The Syndesmosis, Part II
Surgical Treatment Strategies

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KEYWORDS

- Syndesmosis • Syndesmotic instability • Surgical repair • Flexible fixation • Rigid fixation • Screw • Suture button

KEY POINTS

- The clinical consequences of undiagnosed syndesmotic instability far outweigh any incremental implications of its various fixation strategies.
- Effective treatment focuses on restoring fibular and periarticular anatomy, multiplanar fixation of the unstable syndesmosis, and ligamentoplasty or repair.
- Rigid screw and flexible suture button constructs can effectively treat syndesmotic instability.
- When destabilized, an overfixed syndesmosis works better than an underfixed or, worse, an unfixed one.
- Syndesmotic instability remains an incompletely understood continuum of disease severity, and is likely influenced by many other factors beyond injury to the syndesmotic ligaments themselves.

INTRODUCTION

Optimizing clinical outcomes after ankle fracture predicates restoring and maintaining the tibiotalar relationship. Even 1 mm of talar subluxation relative to the tibial plafond markedly alters contact areas.[1,2] Anatomic fixation of the affected malleoli and weight bearing surfaces is critical to this aim, but the ankle's mortise construct also requires that the fibula and tibia effectively bracket the talus. Very little stability is afforded by the tibial incisura itself, which is variable in morphology and can be concave or even convex.[3,4] Therefore, the stability of the distal tibiofibular articulation is instead enabled by a constellation of syndesmotic ligaments, including the anterior inferior tibiofibular ligament (AITFL), interosseous ligament (IOL), and posterior inferior tibiofibular ligament (PITFL).

Failure to diagnose and treat a destabilizing injury to the syndesmosis can result in significant and irreversible morbidity. The onus on the surgeon is, therefore, to first and foremost make the diagnosis given that the clinical implications of undiagnosed (and therefore untreated) syndesmotic instability arguably supersedes that of a slightly malreduced distal tibiofibular articulation.[5] In contrast, reduction and fixation strategies remain critical because patients with syndesmotic malreduction have been shown in some studies to have poorer clinical outcomes.[6] Effectively treating syndesmotic instability therefore requires an understanding of relevant anatomy, diagnostic strategies, reduction techniques, fixation options, as well as the implications of hardware choices and chronicity of injury.

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Orthop Clin N Am 52 (2021) 417–432
https://doi.org/10.1016/j.ocl.2021.05.011

DIAGNOSIS

There is no sine qua non test to diagnose syndesmotic instability, and therefore a high index of suspicion is necessary. Physical examination remains critical, with findings including tenderness over the anterior syndesmosis or a positive squeeze test at the mid fibula.[6] Imaging modalities almost invariably supplement physical examination, and include radiographs, MRI, computed tomography (CT) scans, and ultrasound examination. These modalities vary along 3 primary characteristics, namely, their ability to (1) visualize the ankle joint under stress, (2) afford a contralateral comparison, and (3) evaluate the distal tibiofibular joint in 3 dimensions (3D). Although radiographs allow the application of weight-bearing or external rotation stress, as well as a contralateral comparison, their inherent 2-dimensional nature limits their sensitivity.[7] Although MRI can demonstrate injury, ligamentous disruption may not correlate with instability, and does not afford a contralateral comparison. A CT scan, especially when performed under weight bearing conditions, allows evaluation of the syndesmotic relationship under physiologic load in 3D, and allows bilateral assessment (Fig. 1). The latter is critical because the variability in morphology of the distal tibiofibular articulation between individual patients necessitates use of the contralateral, uninjured ankle as an internal control (Fig. 2).[8] weight bearing CT scan also allows 3D volumetric measurements that have a heightened sensitivity as compared with traditional 1-dimensional distance or even 2-dimensional area measurements.[9] Ultrasound examination may represent the future gold standard for diagnosing instability, especially as compared with invasive arthroscopy, because of its ability to evaluate bilateral tibiofibular articulations under stress and at the point of care, with minimal cost and no ionizing radiation exposure.

ANATOMY

As alluded to elsewhere in this article, the distal tibiofibular articulation has very little inherent bony stability. The tibial incisura that cradles the fibula demonstrates enormous variability in morphology and can be quite shallow in upwards of one-third of patients, implying the critical role of ligamentous constraints in preventing abnormal motion.[10] The AITFL, IOL, and PITFL work in concert to prevent fibular translation in the coronal and sagittal planes, as well as constraining fibular rotation and pistoning (Fig. 3). Notably, the collateral ligaments of the ankle also help to stabilize the distal tibiofibular joint, presumptively by anchoring the fibula to the tibia through the talus. Injury to structures such as the deltoid ligament can contribute to syndesmotic instability.[11]

Much like the shoulder joint, this lack of inherent bony constraint implies that the fibula can and does submit to moving in multiple directions when the syndesmosis is rendered unstable. Although coronal plane diastasis has traditionally been used during fluoroscopic stress examination, sagittal plane fibular motion may be more sensitive in diagnosing instability.[12] The advantage of this preoperatively is that a Cotton maneuver is inherently invasive, and accessible surrogates such as an external rotation test may primarily test deltoid competence rather than syndesmotic ligament integrity.[13,14] Preoperative sagittal plane motion can be assessed using a fibular shuck maneuver and even visualized with ultrasound.[15] Intraoperatively, sagittal plane fibular motion can readily be visualized as the fibula moves relative to the anterior lip of the incisura.

REDUCTION STRATEGIES

The paucity of bony restraints at the distal tibiofibular articulation complicates anatomic reduction because, unlike many other joints, the distal syndesmosis does not simply click into place. A few points, however, are worth noting when considering the published literature on reduction strategies. First, no attempt at avoiding malreduction of the syndesmosis can overcome malreduction of associated fractures, especially of the fibula. Failure of syndesmotic fixation is often representative of fibular shortening and the associated loss of lateral talar buttress, rather than an actual failure of syndesmotic reduction technique (Fig. 4). Second, an assessment of reduction quality inherently requires a comparison with the contralateral, uninjured side given enormous variations in tibiofibular morphology between individuals. Not all published studies incorporated bilateral assessments. Third, qualitative side to side comparisons of bilateral ankle weight bearing CT scan imaging has been shown to have a very poor interobserver interclass correlation coefficient when assessing whether the syndesmosis is malreduced (correlation coefficient, 0.26), whereas advanced, quantitative 2-dimensional techniques such as syndesmotic area demonstrate excellent correlation (correlation coefficient, 0.96).[9] This factor may explain why some

Fig. 1. Patient is a 21-year-old man who was injured while rock climbing and presented 9 months after injury with persistent ankle pain despite a period of immobilization and physical therapy alongside tenderness at the distal syndesmosis and positive fibular squeeze test. A weight bearing CT scan demonstrated subtle asymmetric widening at the distal tibiofibular articulation and MRI revealed chronic AITFL rupture (*white arrows*). Patient underwent surgical fixation of a chronically unstable syndesmosis with suture button fixation and direct AITFL imbrication. (*From* Ramsey P, Hamilton W. Changes in tibiotalar area of contact caused by lateral talar shift: The Journal of Bone & Joint Surgery. 1976;58(3):356-357. https://doi.org/10.2106/00004623-197658030-00010; with permission.)

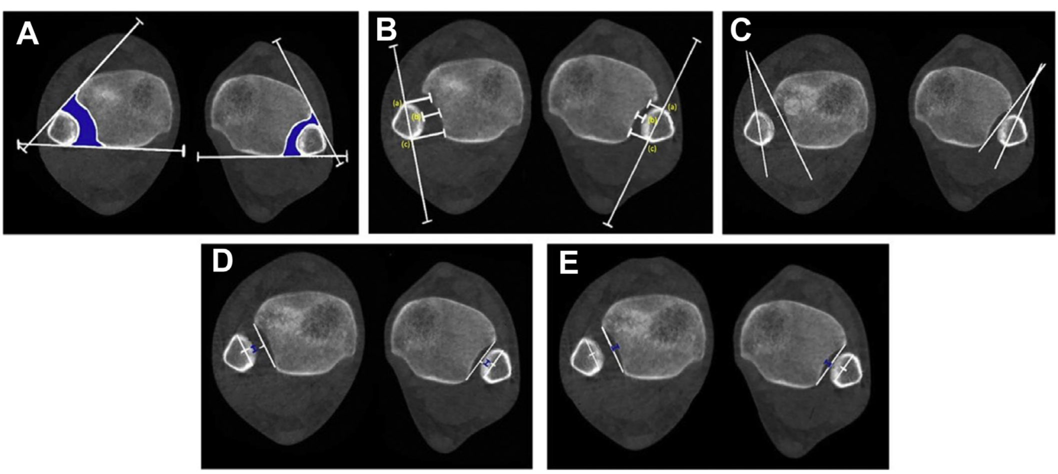

Fig. 2. Tibiofibular joint measurements. (*A*) Syndesmotic area (*shaded area*). (*B*) Direct anterior (a), middle (b), and direct posterior (c) differences. (*C*) Fibular rotation. (*D*) Sagittal translation (*dark line*). (*E*) Incisura depth (*dark line*). The patient had right-sided syndesmosis instability after an acute posterolateral ankle dislocation. (*From* Hagemeijer NC, Chang SH, Abdelaziz ME, et al. Range of Normal and Abnormal Syndesmotic Measurements Using Weightbearing CT. Foot Ankle Int. 2019;40(12):1430-1437. https://doi.org/10.1177/1071100719866831; with permission.)

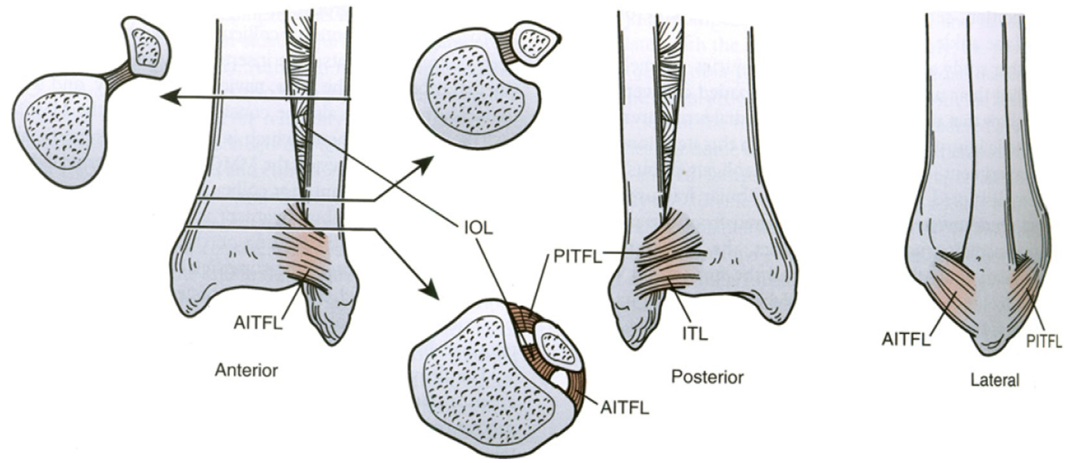

Fig. 3. Drawing of the ligamentous anatomy of the distal tibiofibular syndesmosis with anterior, posterior, lateral, and axial cut views. ITL, inferior transverse ligament. (*From* Davidovitch RI, Egol KA. Ankle fractures. In: Bucholz RW, Heckman JD, Court-Brown CM, Tornetta P, editors. Rockwood and Green's fractures in adults. 7th ed. Philadelphia: Lippincott Williams & Wilkins; 2010. Figure 57-12; with permission.)

studies have concluded that intraoperative use of a CT scan does not necessarily decrease the rate of malreduction.[16] Last, although it may seem intuitive that a malreduced syndesmosis may predicate poorer outcomes, there is a "chicken and the egg" component to such conclusions, wherein the severity of injury that made it more difficult to effectively decrease the syndesmosis may supersede the clinical implications of a malreduction, especially if subtle. It must also be pointed out when reviewing recent reports discussing this concept that gross syndesmotic malreduction is not the same as subtle syndesmotic malalignment. This concept is suggested implicitly by the fact that, although up to one-half of patients may demonstrate syndesmotic malreduction in some published studies, the majority of patients who undergo syndesmotic fixation nonetheless do well postoperatively—and syndesmotic malreduction is often defined as literally being off by a few degrees or 1 to 2 mm after fixation. Although these realignments are not ideal, applying reduction perfection standards to any other orthopedic procedure with 3-dimensional imaging would likely offer similar results, and in this case there are also data to suggest that when the hardware is removed, fails, loosens, or stretches out over time that many of these alignments may indeed end up finding "their real home" a few millimeters or a few degrees away if all other surrounding bony structures were fixed properly.[17] We still do not have the answer to the question "how close do we need to be?", let alone the question "how close can we actually ensure we get?" What is clear, however, just like with routine fracture care, is that there is a big difference over the long term between minor malposition and gross residual malalignment or deformity. Therefore, making the diagnosis may arguably be more critical than the various fixation strategies themselves.

With these ideas in mind, some strategies do exist to minimize malreduction of the distal tibiofibular articulation. In 1 study, open visualization of the anterior fibula relative to the anterior incisura decreased the malreduction rates from 44% to 15% as compared with closed reduction without directly accessing the distal tibiofibular joint.[6] Some investigators have advocated for basing reduction based on a perfect fluoroscopic lateral of the contralateral talus before draping.[18] The distance between the posterior fibula and posterior tibia, as well as the converse anteriorly, is then used to assess the quality of reduction on the operative limb, resulting in a 6% rate of malreduction. When using reduction forceps, the placement of the medial tine is also critical toward achieving an anatomic reduction. Studies suggest that the medial tine should be placed in the anterior one-third of the medial tibia, resulting in 0% rates of malreduction in one study, while placing the tine in the middle or posterior third of the medial tibia will malreduce the syndesmosis 19% and 60% of instances, respectively.[19]

Broadly, effective reduction of the syndesmosis requires first and foremost anatomic reduction of associated fractures, with a special emphasis on avoiding fibular shortening. The

Fig. 4. Example of a 19-year-old patient who presented with an ankle fracture who underwent initial fixation with the fibula in a shortened position and without achieving articular congruency. One year later, she developed severe tibiotalar arthritis with valgus tilt and was referred for additional management. Attempted salvage entailed a fibular lengthening osteotomy and syndesmotic fixation. Initial repair of an unstable syndesmosis cannot overcome fibular or intra-articular malunion, and she will almost certainly need additional procedures in the future for severe post-traumatic arthritis.

diagnosis of instability is more readily based on a sagittal anterior–posterior and posterior–anterior stress than a Cotton maneuver, although both tactics may be pursued. An excess of 2 mm of total fibular motion in the sagittal plane is considered unstable.[12] The anterior lip of the incisura should always be visualized relative to the anterior fibula when performing a reduction, ensuring that a freer or other thin instrument cannot be readily inserted into this space. Especially when treating chronic instability, the distal tibiofibular joint should be formally debrided while protecting the articulation's cartilage; a laminar spreader can facilitate access with a pituitary rongeur. Preoperative, bilateral CT scans can be incredibly useful in more severe cases of distal tibiofibular diastasis, especially if the fibular fracture is proximal and will not be directly reduced, to facilitate an understanding of the reduction maneuver. The medial tine of a reduction clamp should be placed in the anterior one-third of the medial tibia but, if the fibula is significantly translated, a rotational motion of the clamp may also be necessary in addition to any simple, single vector compression.

RIGID FIXATION

Technical considerations inherent to screw fixation across the syndesmosis have included screw location, orientation, diameter, the number of screws used, and the number of cortices incorporated into the construct.[20,21] The most controversial topic, however, is the potential for syndesmotic malreduction using rigid fixation. Inextricable from this concern is the underlying reality that, if the syndesmosis is malreduced before the screw is placed, it will almost certainly stay malreduced after screw fixation.

Miller and colleagues examined the potential for syndesmotic malreduction with screws in a cadaveric study using a CT scan and found that the clamp must be placed from the posterolateral fibula to the anteromedial tibia angled at 15° relative to a direct lateral of the talus (as compared with 0° or 30°) to minimize malreduction (Fig. 5).[22] With the clamp in this position, they then went on to conclude that a syndesmotic screw placed from the lateral fibula should be angled 0° and a screw placed from the posterolateral fibula should be angled 30°. It should be noted that the absolute amount of malreduction averaged less than 1 mm in each instance. Therefore, a statistically significant malalignment may not translate into clinical significance. A separate study examining CT scans of uninjured syndesmoses among patients presenting with calcaneal fractures found that syndesmotic screws should be angled 18° relative to the coronal plane.[23] Given recent studies showing the usefulness of manual reduction, we preferentially use a lag screw technique rather than a clamp to reduce the syndesmosis when using rigid fixation unless displacement is severe, though one must avoid overtightening to prevent overcompression.[24]

Biomechanical and clinical studies have demonstrated no significant impact on the

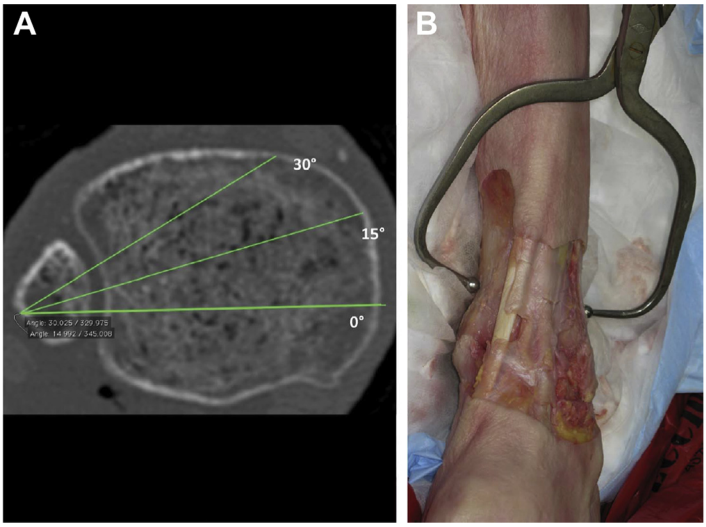

Fig. 5. Examples of angulation measurement for clamp and screw placement. (*A*) An axial CT scan measurement showing 0°, 15°, and 30° angulation from the posterolateral corner of the fibula. These are measured 2 cm proximal to the joint and compared with the Kirschner wires 4 cm proximal to the joint for clamp pilot hole placement. (*B*) A clinical example of a cadaver limb postdissection with clamp in place and ready for CT evaluation. (*From* Miller AN, Barei DP, Iaquinto JM, Ledoux WR, Beingessner DM. Iatrogenic syndesmosis malreduction via clamp and screw placement. J Orthop Trauma. 2013;27(2):100-106. https://doi.org/10.1097/BOT.0b013e31825197cb; with permission.)

mechanical stability between tricortical versus quadricortical fixation. Likewise, although 4.5-mm screws afford greater resistance to breakage, this factor may not translate into better clinical outcomes when compared with 3.5-mm screws.[25] The composition of the screw has not shown differences in clinical or radiographic results.[26] However, bioabsorbable screws have been associated with increased foreign body reactions.[27]

Whether 1 or multiple screws are required to achieve adequate syndesmotic fixation is debatable. Multiple screws are usually considered in neuropathic, severely osteoporotic patients, or patients with Maisonneuve injuries to increase the stability of the construct. In grossly unstable syndesmotic injuries with severe fracture comminution or poor bone quality we lean toward screw fixation owing to the rigidity of the system, which also augments fixation of the fibula fracture. In the setting of rigid fixation, we recommend using two 3.5- or 4.0-mm screws starting at or slightly above the physeal scar. The screws may be placed in a slightly divergent direction to maximize fixation strength.

FLEXIBLE FIXATION

As discussed elsewhere in this article, the fixation principles designed to most closely restore natural syndesmotic ligament function for rigid fixation constructs apply equally well to implementation of any flexible construct. Flexible syndesmotic fixation has over the past 15 years become an increasingly popular method for syndesmotic repair. Although there are multiple forms of flexible syndesmotic fixation, the suture button construct is the most commonly used. The purported advantage of flexible fixation, as implied by its name, is that it allows some degree of fibular motion relative to the tibia, more closely mimicking physiologic fibular motion. In theory, this factor also enables the fibula to reduce within the incisura without being entirely bound to its initial reduction position.[28–31] Suture button devices also potentially obviate the need for removal of hardware as is sometimes performed after rigid screw fixation.

Studies have indeed shown that flexible syndesmotic fixation can decrease malreduction rates at the distal tibiofibular joint. A cadaveric study by Westermann and colleagues[32] found that, even with deliberate malreduction using a clamp, suture button constructs can compensate for both anterior and posterior off-axis clamping (Fig. 6). With deliberate anterior off-axis clamping, sagittal malreduction was 2.7 $\pm$ 2.0 mm with screw fixation as compared with 1.0 $\pm$ 1.0 mm with suture button fixation (P = .02). With deliberate posterior off-axis clamping, sagittal malreduction was 7.2 $\pm$ 2.3 mm with screw fixation as compared with 0.5 $\pm$ 1.4 mm with suture button fixation (P<.01). The authors concluded that flexible syndesmotic fixation allowed for a self-reduction toward an anatomic distal tibia–fibula relationship.

By providing a tension vector across the distal tibiofibular articulation, a suture button construct attempts to mimic the constraint afforded by an intact ligament. In contrast,

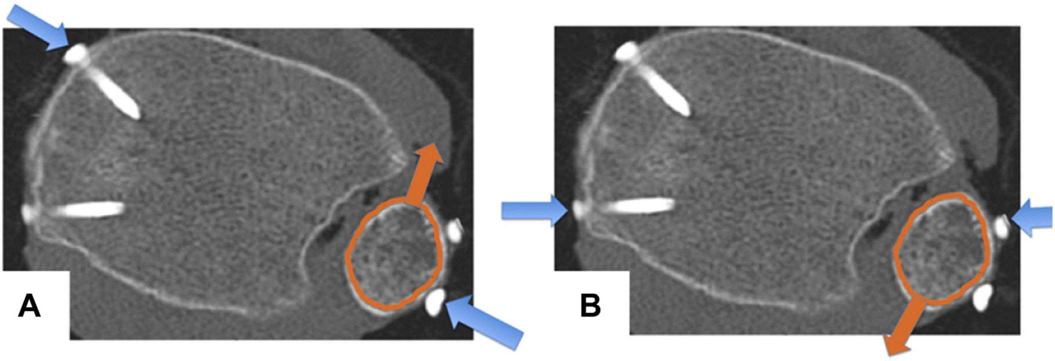

Fig. 6. Representative axial CT images 10 mm proximal to the tibiotalar joint illustrating the 2 malalignment conditions. To produce anterior displacement of the fibula (*orange arrow*) relative to the incisura fibularis (*A*), prongs of the tenaculum were placed engaging the posterior fibular screw head and the anterior tibial screw head (*blue arrows*). To produce posterior displacement of the fibula (*orange arrow*) relative to the incisura fibularis (*B*), prongs of the tenaculum were placed engaging the anterior fibular screw head and the posterior tibial screw head (*blue arrows*). (*From* Westermann RW, Rungprai C, Goetz JE, Femino J, Amendola A, Phisitkul P. The effect of suture-button fixation on simulated syndesmotic malreduction: a cadaveric study. J Bone Joint Surg Am. 2014;96(20):1732-1738. https://doi.org/10.2106/JBJS.N.00198; with permission.)

because the incisura itself offers very little bony constraint, a ligament that works under tension affords very little restraint to orthogonal forces. The AITFL, IOL, and PITFL overcome this by being divergent in orientation. Accordingly, Clanton and colleagues[33] compared 3 methods of syndesmotic fixation in a cadaver model: (1) one 3.5-mm syndesmotic screw, (2) 1 suture button construct, and (3) 2 divergent suture button constructs. They found similar resistance to internal and external rotation between all 3 constructs and the intact syndesmosis, but posterior sagittal plane translation was best constrained by screw fixation with only 2.5 mm of translation as compared with 4.6 mm with a single suture button construct and 2.9 mm with 2 suture buttons. Similarly, anterior sagittal translation was only 0.1 mm with screw fixation compared with 2.7 mm with a single suture button construct and 2.9 mm with 2 suture buttons. The authors concluded that a single suture button construct for syndesmotic repair was insufficient to control sagittal translation of the fibula.

A separate cadaveric study by Klitzman and colleagues[30] demonstrated that, after 100 cycles of loading, suture button fixation resulted in significantly increased sagittal plane motion (3.17 mm) as compared with the intact syndesmosis (2.77 mm, $P = .006$), but that screw fixation resulted in overconstraint (1.16 mm; $P \leq .001$). The relative advantage of overconstraint versus underconstraint during the initial healing period remains to be entirely elucidated.

The role of suture button constructs in obviating the need for hardware removal has been highlighted as a cost-saving benefit. Neary and colleagues[34] performed a cost-effectiveness analysis for the use of suture button versus syndesmotic screw fixation in supination–external rotation type IV ankle injuries. Through their comparative decision analysis model, assuming a 4% suture button hardware removal rate and 20% syndesmotic screw removal rate, the total cost for 2 syndesmotic screws was US$20,836 compared with $19,354 for syndesmotic repair using a suture button fixation. Therefore, it seemed that, when a return to the operating room for hardware removal was included in the cost of the implant, syndesmotic fixation using flexible options or screws are quite comparable in terms of overall costs. Their analysis modeled an estimated implant cost of 2 screws versus 1 suture button construct as $64.50 versus $880.00, respectively. The results of a cost analysis may change as surgeons start using multiple, divergent suture buttons to better approximately normal ligamentous orientation. In contrast, the indirect costs to the patient of a return to the operating room, such as lost wages, should also be taken into account.

One must note, however, that not all studies have replicated a low return to the operating room with suture button constructs. One early case series of 24 patients demonstrated suture button removal of rates of 25% and another case series of 19 patients demonstrated a removal rate of 26%, most frequently owing to skin irritation.[35,36] More recent studies have not necessarily replicated these high numbers, and it is possible that knotless constructs may obviate removal.

From a technical point of view, most versions of flexible syndesmotic fixation rely on fixation on the medial aspect of the distal tibia, which can put the saphenous neurovascular structures at risk.[37] Furthermore, tunnel placement on the relatively narrow fibula at an oblique angle can be challenging, especially because most forms of flexible syndesmotic fixation require drilling that is, larger than the comparable drill size for a standard syndesmotic screw, often in the 3.2 mm to 3.7 mm range to allow passage of the device. The combination of larger size tunnel along with the nonabsorbable suture construct and fibular motion can lead to tunnel widening and osteolysis.[35,38] Some of this may be mitigated by routinely using a fibular plate to act as a washer, even in Maisonneuve injuries when there is no distal fibular fracture. One should also have a low threshold for making small incisions medially, which not only protects the saphenous vein and nerve, but also has the secondary benefit of ensuring the medial hardware sits directly on bone rather than on soft tissue that can attenuate over time.

Allograft and Autograft Reconstruction

Allograft reconstruction of the syndesmosis is far less common than screw fixation or flexible syndesmotic fixation but some of its concepts of specific ligament repair such as the AITFL are being used readily with suture tape or allografts constructs. Recent biomechanical studies that have isolated the different ligamentous components of the ankle syndesmosis have demonstrated the importance of the AITFL and PITFL with regards to syndesmotic integrity. In a cadaveric study Clanton and colleagues,[33] under simulated physiologic conditions, tested the intact syndesmosis demonstrating 4.3° of fibular rotation and 3.3 mm of fibular sagittal translation. Sectioning of the AITFL resulted in the greatest reduction of resistance to external rotation—an average of 24% (**Fig. 7**). Similarly, Littlechild and colleagues[39] evaluated the effects of the individual syndesmotic components on preventing talar shift in ankle fractures. They found that division of the AIFTL resulted in a 3 times greater lateral talar shift when compared with the PITFL. Therefore, the authors concluded that repairing the PITFL—often through repair of a posterior malleolus fracture—may not be sufficient to prevent lateral talar shift and AITFL reconstruction should be considered as an augment to syndesmotic fixation.

Several studies have described different techniques for reconstruction of the syndesmosis using autograft or allograft tendon, but are limited to case reports or small retrospective case series without control or comparison groups. Nevertheless, they offer possible techniques for tendinous syndesmotic reconstruction in cases of chronic instability where prior screw holes may prevent or impair revision hardware placement and provide possible means to reconstruct the individual important components of the syndesmosis such as the AITFL in the acute syndesmotic injury as our understanding of this specific augmentation evolves. Nelson and colleagues[40] reported on a case series of 50 patients with trimalleolar ankle fractures who additionally underwent isolated AITFL repair using an extensor digitorum longus tendon autograft or suture that was anchored with screws and washers at the native AITFL footprints as the sole means of syndesmotic reconstruction. Forty-nine patients (98%) reportedly demonstrated stabilization of the ankle mortise intraoperatively after this procedure.[40] Yasui and colleagues[41] reported on 6 patients with chronic syndesmotic instability undergoing screw fixation alongside anatomic AITFL autograft reconstruction with bone tunnels. Patients demonstrated significant improvements in median AOFAS (AOFAS) scores from 53 preoperatively to 95 at the final follow-up.

Future studies are necessary, especially regarding the indications for ligament reconstructions and the relative usefulness to nonabsorbable suture tape constructs. Importantly, ligamentous procedures to supplement any additional fixation may become more critical in the chronic as compared with the acute state of syndesmotic instability.

CLINICAL OUTCOMES: RIGID VERSUS FLEXIBLE FIXATION

There have been multiple prospective, randomized clinical trials comparing suture button versus screw fixation. Anderson and colleagues[28] randomized 97 patients with acute syndesmotic injuries to stabilization with a suture button or with a single quadricortical 4.5 mm syndesmotic screw. Full weight bearing was initiated at 6 weeks postoperatively and the syndesmotic screw was removed 10 to 12 weeks after surgery. The median AOFAS score at 2 years postoperatively was higher in the suture button group at (96; interquartile range, 90–100) compared with the syndesmotic screw group (86; interquartile range, 80–96; P = .001), and similar differences were seen in other legacy scales such as the Olerud–Molander Ankle (OMA) Scale, a self-reported

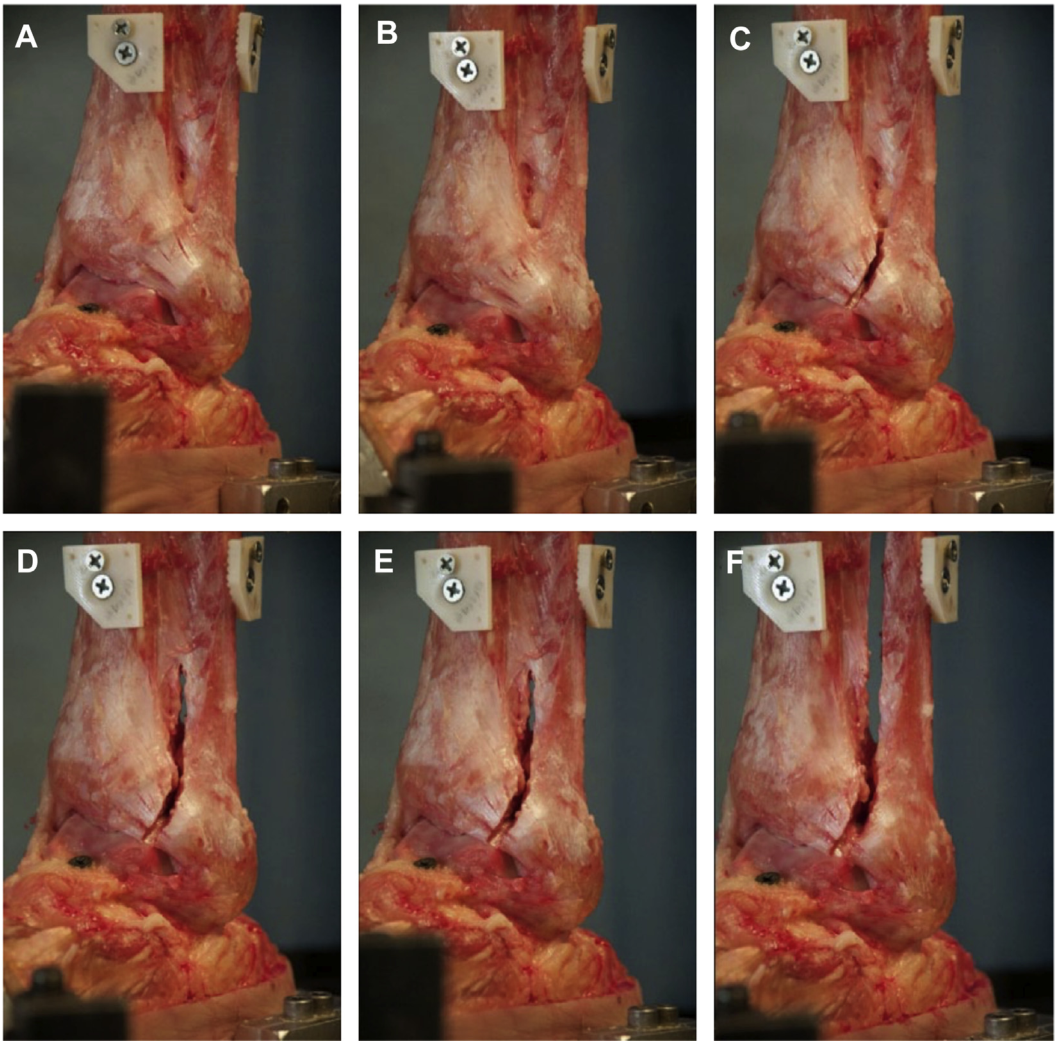

Fig. 7. Photographs of a left lower leg specimen following sequential anterior-to-posterior sectioning. Neutral rotation. (*A*) Intact syndesmosis with 15° external rotation. (*B*) Intact syndesmosis. (*C*) AITFL sectioned (state 1AP). (*D*) AITFL + ITFL sectioned (state 2AP). (*E*) AITFL, ITFL, deep PITFL, and superficial PITFL sectioned (state 4AP). (*F*) IOM sectioned (all cut). (*From* Clanton TO, Williams BT, Backus JD, et al. Biomechanical Analysis of the Individual Ligament Contributions to Syndesmotic Stability. Foot Ankle Int. 2017;38(1):66-75. https://doi.org/10.1177/1071100716666277; with permission). IOM, interosseous membrane.

functional scale. Additionally, they found that the suture button group reported less pain with walking (but not daily activity) at 2 years postoperatively, although pain scores were low in both groups with a median visual analog scale scores of 1 or less. They also attained bilateral, non-weightbearing CT scans at 2 weeks or less, 1 year, and 2 years with a threshold of 2 mm of asymmetry between the injured and uninjured side defining malalignment. Whereas no significant difference in alignment was seen at the initial CT scan at 2 weeks or less, 20 of 40 patients in the syndesmotic screw group had a difference in the tibiofibular distance 2 mm or greater compared with 8 of 40 patients in the suture button group (P = .009) (Fig. 8). There were no cases of symptomatic recurrent diastasis in the suture button group compared with 7 in the screw group. The authors concluded that the suture button group demonstrated better clinical outcomes and radiographic alignment then the screw fixation group. They additionally performed a subgroup multivariable analysis because, despite randomization, the screw fixation group included more patients who also sustained posterior malleolar

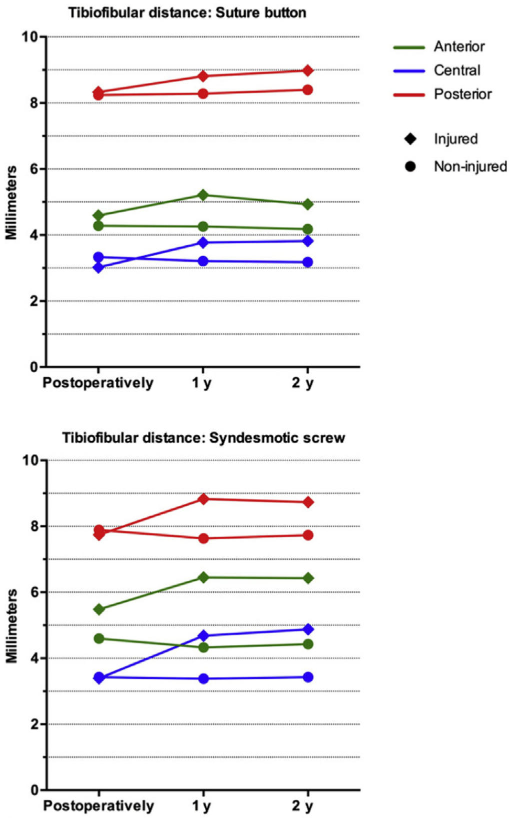

Fig. 8. Graphs comparing the mean anterior, central, and posterior tibiofibular distances between the injured and uninjured ankles over time in the 2 groups. At 1 and 2 years, the differences between the injured and uninjured ankles with respect to the anterior (P = .01) and central (P = .01) tibiofibular distances in the SS group were significantly greater than those in the SB group. The differences in the anterior, central, and posterior tibiofibular distances between the injured and uninjured ankles increased from the radiographs made within 2 weeks postoperatively to those made at 1 year in both the SS group (P = .003 for anterior, $P < .001$ for central, and $P < .001$ for posterior) and the SB group (P = .02 for anterior, $P < .001$ for central, and P = .03 for posterior). (*From* Andersen MR, Frihagen F, Hellund JC, Madsen JE, Figved W. Randomized Trial Comparing Suture Button with Single Syndesmotic Screw for Syndesmosis Injury. J Bone Joint Surg Am. 2018;100(1):2-12. https://doi.org/10.2106/JBJS.16.01011; with permission.)

fractures (73% vs 52%) and combined posterior/medial malleolar fractures (43% vs 25%). They still found that the method of fixation was the single determining aspect.

Notably, contemporaneous commentary about the study cautioned against the use of legacy scales (such as the AOFAS hindfoot score) that are nonvalidated and hampered by the fact that data becomes skewed when the subelements of the score (in this case “categories of measurement, surgeon evaluation, and patient report” that make up the AOFAS score) interact with each other. It also noted that in this specific study the data was skewed when examined for normality, and that the magnitude of differences in pain were quite small.

Laflamme and colleagues[42] conducted a prospective, multicenter randomized double-blind controlled trial to compare the clinical and radiographic outcomes of acute syndesmotic injuries stabilized with a suture button (n = 33) versus 1 quadricortical 3.5-mm syndesmotic screw (n = 32). Better OMA scores were seen at 3 months (68.8 vs 60.2; P = .067), 6 months (84.2 vs 76.8; P = .082), and 12 months (93.3 vs 87.6; P = .046) in the suture button group compared with the syndesmotic screw group. However, although the AOFAS scores were better in the suture button group as compared with the screw fixation group at 3 months postoperatively (78.6 vs 70.6; P = .016), there was no significant difference at 6 months (87.1 vs 83.8; P = .26) or 12 months (93.1 vs 89.9; P = .26). They reported loss of reduction in the syndesmotic screw group in 4 cases (11.1%) compared with none in the suture button group, defined by plain radiographs. They also noted that in 3 of those 4 cases the loss of reduction was after screw removal, and that if these 3 patients were omitted from the analysis, radiographic differences were no longer present. Additionally, there was a higher implant failure rate, described as screw breakage, in the screw group compared with the suture button group (36.1% vs 0%; $P<.05$), although none of these breakages were associated with the loss of radiographic reduction. There were no significant differences in return to sporting activities. The authors concluded that suture button fixation was a reliable method of repair and seemed to have slightly better clinical and radiographic outcomes compared with screws with a lower failure and reoperation rate.

The explicit clinical consequences of syndesmotic malreduction, and therefore the benefit of suture buttons, can be difficult to tease out given the myriad of factors that may interplay in predicating malreduction. One study by Sagi and colleagues[6] identified 68 patients who were at least 2 years status post surgical treatment of an ankle fracture with syndesmotic fixation and invited them for clinical, radiographic, and bilateral CT evaluation. They found a malreduction rate of 39.7% overall, although this rate decreased to 15% among patients who had open rather than closed reduction of the distal tibiofibular articulation, and statistically poorer outcomes on the Selective Functional Movement Assessment general health questionnaire and OMA scale in malreduced patients. Malreduction was subjectively defined by 1 reviewer, and it was unclear whether injury severity predicated the malreduction and therefore confounded clinical outcomes. A study by Andersen and colleagues[28] examined 87 patients who had undergone syndesmotic screw fixation and found that a diastasis of more than 2 mm on a CT scan measured at the anterior incisura (but not the posterior incisura) seemed to correlate with poorer outcomes on OMA and AOFAS scores. In contrast, a study by Warner and colleagues[43] failed to find significant differences in Foot and Ankle Outcome Scores among patients who had undergone screw fixation and had residual malreduction on a CT scan as defined by a series of quantitative measurements. They had set out to redefine the 2-mm threshold that traditionally described clinically impactful malreduction, and were unable to do so. They concluded that adequacy of fracture and articular reduction may play a much more significant role.

It should be noted that many of these studies found that malreduction rates increase over time. In the study by Anderson and colleagues there was no significant difference in measured tibiofibular distance on CT between screws and suture buttons at the 2-week scan, but such differences manifested at 1 year when only screws had been routinely removed. The study by Laflamme and colleagues[42] used radiographic measurements and similarly found no significant differences immediately postoperatively nor at 3 months, but did note differences starting at 6 months. This finding may suggest that the length of time during which stabilizing hardware is necessary across the syndesmosis may be longer than traditionally thought.

From these authors' point of view, although it has been reported that less rigid fixation better enables the body to finds its natural position after fixation, it does not state that using flexible fixation enables better anatomic reduction. In both cases, we are still falling short in achieving perfect reduction, and rather than aspiring to such, perhaps more focus and debate in the years ahead should focus on the manner in which we insert fixation and restore bony and ligamentous balance instead of the kind of fixation we use. Said differently, these authors feel that our most effective treatment strategy would focus on (1) restoring fibular and periarticular fracture anatomy, (2) providing multiplanar syndesmotic fixation to confer sufficient stability after reduction in a manner that is most consistent with the uninjured state, and (3) restoring normal resting length and orientation to the distal syndesmotic ligament complex through either direct reapposition, repair, or ligamentoplasty when necessary (depending on whether this is done in the acute or chronic setting). If these 3 tenets are followed during any syndesmotic fixation procedure, then on a relative scale of import, it is probably a matter of personal preference what "kind" of hardware one ultimately chooses to insert.

REMOVAL OF HARDWARE

Generally speaking, arguments supporting removal of syndesmotic screws are based on concerns that rigid trans-syndesmotic fixation may contribute to abnormal ankle kinematics.[44–46] Functionally, screw fixation immobilizes the distal tibia–fibula articulation allowing for ligamentous healing. Rigid fixation, however, inhibits physiologic fibular translation and rotation and may also limit dorsiflexion.[44,45] Hardware removal after successful healing may serve to restore physiologic motion of the syndesmosis and ankle joint. As such, some investigators continue to support removal before weight-bearing at 6 to 8 weeks.[47] Unfortunately, formal recommendations, as well as the timing of removal if indicated, have not been well-established in the literature and clinical practice remains highly variable.

The removal of syndesmotic fixation has been examined extensively with a range of levels of evidence present in the current literature. The majority of such studies are level IV evidence and have focused on removal of metal screws. To the best of our knowledge, no study has examined outcomes after removal of suture button devices. Although an exhaustive review is beyond the scope of this article, the literature supports the fact that there is little clinical, radiographic, or functional benefit to screw removal for the majority of patients. However, the more recent literature seems to support the notion that syndesmotic screw removal should be considered in symptomatic patients with intraosseous screw breakage (where pain can be directly attributable to the screw), well-fixed screws limiting motion, and/or in cases of syndesmotic malreduction. Furthermore, newer studies have revisited the effects of screw removal on ankle dorsiflexion.

Boyle and colleagues[48] performed a level I investigation examining syndesmotic screw removal. The authors randomized 51 patients to either screw retention or removal at approximately 3 months postoperatively. Clinical, radiographic, and patient-reported outcome measures such as the OMA score, American Orthopedic Foot and Ankle Society ankle–hindfoot score, American Academy of Orthopedic Surgeons foot and visual analog score were used. Trans-syndesmotic screw removal yielded no significant functional, clinical, or radiologic benefit in adult patients at the 1-year follow-up.

Several systematic reviews have similarly echoed these findings. Schepers[49] challenged the practice of routine screw removal in their 2011 review drawing evidence from 7 studies published from January 2000 to October 2010. Six of those studies found no difference in outcomes in patients when comparing screw retention versus removal.[50–54] Only 1 study showed favorable outcomes with screw removal, demonstrating that an intact screw was associated with worse functional outcome as compared with loose, broken, or removed screws.[55] These authors provided evidence that screw removal is unlikely to benefit patients with loose or fractured screws, but may be indicated in patients with intact screws and that removal should be pursued if still intact after 6 months. The mean time of removal for all 7 studies was approximately 3 months. Walley and colleagues[56] examined the literature from 2010 to 2016. A total of 9 studies were included. Overall, there was no difference in the functional, clinical, or radiographic outcomes in patients who had screw removal. The authors reported a higher likelihood of recurrent syndesmotic diastasis when screws were removed between 6 and 8 weeks and higher rates of postoperative infections when screws were removed without administering preoperative antibiotics.

Ankle range of motion after screw removal, in particular dorsiflexion, continues to be examined in the literature. Although improving ankle motion is a commonly considered clinical indication for screw removal, the current literature is conflicting. Miller and colleagues[45] examined range of motion after removal of a locking plate/screw construct for syndesmotic stabilization in 2010. Although the authors noted significant improvements in range of motion, Foot and Ankle Outcome, and OMA scores at the immediate postoperative visit in 25 patients, methodologic issues existed. A less commonly used locking screw construct was used in their study. Furthermore, range of motion was assessed by an unblinded researcher using goniometric measurements and unmeasured applied ankle dorsiflexion force, which has been demonstrated to be of relatively poor reliability. In 2019, Briceno and colleagues[57] examined ankle dorsiflexion before and after nonlocked screw removal using a standardized dorsiflexion force with range of motion assessed radiographically. A standardized torque force was applied to the ankle and a perfect lateral radiograph was obtained immediately before removal, immediately after removal, and at 3 months after removal (Fig. 9). The authors demonstrated no statistically significant difference in ankle dorsiflexion at all 3 time points. Most recently, Kohring and colleagues[58] published results of a 2020 investigation compared 58 patients with ankle fractures who underwent syndesmotic screw removal with 71 patients who did not undergo removal. The authors demonstrated significant improvements in Patient-Reported Outcomes Measurement Information System physical function outcomes and mean improvement of total arc ankle range of motion by 17°.

Syndesmotic screw breakage may be more problematic than previously reported. Ibrahim

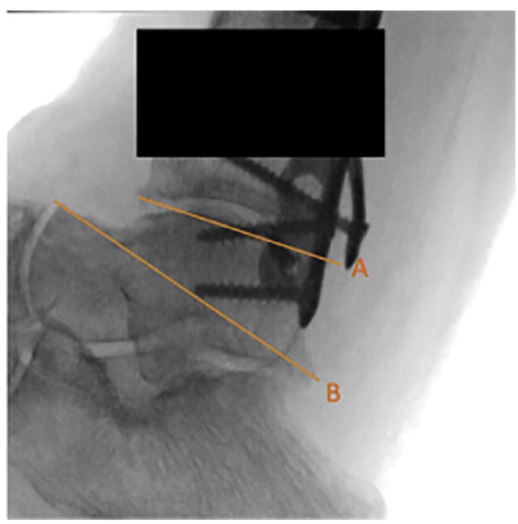

Fig. 9. Example of lateral ankle radiograph edited to blind syndesmotic screw presence (*black box*) with reference lines for angle measurement. The tibial reference line connects the 2 most distal points on the anterior and posterior tibial plafond (A). The talus reference line connects the points between the posterior process (lateral tubercle) of the talus and the anterodorsal aspect of the talus head (B). (*From* Briceno J, Wusu T, Kaiser P, et al. Effect of Syndesmotic Implant Removal on Dorsiflexion. Foot Ankle Int. 2019;40(5):499-505. https://doi.org/10.1177/1071100718818572; with permission.)

and colleagues[59] examined 43 patients (with 58 screws) experiencing postoperative screw breakage. Intraosseous screw breakage, as defined by breakage within either the fibula or tibia, occurred in 32 patients (74.4%). Screw breakage occurred exclusively in the tibiofibular clear space in the remaining 11 instances (25.6%). Intraosseous breakage was associated with significantly higher rates of implant removal secondary to pain.

Patients with retained syndesmotic screws with known syndesmotic malreduction should be considered for screw removal. Although limited by a small patient cohort, Song and colleagues[60] demonstrated that screw removal may lead to auto-reduction of the malaligned syndesmosis. Nine patients demonstrated evidence of tibiofibular malreduction on initial postoperative CT scans. After removal, 8 of 9 showed adequate reduction of the tibiofibular syndesmosis on CT scans. Although promising, further investigations are required to assess effects of implant removal on alignment in a larger patient cohort.

SUMMARY

As one examines the literature exploring syndesmotic instability, including studies comparing rigid versus flexible syndesmotic fixation, a few critical points must be considered. Poor outcomes after a destabilizing syndesmotic injury are much more likely to result from failure to diagnose (and therefore treat) syndesmotic instability, technical malreduction of a concomitant fibular fracture (eg, failure to attain length), or failure to attain articular congruency, than it is to arise from a malreduction of the syndesmosis itself. Malreduction of the distal tibiofibular articulation has been correlated with poorer outcomes in some but not all studies, and its independent contribution is more difficult to elucidate. Importantly, the distinction between gross malreduction and more subtle malreductions are often confounded in the literature but likely entail very different clinical consequences. Ultimately, both rigid and flexible fixation of syndesmotic instability are excellent approaches to treat the unstable syndesmosis. Less discussed is the role of repair or reconstruction of the syndesmotic ligaments themselves, which may play an increasingly important role in the setting of chronic instability. Furthermore, both the lateral ankle ligaments and the deltoid ligamentous complex contribute toward stabilizing the syndesmosis, and yet they are rarely discussed in treatment algorithms.

Suture button constructs are less likely to result in syndesmotic malreduction and this may partly stem from their ability to compensate for an error in surgical technique during clamping or manual reduction maneuvers. In contrast, especially if using only 1 suture button construct, they afford less stability than screws, especially in the sagittal plane, and multiple suture buttons with divergent orientation should be considered.

Flexible constructs also have significantly lower rates of removal of hardware. Many of the well-designed, prospective studies that describe loss of reduction with screw fixation compare a screw cohort in which hardware is electively removed, often before 3 months, with a suture button cohort in which it is not. Additional studies may be necessary to understand the timing of screw removal as well as its necessity, especially given that many studies show increased tibiofibular diastasis over time after screw removal. Furthermore, the description of screw breakage because a hardware failure may overshadow a natural phenomenon that enables normal fibular motion rather than representing an actual complication.

The cost savings inherent to avoiding an elective removal of hardware are overshadowed by the higher cost of flexible implants, especially if multiple suture buttons are used. In contrast, such analyses should also take into account the indirect patient costs, not just the direct healthcare costs, of a return to the operating room for the removal of hardware.

Ultimately, both rigid and flexible fixation seem to have excellent clinical outcomes, with the majority of patients enjoying significant long term pain relief. Both have an integral role, wherein more complex fractures and patients with neuropathy or osteoporosis may benefit from the rigidity of screw constructs and their contribution toward maintaining fibular length, whereas other patients may benefit from the ability of flexible constructs to better replicate normal fibular motion and distal tibiofibular alignment.

CLINICS CARE POINTS

- Diagnosis of syndesmotic instability associated with ankle injuries is critically important to maximize patient outcome and minimize morbidity.
- Weight bearing x-rays and CT complement the role of the physical exam in diagnosing subtle syndesmotic injuries.

- The benefits of flexible over screw fixation remains an ongoing area of debate and study at this time.

DISCLOSURE

The authors have nothing to disclose.

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