain without instability. Grade II represents an AITFL tear and a partial IOL tear with mild instability. Grade III represents a complete rupture of all three syndesmotic ligaments with evident instability [15, 54].

The severity of the syndesmotic instability guides the choice of treatment. Grade I injuries are treated nonsurgically [59] while the treatment of grade II injuries depends on the presented syndesmotic (in)stability testing [16]. Stable syndesmotic injuries (type I and IIa) should be treated conservatively, whereas unstable injuries (type IIb and III) warrant surgical fixation. A recent study found that a positive squeeze test and combined injury to the ATFL and deep deltoid ligament are key factors in differentiating stable (type IIa) from unstable grade II injuries (type IIb).

Nowadays, there is a consensus to perform an examination under anesthesia and arthroscopic evaluation of the syndesmosis in case of a grade II injury with clinical and/or radiological suspicion of dynamic instability (type IIb) [16, 60, 61]. In case of 2 mm or more dynamic distal tibiofibular diastasis, arthroscopic-assisted surgical fixation is warranted [59] (Fig. 6.6).

Grade III injuries often present with associated injuries and are inherently unstable. Surgical fixation by means of screws or suture buttons can be used to reduce the mortise and stabilize the syndesmosis [16, 62]. The Hook or Cotton test is regarded as reliable intraoperative stress tests to evaluate syndesmotic (in)stability [63] (Fig. 6.7b).

Fig. 6.7 (**a**) Intraoperative fluoroscopy of ankle fixation. Left: Stress radiograph following fixation of a Weber B fibula fracture with medial clear space widening [40]. Right: Radiograph following syndesmotic screw fixation. (**b**) Hook test performed in which the fibula is pulled lateral to assess for medial clear space widening [40]

Cadaveric studies have shown that the syndesmosis becomes unstable (opens more than 5 mm in tibiofibular clear space) when a force above 87–100 N is applied [63]. Arthroscopy is considered 'the golden standard' in the diagnostic assessment of syndesmotic (in)stability [64] and in case of doubt, fixation is advised because of the problems caused by chronic syndesmotic instability [63].

6.7.2 Management of Syndesmotic Injuries

6.7.2.1 Purely Ligamentous Injuries

In the case of sprains without diastasis, nonoperative management has been shown to result in good functional outcomes [65]. However, there is currently no consensus on the nonoperative regimen, with treatments ranging from taping to fracture boots to non-weight-bearing cast immobilization. Other interventions such as injections, physical therapy, ultrasonography, and nonsteroidal anti-inflammatory drugs are discussed throughout the literature without consensus. Reported lengths of immobilization vary from 1 to 6 weeks [46, 66].

Athletes should be informed that return to full sport takes longer compared to lateral ankle sprains.

The syndesmosis tenderness length can be used to estimate the time loss from sports using the equation [67]: Days lost from competition = 5 ± (0.93 × [tenderness length in centimeters]) ± 3.72 days.

Rehabilitation is implemented in three phases. Phase I is the acute phase. Goals include joint protection, minimization of inflammation, and pain control. Phase II is the subacute phase in which restoration of mobility, strength, and gait is emphasized. Finally, in phase III, emphasis is placed on strengthening, neuromuscular control, and sports-specific tasks [68].

A recent cohort-controlled study by Samra et al. suggested that ten rugby players with MRI-confirmed syndesmosis injury (involvement of the AITFL, IOL, and PITFL) treated without surgery who received a single autologous PRP injection into the AITFL had significantly shorter time to return to play than a historical cohort (20.7 days less for the intervention group vs. historical control). Following return, these patients had higher agility, increased vertical jump, and lower level of fear avoidance [69]. However, although they reported similar baseline characteristics between groups, the intervention was not blinded and there was no placebo control, both of which could have resulted in bias.

In contrast, all injuries with frank diastasis require syndesmotic fixation [70]. Taylor et al. reported on six intercollegiate athlete patients with grade III syndesmosis injuries treated with a 4.5-mm stainless steel cortical screw and reported good to excellent clinical outcomes in all patients with a mean return to sports at 40.7 days [71]. In their series, all hardware was removed at an average of 74 days (range 52–97) [40].

6.7.2.2 Fractures with Syndesmotic Instability

Carr et al. recently performed a large database analysis of ankle fracture and syndesmotic fixation between 2007 and 2011 and found no significant increase in procedures for all ankle fracture types (lateral malleolus, bimalleolar, and trimalleolar) during that time [72]. However, the number of procedures to treat isolated syndesmotic injuries increased by 18% during that time period. In addition, the rate of syndesmotic fixation that accompanied fixation of ankle fractures significantly increased with a nearly twofold increase among bimalleolar fractures. The authors also reported that the rate of implant removal after syndesmotic fixation significantly decreased. This suggests an overall increase in recognition and operative treatment of isolated syndesmotic injuries and those associated with ankle fractures. Although factors associated with higher energy ankle fractures (e.g., bimalleolar involvement or the need for initial external fixation) are associated with delayed union, the need for syndesmotic screw fixation has not been shown to be associated with delayed union of ankle fractures that undergo fixation.

Nevertheless, although bony union can be followed via routine radiographs, the healing of the syndesmosis is significantly slower, requiring prolonged periods of non-weight-bearing up to 12 weeks [73]. Following fixation of medial and/or lateral malleolus fractures, an intraoperative stress radiograph can assess the integrity of the syndesmosis and guide the decision of whether or not syndesmotic fixation is of benefit (Fig. 6.7a).

Special consideration should be given to cases of bimalleolar ankle fractures in which there is an anterior colliculus avulsion of the medial malleolus. Tornetta reported on 27 patients with bimalleolar fractures who underwent external rotation stress radiographs intraoperatively after medial malleolar fixation and found that 7 (26%) had MCS widening even after medial fixation. He explained that this represents an injury to the deltoid ligament in which the stronger deep component has been ruptured and the weaker superficial component, which attaches to the anterior colliculus, remains intact. If this occurs in conjunction with a syndesmotic injury, it has the potential to present as late syndesmotic widening and significant instability [74].

6.7.2.3 Syndesmotic Fixation

Syndesmotic Screws

Syndesmotic screws have long been considered the gold standard for fixation of syndesmotic injuries (Fig. 6.7a). Most authors prefer 3.5 or 4.5 cortical screws which have equivalent biomechanical characteristics [75].

While some cadaveric studies have shown increased resistance to an applied load, specifically in shear stress, with a larger diameter screw [55] this has not been reproduced in clinical studies [66, 75]. In Europe, most surgeons utilize a single 3.5-mm tricortical screw, 2.1–4 cm above the joint line for stabilization of Weber B or C fractures [46]. However, a cadaveric study suggested that two screws provide a superior biomechanical construct compared to one [76].

Location of screw placement is often debated. McBryde et al. reported less syndesmotic widening when the screw was placed at 2 cm above the joint compared to 3 cm [77]. However, other studies have reported that screw placement at 2, 3, or 5 cm above the joint line shows no difference in functional outcome [77].

Tricortical screws (3.5 mm) were compared to quadricortical lag screws (both 3.5 and 4.5 mm) in terms of compression force in a 2012 cadaveric study. The lag screws maintained a significantly greater compression force after forceps removal compared to the tricortical screw.

Additionally, after each 100 cycles of loading, the lag screws significantly exceeded the amount of compression force maintained by the tricortical screw. No differences were seen between the 3.5- and 4.5-mm lag screws [78].

Ultimately, although cadaveric studies have suggested that four cortices provide more rigid fixation, screws with purchase in three cortices have been shown to more closely replicate tibiotalar biomechanics [66] (Fig. 6.7a). Additionally, tricortical screws have decreased risk of screw breakage albeit at the cost of an increased rate of screw loosening [57, 75, 79]. There is no current evidence to suggest a clinically appreciable difference between these two methods of screw fixation [76].

In terms of screw removal, there has been a longstanding debate in the literature. Although some recommend removal of quadricortical screws to prevent screw breakage [79, 80], there is no consensus on when this should be performed and there have been reports of diastasis at screw removal [46].

Additionally, studies have suggested similar or better outcomes when the screw is retained [81] and therefore, there is growing consensus that screw removal should be reserved for screws that are symptomatic (i.e., painful prominence) [66, 82–84].

A recent systematic review by Dingemans et al. concluded that although there is insufficient evidence overall to draw definitive conclusions regarding routine removal, the lack of evidence to justify removal along with the additional cost and increased risk to the patient would suggest that routine removal should be avoided [85].

Fig. 6.8 Intraoperative fluoroscopic antero-posterior view of a double suture-button fixation

Suture-Button Constructs

While screw fixation is still considered the gold standard, there are a number of theoretical advantages of suture-button fixation (Fig. 6.8).

These have been theorized to allow physiologic motion at the syndesmosis while maintaining reduction. Further, there is less risk of symptomatic hardware and need for implant removal.

Finally, these constructs have been suggested to safely allow earlier ankle range of motion as the reduction can be held with progression of motion without the concern for implant failure (i.e., screw breakage) and recurrent diastasis [46].

The argument that these constructs might be superior because they do not require routine removal is weakened by the growing evidence against routine screw removal. However, it has been suggested that these constructs might allow earlier weight-bearing. This is due to concern that early stress on a syndesmotic screw might lead to breakage prior to ligamentous healing.

Conversely, less rigid constructs such as the TightRope (Arthrex, Naples, FL) are purported to be sturdy enough to withstand physiologic loading that occurs with weight-bearing and normal ankle motion [86].

Teramoto et al. performed a cadaveric study on six ankles comparing single suture-button fixation, double suture-button fixation, anatomic suture-button fixation (from posterior fibula to anterolateral distal tibia), and screw fixation. The authors evaluated the amount of diastasis with various stresses on the ankle, including anterior traction, medial traction, and external rotation. With single suture-button fixation the diastasis increased significantly with all forces, whereas with double fixation the diastasis increased significantly with medially directed force and with external rotation but not with anterior traction. They found that with anatomic suture-button placement, there were no significant differences compared to ankles tested prior to syndesmotic disruption. The screw fixation proved to be the most rigid fixation, with significantly decreased diastasis compared to suture-button results [87].

However, the clinical implications of that amount of motion are not currently known. Naqvi et al. reported retrospectively on 49 patients with suture-button syndesmotic fixation. Patients with syndesmotic injuries associated with ankle fractures underwent single suture-button fixation and those with Maisonneuve injury underwent double suture-button fixation. The authors reported a mean time to weight-bearing of 7.7 ± 1.1 weeks (range 5–10) and a mean return to normal activities at 11.2 ± 1.8 weeks. They reported that the original technique of tying the knot over the lateral aspect of the fibular button resulted in a significantly higher rate of wound complications compared to their reported modified technique of creating a subperiosteal recess in the posterior fibula in which they buried the knot. They reported satisfactory results at 2 years postoperatively [86].

A recent prospective randomized trial comparing screw fixation with a single 3.5-mm screw ($n = 22$) vs. suture-button fixation ($n = 22$) of the syndesmosis revealed no difference in quality or maintenance of reduction between the two as seen on postoperative imaging. Additionally, there was no difference at 2-year follow-up in the incidence of ankle joint osteoarthrosis [88].

In 2013, Ebramzadeh et al. compared two suture-button devices (ZipTight [Biomet] and TightRope [Arthrex]) along with a 3.5-mm quadricortical screw fixation in a cadaveric, failure-to-load model. In 12 of 20 specimens, failure occurred via a fibula fracture. The screw construct was found to provide a significantly higher torsional strength than the ZipTight (30.1 vs. 22.2 Nm) but the difference seen between the screw and the TightRope was not significant.

The authors reported that there were no significant differences between the two suture-button constructs. Ultimately, they suggested that the torsional fixation strengths of all three constructs were above the physiologic loads that would "likely" be experienced during the healing process, citing that level ground walking generally creates syndesmotic torsional stresses below 2 Nm and "various other activities" generally create stresses less than 20 Nm [89].

One issue that arises with regard to the use of a suture button is how to determine the amount of force to put on the construct while securing the syndesmosis. Additionally, there has been debate regarding which position the foot should be in at the time of final tightening. A recent cadaveric study revealed that with the use of suture-button syndesmotic fixation, there was consistent overcompression compared to the intact state, with significant volume reduction and medial displacement of the fibula [50].

Overcompression, however, is not unique to suture-button constructs as it has been reported to occur with forceps reduction and screw fixation as well [90].

However, the clinical impact of overcompression of the syndesmosis is not known and it has been shown that this compression does not appear to affect ankle dorsiflexion/plantarflexion. Further, it has been shown that the position of the foot (i.e., plantarflexion, neutral, or dorsiflexion) during the time of compression and fixation has no significant effect on postoperative ankle motion [90–92].

Another recent cadaveric study compared a single screw to either a single suture-button construct or a divergent double-suture button construct [93]. The authors found that while all fixation techniques provided significant torsional stability, no technique provided the rotational stability and native anatomic relationships provided by the intact ligaments.

Further, the screw provided the most rigid restraint to anterior-posterior translation of the fibula with the highest amount of translation seen in the single suture-button group [94].

Although multiple studies have addressed biomechanical stability, Laflamme et al. reported on functional scores in addition to radiographic outcomes of patients randomized to either static fixation with a single 3.5-mm quadricortical screw ($n = 36$) or dynamic fixation with a single TightRope ($n = 34$).

Dynamic fixation resulted in improved Olerud-Molander functional scores at 3, 6, and 12 months (significant at 12 months). AOFAS scores were significantly better in the TightRope group at 3 months only. There were four cases of lost reduction in the screw group compared to zero in the TightRope group.

Anatomic Repair of Syndesmotic Ligaments

There has been recent support for anatomic repair of the syndesmosis.

Schottel et al. in 2016 reported from a cadaveric model that anatomic repair using suture anchors for the deltoid ligament and PITFL was not significantly inferior to screw fixation in terms of external rotational stability [95].

Zhan et al. reported that patients who had augmented anatomic repair of the AITFL with a 5.0-mm anchor placed into tibia and tied to the fibular plate had better functional outcomes and earlier return to work than patients with screw fixation.

Additionally, there were significantly fewer cases of malreduction in the repair group (19.2% vs. 7.4%). The repair group had significantly higher overall range of motion, although they had significantly decreased plantarflexion compared to the screw group [68].

A recent topic of debate is in relation to fixation of the posterior malleolus and the role that it plays in syndesmotic reconstruction and stabilization. Even small posterior fragments in trimalleolar fractures can represent complete avulsion of the PITFL. Therefore, the previous teaching that posterior malleolar fractures that constitute less than 20% of the joint surface do not require fixation has been called into question.

Posterior malleolar fixation has been found to further stabilize the syndesmosis and decrease the risk of post-traumatic arthritis [53].

A cadaveric study by Gardner et al. found that in specimens with unstable syndesmoses, fixation of a posterior malleolus fracture restored 70% of preinjury stiffness compared to only 40% with screw fixation [96].

A prospective clinical study of 31 patients (9 who underwent posterior malleolus fixation and 14 who underwent screw fixation of their syndesmotic injury) revealed that fixation of a posterior malleolus fracture with the PITFL attached resulted in at least equivalent stability and clinical outcomes as trans-syndesmotic screw fixation [97]. This is typically performed through a posterolateral approach with the patient in a prone position [98].

Syndesmotic injuries are increasingly common in both competitive and recreational athletes. Although screw fixation has been shown to provide greater stability than newer suture-button constructs, the benefit of the earlier motion allowed by these constructs is not completely understood.

Although both of these techniques have the ability to overcompress the syndesmosis, it is unclear what effect this has on healing and ankle motion. Additionally, direct anatomic repair of syndesmotic ligaments with or without augmentation has shown promising results in terms of anatomic restoration of the joint with acceptable strength. At present, more work is needed to understand the long-term impact of newer treatments and the utility of more aggressive rehabilitation techniques.

6.8 New Ideas: "Syndhoo" [41]

There are no standardized criteria for the diagnosis and management of syndesmotic injuries, creating great ambiguity regarding optimal treatment. Future challenges are to identify clinical syndesmotic instability without the need of invasive arthroscopic procedures, especially in subtle (grade IIb) instabilities [41].

A grade II isolated syndesmotic injury is defined as a lesion to the antero-inferior tibiofibular ligament and the interosseous ligament of the ankle with involvement of the deltoid ligament on magnetic resonance scanning (MRI).

We tested 15 registered athletes between the age of 18 and 36 years, who presented with a grade II isolated syndesmotic injury (confirmed on MRI) between 1 January 2015 and 1 May 2017. All 15 athletes were independently tested by an experienced physiotherapist with the "syndhoo" device that we developed. They all had a grade II isolated syndesmotic injury with clinical and radiological signs of potential instability and therefore all were indicated for arthroscopy [37].

For every "syndhoo"-tested athlete, an arthroscopy was performed by the same experienced ankle surgeon at our Center between January 2017 and September 2017. During arthroscopy, the syndesmosis was considered positive (unstable) if a 4.5-mm arthroscopic shaver could be pushed through the distal syndesmosis, 1 cm proximal from the tibiotalar joint. The physiotherapist and surgeon were blinded to the other one's results. All patients were tested and treated between 1 and 4 weeks from the initial injury. The principle of this "syndhoo" device is to dynamically evaluate the distal tibiofibular stability during external rotation of the ankle as an extension to the available clinical tests. Cadaveric testing has shown that the distal syndesmosis is unstable when a force of 87–100 N is applied. The foot is positioned and fixed on the syndhoo board that rotates over the heel (Fig. 6.9a, b).

The board can be put in neutral position, 20° of plantar flexion and 20° of dorsiflexion (Fig. 6.9c, d).

The knee is stabilized through a patellar strap and the patient is tested in sitting position (Fig. 6.9b). With a dynamometer, the foot is passively externally rotated with the hinge positioned over the heel (Fig. 6.9e, f).

When the patient experiences clinical apprehension at a force <87 N, the "syndhoo" test is considered positive.

If the apprehension occurs during a force 87–100 N, the syndhoo test is considered equivocal.

When no apprehension occurs or the apprehension occurs with a force >100 N, the "syndhoo" test is considered negative.

Statistically, Cohen's kappa (κ) has been used to determine the inter-rater agreement between

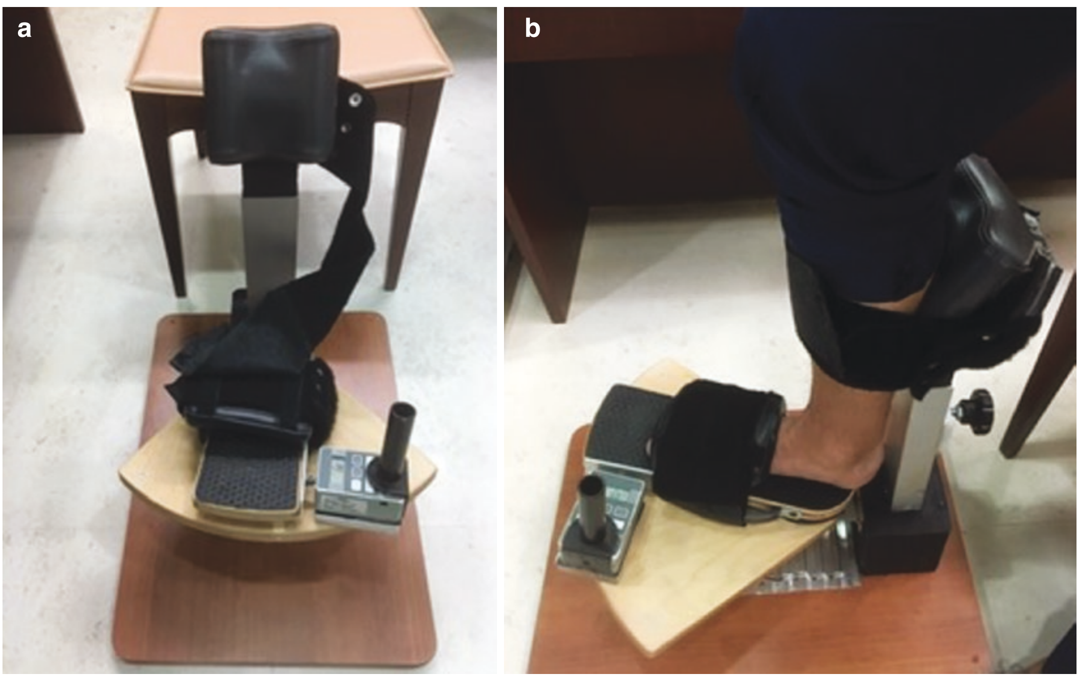

Fig. 6.9 (**a**) Image of the "syndhoo" device (front side). (**b**) Image of the "syndhoo" device from the side with the foot placed on the rotating board in neutral position. (**c**) Image of the syndhoo device from the side with the foot placed on the rotating board in 20° of plantar flexion. (**d**) Image of the syndhoo device from the side with the foot placed on the rotating board in 20° of dorsiflexion. (**e**) Image close up of the dynamometer, placed at the medial foot side of the rotating board. (**f**) Overview image of the dynamometer, linked to the rotating board

Fig. 6.9 (continued)

the arthroscopy method (as a reference) and the three "syndhoo" methods (dorsiflexion, neutral, plantar flexion).

Based on the guidelines from Altman, and adapted from Landis and Koch, Cohen's kappa (κ) is interpreted as poor agreement if less than 0.20, fair agreement if between 0.20 and 0.40, moderate agreement if between 0.40 and 0.60, good agreement if between 0.60 and 0.80, and very good agreement if between 0.80 and 1.00.

6.8.1 "Syndoo" Testing Results

"Syndhoo" dorsiflexion: When pushing manually the dynamometer in external rotation (with the board in 20° of dorsiflexion), the test is considered positive if the athlete feels apprehension at a force <87 Newton (N).

"Syndhoo" neutral: When pushing manually the dynamometer in external rotation (with the board in neutral position), the test is considered positive if the athlete feels apprehension at a force <87 Newton (N).

"Syndhoo" plantar flexion: When pushing manually the dynamometer in external rotation (with the board in 20° of plantar flexion), the test is considered positive if the athlete feels apprehension at a force <87 Newton (N).

There was very good agreement between arthroscopy and syndhoo dorsiflexion diagnosis ($\kappa = 1$, $p < 0.001$) but no significant agreement was found between arthroscopy, and "syndhoo" neutral and "syndhoo" plantar flexion ($p = 0.053$ and $p = 0.99$, respectively).

Traditionally, individuals with clinical and/or radiological suspicion of syndesmotic instability warrant an examination under anesthesia and/or diagnostic arthroscopy to confirm and treat. However, the invasive process of this has inherent risks to the patient. The described noninvasive "syndhoo" device in this chapter can be a valuable tool in the evaluation of isolated syndesmotic ankle instability.

Further studies on the correlation of this noninvasive test with clinical examination, imaging, and arthroscopic findings are needed. Ongoing work at our institution is seeking to establish the agreement between the examination described here and MR quantification of syndesmotic injury which we hope will better depict the cut-point for a positive test.

We have incorporated these finding in this chapter on novel techniques since we have found this "syndhoo" device very helpful as part of the available noninvasive options in the clinical diagnosis of syndesmotic instability [41].

6.9 Return to Play

Athletes who sustain a syndesmotic ankle sprain typically should go through much longer recovery periods than those who sustain a lateral ankle sprain [9]. Return to play (RTP) in grade I injuries is usually at 6–8 weeks post-injury, but is variable. Professional athletes with stable isolated grade II syndesmotic injuries are reported to RTP at a mean of 45 days, compared with 64 days for those with unstable grade II injuries [99]. Also, athletes with injury to both the AITFL and deltoid ligament took longer to RTP than those with an AITFL injury alone and IOL injury on MRI and PITFL injury on MRI were both independently associated with a delay in RTP [99]. In the case of surgically treated grade III injuries, the expected time frame to RTP is between 10 and 14 weeks [9, 100] although RTP as early as 6 weeks has been described in case series [101]. RTP in syndesmotic injury is permitted when able to single-leg hop for 30 s without significant pain [5]. To our knowledge, there are no specific studies on prevention of syndesmotic re-injury. Although it might be assumed that neuromuscular bracing and bracing or taping is beneficial, injury mechanisms differ and further investigation is required to increase our understanding of syndesmosis injuries and improve treatment and prevention of this significant injury [9, 28, 40].

6.10 Conclusion

Syndesmosis injuries are increasingly common in both competitive and recreational athletes. Recent advances in the diagnosis and management enable early detection of these injuries that can avoid evolution to chronic debilitating ankle conditions.

Despite improved insights in this multifactorial pathology, more work is needed to understand the long-term impact of the newer treatments and the utility of more aggressive rehabilitation techniques.

References

1. Mei Dan O, Kots E, Barchilon V, Massarwe S, Nyska M, et al. A dynamic ultrasound examination for the diagnosis of ankle syndesmotic injury in professional athletes: a preliminary study. Am J Sports Med. 2009;37:1009–16.
2. Kofotolis ND, Kellis E, Vlachopoulos SP. Ankle sprain injuries and risk factors in amateur soccer players during a 2-year period. Am J Sports Med. 2007;35:458–66.
3. Roemer FW, Jomaah N, Niu J, Almusa E, Roger B, et al. Ligamentous injuries and the risk of associated tissue damage in acute ankle sprains in athletes: a cross-sectional MRI study. Am J Sports Med. 2014;42:1549–57.
4. Woods C, Hawkins R, Hulse M, Hodson A. The football association medical research programme: an audit of injuries in professional football: an analysis of ankle sprains. Br J Sports Med. 2003; 37:233–8.
5. Van den Bekerom MP. Diagnosing syndesmotic instability in ankle fractures. World J Orthop. 2011;2:51–6.
6. Wright RW, Barlie J, Suprent DA, Matave MJ. Ankle syndesmosis sprains in national hockey league players. Am J Sports Med. 2004;32:1941–5.
7. Gerber JP, Williams GN, Scoville CR, Arciero RA, Taylor DC. Persistent disability associated with ankle sprains: a prospective examination of an athletic population. Foot Ankle. 1998;19:653–60.
8. Waldén M, Hagglund M, Ekstrand J. Time-trends and circumstances surrounding ankle injuries in men's professional football: an 11-year follow-up of the UEFA champions league injury study. Br J Sports Med. 2013;47:748–53.
9. Williams GN, Jones MH, Amendola A. Syndesmotic ankle sprains in athletes. Am J Sports Med. 2007;35:1197–207.
10. Xenos JS, Hopkinson WJ, Mulligan ME, Olson EJ, Popovic NA. The tibiofibular syndesmosis: evaluation of the ligamentous structures, methods of fixation, and radiographic assessment. J Bone Joint Surg Am. 1995;77:847–56.
11. Waterman BR, Belmont PJ, Cameron KL, Svoboda SJ, Alitz CJ, et al. Risk factors for syndesmotic and medial ankle sprain: role of sex, sport, and level of competition. Am J Sports Med. 2011;39:992–8.
12. Williams GN, Allen EJ. Rehabilitation of syndesmotic (high) ankle sprains. Sports Health. 2010;2:460–70.
13. Beumer A, Valstar ER, Garling EH, Niesing R, Ginai AZ, et al. Effects of ligament sectioning on the kinematics of the distal tibiofibular syndesmosis. Acta Orthop. 2006;77:531–40.
14. Zalavras C, Thordarson D. Ankle syndesmosis injury. J Am Acad Orthop Surg. 2007;15:330–9.
15. Calder JD, Bamford R, Petrie A, McCollum GA. Stable versus unstable grade ii high ankle sprains: a prospective study predicting the need for surgical stabilization and time to return to sports. Arthroscopy. 2016;32:634–42.
16. van Dijk CN, Longo UG, Loppini M, Florio P, Maltese L, Ciuffreda M, et al. Conservative and surgical management of acute isolated syndesmotic injuries: ESSKA-AFAS consensus and guidelines. Knee Surg Sports Traumatol Arthrosc. 2016;24(4):1217–27.
17. Thormeyer JR, Leonard JP, Hutchinson M. Syndesmotic injuries in athletes. In: Zaslav KR, editor. An international perspective on topics in sports medicine and sports injury: InTech; 2012. isbn:978-953-51-0005-8. Available from http://www.intechopen.com/books/an-international-perspectiveon-topics-in-sports-medicine-and-sports-injury/syndesmotic-injuries-in-athletes.
18. Hermans JJ, et al. Anatomy of the distal tibiofibular syndesmosis in adults: a pictorial essay with a multimodality approach. J Anat. 2010;217(6):633–45.
19. Kelikian H, Kelikian AS. Disorders of the ankle. Philadelphia: Saunders; 1985. p. 893.
20. Elgafy H, et al. Computed tomography of normal distal tibiofibular syndesmosis. Skeletal Radiol. 2010;39(6):559–64.
21. Hocker K, Pachucki A. [The fibular incisure of the tibia. The cross-sectional position of the fibula in distal syndesmosis]. Unfallchirurg. 1989; 92(8):401–406.
22. Sora MC, et al. Evaluation of the ankle syndesmosis: a plastination slices study. Clin Anat. 2004;17(6):513–7.
23. Grass R. [Injuries of the inferior tibiofibular syndesmosis]. Unfallchirurg, 2000;103(7):519.
24. Yildirim H, et al. Evaluation of the fibular incisura of the tibia with magnetic resonance imaging. Foot Ankle Int. 2003;24(5):387–91.
25. Bassett FH 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):55–9.
26. Rammelt S, Zwipp H, Grass R. Injuries to the distal tibiofibular syndesmosis: an evidence-based approach to acute and chronic lesions. Foot Ankle Clin. 2008;13(4):611–33.. vii-viii
27. D'Hooghe P, Alkhelaifi K, Abdelatif N, Kaux JF. From "low" to "high" athletic ankle sprains: a comprehensive review. Oper Tech Orthop. 2018;28(2):54–60. https://doi.org/10.1053/j.oto.2018.01.002.

28. Lubberts B, D'Hooghe P, Bengtsson H, DiGiovanni CW, Calder J, Ekstrand J. Epidemiology and return to play following isolated syndesmotic injuries of the ankle: a prospective cohort study of 3677 male professional footballers in the UEFA Elite Club Injury Study. Br J Sports Med. 2017;21:bjsports-2017-097710. https://doi.org/10.1136/bjsports-2017-097710.
29. Fritschy D. An unusual ankle injury in top skiers. Am J Sports Med. 1989;17(2):282–5; discussion 85–6.
30. Flik K, Lyman S, Marx RG. American collegiate men's ice hockey: an analysis of injuries. Am J Sports Med. 2005;33(2):183–7.
31. Wright RW, Barile RJ, Surprenant DA, et al. Ankle syndesmosis sprains in national hockey league players. Am J Sports Med. 2004;32(8):1941–5.
32. Kaplan LD, Jost PW, Honkamp N, et al. Incidence and variance of foot and ankle injuries in elite college football players. Am J Orthop. 2011;40(1):40–4.
33. Hunt KJ, George E, Harris AH, et al. Epidemiology of syndesmosis injuries in intercollegiate football: incidence and risk factors from National Collegiate Athletic Association injury surveillance system data from 2004-2005 to 2008-2009. Clin J Sport Med. 2013;23(4):278–82.
34. Boytim MJ, Fischer DA, Neumann L. Syndesmotic ankle sprains. Am J Sports Med. 1991;19(3):294–8.
35. Osbahr DC, Drakos MC, O'Loughlin PF, et al. Syndesmosis and lateral ankle sprains in the National Football League. Orthopedics. 2013;36(11):1378–84.
36. Purvis GD. Displaced, unstable ankle fractures: classification, incidence, and management of a consecutive series. Clin Orthop Relat Res. 1982;165:91–8.
37. Hopkinson St WJ, Pierre P, Ryan JB, et al. Syndesmosis sprains of the ankle. Foot Ankle. 1990;10:325–30.
38. Xenos JS, Hopkinson WJ, Mulligan ME, et al. The tibiofibular syndesmosis: evaluation of the ligamentous structures, methods of fixation and radiographic assessment. J Bone Joint Surg Am. 1995;77:847–56.
39. Beumer A, Valstar ER, Garling EH, et al. Effects of ligament sectioning on the kinematics of the distal tibio-fibular syndesmosis. Acta Orthop. 2006;77:531–40.
40. D'Hooghe P, et al. Fixation techniques in lower extremity syndesmotic injuries. Foot Ankle Int. 2017;38(11):1278–88.
41. D'Hooghe P, Bouhdida S, Whiteley R, Rosenbaum A, AlKhelaifi K, Kaux JF. Stable versus unstable grade 2 high ankle sprains in athletes: a noninvasive tool to predict the need for surgical fixation. Clin Res Foot Ankle. 2018;6(1):252–9. https://doi.org/10.4172/2329-910X.1000252.
42. Sman AD, Hiller CE, Refshauge KM. Diagnostic accuracy of clinical tests for diagnosis of ankle syndesmosis injury: a systematic review. Br J Sports Med. 2013;47:620–8.
43. Harper MC. An anatomic and radiographic investigation of the tibiofibular clear space. Foot Ankle. 1993;14:455–8.
44. Sikka RS, Fetzer GB, Sugarman E, et al. Correlating MRI findings with disability in syndesmotic sprains of NFL players. Foot Ankle Int. 2012;33(5):371–8.
45. van den Bekerom MPJ, Lamme B, Hogervorst M, Bolhuis HW. Which ankle fractures require syndesmotic stabilization? J Foot Ankle Surg. 2007;46(6):456–63.
46. Schnetzke M, Vetter SY, Beisemann N, Swartman B, Grützner PA, Franke J. Management of syndesmotic injuries: what is the evidence? World J Orthop. 2016;7(11):718.
47. Femino JE, Vaseenon T, Phistkul P, et al. Varus external rotation stress test for radiographic detection of deep deltoid ligament disruption with and without syndesmotic disruption. Foot Ankle Int. 2013;34(2):251–60.
48. Dikos GD, Heisler J, Choplin RH, Weber TG. Normal tibiofibular relationships at the syndesmosis on axial CT imaging. J Orthop Trauma. 2012;26(7):433–8.
49. Hermans J, Wentink N, Beumer A, et al. Correlation between radiological assessment of acute ankle fractures and syndesmotic injury on MRI. Skeletal Radiol. 2012;41:787–801.
50. Williams BT, Ahrberg a B, Goldsmith MT, et al. Ankle syndesmosis: a qualitative and quantitative anatomic analysis. Am J Sports Med. 2015;43(1):88–97.
51. van den Bekerom MPJ, Mutsaerts ELAR, Dijk CN. Evaluation of the integrity of the deltoid ligament in supination external rotation ankle fractures: a systematic review of the literature. Arch Orthop Trauma Surg. 2009;129(2):227–35.
52. Gennis E, Koenig S, Rodericks D, Otlans P, Tornetta P. The fate of the fixed syndesmosis over time. Foot Ankle Int. 2015;36(10):1202–8.
53. Drijfhout van Hooff CC, Verhage SM, Hoogendoorn JM. Influence of fragment size and postoperative joint congruency on long-term outcome of posterior malleolar fractures. Foot Ankle Int. 2015;36(6):673–8.
54. Gerber J, Williams G, Scoville C, Arciero R, Taylor D. Persistent disability associated with ankle sprains: a prospective examination of an athletic population. Foot Ankle Int. 1998;19(10):653–60.
55. Hansen M, Le L, Wertheimer S, Meyer E, Haut R. Syndesmosis fixation: analysis of shear stress via axial load on 3.5-mm and 4.5-mm quadricortical syndesmotic screws. J Foot Ankle Surg. 2006;45(2):65–9.
56. Taylor DC, Englehardt DL, Bassett FH 3rd. Syndesmosis sprains of the ankle. The influence of heterotopic ossification. Am J Sports Med. 1992;20(2):146–50.
57. Heim D, Schmidlin V, Ziviello O. Do type B malleolar fractures need a positioning screw? Injury. 2002;33(8):729–34.

58. Amendola A, Williams G, Foster D. Evidence-based approach to treatment of acute traumatic syndesmosis (high ankle) sprains. Sports Med Arthrosc. 2006;14(4):232–6.
59. Mc Collum GA, van den Bekerom MP, Kerkhoffs GM, Calder JD, van Dijk CN. Syndesmosis and deltoid ligament injuries in the athlete. Knee Surg Sports Traumatol Arthrosc. 2013;21:1328–37.
60. Hunt KJ, Phisitkul P, Pirolo J, Amendola A. High ankle sprains and syndesmotic injuries in athletes. J Am Acad Orthop Surg. 2015;23:661–73.
61. Kerkhoffs GMMJ, de Leeuw PAJ, Tennant JN, Amendola A. Ankle ligament lesions. In: The ankle in football. Paris: Springer; 2014. p. 81–96.
62. Schepers T. Acute distal tibiofibular syndesmosis injury: a systematic review of suture-button versus syndesmotic screw repair. Int Orthop. 2012;36:1199–206.
63. van Dijk CN, Longo UG, Loppini M, Florio P, Maltese L, et al. Conservative and surgical management of acute isolated syndesmotic injuries: ESSKA-AFAS consensus and guidelines. Knee Surg Sports Traumatol Arthrosc. 2016;24:1217–27.
64. Nussbaum ED, Hosea TM, Sieler SD, Incremona BR, Kessler DE. Prospective evaluation of syndesmotic ankle sprains without diastasis. Am J Sports Med. 2001;29:31–5.
65. Miller TL, Skalak T. Evaluation and treatment recommendations for acute injuries to the ankle syndesmosis without associated fracture. Sports Med. 2014;44(2):179–88.
66. van Dijk CN, Longo UG, Loppini M, et al. Conservative and surgical management of acute isolated syndesmotic injuries: ESSKA-AFAS consensus and guidelines. Knee Surg Sports Traumatol Arthrosc. 2016;24(4):1217–27.
67. Nussbaum ED, et al. Prospective evaluation of syndesmotic ankle sprains without diastasis. Am J Sports Med. 2001;29(1):31–5.
68. Zhan Y, Yan X, Xia R, Cheng T, Luo C. Anterior-inferior tibiofibular ligament anatomical repair and augmentation versus trans-syndesmosis screw fixation for the syndesmotic instability in external-rotation type ankle fracture with posterior malleolus involvement: a prospective and comparative study. Injury. 2016;47(7):1574–80.
69. Samra DJ, Sman AD, Rae K, Linklater J, Refshauge KM, Hiller CE. Effectiveness of a single platelet-rich plasma injection to promote recovery in rugby players with ankle syndesmosis injury. BMJ Open Sport Exerc Med. 2015;1(1):e000033.
70. Amendola A, Williams G, Foster D. Evidence-based approach to treatment of acute traumatic syndesmosis (high ankle) sprains. Sports Med Arthrosc Rev. 2006;14(4):232–6.
71. Taylor DC, Tenuta JJ, Uhorchak JM, Arciero RA. Aggressive surgical treatment and early return to sports in athletes with grade III syndesmosis sprains. Am J Sports Med. 2007;35(11):1833–8.
72. Carr JBI, Werner BC, Yarboro SR. An update on management of syndesmosis injury: a National US Database Study. Am J Orthop (Belle Mead NJ). 2016;45(7):E472–7.
73. Matson AP, Hamid KS, Adams SB. Predictors of time to union after operative fixation of closed ankle fractures. Foot Ankle Spec. 2017;10(4):308–14.
74. Tornetta P. Competence of the deltoid ligament in bimalleolar ankle fractures after medial malleolar fixation. J Bone Joint Surg Am. 2000;82(6):843–8.
75. Thompson M, Gesink D. Biomechanical comparison of syndesmosis fixation with 3.5- and 4.5-millimeter stainless steel screws. Foot Ankle Int. 2000;21(9):736–41.
76. Beumer A, Campo MM, Niesing R, Day J, Kleinrensink GJ, Swierstra BA. Screw fixation of the syndesmosis: a cadaver model comparing stainless steel and titanium screws and three and four cortical fixation. Injury. 2005;36(1):60–4.
77. McBryde A, Chiasson B, Wilhelm A, Donovan F, Ray T, Bacilla P. Syndesmotic screw placement: a biomechanical analysis. Foot Ankle Int. 1997;18(5):262–6.
78. Darwish HH, Glisson RR, DeOrio JK. Compression screw fixation of the syndesmosis. Foot Ankle Int. 2012;33(10):893–9.
79. van den Bekerom MPJ, Hogervorst M, Bolhuis HW, van Dijk CN. Operative aspects of the syndesmotic screw: review of current concepts. Injury. 2008;39(4):491–8.
80. Høiness P, Strømsøe K. Tricortical versus quadricortical syndesmosis fixation in ankle fractures: a prospective, randomized study comparing two methods of syndesmosis fixation. J Orthop Trauma. 2004;18(6):331–7.
81. Schepers T. To retain or remove the syndesmotic screw: a review of literature. Arch Orthop Trauma Surg. 2011;131(7):879–83.
82. Bell DP, Wong MK. Syndesmotic screw fixation in Weber C ankle injuries—should the screw be removed before weight bearing? Injury. 2006;37(9):891–8.
83. Moore JA Jr, Shank JR, Morgan SJ, Smith WR. Syndesmosis fixation: a comparison of three and four cortices of screw fixation without hardware removal. Foot Ankle Int. 2006;27(8):567–72.
84. Weening B, Bhandari M. Predictors of functional outcome following transsyndesmotic screw fixation of ankle fractures. J Orthop Trauma. 2005;19(2):102–8.
85. Dingemans SA, Rammelt S, White TO, Goslings JC, Schepers T. Should syndesmotic screws be removed after surgical fixation of unstable ankle fractures? A systematic review. Bone Joint J. 2016;98(11):1497–504.
86. Naqvi GA, Shafqat A, Awan N. Tightrope fixation of ankle syndesmosis injuries: clinical outcome, complications and technique modification. Injury. 2012;43(6):838–42.

87. Teramoto A, Suzuki D, Kamiya T, Chikenji T, Watanabe K, Yamashita T. Comparison of different fixation methods of the suture-button implant for tibiofibular syndesmosis injuries. Am J Sports Med. 2011;39(10):2226–32.
88. Kortekangas T, Savola O, Flinkkilä T, et al. A prospective randomised study comparing TightRope and syndesmotic screw fixation for accuracy and maintenance of syndesmotic reduction assessed with bilateral computed tomography. Injury. 2015; 46(6):1119–26.
89. Ebramzadeh E, Knutsen AR, Sangiorgio SN, Brambila M, Harris TG. Biomechanical comparison of syndesmotic injury fixation methods using a cadaveric model. Foot Ankle Int. 2013;34(12):1710–7.
90. Phisitkul P, Ebinger T, Goetz J, Vaseenon T, Marsh JL. Forceps reduction of the syndesmosis in rotational ankle fractures. J Bone Joint Surg Am. 2012;94:2256–61.
91. Schon J, Mikula J, Backus J, et al. 3D model analysis of ankle flexion on anatomic reduction of a syndesmotic injury. Foot Ankle Int. 2017;38(4):436–42.
92. Tornetta P, Spoo JE, Reynolds FA, Lee C. Overtightening of the ankle syndesmosis: is it really possible? J Bone Joint Surg Am. 2001;83(4):489–92.
93. de César PC, Avila EM, de Abreu MR. Comparison of magnetic resonance imaging to physical examination for syndesmotic injury after lateral ankle sprain. Foot Ankle Int. 2011;32(12):1110–4.
94. Clanton TO, Whitlow SR, Williams BT, et al. Biomechanical comparison of 3 current ankle syndesmosis repair techniques. Foot Ankle Int. 2017;38(2):200–7.
95. Schottel PC, Baxter J, Gilbert S, Garner MR, Lorich DG. Anatomic ligament repair restores ankle and syndesmotic rotational stability as much as syndesmotic screw fixation. J Orthop Trauma. 2016;30(2):e36–40.
96. Gardner MJ, Brodsky A, Briggs SM, Nielson JH, Lorich DG. Fixation of posterior malleolar fractures provides greater syndesmotic stability. Clin Orthop Relat Res. 2006;447:165–71.
97. Miller AN, Carroll EA, Parker RJ, Helfet DL, Lorich DG. Posterior malleolar stabilization of syndesmotic injuries is equivalent to screw fixation. Clin Orthop Relat Res. 2010;468(4):1129–35.
98. Verhage SM, Boot F, Schipper IB, Hoogendoorn JM. Open reduction and internal fixation of posterior malleolar fractures using the posterolateral approach. Bone Joint J. 2016;98(6):812–7.
99. Calder JD, Bamford R, Petrie A, et al. Stable versus unstable grade II high ankle sprains: a prospective study predicting the need for surgical stabilization and time to return to sports. Arthroscopy. 2016;32:634–42.
100. Hunt KJ, Phisitkul P, Pirolo J, et al. High ankle sprains and syndesmotic injuries in athletes. J Am Acad Orthop Surg. 2015;23:661–73.
101. Taylor DC, Tenuta JJ, Uhorchak JM, et al. Aggressive surgical treatment and early return to sports in athletes with grade III syndesmosis sprains. Am J Sports Med. 2017;35:1833–8.