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Arthroscopically measured syndesmotic stability after screw vs. suture button fixation in a cadaveric model

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Background: Appropriate management of ankle syndesmotic instability is needed to prevent the development of complications. Previous biomechanical studies have evaluated movement of the fibula after screw or suture button fixations with different results, most likely being caused by variations in experimental setups that did not mirror the in vivo clinical setting. This study aimed to arthroscopically compare in a cadaveric model the stability of syndesmotic fixation with either a suture button or syndesmotic screw.
Methods: Eight fresh matched pairs of human ankle cadaver specimens (above knee) underwent arthroscopic assessment with (1) intact ligaments, (2) after complete disruption, and (3) after repair with either a quadracortical syndesmotic screw or suture button construct. In every stage, four loading conditions were considered under 100N of direct force: 1) unstressed, 2) lateral hook test, 3) anterior to posterior (AP) translation test, and 4) posterior to anterior (PA) translation test. Coronal plane tibiofibular diastasis, as well as sagittal plane tibiofibular translation, were arthroscopically measured.
Results: Coronal plane anterior and posterior tibiofibular diastasis and sagittal plane tibiofibular translation were measured using probes of increasing diameters. Following screw fixation, syndesmotic stability was similar to the uninjured syndesmosis in the coronal plane (anterior, median 0.0 mm [IQR 0.0–0.3] vs. 0.3 mm [IQR 0.2–0.3]; p = 0.57; posterior, median 0.1 mm [IQR 0.0–0.4] vs. 0.2 mm [IQR 0.1–0.3]; p = 1.0) but more rigid in the sagittal plane (median 0.0 mm [IQR 0.0–0.1] vs. 1.0 mm [IQR 0.4–1.5]; p = 0.012). Repairing the unstable syndesmosis with a suture button construct resulted in coronal plane stability similar to the uninjured syndesmosis (anterior, median 0.2 mm [IQR 0.1–0.3] vs. 0.2 mm [IQR 0.1–0.3]; p = 0.48; posterior, median 0.2 mm [IQR 0.1–0.3] vs. 0.3 mm [IQR 0.1–0.5]; p = 0.44). However, sagittal plane fibular motion remained unstable as compared to the uninjured syndesmosis (median 2.2 mm [IQR 1.6–2.6] vs. 0.8 mm [IQR 0.4–1.3]; p = 0.012).
Conclusion: Current fixation methods for syndesmotic disruption maintain coronal plane fibular stability. Screw and suture button constructs, however, respectively resulted in greater or insufficient constraint to fibular motion in the sagittal plane as compared to the intact syndesmotic ligament. These findings suggest that neither traditional screw nor suture button fixations optimally stabilize the syndesmosis, which may have implications for postoperative care and clinical outcomes.

Introduction

Syndesmotic screw or suture button fixations are two commonly used surgical techniques for restoring syndesmotic stability. Their relative effectiveness, however, remains the subject of ongoing debate [1]. Traditionally, syndesmotic repair has been performed with screw fixation, an inherently rigid construct that may result in a degree of screw loosening, breakage, or removal of

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unclear clinical consequence. Suture button constructs have been developed as a means of theoretically restoring anatomical alignment of the syndesmosis while allowing fibular motion in the incisura. Purported advantages of this construct include the avoidance of any need for implant removal. In a clinical study performed by Ryan and Rodriquez [2], however, authors found that it was sometimes necessary to place additional suture buttons to ensure proper translational or rotational control.

Numerous biomechanical studies with varying findings have been conducted to assess fibular motion after screw or suture button fixations [3–8]. While one study found that a single suture button construct was able to adequately control coronal plane fibular motion [6], other studies did not [3,4,8]. Soin et al. found that two suture button constructs provided similar syndesmotic stability in the coronal and sagittal plane compared to a single quadracortical syndesmotic screw, but neither restored native fibula motion [7]. Another study found that one or two suture button constructs were not able to restore stability in both the coronal and sagittal plane as compared to the uninjured syndesmosis or after screw fixation [8]. These differences are possibly caused by variations in experimental setups that did not mirror the in vivo clinical setting. In addition, these studies used an external rotation test to detect instability in the coronal and sagittal. Studies have suggested, however, that the hook test is more effective for testing syndesmotic instability than an external rotation test, which preferentially detects deltoid injuries and may miss syndesmotic instability [9,10].

Arthroscopic evaluation of the ankle syndesmosis is being increasingly used to treat syndesmotic instability, because it allows both direct visualization and immediate management of the distal tibiofibular articulation when indicated [11–13]. The purpose of this study was to mirror the in vivo clinical setting and arthroscopically compare the stability of syndesmotic fixation with either a suture button or syndesmotic screw in a cadaveric injury model using the hook test. We hypothesised that there was no difference of coronal and sagittal plane tibiofibular instability between the uninjured and repaired stage for both screw and suture button fixation.

Materials & methods

Specimen preparation

After gaining institutional review board approval in our institution, eight paired fresh-frozen above-knee cadaver specimens were evaluated. The average age of donors was 58 years, ranging from 22 to 88 years. The thawed limb was affixed to a board using three 5 mm Schanz-type pins placed in the anterior-to-posterior direction through the proximal, middle, and distal third of the tibia. Fluoroscopic anterior-posterior, mortise and lateral views of the ankle were made and specimens with evidence of pre-existing injury were excluded. None of the specimens were excluded from analysis. The ankle was assessed arthroscopically via the standard anteromedial and anterolateral portals using a 2.7 mm arthroscope. The lateral gutter was debrided with a shaver to remove any tissue obscuring view of the syndesmosis or any intended site of measurement. Syndesmotic instability was arthroscopically measured in three different stages; (1) intact specimens, (2) after complete transection of the anterior inferior tibiofibular ligament, distal 10 cm of the interosseous ligament, posterior inferior tibiofibular ligament, and deltoid ligaments, and (3) after fixation with either one quadracortical syndesmotic screw (4.0-mm fully threaded cortical screw, Stryker Instruments, Kalamazoo, MI, USA) or one suture button construct (Tightrope®, Arthrex, Naples, FL, USA). Suture-button repair was randomly assigned to one lower leg of each pair and the contralateral leg underwent screw fixation. Syndesmotic screw fixation was performed with the foot in a neutral position and a clamp was used during reduction. All arthroscopic measurements were taken with the foot in plantigrade position and attained using consecutively sized ball tipped probes ranging from 0.1 mm to 6.0 mm in 0.1 mm increments inserted into the space between the tibia and fibula. Measurements were defined by the largest probe diameter that could be fitted in the distal tibiofibular articulation.

Coronal plane instability

After the syndesmosis was divided and marked into thirds, coronal plane tibiofibular diastasis was measured at both the anterior and posterior third of the tibiofibular articulation (Fig. 1a, b). This was done because the unstable fibula might rotate in the axial plane [11,14], squeezing the distal tibiofibular space at one location, while the other location widens. Both the anterior third and posterior third measurement were first taken in the unstressed setting and, thereafter, repeated while performing the lateral hook test, a laterally directed stress to the distal fibula to assess coronal plane stability of the syndesmosis. Coronal instability was calculated by the difference in diastasis between the unstressed setting and during performance of the lateral hook test. To perform the hook tests, an incision was made laterally 5 cm proximal to ankle joint, and a bone hook was placed around the fibula. A 100N laterally directed force was applied via a force gauge.

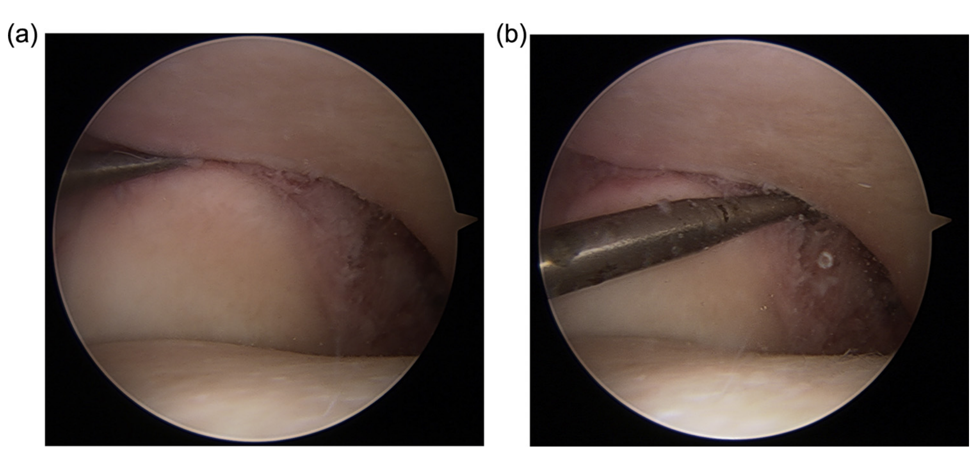

Fig. 1. Arthroscopic view of the tibiofibular articulation of a right ankle. The structure above is tibial plafond; The tissue in between is the fibula; along the bottom the talar dome is shown. Left is anterior and right is posterior. Using a probe, diastasis of the anterior third (a) and posterior third (b) in the coronal plane is measured.

The 100N force used in this study was chosen based on a cadaveric study performed by Stoffel et al. who found that forces of more than 100N did not show substantial increase in syndesmotic displacement [10]. Syndesmotic instability in the coronal plane was defined as the difference in diastasis between the unstressed setting and during performance of the lateral hook test.

Sagittal plane instability

Syndesmotic instability in the sagittal plane was characterized by tibiofibular translation (movement of the fibula with respect to the fixed tibia in the sagittal plane) in both the posterior or anterior direction [9,11,13,15]. In order to assess tibiofibular translation, the anterior-posterior (AP) and posterior-anterior (PA) hook tests were performed. The amount of sagittal instability was calculated by the sum of AP and PA translation.

To perform the AP and PA hook tests, a hook was placed around the fibula through the established incision 5 cm proximal to the ankle joint. A 100N force was applied to the fibula in the sagittal plane, first directed posterior and then anterior. During each test, sagittal tibiofibular translation was measured.

Statistical analysis

The Wilcoxon signed-rank test (a non-parametric test used when comparing two dependent samples) was used to test the null hypothesis that there was no difference of coronal and sagittal plane tibiofibular instability between the uninjured and repaired stage for both screw and suture button fixation. In addition, we used the Wilcoxon signed-rank test to determine the difference of coronal and sagittal plane instability between screw and suture button fixation. A power analysis was conducted to determine the number of specimens necessary to achieve a power of 0.80, an effect size of 1.25, with an alpha of 0.05. Two blinded orthopaedic foot and ankle fellows performed measurements. An intraclass correlation coefficient was calculated through a two-way mixed effects model with absolute agreement. For all comparisons a 2-sided P value of <0.05 was considered significant. Stata® 13.0 (StataCorp LP, College Station, TX, USA) was used for analyses.

Results

The ICCs for anterior third coronal plane tibiofibular diastasis (0.95; 95% confidence interval, 0.79–0.99), posterior third coronal plane tibiofibular diastasis (0.72; 95% confidence interval, 0.33–0.89), and sagittal plane tibiofibular translation (0.91; 95% confidence interval, 0.78–0.97) ranged from 0.72 to 0.95.

Syndesmotic screw fixation

After screw fixation syndesmotic stability was similar compared to the uninjured syndesmosis in the coronal plane (anterior third, median 0.0 mm [IQR 0.0–0.3] vs. 0.3 mm [IQR 0.2–0.3]; p = 0.57; posterior third, median 0.1 mm [IQR 0.0–0.4] vs. 0.2 mm [IQR 0.1–0.3]; p = 1.0). The syndesmosis was significantly more constrained compared to the uninjured syndesmosis, however, in the sagittal plane (median 0.0 mm [IQR 0.0–0.1] vs. 1.0 mm [IQR 0.4–1.5]; p = 0.012) (Table 1).

Suture button fixation

Repairing the unstable syndesmosis with a suture button construct resulted in coronal plane stability similar to the uninjured syndesmosis (anterior third, median 0.2 mm [IQR 0.1–0.3] vs. 0.2 mm [IQR 0.1–0.3]; p = 0.48; posterior third, median 0.2 mm [IQR 0.1–0.3] vs. 0.3 mm [IQR 0.1–0.5]; p = 0.44). In contrast, sagittal plane instability was not affected by suture button fixation and remained significantly unstable compared to the uninjured syndesmosis (median 2.2 mm [IQR 1.6–2.6] vs. 0.8 mm [IQR 0.4–1.3]; p = 0.012) (Table 2).

Screw versus suture button construct

When comparing screw and suture button fixation, there was no difference in coronal plane stability measured at the anterior third (median 0.0 mm [IQR 0.0–0.3] vs. 0.2 mm [IQR 0.1–0.3]; p = 0.52) or at the posterior third of the tibiofibular articulation (median 0.1 mm [IQR 0.0–0.4] vs. 0.2 mm [IQR 0.1–0.3]; p = 0.72). Screw fixation, however, stabilized the syndesmosis significantly more in the sagittal plane compared to suture button fixation (median 0.0 mm [IQR 0.0–0.1] vs. 2.2 mm [IQR 1.6–2.6]; p = 0.012).

Discussion

Ideal fixation of syndesmotic instability remains a matter of ongoing debate [1]. We compared the degree of syndesmotic stability conferred, as measured arthroscopically, between the normal uninjured state and the injury repair state following either screw or suture button fixation in a cadaveric model. No difference could be found in coronal plane stability between the normal state or either of the repair methods following ligamentous transection.

Table 1
Syndesmotic instability–uninjured, complete disruption, and after syndesmotic screw fixation.

	Uninjured (n = 8)	Complete disruption (n = 8)	Repaired (n = 8)	P value Uninjured–Repaired
Coronal anterior TF diastasis (mm)				
Unstressed (median IQR)	1.1 (0.8–1.6)	2.3 (2.0–3.6)	1.6 (1.2–2.4)	
Lateral hook test (median IQR)	1.3 (0.8–1.8)	2.4 (2.0–3.8)	1.7 (1.3–2.3)	
Δ (median IQR)	0.3 (0.2–0.3)	0.2 (0.2–0.3)	0.0 (0.0–0.3)	0.57
Coronal posterior TF diastasis (mm)				
Unstressed (median IQR)	1.7 (1.2–2.3)	2.5 (2.4–4.0)	2.6 (2.1–2.9)	
Lateral hook (median IQR)	1.8 (1.3–2.6)	3.6 (2.8–5.4)	2.5 (2.2–2.6)	
Δ (median IQR)	0.2 (0.1–0.3)	0.6 (0.2–1.4)	0.1 (0.0–0.4)	1.0
Sagittal TF translation (mm)				
AP hook test (median IQR)	0.3 (0.2–0.6)	1.0 (0.7–2.3)	0.0 (0.0–0.0)	
PA hook test (median IQR)	0.5 (0.2–1.0)	1.8 (1.3–3.5)	0.0 (0.0–0.1)	
Δ AP–PA (median IQR)	1.0 (0.4–1.5)	3.2 (2.1–5.8)	0.0 (0.0–0.1)	**0.012**

Significant P values are in **bold** for Wilcoxon signed-rank test.
IQR, interquartile range; *mm*, millimeter; *TF*, tibiofibular; *AP*, anterior-posterior; *PA*, posterior-anterior.
Δ, syndesmotic instability defined as the difference in diastasis between the unstressed setting and during performance of the lateral hook test.

Table 2
Syndesmotic instability–uninjured, complete disruption, and after suture button fixation.

	Uninjured (n = 8)	Complete disruption (n = 8)	Repaired (n = 8)	P value Uninjured–Repaired
Coronal anterior TF diastasis (mm)				
Unstressed (median IQR)	1.2 (0.8–2.3)	2.4 (1.8–5.3)	1.8 (1.2–3.1)	
Lateral hook test (median IQR)	1.5 (0.9–2.3)	2.4 (1.7–5.4)	1.7 (1.1–3.2)	
Δ (median IQR)	0.2 (0.1–0.3)	0.2 (0.1–0.2)	0.2 (0.1–0.3)	0.48
Coronal posterior TF diastasis (mm)				
Unstressed (median IQR)	1.6 (1.3–2.6)	2.7 (2.0–4.4)	1.8 (1.4–3.2)	
Lateral hook (median IQR)	1.9 (1.5–2.5)	3.4 (2.2–4.5)	2.1 (1.8–3.2)	
Δ (median IQR)	0.3 (0.1–0.5)	0.6 (0.1–1.1)	0.2 (0.1–0.3)	0.44
Sagittal TF translation (mm)				
AP hook test (median IQR)	0.2 (0.1–0.5)	1.3 (0.2–1.8)	0.3 (0.0–1.4)	
PA hook test (median IQR)	0.4 (0.1–0.8)	2.1 (1.4–2.8)	1.5 (0.7–2.2)	
Δ AP–PA (median IQR)	0.8 (0.4–1.3)	3.0 (2.2–4.5)	2.2 (1.6–2.6)	**0.012**

Significant P values are in **bold** for Wilcoxon signed-rank test.
IQR, interquartile range; *mm*, millimeter; *TF*, tibiofibular; *AP*, anterior-posterior; *PA*, posterior-anterior.
Δ, syndesmotic instability defined as the difference in diastasis between the unstressed setting and during performance of the lateral hook test.

Syndesmotic screw fixation, however, stabilized the syndesmosis to a significantly greater degree in the sagittal plane when compared to use of a suture button construct (0.0 mm vs. 2.2 mm; p = 0.012).

Numerous biomechanical studies have been conducted to determine if screw or suture button fixations are able to maintain syndesmotic stability, yet with differences in findings. LaMothe et al. assessed fibular motion in a cadaveric model after fixation with a tetracortical 4.0 mm screw or a single suture-button construct using fluoroscopy validated by a 4-camera motion capture system [6]. They found that screw or suture-button fixations were able to constrain coronal plane fibular motion in response to an external rotation stress test. In contrast, Ebramzadeh et al. [3] and Forsythe et al. [4] observed that a single suture button construct was unable to maintain syndesmotic stability in the coronal plane. Adding to these discrepancies, Soin et al. found that two suture button constructs provided similar syndesmotic stability in the coronal and sagittal plane compared to a single quadracortical syndesmotic screw, but neither restored native motion [7]. Furthermore, Teramoto et al. found that one or two suture button constructs were not able to restore stability in both the coronal and sagittal plane as compared to the intact syndesmosis or fixation with a quadracortical syndesmotic screw [8]. A possible explanation for these different study results is the variety in experimental setups that did not mirror the in vivo clinical setting. The current study arthroscopically compared the stability of the syndesmosis after screw and suture button fixation in an experimental setup that mirrored the in vivo clinical setting and therefore we expect our findings to be reliable.

Based on our results, a suture button construct appears to stabilize coronal plane but not sagittal plane motion in our cadaveric model of the injured syndesmosis. Several possible explanations for this finding should be considered. First, the suture button construct inherently works under tension and is positioned in the direction of the coronal plane; it may therefore produce most of its stability in this vector. Secondly, the construct becomes installed through drilled channels which far exceed the diameter of the sutures which eventually reside here, which may permit significant residual sagittal instability given the persistent differences in diameter. Thirdly, at the level of implant insertion the fibula is not flat, so—unless this is placed along the absolute center of rotation of this radius of curvature—once the construct is tightened it may tend to excurse anteriorly or posteriorly until the sutures rest along the canal of the tunnels drilled for passing of the button. Perhaps one or more of these reasons may be responsible for the more limited ability of the suture button construct to prevent fibular motion under forces directed orthogonally to this tension vector. Of course, the overall clinical consequence of these findings remains to be determined, as perhaps some degree of motion—as long as it remains physiologic—is desired for ideal syndesmotic health long term. An important related question may be how much and what direction of motion should be permitted, if any, during the initial phase of fixation and ligament healing in this patient population to maximize long term syndesmotic health and function. These questions have yet to be answered in our literature.

Previous studies have suggested that syndesmotic instability is most prominent in the sagittal plane [9,15,16]. Our study applied a direct sagittal plane force on the fibula that decreased the amount of rotation and maximized the amount of translational motion that would be seen during the stress test. Our results indicate that syndesmotic screw fixation results in greater sagittal plane constraint compared to an uninjured model (0.0 mm vs. 1.0 mm; p = 0.012). Similarly, Klitzman et al. concluded that screw fixation allowed significantly less fibular movement in the sagittal plane as compared to the intact and the repaired syndesmosis with suture button construct [5]. This static fixation may interfere with physiological fibular movement during ankle range of motion and loading [14,17]. Manjoo et al. [18] found that an intact syndesmosis screw was associated with a worse functional outcome compared with loose, fractured or removed screws. Therefore, screw removal may be indicated in patients with intact syndesmosis screws [18]. Screw loosening, breakage, or removal may obviate the associated sagittal plane constraint, but additional studies are necessary to understand the clinical implications of temporary over-constraint.

To date, there are no studies comparing the clinical outcomes of suture button fixation versus syndesmotic screw fixation in patients with isolated syndesmotic instability [19]. In patients with syndesmotic instability with associated ankle fracture Kortekangas et al. found no difference in the incidence of ankle joint osteoarthritis and functional outcome between the fixation methods [20]. In contrast, a randomized study performed by Laflamme et al. concluded that a suture button construct (Arthrex, Tightrope®) outperformed screw fixation clinically with less failure rate and higher Olerud-Molander scores one year after surgery [21]. The authors, however, received a study grant from Arthrex, which may have biased the results. Another limitation was that the syndesmotic screw was not electively removed causing screw breakage in 13 (41%) patients – which was counted as failure of the fixation method, and ankle pain in 11 (34%) patients. Hence, currently there is no high quality clinical evidence to support or refute suture button fixation or syndesmotic screw fixation for syndesmotic instability.

The strength of this study is that we arthroscopically compared the stability of the syndesmosis under direct visualization and measurement of the syndesmosis in an experimental setup that mirrored the in vivo clinical setting. In addition, by using the hook tests we were able to individually assess sagittal and coronal plane instability with the fibula specifically stressed in each direction. There are, however, a few limitations. First, the anatomical transection of all ligaments in cadaveric specimens does not necessarily reflect traumatic ligament injury in vivo. Second, this study did not evaluate syndesmosis stability using a 3.5-mm threaded screw. Third, we were not able to determine syndesmotic rotational instability in the axial plane [11]. Performing an external rotation stress test in addition to the hook tests might have been useful providing this data, but this test could not be performed during arthroscopy because the test had the propensity push the arthroscope out anterolaterally. Additional studies are necessary to understand the clinical implications of these biomechanical findings.

In conclusion, current fixation methods for syndesmotic disruption using screw or suture button constructs effectively maintain coronal plane fibular stability. Screw and suture button constructs, however, respectively resulted in greater or insufficient constraint to fibular motion in the sagittal plane as compared to the intact syndesmotic ligament.

Conflicts of interest

Dr. D. Guss reported receiving consulting fees for Extremity Medical. Dr. C.W. DiGiovanni reported receiving personal fees from Extremity Medical Inc, Wright Medical, Paragon 28, CreOsso, Elsevier, Lippincott, and Saunders. No other disclosures were reported.

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