Current trends in the diagnosis and management of syndesmotic injury

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Abstract Ideal management of the various presentations of syndesmotic injury remains controversial to this day. High quality evidentiary science on this topic is rare, and numerous existing studies continue to contradict one another. The primary reasons for these discrepancies are that previous studies have failed to (1) properly distinguish between isolated (non-fractured) and non-isolated injuries, (2) accurately define stable from unstable injuries, and (3) sufficiently differentiate between acute and chronic injuries. The purpose of this review is to summarize today's body of literature regarding diagnosis and management of syndesmotic injury and discuss current trends and important future directions to optimize care of this very heterogeneous population.

Keywords Syndesmosis · Syndesmotic injury · Ankle fracture · High ankle sprain

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Epidemiology

Syndesmotic injury is not common. Despite an incidence of only 2.09 per 100,000 person-years [1], however, such problems can be devastatingly time consuming for patients who are affected, and often lead to significant morbidity and degenerative ankle disease—particularly if managed improperly [1, 2, 3, 4•, 5–7]. This is especially troublesome when considering that this injury is most prevalent between the ages of 18 and 34 [1]. Non-isolated injury to the syndesmosis has been reported to be associated with 8.5% of all ankle injuries [8], although studies have documented up to 25% of operatively treated ankle fractures being identified with unstable syndesmosis injuries, most commonly occurring in Weber type C injuries [9–11].

Isolated syndesmotic injury occurs when there is disruption of the distal tibiofibular articulation without associated fracture. This appears to be an entirely different population than the traditional syndesmosis disruption that occurs in the presence of a fracture; further, these patients remain some of the most poorly studied. The rate of isolated syndesmotic injury in ankle sprains has been reported to occur in up to 20% of the athletic population [12]. Both stable and unstable syndesmotic injuries are more common in collision sports, and when not treated properly they have been associated with prolonged disability [7, 13, 14•]. Most of these injuries happen during direct contact like tackling and blocking and have higher incidence on artificial turf relative to natural grass [15, 16]. 5.74% of documented foot and ankle injuries in college football players are syndesmotic sprains, and 32% of these injuries happen in offensive lineman [17]. Similarly, Osbahr et al. found the highest incidence of syndesmotic injuries in lineman and linebackers [15]. Usually, these are associated with external rotation patterns. There is no literature that has accurately distinguished acute from chronic isolated syndesmotic injuries. A systematic review performed by Lubberts et al.

found that there were only 143 patients described in literature diagnosed with chronic unstable isolated syndesmotic instability and that there were no studies describing patients with chronic stable isolated injuries [18].

Anatomy

Stability of the syndesmosis depends on the integrity of the three major ligaments which comprise it. These join to span the course of the entire tibiofibular intermediary space and are known as the tibiofibular interosseous ligament (IOL), the anterior tibiofibular ligament (AITFL), and the posterior tibiofibular ligament (PITFL). Their primary function is to stabilize the proximal and, in particular, distal associations between the tibia and fibula—the latter comprising the important bony mortise of the ankle. The AITFL is a multilayer ligament that extends obliquely from the anterolateral tubercle of the distal tibia, 5 mm above the plafond, to the longitudinal tubercle on the anterior portion of the lateral malleolus [3]. The PITFL consists of two layers—deep and superficial. The superficial layer extends obliquely from the lateral malleolus to the posterolateral tibial tubercle. The deep layer, or transverse ligament, which is only prominent 70% of the time, is a thick structure that originates at the round posterior fibular tubercle and inserts on the lower portion of the posterior border of the tibial articular surface [3, 19•]. The IOL spans and connects most of the tibia and fibula. It is a pyramidal thickening of the distal membrane that ends just superior to the AITFL and PITFL, which helps stabilize the talocrural joint during loading [3]. Although not specifically a part of the syndesmosis, disruption of the deltoid ligament is a frequently encountered finding with syndesmotic injuries.

Classification

In 2015, the European Society for Sports Traumatology, Knee Surgery and Arthroscopy-the Foot & Foot Associates (ESSKA-AFAS) consensus panel recommended that the most important feature to effectively classify syndesmotic injury rests with distinguishing acute isolated syndesmotic injuries as either stable or unstable; such discernment enables a timely and accurate diagnosis which facilitates more impactful and appropriate treatment of these injuries [20•]. It is also important to note that an unstable isolated syndesmotic injury can be further classified as either a latent or frank diastasis. In cases of latent diastasis, instability is not evident on routine plain films; the diastasis can only be detected by stress radiography, standing computed tomography (CT) scan, MRI, and/or arthroscopic assessment. In contradistinction, frank diastasis is evident on routine standard radiographs [20•]. Some authors have proposed more detailed grading systems that use physical and

radiographic findings to distinguish the severity of injury from grade-I to grade-III [2, 3, 4•]. Grade-I is characterized by a stable syndesmotic joint that has mild tenderness at the distal tibiofibular joint with normal radiographic findings [2, 3, 4•]. These injuries are considered stable and are usually treated non-operatively [2, 3, 4•, 5, 6]. Grade-II is defined as partial syndesmotic ligament disruption with normal radiographic findings and has a positive external rotation and squeeze test on physical exam [2, 3, 4•]. The treatment for these injuries is where the literature differs on when to treat non-operatively or operatively [2, 3, 4•, 5, 6]. This is from the result of inadequate diagnostic methods to differentiate a stable from an unstable injury [2, 3, 4•, 5, 6, 21, 22, 23•, 24•, 25, 26]. Grade-III is characterized by complete rupture of the syndesmotic ligaments, with or without deltoid ligament involvement. These injuries usually require operative stabilization [2, 3, 4•, 5, 6]. Although such classifications try to distinguish between stable and unstable injuries based on ligament rupture severity, it is important to point out that the continuum between the severity of ligament integrity and the degree of syndesmotic instability is still poorly understood. When one or more of the syndesmotic ligaments are described as having components of “injury,” “attenuation,” “damage,” “rupture,” “tear,” and similar assessments, none of these necessarily confer or predict syndesmotic instability. Current classifications, therefore, remain insufficient for differentiating between injury and instability, i.e., those that require stabilization and those that do not—and thus this represents an area much in need of further scientific investigation.

Syndesmotic injuries can be further classified on the basis of the time between initial trauma and diagnosis. It has been arbitrarily suggested that acute injuries be considered those that have been diagnosed within 6 weeks, sub-acute injuries as those having a diagnosis made between 6 weeks and 6 months, and chronic ones classified as presenting more than 6 months after trauma. There is currently little evidence, however, that the natural history of syndesmotic injury management should actually change between these groups, including how it should change, once a patient presents more than several months out [20•]. What is perhaps more relevant is whether or not the injuries are unstable and—if they are—what kind of associated damage has occurred over the timeframe they have existed which might impact the outcome of any treatment rendered. This could potentially include osteochondral lesions, overt ankle laxity, and arthritic change. Inclusion of such variables may end up comprising a better classification guide for management in the future.

Diagnosis

Syndesmotic injuries can be easily missed when they are subtle or uninvolved with significant fracture. It is therefore

important to perform a careful history and physical exam, obtain appropriate imaging, and maintain a high index of suspicion to render a prompt diagnosis. Data suggest that an early diagnosis which facilitates proper, timely management can affect prognosis [2, 3, 4•, 5, 6]. Signs of syndesmotc injury include complaints of pain along the distal anterolateral ankle radiating above the leg, often worsened with stress of the articulation, and feelings of vague instability or awkwardness of the ankle. Common symptoms include tenderness to palpation over the anterior tibiofibular ligament during the fibular translation test, squeeze test, and the cotton test [20•, 25, 27]. A correlation has been suggested between the height of anterolateral leg tenderness above the tibiotalar joint with likelihood and possibly even severity of syndesmotc injury [28].

Sman et al. evaluated the diagnostic accuracy of the various clinical tests available for diagnosis of potential syndesmotc injury. Notably, however, they looked at identifying syndesmotc injury itself rather than at reliably diagnosing overt instability [27]. They found that the single-leg hop had the highest sensitivity (89%) to diagnose a syndesmotc injury, while pain out of proportion to the apparent injury had the highest specificity (79%) for diagnosing a syndesmotc injury. Of all described clinical tests examined, the squeeze test had the highest specificity (88%) to diagnose injury, while tenderness to palpation of the syndesmotc ligaments and pain as a result of the dorsiflexion-external rotation stress test had the highest sensitivity at the values of 92 and 71%, respectively [27].

In order to diagnose unstable syndesmotc injuries, the ESSKA-AFAS consensus panel recommended that standard radiographic imaging should include an AP and mortise view of the syndesmosis to analyze the tibiofibular clear space, medial clear space overlap, and tibiofibular overlap (Table 1) [20•]. When radiographs are normal, but instability is still suspected based on history and physical exam, however, further diagnostic testing is indicated—including stress radiographs, standing axial CT imaging, 3-dimensional CT scan, magnetic resonance imaging (MRI), and/or arthroscopic assessment [20•, 26, 31]. Unfortunately, though, there is as yet no clear consensus as to which of these tests is most valuable with respect to accurate and reliable diagnosis of occult (latent) syndesmotc instability. While it is still common practice to rely only on plain film assessment for such patients, this form of testing has the potential for demonstrated diagnostic inaccuracy due to variability in positioning and rotation of the

tibiofibular joint [32]. In arguably questionable cases, similar comparative films of the opposite (presumably normal) ankle can be very helpful before more complex imaging modalities are pursued. The ESSKA-AFAS consensus panel recommended an MRI for additional imaging if instability is suspected [20•], although some surgeons currently advocate for the use of diagnostic stress views, weight bearing comparative bilateral CT scanning, and/or arthroscopic assessment—better level I and 2 prospective comparatively controlled data will be required to answer this question definitively. MRI is capable of highly accurate diagnosis of syndesmotc ligament rupture, but as a static test, it remains less able to detect the presence of what is often a dynamic underlying instability. Bilateral standing CT scan may be emerging as a better test to determine syndesmosis instability due to it being a dynamic test and the fact that such machines are now becoming more affordable and routinely available at major centers.

What has rapidly become perhaps the most accurate way to diagnose instability is via direct arthroscopic visualization of the tibiofibular joint—although validated, definitive parameters for measurement are still in the process of being defined [21, 22, 23•, 24•]. Previous studies used a wide range between 2 to 4 mm widening of the syndesmosis as a cut-off point for this diagnosis [24•]. A cadaver study by Watson et al. looked at the arthroscopic evaluation of subtle displacement in multiple planes and found that sagittal and traverse planes appeared to have instability earlier in the spectrum of syndesmotc injury. Furthermore, they concluded that arthroscopic evaluation of subtle displacement in multiple planes may help assist the surgeon as to the extent of syndesmotc injury [23•].

Calder et al. looked at the evaluation of grade-II high ankle sprains and assessment of predicting the need for surgical stabilization and time to return to sport in athletes. This group found that patients with AITFL and deltoid ligament tenderness together with positive squeeze and external rotation testing were almost universally found to have an unstable syndesmosis injury during arthroscopy. This was determined by using the diameter of the arthroscopic shaver at 3 mm to in measuring diastasis, because anything beyond this degree was felt consistent with a diagnosis of unstable syndesmosis [24•]. Another way to determine the stability of both the syndesmosis and deltoid ligament is by the arthroscopic ankle drive-through sign [33]. This maneuver tests the stability by trying to pass a 2.9-mm shaver easily through the medial ankle gutter

Table 1 Normal anatomic parameters of the syndesmosis using radiographs [29, 30]

Views	Tibiofibular clear space	Tibiofibular overlap	Medial clear space
A/P	<5 mm or <44% of the fibular width	>5 mm or >24% of the fibular width	
Mortise		>1 mm	>4 mm or >2 mm more than contralateral side

during arthroscopy. In which this would not be possible if there is an intact syndesmosis and deltoid ligament [33]. Importantly, however, these interpretations, while seemingly reasonable, remain essentially invalidated in today's literature.

Few, if any, of such studies specifically describe where in the syndesmosis these measurements are taken from, and no standard average measurement range as "normal" has ever been clearly determined scientifically. Moreover, to our knowledge, none of the reported cut-off points in the available literature have been linked to known radiographic parameters [24•]. Preliminary cadaveric data from our own lab suggest that sagittal instability seen during anterior and posterior stress of the fibula is likely to be far more accurate than coronal plane movement for accurately diagnosing syndesmotic instability [23•]. However, future research is necessary to test this hypothesis fully. Another potentially useful modality for fast and accurate diagnosis of dynamic and even occult instability is dynamic ultrasound. This form of testing offers a number of advantages: it is inexpensive, readily available in the office setting, actively dynamic for ready interpretation of results after various forms of on table stress testing, and devoid of radiation exposure. As such, this might become the imaging modality of choice in the near future for diagnosing unstable syndesmotic injuries [34–37]. Future studies will still be required, though, to define the overall accuracy and interobserver reliability of this emerging technology in orthopedics.

Based on available data, it is currently recommended that if patients exhibit clinical evidence of instability that can be corroborated by plain radiograph, stress radiograph, standing CT, or stress arthroscopy, it is reasonable to consider their syndesmosis unstable. This distinction is of paramount importance because such diagnoses are likely to benefit most from surgical stabilization, whereas patients for whom instability cannot be clearly demonstrated are probably best managed via conservative measures. However, it should also be noted that syndesmotic injuries which are subluxable with stress but are in an anatomic position without stress may heal in a stable position without surgery given the appropriate immobilization or at the very least may be amenable to less invasive surgical interventions. We support using a bilateral standing axial cut CT scan as the best test for identifying syndesmotic asymmetry between the injured and contralateral ankle (Fig. 1)—instead of MRI—if instability is suspected. If comparative CT scanning is normal but there is still a high suspicion, further analysis is probably best done via arthroscopic stress evaluation of the syndesmosis (Fig. 2) in both the sagittal and coronal planes.

Treatment

Stable syndesmotic injuries are best treated conservatively with a functional and proprioceptive rehabilitative program, short term activity modification, and interim brace wear.

Conversely, unstable injuries typically require surgical stabilization [2, 3, 4•, 5, 16]. The four most important considerations when treating syndesmosis injuries can be summarized as follows: (1) early recognition of the injury and its severity, (2) accurate assessment of the degree of (in)stability and any other associated pathology, (3) prompt reduction and stabilization of all unstable injuries along with treatment of any associated pathology as indicated, and (4) progressive rehabilitation focusing on full range of motion and return of normal strength [2].

Conservative treatment for isolated syndesmotic injuries

Stable isolated syndesmotic injuries should be treated with supervised non-operative management. This includes rest, elevation, compression, and anti-inflammatory medication. Treatment also can include therapeutic modalities such as electric stimulation and massage [3]. At about 4–6 weeks post-injury, patients can be placed into a lace-up ankle brace and begin a more intensive functional rehabilitative program guided by symptom tolerance [3]. For more significant stable syndesmotic injuries, the lace-up brace should be worn for six more weeks to minimize symptoms [3].

Elite athletes are treated with rest, ice and immobilization in a non-weight-bearing cast or a removable boot for 3–5 days to allow the acute inflammation and edema to resolve [4•]. The athlete can then be allowed to weight bear as tolerated in a boot while both passive- and active-assisted motion are initiated through trainers or physical therapists, followed by resistance and proprioception exercises [4•]. Typically, if the athlete is pain free for 7 to 10 days in the boot, then he or she can be placed in a stabilizing brace, and strengthening and functional exercise begins, followed by running and integration of sport-specific activities [4•]. Hunt et al. has recommended that repeated successful performance of a single-leg hop test is a reliable sign of the patient's injury status [4•].

To enhance the outcomes in non-operative syndesmosis injuries, Laver et al. evaluated using plasma-rich plasma (PRP) ultrasound injections in the AITFL in the 16 elite athletes [38]. They found that there was a difference ($p = 0.006$) in time to return to play between the (PRP) injection group (41 days) and the control group (60 days) [38]. Further, their results showed a difference in residual pain between the treatment and control group (62.5 vs. 12.5%), respectively [38]. Use of PRP for such injuries in foot and ankle remains very controversial and without high quality evidential support to date, further study is warranted for this potential treatment modality before it can be recommended as part of routine management options. Another non-operative treatment option one can consider is a periligamentous corticosteroid injection of the tibiotalar joint for a syndesmotic injury [39, 40]. However, even though it has been shown to be safe and effective, it is only meant to be a short term treatment plan [40].

Fig. 1 A 23-year-old rugby player presented with 3 months of right ankle pain after an eversion injury. The weight bearing Mortise (a) and lateral (b) X-rays demonstrated no diastasis of the tibiofibular overlap or medial clear space. However, calcification of the syndesmosis is seen consistent with a prior syndesmosis injury. Clinical exam was consistent with

syndesmosis instability, therefore a weight bearing CT was obtained. The axial cuts (c) demonstrate diastasis of the syndesmosis of the right ankle (*on the left*) when compared to the contralateral ankle indicative of an unstable syndesmosis

Operative treatment for isolated syndesmosis injuries

Unstable syndesmosis injuries need to be treated operatively with some combination of rigid (plate or screw/washer) or “dynamic” (suture button) fixation. Sometimes, this may depend on injury severity. Recently, these two types of fixation have been compared through early investigational efforts, but data remain inconclusive and of questionable scientific quality. Thus, there exists neither definitive recommendation regarding the ideal type of fixation that should be used, nor consensus as to how long it should remain or whether or not it should be accompanied by other forms of soft tissue ligament reconstruction. Historically, screw fixation has been the most popular operative treatment of an unstable tibiofibular syndesmosis injury. Classical AO teaching recommends that a syndesmosis screw should be inserted at 25°–30° to the coronal plane of the ankle beginning at least 1 cm above the ankle joint in the proximity of the physal scar.

Fig. 2 If comparative CT scanning is normal but there is still a high suspicion, further analysis can be performed by arthroscopic stress evaluation of the syndesmosis (a) in both the sagittal and coronal planes. A probe is placed to be able to determine the amount of diastasis in the coronal and sagittal plane when a cotton test is performed in both planes. However, values for the amount of diastasis needed to indicate syndesmosis instability have still not been validated

The majority of studies regarding screw fixation for the syndesmosis have looked at patients with combined ankle fractures and syndesmosis instability. The authors consider this injury pattern to have an entirely different natural history and spectrum of implications compared to those syndesmosis injuries which occur without fracture. Regardless, most surgeons advocating the above technique place one or two screws starting between 2.1 and 4.0 cm above the tibial plafond [41]. McBryde et al. performed a cadaveric study that found that less syndesmosis widening was found at 2.0 cm when compared with 3.5 cm proximal to the tibiotalar joint [42]. Furthermore, they recommend to place the syndesmosis screw at 2.0 cm above the tibiotalar joint [42]. However, Verim et al. had contradicting recommendations due to their biomechanical evaluation of syndesmosis screw position using CT scan data of an ankle a 3-dimensional finite element [43]. They found that the von Mises stress (effective stress where yielding is estimated to occur in ductile materials) was lowest when the screw was placed at 3–4 cm above the tibiotalar joint and highest 2.0–2.5 cm above the tibiotalar joint [43]. They recommended placement of the syndesmosis screw at 3–4 cm above the tibiotalar joint [43]. This may also decrease damage to the tibiofibular articulation at the incisura.

Other fixation considerations include proper screw size for use in this population as well as the need to gain three or four cortices fixation, and again there remains no consensus on either topic. Stuart et al. did a retrospective study and found that 3.5 mm diameter screws were statistically more likely to break than 4 or 4.5 mm screws, but there was no difference in the frequency of the loss of reduction of the syndesmosis as a function of screw diameter [44]. However, this study did not look at if this hardware failure resulted in a loss of reduction or if failure of the syndesmosis fixation had any real clinical significance [44].

Recently, Schepers et al. found that 87% of surgeons routinely remove the syndesmosis screw [41]. There has been disagreement in the literature, however, as to whether or not these screws should be retained as well as timing of removal

[45–48]. One argument that has been made is that the screw should be removed due to idea of restoring normal function and stress transfer mechanism of the normal ankle joint at around 8–12 weeks postoperatively [45–47]. Gennis et al. found that the mortise remained intact and found no tibia-fibula diastasis after weight bearing regardless of the syndesmotom screws were removed, loosened, or remain solid and in place [49]. Tucker et al. found similar results in functional outcomes and advocated that the syndesmotom screws be left unless the patients continued to have stiffness greater than 6 months postoperatively [11]. In contrast, Song et al. had eight of nine (89%) patients with malreduced syndesmoses that demonstrated adequate reduction of tibiofibular syndesmosis after syndesmosis screw removal [50]. Hence, they concluded that removal of the screw could be advantageous to achieve final anatomic reduction of the distal tibiofibular joint and recommended to remove the screw for a malreduced syndesmosis [50]. Cost represents another argument that is becoming more relevant to the type and nature of syndesmotom fixation that should be advocated today. Lalli et al. demonstrated that at their institution removal of the screw resulted in an average individual patient operating room cost of \$3579, but this has yet to be compared in a properly powered, prospective cost containment study which involves the various methods of fixation [48].

“Dynamic” fixation of the syndesmosis with a suture button device has recently gained popularity due to a number of as yet unproven and predominantly hypothetical benefits, including the following: allowing physiological micromotion of the tibiofibular joint, no routine necessity for secondary surgery involving implant removal, the facilitation of early weight bearing, and the possible earlier return to work or sport [4, 51–54, 55]. Early short-term studies of the suture button device have suggested it to enable outcomes comparable to syndesmotom screw fixation, and as such it is now considered to be a viable alternative to positioning screw fixation. It is important to recognize, however, that these systems do not yet enjoy long-term follow-up, are still prone to technical complications, remain unproven for conferring any stability in the sagittal plane, and continue to be ill-defined with respect to what might be an appropriate number and placement of these devices. Because some data suggest that sagittal plane motion is more sensitive and perhaps even more important than coronal plane motion for syndesmotom instability, it remains unclear if these devices can be as effective as screw fixation in stabilizing the syndesmosis in all physiologic axes of movement while it heals [55, 56]. It is not yet known for how long these devices remain sufficiently effective, nor whether this form of “dynamic” fixation allows enough stability for the syndesmosis to adequately scar into place and maintain stability—particularly in the isolated syndesmotom instability pattern when no fracture is present—and when there may be plastic deformation of the fibula. It remains equally unclear, however,

if proper syndesmotom fixation benefits most from the rigid multiplanar fixation conferred by traditional screw and plate constructs. While some publications have documented excellent results using a form of suture button fixation, reports of superficial wound infection, chronic osteomyelitis, irritation from the suture knots, and creeping button migration/bony subsidence have been published using one version of this type of construct (Tightrope, Arthrex, Naples, FL) [51–53]. Both construct types seem equally prone to malreduction and technical limitation when there is lack of user familiarity.

Some limited investigations have attempted to compare dynamic suture button fixation with syndesmotom screw fixation [54, 57–62]. Westermann et al. performed a cadaveric study to see if there was a difference in the malreduction of syndesmotom injuries when comparing screw fixation with tightrope fixation [58]. They found that with anterior off-axis clamping, the mean sagittal malreduction was 2.7 ± 2.0 mm with screw fixation and 1.0 ± 1.0 mm with suture button fixation. They also found a difference in posterior off-axis clamping; the sagittal malreduction was 7.2 ± 2.3 mm with screw fixation and $.05 \pm 1.4$ mm with suture button fixation [58]. They concluded that suture button fixation of the syndesmosis results in less postoperative displacement in comparison to the more traditional screw fixation. However, Song et al. found patients who presented with a malreduced syndesmosis via initial postoperative axial CT scan actually reduced to normal following screw removal [50]. The science defining this problem is clearly limited at this time, and further research is needed on the long-term effects of dynamic fixation, whether it allows for the syndesmosis to adequately heal, and whether there is greater or lesser long-term benefit from constructs which confer less rigid initial fixation to the syndesmosis during the initial healing process [55, 63]. The authors also believe, based on clinical experience, that the importance of these questions is likely to differ dependent upon whether the syndesmotom injury is acute or chronic as well as isolated or associated with fracture—but ultimately this hypothesis must be proven by good scientific evidence, which currently does not exist.

Our current treatment of choice for isolated unstable syndesmotom injury is to perform arthroscopy to debride the interposed tissue in the syndesmosis and facilitate reduction. This also has the added benefit of diagnosing and treating any acute osteochondral defects at the time of surgery. At the very least, these injuries can be documented since they may correlate with a worse prognosis. This is followed by direct reduction under fluoroscopic control and then placement of two 4.0 mm quadricortical screws through a small one third tubular plate starting approximately 1.5 cm proximal to the joint line (Fig. 3). These screws are placed in a slightly divergent orientation to maximize fixation (pullout) strength. The patient is instructed to avoid weight bearing for the first 6 weeks, but is asked to commence range of motion exercises at 2 weeks

Fig. 3 Mortise (a) and lateral (b) weight bearing x-rays 6 weeks after fixation of an isolated syndesmotic injury demonstrate maintenance of the syndesmosis reduction. The screws are placed divergent through a plate

in order to maximize fixation strength. Three months after fixation the hardware was removed and the mortise (c) demonstrates maintenance of reduction

followed by progressive weight bearing and functional physical therapy over the next 4 weeks. Pre-planned screw removal is then scheduled for between 3 and 4 months postoperatively if the patient is doing well and there is evidence of sufficient scar formation to enable a durable syndesmotic alignment long term. Return to low impact non-pivot sporting activities is initiated when the patient can perform a single-leg hop after the screws are removed, but high impact competitive sports are avoided until 6 months postoperatively in all but the professional athlete. Acute injury fixation is accompanied by ligament repair, and chronic injury fixation is increasingly accompanied by ligamentoplasty (reefing), particularly when there has been no fracture present and hence a lesser chance of stimulating post-traumatic scar formation which can help stabilize the reconstruction. It should be remembered that there exists abundant literature over the past 50 years documenting relatively good outcomes after ORIF of rotational ankle fractures with fixation of concurrent syndesmotic instability using various combinations of traditional plate/screw/washer constructs. In the face of syndesmotic injury with associated fractures requiring ORIF, this form of repair in the absence of any other management has proven reliable over time for myriad patients [57, 64–67].

Other treatment options

Various additional repair and reconstructive augments to the syndesmotic ligaments have been described. If there are still remnants of the AITFL in place, then anatomical suture repair or imbrication of the anterior syndesmotic ligament is recommended, along with syndesmotic screw placement to protect this repair for at least 6 to 8 weeks [68]. These are usually for more acute injuries, though, and some authors such as Van den Bekerom et al. do not advocate this procedure if the problem is beyond 6 months post-injury [68]. Other studies have looked at ligamentous reconstruction if the AITFL is not spared [69–73]. Grass et al. describes a ligamentoplasty with a split peroneus longus tendon graft in 16 patients and found reliable

ankle stability and pain relief [73]. Similar techniques have been described for anterior syndesmosis reconstruction, but using either the extensor tendon of the fourth or fifth toe, or the plantaris tendon [69].

When patients have chronic instability or continue to have syndesmosis instability after fixation, they will have a higher chance of nonunion. A syndesmosis fusion can then be used as a salvage procedure in this setting [68, 74, 75]. Olson et al. looked at treating chronic syndesmotic instability after ankle fractures with reduction and arthrodesis of the distal tibiofibular articulation in 10 patients with a mean follow-up of 41 months (range, 29 to 44) [75]. The mean AOFAS ankle-hindfoot clinical rating score increased from 37 ± 15 preoperatively to 87 ± 11 at final follow-up ($p < 0.005$). All the patients were satisfied with their results and reported that they would repeat the operation again [75].

Treatment of non-isolated syndesmotic injuries

Non-isolated syndesmotic injuries with associated distal fibular fractures are common, particularly in the presence of Weber B and more often Weber C ankle fractures [11, 57, 76, 77]. Gill et al. found that in SER IV (Weber B) ankle fractures, the rate of revision fixation secondary to syndesmotic diastasis was 5% of all fractures that did not have a syndesmosis screw in the primary fixation [77]. In the setting of Weber B or C fractures, it is paramount that the fibula be anatomically reduced to obtain appropriate length; however, because in the absence of doing this, there will often end up being progressive lateral translation of the talus even when the syndesmosis is stable and/or properly stabilized surgically [2]. However, even though it is not as common, it needs to be noted that non-isolated syndesmotic injuries can also happen in Maisonneuve fibula fractures and isolated posterior malleolus fractures [2, 78–80].

Overall, syndesmosis instability is likely a complete different scenario when comparing isolated vs fractured and frank vs latent. Success is generally predicated on three things: (1)

restoring alignment, (2) maintaining alignment through sufficient fixation and/or scar long term, and (3) doing all this before more pathology develops in the unaddressed syndesmotic instability patient. It is our belief that isolated syndesmotic injuries may not sufficiently scar in comparison with an un-isolated syndesmotic injury because they do not bleed as much and/or have as much trauma to the area to stimulate scar formation.

Conclusion

Syndesmotic injury and syndesmotic instability are not interchangeable terms—and they do not represent the same pathophysiology. While prompt diagnosis and treatment of frank or non-isolated syndesmotic instability can be easy, ensuring such care for the latent and/or isolated presentation can be challenging and requires a high index of suspicion. It is becoming increasingly clear that overtreatment for such unstable injuries when they exist (i.e., early fixation and stabilization, even when perhaps not absolutely necessary) is probably better than under or non-treatment, since over time, the natural history of unaddressed syndesmotic instability appears to be associated with a poorer prognosis. Currently available data also suggest that the patient who presents with isolated or latent syndesmotic instability may have an entirely different pathology and natural history than those having syndesmotic instability associated with fracture and/or obvious displacement—and this may be related to the degree of surrounding trauma, the potential for post-injury native scar formation, and/or perhaps the confounding presence of underlying residual plastic deformity of the fibula in the absence of fracture. More attention needs to be paid to the differences between these patient populations and how best to manage them, including the need for any adjunct interventions.

Prompt diagnosis of syndesmotic instability is paramount for maximizing patient outcome, and it seems that in the near future, dynamic ultrasound and weight-bearing comparative CT scanning will become the non-invasive modalities of choice for this purpose. The role of arthroscopic assessment has yet to be truly defined, but this too represents a promising adjunct to both diagnosis and management, and its usefulness will be predicated on being able to reliably define parameters of instability as well as being able to simultaneously diagnose and manage the problem for the patient. Since natural history of these various presentations remains somewhat controversial, further science will be important for clarifying an ideal treatment algorithm for future patients, including determination of the specific roles for simple ORIF, ligamentoplasty augmentation, and overt syndesmotic fusion.

Clearly, there is a continuum of disease between the stable syndesmotic ligament injury which does not require surgery for good result, and the more severe ligamentous complex

injury which goes on to confer a clinical instability that responds best to operative stabilization. Another challenge for our field will be to better define the injury patterns that result in each patient subset so proper diagnosis and treatment can be more readily applied—and outcomes thereby improved. Optimized treatment techniques regarding fixation type, duration, and location also remain without consensus, even though it does seem clear that fixing unstable patterns by any means portends better long-term results than leaving such instability unaddressed.

Compliance with ethical standards

Conflict of interest Matthew L. Vopat, Bryan G. Vopat, and Bart Lubberts declare that they have no conflict of interest.

Christopher W. DiGiovanni reports stock options with Wright Medical, Paragon 28, and CreOsso. He is a consultant for Wright Medical and Extremity Medical. He also reports royalties from Extremity Medical.

Human and animal rights and informed consent This article does not contain any studies with human or animal subjects performed by any of the authors.

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