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# Biomechanical Comparison of an Open vs Arthroscopic Approach for Lateral Ankle Instability

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**Abstract**

**Background:** The current clinical standard for the surgical treatment of ankle instability remains the open modified Broström procedure. Modern advents in arthroscopic technology have allowed physicians to perform certain foot and ankle procedures arthroscopically as opposed to traditional open approaches.

**Methods:** Twenty matched lower extremity cadaver specimens were obtained. Steinman pins were inserted into the tibia and talus with 6 sensors affixed to each pin. Specimens were placed in a Telos ankle stress apparatus in an anteroposterior and then lateral position, while a 1.7 N-m load was applied. For each of these tests, movement of the sensors was measured in 3 planes using the Optotrak Computer Navigation System. Changes in position were calculated and compared with the unloaded state. The anteriortalofibular ligament and the calcaneofibular ligament were thereafter sectioned from the fibula. The aforementioned measurements in the loaded and unloaded states were repeated on the specimens. The sectioned ligaments were then repaired using 2 corkscrew anchors. Ten specimens were repaired using a standard open Broström-type repair, while the matched pairs were repaired using an arthroscopic technique. Measurements were repeated and compared using a paired *t* test.

**Results:** There was a statistically significant difference between the sectioned state and the other 3 states ($P < .05$). There were no statistically significant differences between the intact state and either the open or arthroscopic state ($P > .05$). There were no significant differences between the open and arthroscopic repairs with respect to translation and total combined motion during the talar tilt test ($P > .05$). Statistically significant differences were demonstrated between the 2 methods in 3 specific axes of movement during talar tilt ($P = .04$).

**Conclusion:** Biomechanically effective ankle stabilization may be amenable to a minimally invasive approach.

**Clinical Relevance:** A minimally invasive, arthroscopic approach can be considered for treating patients with lateral ankle instability who have failed conservative treatment.

**Keywords:** ankle stabilization, Broström, arthroscopic ankle instability repair

The advent of arthroscopic intervention in the ankle has not had the same amount of success and broad application compared with the shoulder, knee, and hip. Due to the smaller size and articular complexity of the ankle joint, the general need for distraction, difficulty visualizing specific anatomic structures, and surgeon unfamiliarity with advanced arthroscopic techniques, research has shown that ankle arthroscopy is primarily indicated for treating intra-articular pathologies such as ankle impingement and osteochondral lesions of the talus.[7] However, smaller arthroscopes, newer noninvasive traction techniques, and novel suture anchor devices may now provide surgeons the tools necessary to address ankle instability arthroscopically.

Recent reports revealing a high (up to 93%) incidence of associated intra-articular pathology with chronic ankle instability have led some authors to incorporate ankle arthroscopy into the repair by first arthroscopically documenting and addressing intra-articular pathology and thereafter transitioning to an open Broström-Gould type of reconstruction.[2,5,9,11,18,19,21-23] Our experience over the past 2 years, however, suggests that the whole procedure may be performed safely and effectively using an entirely arthroscopic approach—obviating the need to make more

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formal open exposures that jeopardize numerous structures on the lateral aspect of the ankle. The smaller portals associated with arthroscopic intervention improve immediate postoperative pain, decrease swelling, lower the risk of wound breakdown and infection, and in some cases allow return to function more quickly by allowing for earlier mobilization of the ankle.[8,13,14] To date, there exist few reports of arthroscopic ankle stabilization and no randomized controlled clinical trials comparing open vs arthroscopic techniques.[4,10,12,16,20,21] To our knowledge, there are limited clinical studies using modern suture anchor techniques to address these pathologies arthroscopically.[3,4,15,16,21] In all initial reports, the authors observed good results. However, these reports have been met with some skepticism and still provide little evidence to dissuade surgeons from continuing to perform the more conventional open procedures that have also had generally excellent results.

The purpose of this biomechanical study was to compare the ability of an arthroscopic and traditional standard open approach to confer lateral ankle stabilization in both the unstable as well as the intact state. This information could help determine the efficacy of an arthroscopic approach and define appropriate indications for use. We hypothesized that there would be no significant biomechanical difference when the arthroscopic repair was compared with the more traditional, open approach. Furthermore, we hypothesized that both repairs would effectively stabilize the tibiotalar joint when subjected to stress testing.

## Materials and Methods

Twenty lower extremity cadaver specimens (from the proximal tibia to the toes) were obtained from 10 cadavers (mean age, 40 ± 12 years). These matched pairs were screened for gross anatomical defects and preexisting ankle laxity and placed in a freezer at −20°C until 24 hours prior to testing. Measurement of anterior drawer (AD) translation and talar tilt (TT) angle was performed on the specimens using both 2-dimensional radiographs and the 3-dimensional system in the intact state. To measure AD translation and TT angle, a 3-dimensional navigation system, the Optotrak System (Optotrak 3020; NDI, Waterloo, Canada), which tracks the movements of the rigidly affixed sensors in 3-dimensional space, was used. One 5-mm Steinman pin was inserted into the tibia and one into the talus, with 6 Optotrak sensors rigidly affixed to each pin. The pins were placed so that they had freedom of motion and would not impinge on any adjacent anatomic structures. The tibial pins were placed bicortically in an anterior to posterior direction. The talar pins were placed unicortically in an oblique direction along the longitudinal plane of the talar neck. The location of each sensor in 3-dimensional space was tracked using the Optotrak camera system and First Principles software (NDI).

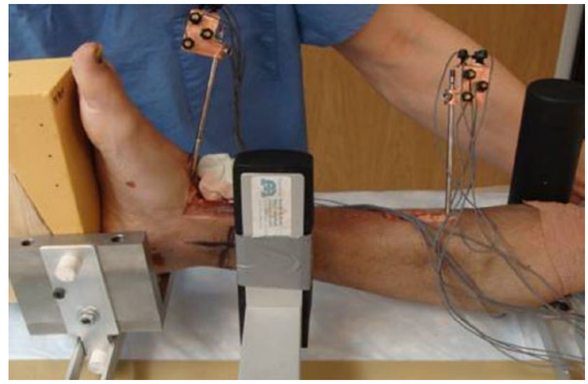

**Figure 1.** Telos ankle stress apparatus at neutral ankle dorsiflexion.

Each specimen was placed in a Telos ankle stress apparatus (Telos, Hungen, Germany) at neutral ankle dorsiflexion confirmed with fluoroscopy (Figure 1). Following this, the ankle was loaded in an anteroposterior direction (sagittal plane) with a 1.7 N-m load applied to simulate the AD test. The ankle was then loaded with a varus stress, and a 1.7 N-m load simulated the TT. Measurements of translation and angular rotation in the x, y, and z planes were then recorded electronically to establish the maximum anterior translation and varus tilt. The measurements were repeated 2 times so that 3 data sets were performed for each trial. The experiment was then repeated at 15 degrees of dorsiflexion and 15 degrees of plantarflexion.

After these measurements were performed in the intact state, a lateral incision was made along the fibula. The anteriortalofibular ligament (ATFL) and calcaneofibular ligament (CFL) origins were identified. The ATFL and the CFL were both sectioned along their origins on the fibula distally to the level of the peroneal tendons (Figure 2). This was performed to simulate an unstable ankle. The skin was closed using a running suture, but the lateral ligamentous and capsular structures were left unrepaired. To determine if the measurements obtained with plain film radiographs differed significantly from the measurements obtained with the 3-dimensional motion tracking system, the AD translation and TT angular values were each compared independently using a paired *t* test. The experimental conditions were then repeated and data were collected for the sectioned state.

Matched pairs of specimen were then randomly divided into 2 groups: an "open" repair group and an "arthroscopic" repair group. There were 10 specimens in each group. There were 5 right legs and 5 left legs in each group. In the open group, the sectioned ligaments were repaired using two 3.5-mm diameter corkscrew suture anchors (Arthrex, Inc, Naples, FL). Each of these anchors was double loaded with

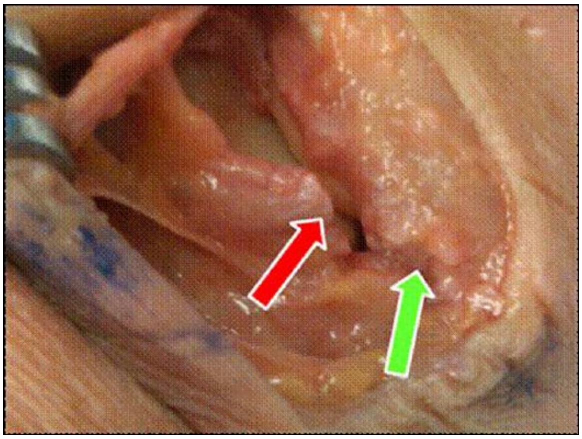

**Figure 2.** Sectioned anteriortalofibular ligament (green arrow) and the calcaneofibular ligament (red arrow) along their origins on the fibula distally to the level of the peroneal tendons.

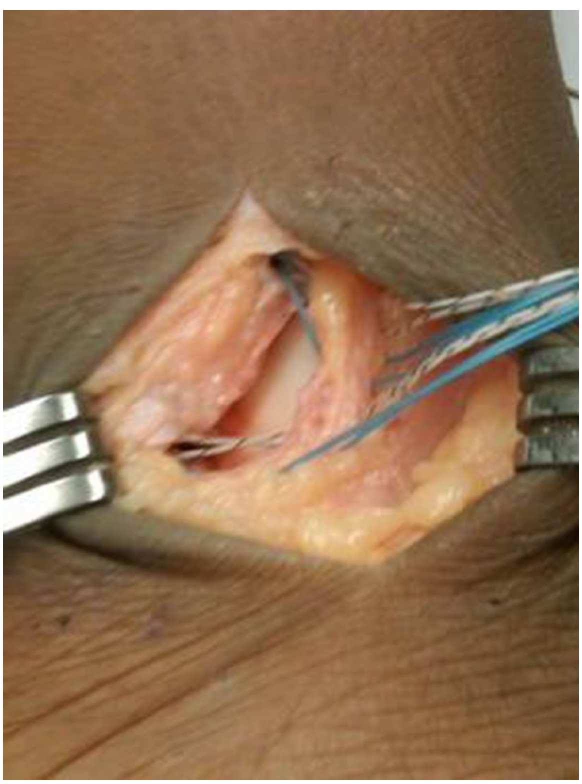

**Figure 3.** Anchor placed at the anteriortalofibular ligament origin and the calcaneofibular ligament origin.

a No. 2 fiberwire suture. One anchor was placed at the ATFL origin and one at the CFL origin (Figure 3). The ankle ligaments were then repaired with a mattress-type suture in a pants-over-vest–type fashion with approximately 10 to 15 mm of overlap (Figure 4). The ankle was then reduced using a combination of hindfoot posterior translation and eversion. The suture knots were thrown with the ankle in this position to set the appropriate tension on the repair. The experimental conditions were then repeated and data were collected for the open state.

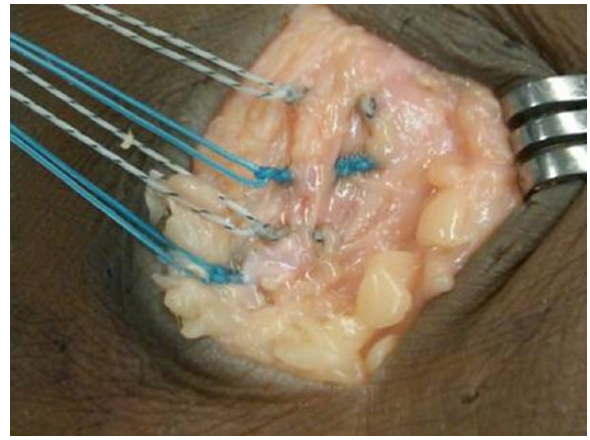

**Figure 4.** Repaired ankle ligaments with a mattress-type suture in a pants-over-vest–type fashion.

The contralateral limbs were then prepared. The proximal tibia and fibula were stripped of their soft tissue attachments. A vice grip was then secured around the proximal tibia and fibula. Gravity alone was used for distraction of the ankle joint. Standard anterolateral and anteromedial portals were made. Diagnostic arthroscopy was performed. A third accessory anterolateral portal was then established approximately 2 to 3 cm inferior to the anterolateral portal (Figure 5). While visualizing through the anteromedial portal, an electrocautery device was used to clear the remaining soft tissue off the entire anterior aspect of the fibula from the level of the tibiotalar joint to the distal-most aspect of the fibula that could be visualized from the anterolateral portal. Occasionally, a 70-degree arthroscope was used to facilitate visualization at this point. Care was taken to avoid injury to the articular cartilage during this procedure. This was often the distal-most tip of the fibula. Similar to the open procedure, one 3.5-mm diameter corkscrew suture anchor was placed at the ATFL origin and one at the CFL origin (Figures 6 and 7). Using a suture lasso device (Arthrex, Inc), the ATFL tissue was pierced approximately 7 to 10 mm from its origin. Careful attention was paid not to violate any adjacent tissues or structures such as the peroneus tertius, extensor tendons, or superficial peroneal nerve. Through the anterolateral accessory portal, the capsule and extensor retinaculum were pierced. Each of the 4 stands of suture was sequentially shuttled through the tissue. The ankle was then reduced using posterior talar translation and

**Figure 5.** Third accessory anterolateral portal approximately 2 to 3 cm inferior to the anterolateral portal.

eversion of the hindfoot. The sutures were tied in an inferior to superior direction in a mattress-type fashion. Measurements using the Optotrak were repeated on the specimens following repair. The results of the calculations of the 4 different states (intact, sectioned, open, and arthroscopic) were compared using a paired *t* test.

## Results

There was a statistically significant difference between the sectioned state and the other 3 states ($P < .05$) in all 3 different positions of ankle dorsiflexion (Tables 1 and 2). This was true for both AD and TT. There were no statistically significant differences between the intact state and either the open or arthroscopic state with respect to these parameters ($P > .05$). There were also no significant differences between the open and arthroscopic repairs with respect to translation in any plane during the anterior drawer test and total combined motion during the talar tilt test ($P > .05$). There were significant differences demonstrated between the 2 methods of repair in 3 specific axes of movement during the talar tilt test: in 15 degrees of plantarflexion, the open procedure had an average talar tilt of 5.7 degrees, and the arthroscopic procedure had an average talar tilt of 9.8

**Figure 6.** Fluoroscopic view of 3.5-mm diameter corkscrew suture anchors at the anteriortalofibular ligament and calcaneofibular ligament origins.

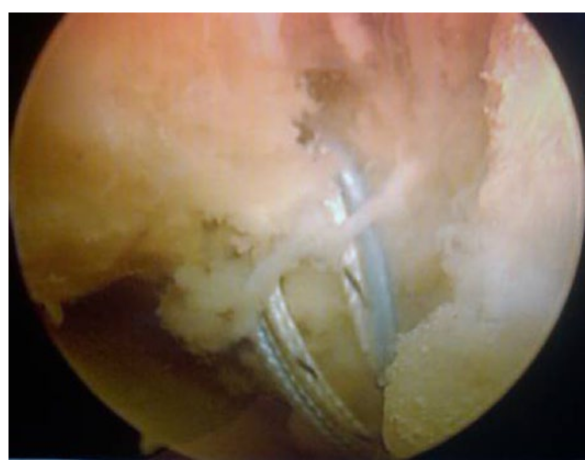

**Figure 7.** Arthroscopic view of 3.5-mm diameter corkscrew suture anchors at the anteriortalofibular ligament and calcaneofibular ligament origins.

degrees ($P = .04$). With the foot in plantarflexion, there was an average of 10.5 degrees of dorsi/plantarflexion during the talar tilt test in the open group and only 4.0 degrees in

**Table 1.** Intact vs Open vs Arthroscopic Motion Analysis.

| Intact | z | y | x | |
|---|---|---|---|---|
| Anterior Drawer | Tension/Compression | Anterior/Posterior Translation | Medial/Lateral Translation | Translation Magnitude |
| Plantarflexion | −0.5 ± 1.5 | −4.3 ± 2.5 | −0.3 ± 3.2 | 5.6 ± 2.3 |
| Neutral | −0.3 ± 1.5 | −4.2 ± 2.1 | 0.7 ± 3.8 | 5.8 ± 2.1 |
| Dorsiflexion | 0.3 ± 1.5 | −1.8 ± 1.7 | 0.7 ± 2.7 | 3.8 ± 1.1 |
| Talar Tilt | External/Internal Rotation | Inversion/Eversion | Dorsiflexion/ Plantarflexion | Rotation RMS |
| Plantarflexion | 0.3 ± 6.4 | 8.1 ± 7.9 | −13.5 ± 7.96 | 17.8 ± 9.7 |
| Neutral | −0.8 ± 7.7 | 9.5 ± 6.1 | −13.3 ± 12.2 | 20.1 ± 10.1 |
| Dorsiflexion | −0.5 ± 4.1 | 5.9 ± 5.0 | −7.2 ± 5.8 | 11.3 ± 5.6 |
| Open | z | y | x | |
| Anterior Drawer | Tension/Compression | Anterior/Posterior Translation | Medial/Lateral Translation | Translation Magnitude |
| Plantarflexion | −1.0 ± 1.5 | −5.1 ± 2.8 | 0.3 ± 2.8 | 6.1 ± 2.5 |
| Neutral | −0.9 ± 1.4 | −4.4 ± 1.8 | 0.4 ± 5.1 | 6.7 ± 2.3 |
| Dorsiflexion | 0.3 ± 0.7 | −3.3 ± 3.9 | 1.1 ± 4.7 | 5.6 ± 4.0 |
| Talar Tilt | External/Internal Rotation | Inversion/Eversion | Dorsiflexion/ Plantarflexion | Rotation RMS |
| Plantarflexion | 0.9 ± 4.4 | 5.7 ± 2.5 | −10.5 ± 5.8 | 12.8 ± 5.8 |
| Neutral | 2.5 ± 3.0 | 8.6 ± 3.0 | −13.8 ± 7.0 | 17.3 ± 5.9 |
| Dorsiflexion | 0.5 ± 3.5 | 7.3 ± 3.9 | −8.5 ± 7.0 | 12.4 ± 6.7 |
| Arthroscopic | z | y | x | |
| Anterior Drawer | Tension/Compression | Anterior/Posterior Translation | Medial/Lateral Translation | Translation Magnitude |
| Plantarflexion | −0.0 ± 2.3 | −3.3 ± 5.5 | −1.3 ± 2.4 | 6.3 ± 3.3 |
| Neutral | 0.1 ± 1.0 | −4.6 ± 2.0 | −0.8 ± 4.2 | 6.1 ± 2.3 |
| Dorsiflexion | 0.2 ± 1.0 | −2.8 ± 1.3 | −0.6 ± 4.4 | 4.6 ± 2.7 |
| Talar Tilt | External/Internal Rotation | Inversion/Eversion | Dorsiflexion/ Plantarflexion | Rotation RMS |
| Plantarflexion | 0.4 ± 3.5 | 9.8 ± 5.7 | −4.0 ± 4.8 | 11.6 ± 6.6 |
| Neutral | 1.2 ± 5.5 | 9.6 ± 6.7 | −6.7 ± 7.6 | 15.4 ± 6.2 |
| Dorsiflexion | 0.9 ± 6.0 | 8.8 ± 3.7 | −4.6 ± 5.4 | 13.2 ± 2.9 |

RMS, Root Mean Square.

the arthroscopic group ($P$ = .02). With the foot in neutral alignment, there was an average of 13.8 degrees of dorsi/plantarflexion during the talar tilt test in the open group and only 6.7 degrees in the arthroscopic group ($P$ = .04).

## Discussion

For many reasons, arthroscopic stabilization procedures represent an attractive option. Foremost, there exists the potential to lower morbidity and accelerate recovery through a minimally invasive approach. Furthermore, however, given the high incidence of associated intra-articular lesions, an arthroscopic approach enables the surgeon to address both intra-articular pathology and instability concomitantly with a singular rather than combined exposure.[5,11,17,21,22] Considering what can be done arthroscopically in some of the other major extremity joints, it would make sense anatomically that the ankle should also lend itself to an arthroscopic intervention.

To our knowledge, however, this is only the second study to compare the biomechanical properties of open vs arthroscopic ankle stabilization procedures.[6]

Our findings suggest that there is a similar restoration of biomechanical function in the ankle after both the arthroscopic and open lateral ligament repairs compared with the sectioned state using AD and TT testing. No significant differences were identified in translation when an anterior drawer test was performed between the arthroscopic

**Table 2.** Open vs Arthroscopic Specimen Group Comparison.

| | Anterior/Posterior Translation | Translation Magnitude |
|---|---|---|
| Open | | |
| Anterior drawer, mm | | |
| Plantarflexion | | |
| Intact | −5.2 ± 2.1 | 6.0 ± 1.8 |
| Sectioned | −9.1 ± 2.0 | 10.3 ± 1.7 |
| Repaired | −5.1 ± 2.8 | 6.1 ± 2.5 |
| Neutral | | |
| Intact | −4.1 ± 2.3 | 5.9 ± 2.2 |
| Sectioned | −9.4 ± 2.4 | 12.4 ± 4.4 |
| Repaired | −4.4 ± 1.8 | 6.7 ± 2.3 |
| Dorsiflexion | | |
| Intact | −1.6 ± 1.9 | 4.0 ± 1.3 |
| Sectioned | −5.9 ± 3.1 | 8.8 ± 3.6 |
| Repaired | −3.3 ± 3.9 | 5.6 ± 4.0 |
| Talar tilt, deg | Inversion/Eversion | Rotation RMS |
| Plantarflexion | | |
| Intact | 10.2 ± 5.9 | 18.6 ± 9.2 |
| Sectioned | 16.6 ± 6.2 | 22.6 ± 6.7 |
| Repaired | 5.7 ± 2.5[a] | 12.8 ± 5.9 |
| Neutral | | |
| Intact | 10.5 ± 7.0 | 20.6 ± 10.7 |
| Sectioned | 22.2 ± 6.5 | 32.9 ± 7.7 |
| Repaired | 8.6 ± 2.9 | 17.3 ± 5.9 |
| Dorsiflexion | | |
| Intact | 6.9 ± 3.7 | 10.3 ± 4.9 |
| Sectioned | 16.4 ± 9.8 | 24.8 ± 15.3 |
| Repaired | 7.3 ± 3.9 | 12.4 ± 6.7 |
| Arthroscopic | | |
| Anterior drawer, mm | | |
| Plantarflexion | | |
| Intact | −3.5 ± 2.6 | 5.3 ± 2.8 |
| Sectioned | −10.8 ± 4.3 | 12.6 ± 5.5 |
| Repaired | −3.3 ± 5.5 | 6.3 ± 3.3 |
| Neutral | | |
| Intact | −4.2 ± 2.1 | 5.7 ± 2.2 |
| Sectioned | −9.2 ± 2.3 | 12.9 ± 2.8 |
| Repaired | −4.6 ± 2.0 | 6.1 ± 2.3 |
| Dorsiflexion | | |
| Intact | −2.0 ± 1.5 | 3.6 ± 0.9 |
| Sectioned | −4.7 ± 4.0 | 7.6 ± 5.3 |
| Repaired | −2.8 ± 1.3 | 4.6 ± 2.7 |
| Talar tilt, deg | Inversion/Eversion | Rotation RMS |
| Plantarflexion | | |
| Intact | 6.1 ± 9.4 | 17.0 ± 10.7 |
| Sectioned | 15.4 ± 6.6 | 21.7 ± 5.4 |
| Repaired | 9.8 ± 5.7[a] | 11.6 ± 6.6 |
| Neutral | | |
| Intact | 8.5 ± 5.3 | 19.7 ± 9.9 |
| Sectioned | 21.8 ± 6.6 | 29.6 ± 6.6 |
| Repaired | 9.6 ± 6.7 | 15.4 ± 6.2 |
| Dorsiflexion | | |
| Intact | 4.9 ± 6.0 | 12.3 ± 6.3 |
| Sectioned | 16.2 ± 10.1 | 22.6 ± 11.6 |
| Repaired | 8.8 ± 3.7 | 13.2 ± 2.9 |

Positive values are defined as posterior translation and inversion. Negative values are anterior translation and eversion. RMS, Root Mean Square

[a]A statistically significant difference exists between the open and the arthroscopic repair in this motion, $P = .042$.

and open procedure groups. Moreover, the total motion using the talar tilt test was also similar between these 2 groups. There was 1 plane of motion where the open procedure was found to be statistically superior to the arthroscopic intervention (inversion in 15 degrees of plantarflexion), although both techniques were shown to be comparable to the intact state. This particular foot position appeared to be the most vulnerable to rolling into varus, and it remains unclear what the implications of this discrepancy are.

There are limitations of our study. Since we worked with a cadaveric model, ligaments had to be overtly sectioned to model instability, whereas in vivo, these ligaments are more commonly found to be attenuated or incompetent from prior (healed) injury. This model has been used in other biomechanical studies evaluating ankle instability.[6] We also only accounted for the static stabilizers of the ankle joint and did not investigate the role of the extensor retinaculum in this instability repair. Many of our arthroscopic suture repairs at the CFL anchor did cross this retinaculum, but the extent that such incorporation may have had in our repairs was not specifically studied. Furthermore, a previous biomechanical analysis of ankle stabilization using a Broström repair vs a modified Broström-Gould technique did not find any difference in ankle stability at the time of surgery when the inferior extensor retinaculum was incorporated in the repair.[1] Finally, we performed biomechanical testing with only 1 torque in 2 specific planes (anteroposterior and varus) and used 1 specific technique for each approach with the same number of anchors. Although these data are based on 1 specific arthroscopic and open technique for stabilizing the laterally unstable ankle, it does suggest that, at least from a biomechanical perspective, effective ankle stabilization can be achieved via a minimally invasive approach. A weakness of this study is that no power analysis was performed to determine the adequate number of specimens. More specimens may have shown different results. Further clinical evaluation is warranted to corroborate our basic science findings and more accurately delineate the specific indications for patients who may be candidates for an arthroscopic intervention.

## Declaration of Conflicting Interests

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