Original Article
Clinics in Orthopedic Surgery 2025;17:324-330 • https://doi.org/10.4055/cios24338

Comparison between Suture-Button Technique with Syndesmotic Repair and Screw Fixation Technique for Complete Ankle Syndesmotic Injury: Biomechanical Cadaveric Study

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Background: The tibiofibular syndesmosis is essential for preserving the stability of the ankle. Acute syndesmotic injuries with evident or latent instability usually warrant surgical interventions. This cadaveric study examines and compares biomechanical characteristics between the following treatments for syndesmosis injuries: suture-button fixation plus syndesmotic repair and screw fixation.

Methods: The lower extremities of 10 cadavers disarticulated at the knee joints were used, yielding 20 feet. Ten feet underwent surgery using the suture-button fixation with syndesmotic repair, while the remaining 10 feet underwent surgery using screw fixation. Before surgical treatment of syndesmosis injuries, each cadaveric lower limb underwent preliminary physiological cyclic loading, which was followed by a series of postfixation cyclic loading tests after the surgical procedure.

Results: Our principal finding is that suture-button fixation with syndesmotic repair provided torsional strength comparable to that of screw fixation. The mean failure torque did not differ between the 2 groups, but the rotational stiffness was significantly lower in the suture-button fixation/augmentation group.

Conclusions: Suture-button fixation/augmentation facilitates flexible (physiological) syndesmosis movement and may be a useful alternative treatment for ankle syndesmosis injury.

Keywords: *Syndesmosis, Syndesmotic instability, Operative fixation, Flexible fixation, Rigid fixation*

The tibiofibular syndesmosis plays a crucial role in maintaining ankle stability, comprising 3 primary stabilizing ligaments: the anterior inferior tibiofibular ligament (AITFL), the posterior inferior tibiofibular ligament (PITFL), and the interosseous ligament.[1] Injuries to the distal tibiofibular syndesmosis, often resulting from high-energy impacts, can occur in isolation or in conjunction with deltoid ligament injuries or ankle fractures.[2] Acute syndesmotic injuries with evident or latent instability usually require surgical interventions to restore and sustain joint stability.

The operative repair of an unstable syndesmosis re-

Received August 20, 2024; Revised October 12, 2024;
Accepted November 26, 2024
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quires a delicate balance between enhancing joint stability and mitigating the risks of complications (i.e., reduction loss, excessive tibiotalar joint constraint, and hardware failure). Conventional syndesmosis screw fixation is associated with favorable clinical outcomes and ensures a short-term joint constraint that facilitates healing. However, the limitations include long-term joint overconstraint and frequent hardware failure requiring hardware removal via reoperation.[3] Suture-button fixation is increasingly used as an alternative to conventional 3.5-mm tricortical or quadricortical screw fixation, considering its provision of long-term dynamic stabilization. Numerous studies have been conducted comparing screw fixation and suture-button fixation. Kortekangas et al.[4] found no significant functional outcome differences but higher malreduction rates with screw fixation. Laflamme et al.[5] reported faster recovery and lower reoperation rates with TightRope fixation. Naqvi et al.[6] observed higher malreduction rates with screw fixation, affecting clinical outcomes negatively. Kocadal et al.[7] noted no significant functional outcome differences but better fibular rotation restoration with suture-button fixation.

However, conventional suture-button fixation may render the syndesmosis susceptible to external rotational stress and reduction loss.[8] Research indicates that while suture-button fixation offers dynamic stabilization and allows for early rehabilitation, it also presents potential drawbacks. For instance, a study noted that dynamic syndesmotic fixation, such as suture-buttons, could lead to instability under external rotational forces, potentially resulting in recurrent diastasis.[9] Similarly, another study highlighted that suture-button constructs could be more vulnerable to external rotational stress compared to screw fixation, emphasizing the risk of reduction loss.[10] A case study reported successful outcomes using suture tape augmentation for syndesmotic injuries, demonstrating good clinical results and anatomical restoration.[11] Building on this evidence, our study aimed to compare the stability provided by suture-button fixation combined with suture tape augmentation to determine if this surgical technique can enhance rotational stability. By focusing on the anterior aspect, we assessed whether this combined approach offered superior stabilization for syndesmosis injuries, potentially providing a more stable outcome than screw fixation alone. This study sought to determine whether adding suture tape augmentation could enhance the effectiveness of suture-button fixation in maintaining rotational stability.

METHODS

The study was conducted in accordance with the Declaration of Helsinki and approved by the Institutional Review Board and Human Research Ethics Committee of Soonchunhyang Bucheon Hospital (IRB No. 2019-08-002). Informed consent was not required as the study used cadaveric specimens.

We used 10 cadavers graciously donated to the Korea University Anam Hospital (Seoul, Korea). The lower extremities were disarticulated at the knee joints, providing a total of 20 feet. However, during the experimental process, 1 pair of specimens was excluded because the loading requirements were not met, resulting in a final analysis of 9 pairs of specimens. Cadavers lacking significant trauma history, surgical interventions, or prior medical complications of the ankle joint were chosen randomly. Individuals with confirmed syndesmotic damage to the ankle joint, which could potentially influence the research outcomes, were excluded. Other exclusion criteria were any history of ankle joint surgery; injury to surrounding structures such as ligaments, bones, and/or ankle syndesmosis, and severe ankle joint trauma. Considering potential anatomical variations among cadavers, distinct surgical techniques were utilized for each leg. Suture-button (TightRope; Arthrex) fixation with syndesmotic repair was performed on one side, whereas screw fixation was performed on the opposite side (Fig. 1).

Specimen Preparation

Each ankle joint was kept frozen until the study began and then brought to room temperature. Two soft tissue sec-

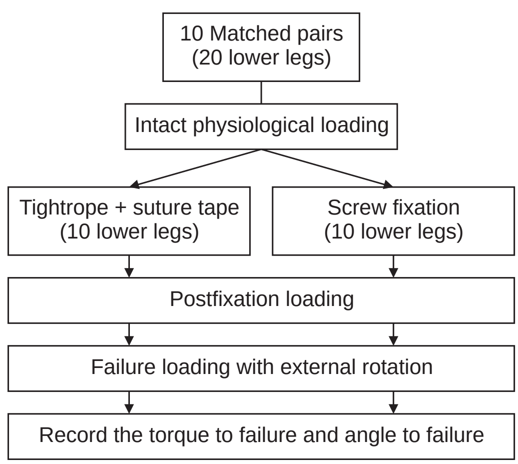

Fig. 1. Flowchart of the study protocol. To minimize the effects of anatomical variations, we performed a suture-button technique with suture tape augmentation on one leg and screw fixation on the opposite leg.

tions, each 1 × 2 cm, were excised. This excision exposed the tibia and fibula while preserving the syndesmosis. To ensure consistent positioning of each specimen, the second toe and heel were aligned with the neutral line of an aluminum foot plate. The hindfoot and forefoot were tightly fixed between 2 L-shaped frames attached to the foot plate; the plantar aspect of the foot was secured using screws through the calcaneus and metatarsals. The aluminum plate with the secured foot was then inverted and horizontally mounted on the ground, allowing the proximal joint to perpendicularly hang under gravity; this technique established the neutral flexion position of the ankle joint. The proximal tibiofibular joint was subsequently placed in gypsum (Samwoo Co.) within a cylindrical plastic container (Fig. 2).

The specimens were placed in an Axial-Torsion Test Machine (TestResources Inc.). A metallic cylindrical jig was connected to an axial actuator equipped with a biaxial load cell, and an x-y stage with an inversion/eversion swing was mounted on the torsional actuator. The plastic container holding the proximal tibiofibular joint was inserted into the cylindrical jig and firmly secured using circumferential set screws. The plate with the fixed foot was securely attached to a metallic plate on the inversion/eversion swing, which was mounted on the x-y stage. During each loading protocol, the degrees of freedom of x-y translation and inversion/eversion rotation were kept unconstrained to prevent the development of shear forces or rotational torques attributable to misalignment in the preparation of cadaver specimens.

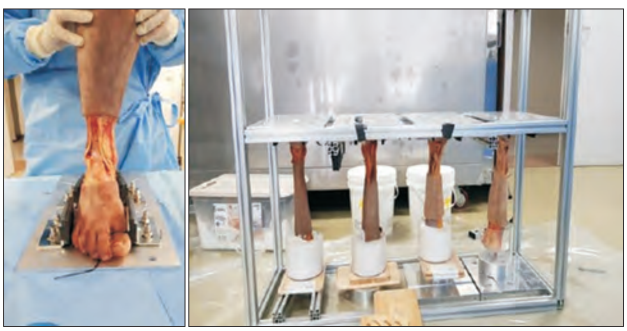

Fig. 2. Proximal and distal fixation of specimens.

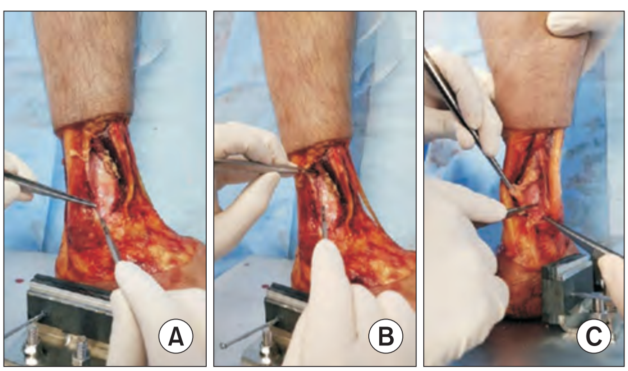

Fig. 3. Injuries to the anterior inferior tibiofibular ligament (A), interosseous membrane (B), and posterior inferior tibiofibular ligament (C) were created using a scalpel.

Intact Loading

Prior to surgical treatment of syndesmosis injuries, each cadaveric lower limb was subjected to initial physiological cyclic loading. The protocol included 10 cycles of axial loading with a peak force of 750 N, 10 cycles of external torsional loading with a peak torque of 7.5 Nm, and 10 cycles of combined axial and external torsional loading with peaks of 750 N and 7.5 Nm, respectively, delivered at a frequency of 0.05 Hz.[12]

Injury Creation and Surgical Fixation

After application of intact physiological loading, injuries to the AITFL, interosseous membrane, and PITFL were induced by direct incision using a fresh scalpel for each ankle joint. Subsequently, either suture-button fixation with syndesmotic repair or screw fixation was performed. All injuries were created and all fixations were conducted by the same surgeon (YKL) (Fig. 3).

To achieve tibiofibular reduction and fixation, a TightRope suture-button implant (Arthrex) was inserted from the lateral aspect of the fibula. To augment the AITFL, a suture tape with a bone anchor (InternalBrace; Arthrex) was utilized. Initially, a 2.7-mm hole was drilled

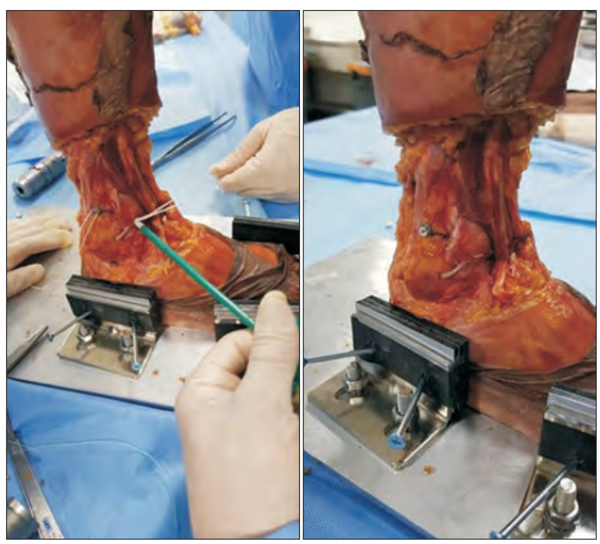

Fig. 4. Suture-button fixation with syndesmotic repair.

over the anterior aspect of the fibula; a 3.5-mm biocomposite anchor, accompanied by a 2-mm-wide suture tape (FiberTape; Arthrex) was inserted into the hole. Subsequently, a 3.4-mm hole was drilled in the anterior aspect of the lateral tibia to ensure alignment of the folded-back portion of the suture tape with the AITFL fibers. A 4.75-mm biocomposite anchor was then inserted in the second hole, and appropriate tension was applied to the suture tape. After tensioning of the tape, the remaining portion was removed (Fig. 4).[13]

Fixation via screw placement through the syndesmosis was conducted using 2 tricortical 3.5-mm cortical screws positioned within 2 cm proximal to the articular surface of the distal tibia and aligned to match the joint surface (Fig. 5).

Postfixation Loading

After surgical an intervention (either screw fixation or suture-button fixation with syndesmotic repair), a series of postfixation cyclic loading tests were conducted. Specimens were subjected to 50 cycles of combined axial and external torsional loading, reaching peaks of 750 N and 7.5 Nm at a frequency of 0.05 Hz. Next, failure loading was applied.[14] This involved exposing the specimens to external rotation at a rate of 0.25°/sec until a sudden torque drop was apparent in the torque-rotation curve. The torque and angle at which this drop occurred were recorded. Rotational stiffness (i.e., the torque generated during external rotation) was assessed by determining the slope of the linear portion of the torque-rotation curve via linear regression analysis (Fig. 6).

Fig. 5. Screw fixation through the syndesmosis.

Statistical Analysis

Differences between the screw fixation and suture-button fixation with syndesmotic repair groups were compared using paired *t*-tests with a significance threshold of a *p*-value less than 0.05. Paired *t*-tests were also used to compare failure torque, failure angle, and rotational stiffness between the 2 groups. All statistical analyses were performed with SPSS software version 25 (IBM Corp.). Based on the work of Ebramzadeh et al.,[12] we anticipated that the maximum rotation difference between the treatment and control groups would be 10.0° ± 9.4°, assuming a correlation coefficient of 0.95 between the 2-sided legs. As we expected no dropouts, a sample size of 10 was required to detect this difference with 80% power and a type I error rate of 0.05 (2-sided). Power calculation was conducted using PASS 12 software (NCSS LLC; www.ncss.com).

RESULTS

After completion of postfixation cyclic loading, 1 pair of specimens was excluded because the loading requirements were not met. The remaining 9 pairs successfully underwent all 50 loading cycles and were subjected to failure testing. The mean failure torque for the screw fixation group was 17.10 ± 10.38 Nm, whereas it was 15.99 ± 8.88 Nm for the suture-button fixation with syndesmotic repair group (p = 0.669). However, the mean failure angle was significantly lower in the screw fixation group (39.37° ± 10.19°) than in the suture-button fixation with syndesmotic repair group

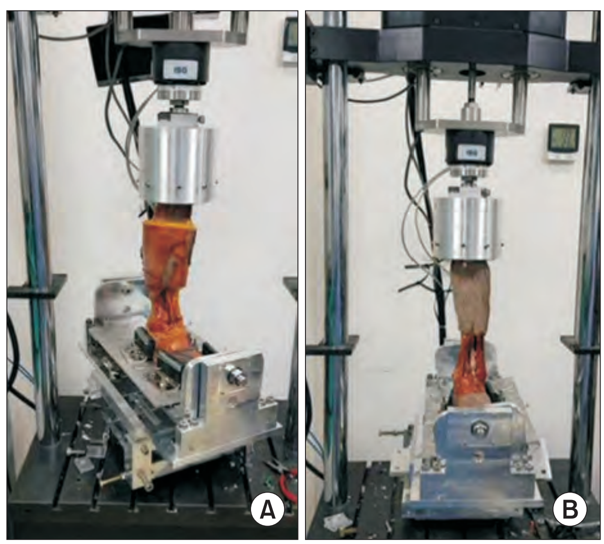

Fig. 6. Postfixation loading (A) and failure testing (B). Fifty cycles of combined axial and external rotation loading with peaks of 750 N and 7.5 Nm at 0.05 Hz were used for postfixation loading; external rotation at 0.25°/sec was used for failure testing.

Table 1. Failure Torque, Failure Angle, and Rotational Stiffness According to the Surgical Method

	Screw fixation (n = 9)	Suture-Button fixation with internal brace augmentation (n = 9)	*p*-value
Failure torque (Nm)	17.10 ± 10.38	15.99 ± 8.88	0.669
Failure angle (°)	39.37 ± 10.19	56.64 ± 9.64	0.001*
Rotational stiffness (Nm/°)	0.53 ± 0.24	0.35 ± 0.19	0.033*

Values are presented as mean ± standard deviation.
*Statistical significance ($p < 0.05$).

(56.64° ± 9.64°) ($p = 0.001$). Additionally, the mean rotational stiffness was significantly higher in the screw fixation group (0.53 ± 0.24 Nm/°) than in the suture-button fixation with syndesmotic repair group (0.35 ± 0.19 Nm/°) ($p = 0.033$) (Table 1).

DISCUSSION

Our primary finding is that suture-button fixation with syndesmotic repair provided torsional strength comparable to that of screw fixation. There was no notable difference in the mean failure torques of the 2 surgical groups, but rotational stiffness was substantially decreased in the suture-button fixation with syndesmotic repair group. This finding implies that suture-button fixation with syndesmotic repair can provide stability similar to that of screw fixation in patients with syndesmosis injuries, validating our hypothesis. The former method is a type of flexible fixation that maintains physiological movement. Fixation with a suture band alone does not maintain diastasis of the syndesmosis or external rotation of the fibula.[13] The suture tape was oriented in the same direction as the AITFL and served as a substitute for the torn AITFL. The suture band facilitated reduction concurrently, and the suture tape strengthened the syndesmosis and maintained the reduction.

The syndesmosis is critical in terms of ankle joint stability. Each component of the syndesmosis exhibits unique characteristics; all play vital roles in the overall function of the ligamentous complex. When choosing a syndesmosis anatomical repair technique that ensures long-term dynamic joint stabilization, it is important to consider the individual biomechanical contributions of the ligaments to the overall stability of the ankle mortise.[15] Techniques for such surgery include syndesmotic screw fixation and flexible fixation methods such as suture-button fixation and direct repair of the AITFL using sutures, anchors, or screws with washers.[14,16] Syndesmotic screw or suture-button fixations are the most common techniques, but disagreement persists regarding their efficacies.[17] Historically, syndesmotic repair utilized screw fixation, which is associated with inherent rigidity that may cause screw loosening or breakage or create a need for clinically problematic screw removal. Typically, syndesmotic screws are inserted using a pointed tenaculum at an angle of approximately 30° to the coronal plane.[14] However, advanced imaging techniques have revealed that the postfixation tibiofibular alignments are often poor; syndesmotic malreduction rates range from 22% to 52%.[6,18] The suture-button technique is an alternative syndesmotic fixation method that is theoretically superior to screw fixation. Suture-buttoning is presumed to permit physiological micromotion during accurate reduction. The theoretical efficacy of suture-buttoning for syndesmotic malreduction is design-based; positional variance is possible within the insertion hole. When a suture-button construct is tensioned and the syndesmosis is compressed, the suture material assumes an oblique position within the hole. Consequently, the fibula is drawn into the natural concavity of the tibial incisura fibularis, facilitating anatomically precise reduction. Suture-button constructs are intended to restore normal anatomical alignment while permitting fibular motion in the incisura. One suggested advantage is that no implant requires removal. However, Ryan and Rodriguez[19] found that additional suture-buttons were sometimes necessary to ensure adequate translational or rotational control. Many biomechanical studies have explored post-surgery fibular motion, with varying results.[12,14,20] The results of some studies suggested that single suture-button constructs provided adequate coronal plane control,[20] whereas the results of other studies suggested that adequate control was not achieved.[12,21]

Our study adds to the growing body of research comparing the efficacy of screw fixation and suture-button fixation in maintaining syndesmotic stability. While many biomechanical investigations have yielded varying results, our findings underscore the comparable torsional strength between both methods, highlighting suture-button fixation's potential as a viable alternative. For instance, LaMothe et al.[20] utilized fluoroscopy combined with a 4-camera motion capture system to assess fibular motion in cadavers fixed with either a tetracortical 4.0-mm screw or a single suture-button construct. They reported that both fixation methods effectively restricted coronal plane fibular motion during external rotation stress tests. In contrast, Ebramzadeh et al.[12] and Forsythe et al.[21] found that a single suture-button construct failed to maintain syndesmotic stability in the coronal plane. These discrepancies may stem from the different experimental setups and loading conditions, which may not accurately reflect clinical scenarios. Our study builds on these findings by showing that suture-button fixation, when combined with augmentation, maintains sufficient stability, suggesting its efficacy in practical applications.

The use of suture-button constructs for syndesmosis repair within the interosseous ligament plane has recently become popular. However, this approach has been associated with greater instability under external rotation compared to screw fixation and native ankle physiology.[12,22] For decades, screw fixation has been the preferred method to manage syndesmotic instability. Despite its advantages, screw fixation introduces excessive joint constraint and has been linked to hardware failure that may require surgical correction. In contrast, our study demonstrates that the combination of suture-button fixation with suture tape augmentation offers stability comparable to that of screw fixation, while allowing for physiological movement. This finding suggests that modern fixation techniques using suture-button constructs, particularly when augmented, may be superior in restoring native biomechanics and ensuring long-term dynamic stabilization of the syndesmosis. The results of clinical studies indicate that both implant strategies can effectively restore syndesmosis stability, as evidenced by similar postoperative American Orthopedic Foot and Ankle Scores and overall clinical outcomes across treatment groups.[5] Seven other studies using the American Orthopedic Foot and Ankle Score/Ankle Hindfoot Score showed no discernible differences in functional outcomes.[6,7,23,24] Furthermore, Andersen et al.[25] conducted a randomized trial comparing the efficacies of suture-button fixation and a single syndesmotic screw, revealing better functional and radiographic outcomes in the suture-button group. Our findings support this notion, highlighting the potential benefits of suture tape augmentation in enhancing the stability of syndesmosis repairs.

This study had some limitations. First, it was not a clinical trial; therefore, we cannot draw clinical conclusions. Second, we did not consider concurrent ankle pathologies that might affect ankle biomechanics. However, we speculate that an appropriate intervention would provide a stable and anatomically precise ankle structure, as observed in the cadavers. Third, the sample size was small. Further research is required to explore the clinical implications of our biomechanical findings.

In conclusion, compared with screw fixation, suture-button fixation with syndesmotic repair provided more physiological syndesmosis movement and thus could be an effective treatment option for patients with ankle syndesmosis injuries.

CONFLICT OF INTEREST

No potential conflict of interest relevant to this article was reported.

ACKNOWLEDGEMENTS

This study was presented at the AOFAS Annual Meeting 2021 in September 22 to 25, 2021.

This work was supported by the Soonchunhyang University Research Fund (2024-0024).

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