Biomechanical profile of varying suture button constructs in cadaveric specimens: a systematic review and meta-analysis

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Background: Suture button fixation of syndesmotic injuries allows for more physiologic motion of the ankle joint while maintaining adequate reduction and may avoid the need for additional surgeries, given the lower risk of syndesmotic diastasis and implant failure. Few studies have examined the optimal number and configuration of suture buttons for syndesmotic disruption. The purpose of this systematic review and meta-analysis is to compare different suture button configurations from the cadaveric literature and to assess their relative effect on the stability of the syndesmotic reduction and functional movement of the ankle.

Methods: A literature search in the databases MEDLINE via PubMed, Embase via Elsevier, Scopus via Elsevier, and SPORTDiscus via EBSCO were searched through December 2022 to identify studies related to cadaveric modeling of the syndesmosis. Only cadaveric studies with suture button fixation and studies in English were included. The quality of cadaveric studies was assessed using the Quality Assessment for Cadaveric Studies (QUACS) tool. Revman 5.3 software was used to perform the meta-analysis.

Results: The meta-analysis included 5 studies and 86 limbs. The systematic review included 15 studies. When comparing single and double suture button configurations, no difference was found between groups with regard to fibular rotation (MD =−0.9; 95% CI: −2.09 to 0.27; I^2=79%; P=0.13) and both groups had similar rotational stability. The double suture button technique did demonstrate less sagittal fibular translation compared to the single suture button (MD =0.48; 95% CI: 0.02–0.94; I^2=66%; P=0.04). When comparing two suture buttons in parallel and divergent configurations, studies did not find any differences with regard to strength or stability.

Conclusions: There were no significant differences in biomechanical parameters when comparing single and double suture button constructs. While single button suture constructs result in minimal fibular rotation, double suture button constructs minimize fibular translation. This review may serve as a guide for clinicians when approaching these injuries.

Keywords: Syndesmosis injury; screw fixation; suture button fixation; suture button constructs; cadaveric studies

Submitted Apr 14, 2023. Accepted for publication Jun 21, 2023. Published online Jun 28, 2023.
doi: 10.21037/atm-23-1527
View this article at: https://dx.doi.org/10.21037/atm-23-1527

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Introduction

The syndesmosis, comprised of four primary ligaments, is the basis for articulation between the distal tibia and fibula and is critical to the stability of the ankle joint (1). Disruption to the syndesmosis typically occurs when there is forceful external rotation of the tibia with internal rotation of the talus on a planted foot (2). These syndesmotic injuries can be present in up to 18% of ankle sprains and 13% of ankle fractures, with even higher estimated incidences in athletic populations (3-5).

Although there is general consensus that syndesmotic injuries should be operatively treated to avoid persistent pain, instability, and early osteoarthritis, the optimal method of fixation for these injuries has been less clear (6,7). Screw fixation, or rigid fixation, of the syndesmosis has historically been found to provide reliable distal tibiofibular stability, good functional outcomes, and low rates of syndesmotic malreduction (8-11). While screw fixation has been considered to be the gold standard, there are concerns of screw loosening and breakage that may necessitate a second surgery for implant removal (12,13). Moreover, some reports have demonstrated high rates of syndesmotic malreduction after rigid internal fixation (14).

Suture button devices, or dynamic fixation, may be a viable alternative to screw fixation for syndesmosis disruption and use of these devices has increased greatly in recent years. Proposed benefits of suture button fixation include allowance for physiologic motion of the ankle joint while maintaining adequate reduction (10). Moreover, despite higher upfront costs, additional surgeries may be avoided when using suture buttons, given lower risks of syndesmotic diastasis and implant failure, which subsequently may improve overall cost-effectiveness (7,15,16). Despite several reported benefits of suture button fixation over screw fixation for syndesmotic injuries, there is ongoing debate over which technique should be utilized in specific patient scenarios. For example, in patients with isolated syndesmotic injuries, perhaps suture buttons would be preferable as syndesmotic malreduction would be catastrophic. In contrast, in patients where there is concern regarding the capacity to heal an ankle fracture, such as those with peripheral neuropathy, suture buttons may fail to provide appropriate stability, so multiple screws would be preferable.

The literature to date has focused almost exclusively on the comparison of screw and suture button fixation, while fewer studies have focused solely on suture buttons and their optimal number and configuration (3,10,12,17,18). Biomechanical cadaveric studies provide an opportunity to test these different configurations under physiological conditions and enhance our understanding of potential impacts on the quality of the syndesmotic reduction and overall ankle stability. The purpose of this systematic review and meta-analysis is to compare different suture button configurations from the cadaveric literature to assess their relative effect on the stability of syndesmotic reduction and functional movement of the ankle. Our goal is to provide a comprehensive synopsis of the cadaveric investigation regarding suture button configuration for syndesmotic injury to guide further translational and clinical discovery. We present this article in accordance with the PRISMA reporting checklist (available at https://atm.amegroups.com/article/view/10.21037/atm-23-1527/rc).

Methods

Eligibility criteria

To be included in the final analysis, the study had to meet the following criteria: (I) evaluate suture button fixation in ankle syndesmotic injury models, (II) include at least two different suture button configurations, and (III) utilize cadaveric specimens. Studies that were excluded include (I) case reports, conference abstracts, studies that did not vary suture button configurations, (II) studies not published in English, and (III) duplicate publications.

Information sources and search strategy

A medical librarian composed a search utilizing keywords and subject headings to represent the concept of syndesmosis. The databases MEDLINE via PubMed, Embase via Elsevier, Scopus via Elsevier, and SPORTDiscus via EBSCO were searched from inception to December 19, 2022. All results were compiled in Endnote and imported into Covidence for deduplication and screening. Key terms used in the search included “syndesmosis”, and “syndesmotic”.

Data collection

Data were independently extracted from each study included in the analysis by three investigators (C.W., T.S., E.L.). The following variables were collected from each study: name of first author, year of publication, study design, number of subjects, age, fixation type, suture button manufacturer, biomechanical testing set-up, primary outcome(s), and other key findings. Disagreements were

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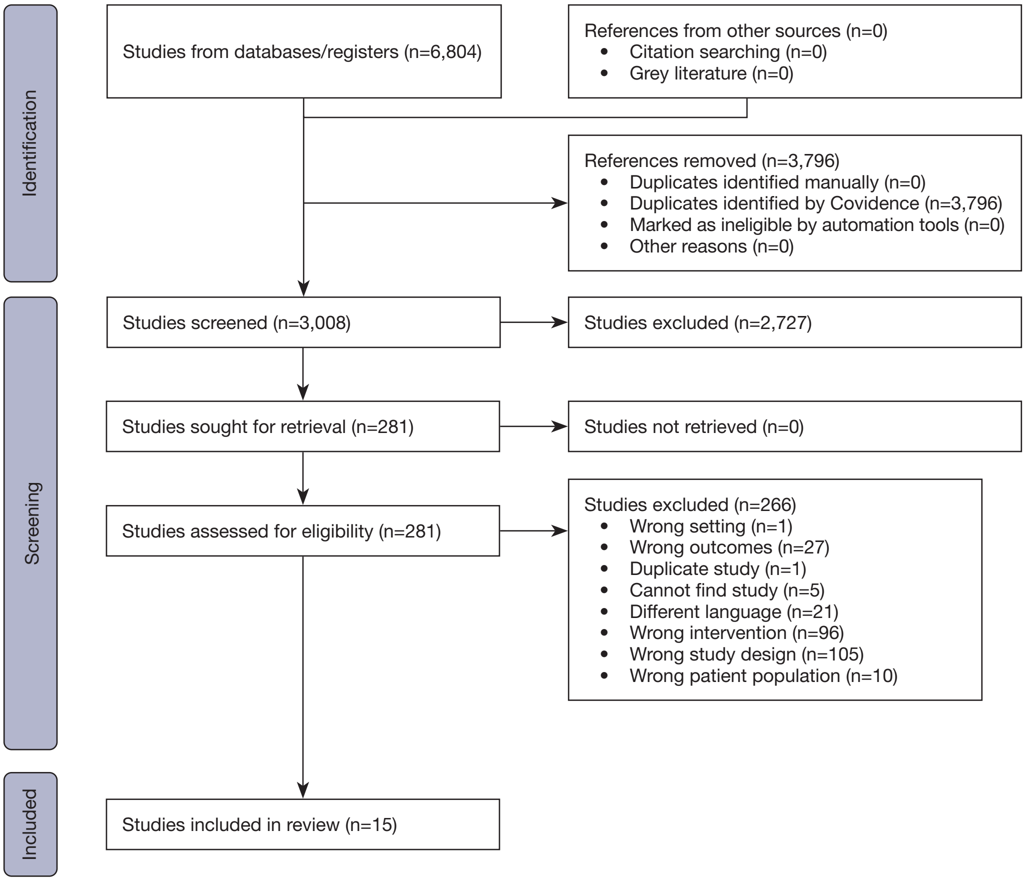

Figure 1 Diagram of study screening process.

resolved by a fourth investigator (A.A.).

Quality assessment

The quality of cadaveric studies was assessed using the Quality Assessment for Cadaveric Studies (QUACS) tool (19). Each study received a score from 0 to 13, and then this score was made into a percentage out of the 13 possible points. Detailed results of QUACS scoring are provided in Appendix 1.

Data synthesis and analysis

The extracted data from the studies were tabulated and organized based on reported outcomes in preparation for meta-analysis. Studies that compared single-button suture with double-button suture were included in all analysis. Mean difference (MD) and standard deviation (SD) were used to synthesize continuous outcome data. Revman 5.3 software was used for meta-analysis with inverse variance and random effects model for the continuous outcomes to produce a 95% confidence interval. Statistical heterogeneity was assessed by visual examination of the forest plots, the τ^2 test, the χ^2 test, the degrees of freedom (df), the I^2 value, and the overall effect Z test.

Results

Literature selection

After removing duplicates, 3,008 abstracts were available for screening. A total of 281 full-text studies were then assessed for eligibility and 15 studies met inclusion criteria (*Figure 1*). These 15 eligible studies were described qualitatively as part of the systematic review (*Table 1*). Due to variation in variable selection and biomechanical testing set-up, only five studies were included in the meta-analysis. The mean QUACS score was 76.9% with a standard deviation of 16.2% (*Table 2*).

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Table 1 Qualitative findings of included studies

First author	Year	Fixation	Manufacturer	N	Age, years, mean [range]	Outcome variables	Key findings
Baker, H.P.	2022	(I) 2 SB, divergent; (II) all suture construct	(I) Zimmer Biomet ZipTight; (II) Arthrex Fiberwire	16	63 [55–71]	(I) Fibular translation; (II) fibular external rotation; (III) construct stiffness	(I) Fibular external rotation increased and construct stiffness decreased compared to intact state for both fixation techniques; (II) all suture construct may be comparable to SB
Clanton, T.O.	2017	(I) 1 3.5-mm tricortical screw; (II) 1 SB; (III) 2 SB, divergent	(I) N/A; (II) Arthrex TightRope; (III) Arthrex TightRope	24	54 [38–68]	(I) Fibular translation; (II) fibular rotation	(I) All repair techniques provide torsional stability to the syndesmosis; (II) no repair technique completely recreates the preinjury state; (III) 1 SB allows the most external rotation and both 1 and 2 SB allows more anterior translation in sagittal plane
Morellato, J.	2016	(I) 1 SB, 4 kg tension; (II) 1 SB, 8 kg tension; (III) 1 SB, 12 kg tension	(I, II, III) Arthrex TightRope	10	79.6	(I) Fibular translation; (II) fibular rotation	(I) Posterior translation of the fibula regardless of tension was observed; (II) lateral translation of the fibula seen only with 4 kg tension; (III) overall the 12 and 8 kg repair maintained syndesmotic reduction better
O'Daly, A.E.	2020	(I) 2 SB, divergent; (II) 2 SB, "new" technique with SB placed through sagittal tunnel in the fibula and across tibia proximal to incisura	(I, II) Arthrex TightRope	18	N/A	(I) Reduction accuracy; (II) instrumentation failure; (III) fibular rotation	(I) "New" technique achieved more accurate reduction in the coronal plane and had better rotational stability than 2 SB; (II) "new" technique showed improved stability in the axial plane with ankle under internal and external rotation
Parker, A.S.	2018	(I) 1 SB; (II) 2 SB, parallel; (III) 2 SB, divergent	(I, II, III) Arthrex TightRope	30	45 [29–52]	(I) Fibular translation; (II) fibular rotation; (III) diastasis	(I) All suture button fixation techniques provide stability; however, no clear superiority of one technique was found; (II) no biomechanical benefit to 2 SB over 1 SB; (III) all configurations overcompress the syndesmosis compared to the intact state
Patel, N.K.	2018	(I) 1 3.5mm tricortical screw; (II) 2 screws; (III) 1 screw + 1 SB; (IV) 1 SB; (V) 2 SB, divergent	(I, II) n/a; (III, IV, V) SNN Invisiknot	9	65 [26–88]	(I) Fibular translation; (II) fibular external rotation	(I) Single screw and suture button constructs were unable to restore native kinematics but double screw and hybrid fixation overconstrained the joint; (II) no differences in posterior translation or external rotation between 1 SB and 2 SB
Schermann, H.	2022	(I) 1 SB + ST; (II) 2 SB, divergent + ST; (III) 2 SB, divergent	(I, II) Arthrex TightRope + Arthrex InternalBrace; (III) Arthrex TightRope	15	54 [26–65]	(I) Coronal plane instability under arthroscopy; (II) sagittal plane instability under arthroscopy; (III) diastasis under external rotation stress	(I) ST alone could not effectively stabilize the syndesmosis and nor could 2 divergent SB; (II) combination of ST and SB had similar stability as intact ankle

Table 1 *(continued)*

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Table 1 *(continued)*

First author	Year	Fixation	Manufacturer	N	Age, years, mean [range]	Outcome variables	Key findings
Schon, J.M.	2017	(I) 1 SB, dorsiflexion; (II) 1 SB, plantarflexion; (III) 1 SB, neutral	(I, II, III) Arthrex TightRope	24	56 [26–65]	(I) Syndesmostic volume differential	(I) No significant differences were observed regarding volumetric changes among the three ankle positions
Schon, J.M.	2017	(I) 1 3.5 mm tricortical screw; (II) 1 SB; (III) 2 SB, divergent	(I) Arthrex; (II, III) Arthrex TightRope	24	54 [38–64]	(I) Syndesmostic volume differential	(I) 2 SB resulted in significantly greater decreased volume versus screw fixation; (II) 1 SB volume differential was not significantly different when compared to screw or 2 SB; (III) all fixation methods reduce the volume of the syndesmosis beyond the intact state
Teramoto, A.	2011	(I) 1 SB; (II) 2 SB, divergent; (III) 1 SB, anatomic; (IV) 1 4.5-mm screw	(I, II, III) Arthrex TightRope; (IV) DePuy	6	84 [73–90]	(I) Diastasis; (II) fibular rotational angle	(I) 1 SB did not provide multidirectional stabilization; (II) 1 SB and 2 SB did not maintain anatomic reduction under external rotation force; (III) anatomic SB had similar dynamic stabilization to the intact state
Tsai, J.	2016	(I) 2 SB, pathway not specified; (II) 1 SB + 1 plate + 1 screw	(I) Arthrex TightRope; (II) Arthrex TightRope, Stryker 1/3 tubular plate, 3.5 mm tricortical screw	14	65 [42–89]	(I) Maximum torque to failure; (II) maximum rotation to fracture after fixation	(I) No significant differences between constructs in terms of maximum torque and maximum rotation to fracture, which implies similar stiffness
Turnbull, T.L.	2016	(I) 1 3.5-mm tricortical screw; (II) 1 SB; (III) 2 SB	N/A	24	N/A	(I) Syndesmostic volume differential	(I) All fixation methods resulted in significantly decreased volumes compared to the intact state; (II) the decrease in volume for 1 SB was not significantly different from 2 SB or screw fixation; (III) 2 SB had a greater total decrease in volume compared to screw fixation
Wood, A.R.	2020	(I) 1 SB; (II) 2 SB, divergent; (III) 2 SB, divergent + 1 suture anchor; (IV) 1 SB + 1 suture anchor	(I) Arthrex TightRope; (II, III, IV) Arthrex TightRope + Arthrex InternalBrace	11	59 [48–65]	(I) Fibular translation; (II) tibiofibular clear space	(I) 1 SB and 2 SB show minimal improvement in posterior translation and external fibular rotation compared to the injured state; (II) the addition of a suture anchor augment increases the ability of SB to constrain external rotation of the fibula
Zhang, L.	2021	(I) 1 3.5-mm tricortical screw; (II) 1 SB; (III) "novel" endobutton	(I) N/A; (II) N/A; (III) N/A	24	42 [28–62]	(I) Displacement under axial loading (II) displacement in internal and external rotation	(I) Biomechanical characteristics of the novel double endobutton were better than screw and SB fixation
Zhang, L.	2022	(I) 1 3.5-mm tricortical screw; (II) 1 SB; (III) "novel" endobutton	(I) N/A; (II) N/A; (III) N/A	24	43 [28–62]	(I) Displacement under axial loading (II) displacement in internal and external rotation	(I) Screw fixation resulted in the smallest displacements; (II) 1 SB and the novel endobutton achieved similar dynamic stability as the intact syndesmosis

SB, suture button; ST, suture tape.

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Table 2 Complete results of QUACS scoring criteria

First author	Score													Points possible
	1	2	3	4	5	6	7	8	9	10	11	12	13	
Baker, H.P.	1	1	1	1	0	0	1	1	1	0	1	1	1	76.9%
Clanton, T.O.	1	1	1	1	1	0	1	1	1	1	1	1	1	92.3%
Morellato, J.	1	1	1	1	0	0	1	0	1	1	1	1	1	76.9%
O'Daly, A.E.	1	0	1	0	0	0	1	1	1	1	1	1	1	69.2%
Parker, A.S.	1	1	1	1	0	0	1	1	1	1	1	1	1	84.6%
Patel, N.K.	1	1	1	1	0	0	1	1	1	1	1	1	1	84.6%
Schermann, H.	1	1	1	1	0	1	1	1	1	1	1	1	1	92.3%
Schon, J.M.	1	1	1	1	0	0	1	1	1	1	1	1	1	84.6%
Schon, J.M.	1	1	1	1	0	1	1	1	1	1	1	1	1	92.3%
Teramoto, A.	1	1	1	0	0	0	1	0	1	1	1	1	1	69.2%
Tsai, J.	1	1	1	1	0	0	1	1	0	0	0	0	0	46.2%
Turnbull, T.L.	1	0	1	0	0	0	1	0	0	1	0	1	0	38.5%
Wood, A.R.	1	1	1	1	0	1	1	1	1	1	1	1	1	92.3%
Zhang, L.	1	1	1	0	0	0	1	1	1	1	1	1	1	76.9%
Zhang, L.	1	1	1	0	0	0	1	1	1	1	1	1	1	76.9%

QUACS, Quality Assessment for Cadaveric Studies.

Single suture button vs. double suture button

Six studies compared the outcomes of a single suture button compared to a double suture button. Single and double suture button constructs were found to be comparable in terms of biomechanical stability with no significant evidence that an extra suture button provides an increase in postoperative stability (3,20-24). However, two studies reported that neither a single button or a double button provided stabilization to the syndesmosis when looking at syndesmotic diastasis under medial, internal, and external rotation forces (21,23).

There were concerns about resistance to sagittal translation with a single button construct (3). However, when using volume differentials to assess anatomic reduction of the syndesmosis, single and double button constructs were not found to be significantly different from each other. Furthermore, double button constructs may over-compress the syndesmosis as evidenced by a larger reduction in syndesmotic volume compared to that of screw fixation (22).

Two suture buttons parallel vs. two suture buttons divergent vs. other configurations

No differences were found with regard to strength or stability of the fixation construct when comparing parallel and divergent configurations of two suture buttons (20). Two suture buttons in a divergent pathway provide increased resistance to sagittal translation of the fibula when compared to single button constructs (3). However, under lighter axial compression loads and external rotation forces, divergent 2 suture button constructs resulted in >5 mm of diastasis and lateral displacement of the fibula (25).

In addition to parallel and divergent configurations, other techniques have been developed for suture button configuration. For example, 2 suture buttons can be placed through a sagittal tunnel in the fibula across the tibia, just proximal to the incisura. This technique was found to lead to more accurate reduction of the fibula and better rotational stability when compared to divergent suture buttons (26). Zhang *et al.* investigated a novel endobutton technique and found this system to have comparable

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Study or subgroup	Single-Button suture Mean	SD	Total	Double-Button suture Mean	SD	Total	Weight	Mean difference IV, Random, 95% CI	Year
Teramoto 2011	2.6	1.5	6	2.3	1.2	6	20.9%	0.30 [−1.24, 1.84]	2011
Clanton 2017	2	1.4	24	4.1	1.6	24	27.7%	−2.10 [−2.95, −1.25]	2017
Parker 2018	5.17	2.13	30	6.75	2.4	30	24.8%	−1.58 [−2.73, −0.43]	2018
Wood 2020	2.5	1.2	11	2.5	1.1	11	26.6%	0.00 [−0.96, 0.96]	2020
Total (95% CI)			71			71	100.0%	−0.91 [−2.09, 0.27]	

Heterogeneity: Tau^2 =1.12; Chi^2 =14.19, df =3 (P=0.003); I^2=79%
Test for overall effect: Z=1.51 (P=0.13)

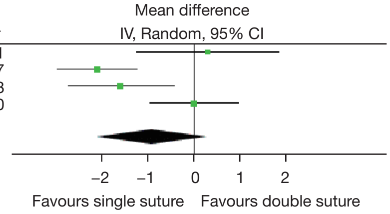

Figure 2 Forest plots for fibular rotation in single suture button *vs*. double suture button (inverse variance and random effects model).

Study or subgroup	Single-Button suture Mean	SD	Total	Double-Button suture Mean	SD	Total	Weight	Mean difference IV, Random, 95% CI	Year
Clanton 2017	0.3	1.4	24	0.4	1.5	24	19.7%	−0.10 [−0.92, 0.72]	2017
Wood 2020	5.7	0.3	11	4.9	0.3	11	45.4%	0.80 [0.55, 1.05]	2020
Schermann 2022	0.91	0.66	15	0.53	0.6	15	34.9%	0.38 [−0.07, 0.83]	2022
Total (95% CI)			50			50	100.0%	0.48 [0.02, 0.94]	

Heterogeneity: Tau^2 =0.11; Chi^2 =5.96, df =2 (P=0.05); I^2=66%
Test for overall effect: Z= 2.03 (P=0.04)

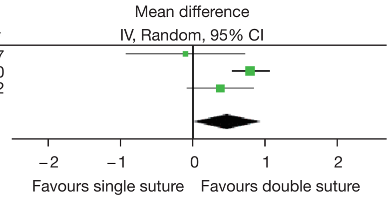

Figure 3 Forest plots for fibular translation (sagittal plane) in single button suture *vs*. double button suture (inverse variance and random effects model).

dynamic stability to a single suture button (24,27).

Suture button augmentation

Two studies assessed whether augments including suture tape and suture anchors could affect the stability of the syndesmosis repair with suture buttons (23,28). Schermann *et al*. found divergent suture buttons alone did not successfully stabilize the syndesmosis but a combination of one suture button and suture tape augmentation resulted in similar stability of an intact ankle (28). Wood and colleagues reported that combined suture anchor and suture button constructs significantly reduced fibular external rotation whereas suture button constructs alone were not significantly different from the injured state (23).

Single suture button vs. double suture button meta-analysis

The five studies in the meta-analysis included 86 limbs. Each limb underwent repairs with a 1 suture-button construct and a 2 suture-button construct.

Fibular rotation

Fibular rotation was evaluated in 4 of the 5 studies examining the single suture button technique compared to the double suture button technique. Fibular rotation was determined by the rotation of the distal fibula with respect to the tibia relative to the loaded intact state. The results of the meta-analysis showed no significant difference between the 2 groups (MD =−0.9; 95% CI: −2.09 to 0.27; I^2=79%; P=0.13) (*Figure 2*). The single suture button and double suture button repair techniques had similar rotational stability.

Fibular translation

Fibular translation was assessed in the sagittal plane by 3 of the 5 studies. Fibular translation was quantified as displacement of the distal fibula in relation to the tibia relative to the loaded intact state. The results of the meta-analysis showed a significant difference between the 2 groups (MD =0.48; 95% CI: 0.02 to 0.94; I^2=66%; P=0.04) (*Figure 3*). The double suture button technique had less sagittal fibular translation compared to single suture button technique.

Discussion

Screw fixation of the syndesmosis has been used to treat syndesmotic injury for decades but has been associated with implant failure requiring additional surgeries and overconstraint of the ankle joint (29). Suture button fixation has been increasingly recognized as a viable alternative to screw fixation, theorized to provide dynamic stability to the ankle joint and more closely restores physiologic motion. Different configurations of suture buttons have been described, tested in cadaveric models of syndesmotic

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instability, and found to vary with regard to the amount of stability they provide. The purpose of this systematic review is to curate the cadaveric literature to determine the biomechanical profile of different suture button configurations for fixation of syndesmotic injuries. Our goal was to provide a comprehensive and systematic summation of the cadaveric work regarding suture button configuration for syndesmotic injury to guide further translational and clinical investigation.

There are generally few differences between single and double suture button configuration outcomes across the literature. Multiple studies have found no added biomechanical benefit with the addition of an extra suture button (3,20-24). While a double suture button could provide backup in the case of implant failure in the clinical setting, the use of a second suture bottom for enhanced stability is not supported by the cadaveric literature (20). It should be noted, however, that in some studies both single and double suture button constructs had difficulties with maintaining reduction under external rotation forces (21). In addition, there may be clinically meaningful differences in biomechanical parameters when using single versus double suture button constructs; however, this is not able to be assessed within a cadaveric study.

When looking at direct comparison of parallel and divergent configurations of double suture buttons, Parker *et al.* found that, surprisingly and counterintuitively, the divergent double suture button configuration resulted in weaker control of fibular rotation compared to the parallel configuration (20). However, this difference was not statistically significant after 500 cycles (20). Other studies compare either parallel or divergent double suture button configurations to either screw fixation or other experimental suture button techniques. O'Daly *et al.* introduced a novel stabilization technique that expands upon the typical two suture button orientation to include two suture buttons anterior and posterior to the fibula at the same plane of the native anterior- and posterior-inferior tibiofibular ligaments, as well as a third sagittal fibular tunnel with a suture button passed posterior-to-anterior (26). Interestingly, this new technique provided greater rotational stability and a more accurate reduction in the coronal plane when compared to the more conventional divergent double suture configuration (26). This improvement may be due to better replication of the native anterior- and posterior-tibiofibular ligaments. While this new technique offers an advancement on the conventional parallel and divergent double suture button orientations, further studies are needed to validate the biomechanical advantages of this novel configuration.

The results of this study hold important implications beyond the realm of biomechanical testing. Here, we demonstrate the current biomechanical results of multiple suture button configurations in the literature, with differing constructs offering variable stability parameters depending on position and number of constructs. The application of suture button biomechanical testing to clinical practice has been previously investigated, with most studies demonstrating superiority to traditional screw fixation, with minimization of issues such as breakage, loosening, and late diastasis (7,20,30-32). Further, there are multiple studies comparing screw fixation geometry and screw composition in patients, with recommendations for screw fixation with the ankle in neutral positioning during tightening, in addition to improved fixation with quadricortical screws preferred over tricortical screws (33,34).

Despite the preponderance of cadaveric investigation, there is a paucity of studies that compare multiple suture button configurations in clinical practice. A 2021 prospective study by Kurtoglu *et al.* demonstrated no difference between single and double interosseous suture endobutton systems among 43 patients (35). Similarly, Anand *et al.* reported no difference in patient outcomes regarding the number of suture endobuttons used with Arthrex Tightrope (Naples, Florida) fixation for Weber C ankle injuries (36). The findings of these studies highlight the importance of translating biomechanical findings to practice, but also raise the question if a less costly, single button system would be an overall better choice. Ultimately, providers may use this analysis as guidance when choosing the proper construct for their patients.

Limitations of this systematic review and meta-analysis include the small number of studies included in our meta-analysis, which may be attributed to the low numbers of biomechanical studies that are currently available in the literature. Furthermore, there was high heterogeneity among these studies included in the meta-analysis because of the limited number of studies available within the literature. With further investigation, the power of the study and its clinical applicability will undoubtedly increase. Further, while each study included evaluated similar parameters (e.g., fibular rotation, translation, etc.), biomechanical testing set-ups were distinct and not standard across each institution. Further, experimental design varied slightly, with some authors recording at different cycle timepoints (e.g., after 0, 200, and 500 cycles, and some after one final cycle). Suture buttons also vary in materials utilized, production company,

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and augmentation techniques. Lastly, some studies evaluated additional parameters that cannot be included into the metanalysis due to the inability to compare the data, such as maximum volume reduction, and maximum torque to failure. These limitations highlight the need for not only further biomechanical research, but also draw attention to the need for a standardized and systematic set-up and protocol for cadaveric modeling of syndesmosis injuries. Besides cadaveric modeling, a large randomized controlled trial that prospectively evaluates the outcomes of different suture button constructs in a diverse patient population would be most beneficial. This would allow surgeons to further tailor treatment options to specific characteristics of their patient. Despite these limitations, our study does demonstrate consistency in the overall findings and is the most comprehensive summation of the biomechanical testing of various suture button configurations for ankle syndesmotic injuries.

Conclusions

With the introduction of suture button constructs for the treatment of syndesmotic complex injuries, there is currently no consensus regarding surgical approach to these injuries, especially given the variability among suture button configuration and quantity of suture buttons employed for fixation. The most important finding of this meta-analysis is that there are significant differences in biomechanical parameters, specifically fibular translation in the sagittal plane, with regards to single versus double suture button constructs. Interestingly, while decreasing fibular rotation favors the use of a single suture button, decreasing fibular translation favors the use of a double suture button construct. Further, this study outlines the current literature assessing new constructs in addition to constructs with varying footprints, serving as a guide for clinicians when approaching these injuries. Future research is needed to standardize biomechanical testing and to translate these results effectively and safely into clinical practice.

Acknowledgments

Funding: None.

Footnote

Provenance and Peer Review: This article was commissioned by the editorial office, *Annals of Translational Medicine* for the series "Foot and Ankle Surgery". The article has undergone external peer review.

Reporting Checklist: The authors have completed the PRISMA reporting checklist. Available at https://atm.amegroups.com/article/view/10.21037/atm-23-1527/rc

Peer Review File: Available at https://atm.amegroups.com/article/view/10.21037/atm-23-1527/prf

Conflicts of Interest: All authors have completed the ICMJE uniform disclosure form (available at https://atm.amegroups.com/article/view/10.21037/atm-23-1527/coif). The series "Foot and Ankle Surgery" was commissioned by the editorial office without any funding or sponsorship. ATA served as the unpaid Guest Editor of the series. SBA reports consulting fees from Coventus/Flower, Stryker, DJO, Orthofix, Inc, Regeneration Technologies, served as a Board or Committee member for AOFAS, and holds stock or stock options of Medshape. The authors have no other conflicts of interest to declare.

Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

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Cite this article as: Wixted CM, Luo EJ, Stauffer TP, Wu KA, Adams SB, Anastasio AT. Biomechanical profile of varying suture button constructs in cadaveric specimens: a systematic review and meta-analysis. Ann Transl Med 2023;11(10):344. doi: 10.21037/atm-23-1527

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Supplementary

Appendix 1

Complete Results of Quality Assessment for Cadaveric Studies (QUACS) scoring

Quality Assessment for Cadaveric Studies Criteria

1. Objective is clearly stated.
2. Basic information about the sample is included (age, gender, and sample size).
3. Applied methods are described comprehensibly.
4. Study reports condition of the examined specimens.
5. Education of dissecting researchers is stated.
6. Findings are observed by more than one researcher.
7. Results presented thoroughly and precisely.
8. Statistical methods are appropriate.
9. Details about consistency of findings are given.
10. Photographs of the observations are included.
11. Study is discussed within the context of the current evidence.
12. Clinical implications of the results are discussed.
13. Limitations of the study are addressed.

Each criterion is scored as 0 (unfulfilled) or 1 (fulfilled) and the overall score is taken as a percentage of the total possible score.

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https://dx.doi.org/10.21037/atm-23-1527