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Biomechanical Analysis of an Arthroscopic Broström Ankle Ligament Repair and a Suture Anchor–Augmented Repair

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Abstract

Background: Secondary surgical repair of ankle ligaments is often indicated in cases of chronic lateral ankle instability. Recently, arthroscopic Broström techniques have been described, but biomechanical information is limited. The purpose of the present study was to analyze the biomechanical properties of an arthroscopic Broström repair and augmented repair with a proximally placed suture anchor. It was hypothesized that the arthroscopic Broström repairs would compare favorably to open techniques and that augmentation would increase the mean repair strength at time zero.

Methods: Twenty (10 matched pairs) fresh-frozen foot and ankle cadaveric specimens were obtained. After sectioning of the lateral ankle ligaments, an arthroscopic Broström procedure was performed on each ankle using two 3.0-mm suture anchors with #0 braided polyethylene/polyester multifilament sutures. One specimen from each pair was augmented with a 2.9-mm suture anchor placed 3 cm proximal to the inferior tip of the lateral malleolus. Repairs were isolated and positioned in 20 degrees of inversion and 10 degrees of plantarflexion and loaded to failure using a dynamic tensile testing machine. Maximum load (N), stiffness (N/mm), and displacement at maximum load (mm) were recorded.

Results: There were no significant differences between standard arthroscopic repairs and the augmented repairs for mean maximum load and stiffness (154.4 ± 60.3 N, 9.8 ± 2.6 N/mm vs 194.2 ± 157.7 N, 10.5 ± 4.7 N/mm, $P = .222$, $P = .685$).

Conclusions: Repair augmentation did not confer a significantly higher mean strength or stiffness at time zero.

Clinical Relevance: Mean strength and stiffness for the arthroscopic Broström repair compared favorably with previous similarly tested open repair and reconstruction methods, validating the clinical feasibility of an arthroscopic repair. However, augmentation with an additional proximal suture anchor did not significantly strengthen the repair.

Keywords: ankle sprains, lateral ankle ligaments, anterior talofibular ligament, arthroscopy

Ankle injuries are among the most commonly observed injuries in athletic populations, accounting for 15% or more of all athletic injuries,[10,11,14,18,19,37] totaling nearly 2 million ankle sprains in the United States annually.[32] Of these ankle sprains, up to 85% (1.7 million) involve inversion injuries that affect the lateral ligaments of the ankle.[13,32] The majority of ankle sprains can be treated nonoperatively; however, a significant number of injured patients will experience chronic instability or reinjury, which can contribute significantly to persistent pain, functional limitations, and further chondral damage due to altered joint kinematics.[5,8,10,14,17,21,26,28,33,34] In such cases where patients do not respond to nonoperative treatment—including proprioceptive training, peroneal strengthening, and/or external stabilization—surgical treatment is often indicated to restore mechanical and functional stability.[20,26,27,31]

Open repairs of the lateral ankle ligaments have been described in the literature since their initial characterization by Broström in 1966.[4] Arthroscopic Broström techniques have recently been described, biomechanically validated, and clinically evaluated as minimally-invasive alternatives to traditional open repairs.[1,7,9,15,24,29] However, regardless of

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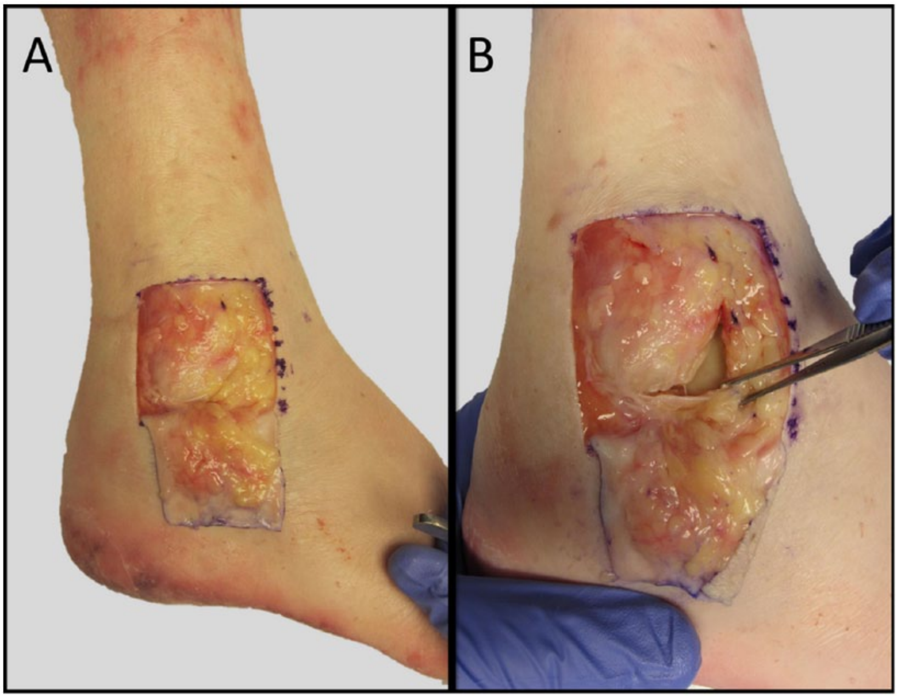

Figure 1. A, Inferiorly based lateral skin flap (4 × 4 cm) that allowed for lateral ligament sectioning. B, Anterior talofibular ligament and calcaneofibular ligament surgically dissected off their respective fibular footprints.

technique, biomechanical research has repeatedly demonstrated that standard repairs are significantly weaker than the intact lateral ankle ligaments.[36] Therefore, significant research has been dedicated to optimizing and strengthening repairs, with the goal of developing a Broström variation that would provide superior repair strength, facilitate early and aggressive postoperative rehabilitation, and ultimately accelerate return to preinjury activity levels.[2,3,6,16,20,35,36] The purpose of the current investigation was to evaluate the biomechanical properties of an arthroscopic Broström technique as well as an arthroscopic Broström variation in which an additional suture anchor was placed proximally in the fibula. Repairs were tested utilizing a standard testing protocol used previously for biomechanical evaluation of open Broström repairs, including those performed with suture only as well as suture anchors. We hypothesized that the strength of the arthroscopic repairs would compare favorably to previous open techniques and that the augmentation would significantly increase the strength of the repair.

Materials and Methods

Specimens

Twenty cadaveric foot and ankle specimens (10 matched pairs) with an average age of 57 years (range, 29 to 71) were utilized in this study. Lateral ankle ligaments were exposed through an inferiorly-based skin flap (4 × 4 cm; Figure 1A). Lateral ankle ligaments—including the anterior talofibular ligament (ATFL) and calcaneofibular ligament (CFL)—were sharply dissected off their fibular origins (Figure 1B). The skin flap was subsequently sutured closed prior to the arthroscopic procedure. Mechanical instability was verified by the anterior drawer, Cotton, and talar tilt tests. The first specimen pair was randomly split between the standard and augmented arthroscopic Broström treatment, while remaining specimens were alternately split left/right between repair techniques to achieve an equal distribution of left and right specimens between techniques.

Surgical Procedure

An arthroscopic Broström repair was then performed on each foot and ankle specimen in both treatment groups. The surgical repair consisted of two 3.0-mm biocomposite suture anchors (BioComposite SutureTak, Arthrex Inc, Naples, Florida) loaded with #0 braided polyethylene/polyester multifilament suture (#0 FiberWire, Arthrex Inc), placed arthroscopically at the anatomic fibular origins of the ATFL and the CFL, per a previously described arthroscopic technique (Figure 2A).[7,15] Suture limbs were passed percutaneously through the ATFL and CFL using a curved suture passer, each incorporating the inferior extensor retinaculum.

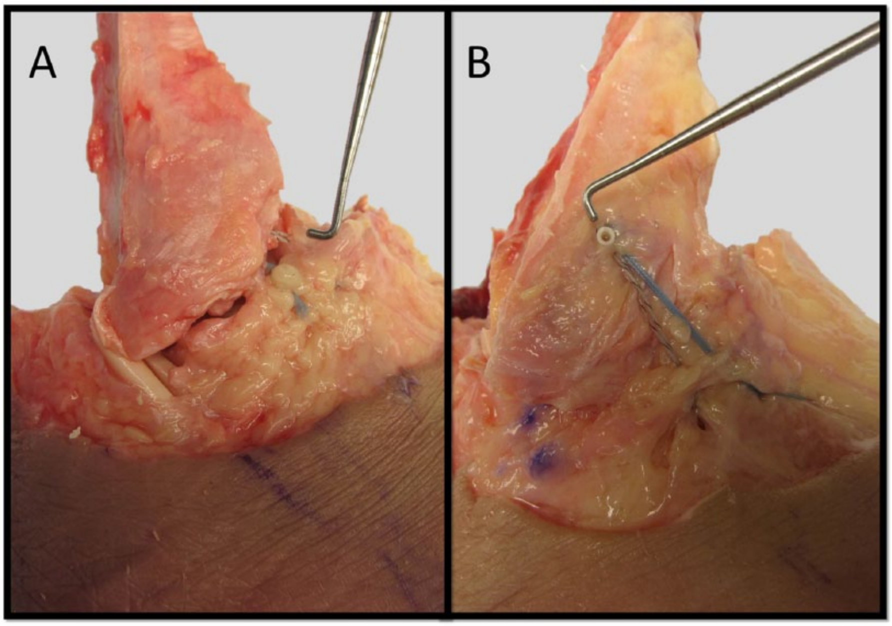

Figure 2. A, Isolated standard arthroscopic Broström repair. Probe indicates the location of the two 3.0-mm suture anchors loaded with #0 braided polyethylene/polyester multifilament sutures used in the arthroscopic repair. B, Isolated standard arthroscopic Broström repair augmented with a 2.9-mm knotless suture anchor (indicated by probe) placed 3 cm from the inferior tip of the lateral malleolus.

The sutures were retrieved subcutaneously via the lateral arthroscopic portal and then tied with the ankle held in neutral position. Anterior drawer, Cotton, and talar tilt testing verified surgical fixation and restoration of ankle stability.

One repair from each matched pair was augmented with a 2.9-mm biocomposite knotless suture anchor (BioComposite PushLock, Arthrex Inc) placed 3 cm proximal to the inferior tip of the lateral malleolus (Figure 2B). Each of the 4 suture arms was passed subcutaneously to a 5-mm longitudinal incision at this location, tensioned manually while the ankle was held in dorsiflexion and eversion, then secured. Sutures were cut flush with the bone. A distance of 3 cm was chosen as it was reproducible in all specimens, where the anchor would be clear of anchors placed in the distal fibula but remain within solid metadyaphyseal bone. Specimens were refrigerated until testing. All specimens were tested within 24 hours of preparation.

Specimen Preparation and Biomechanical Testing

Prior to biomechanical testing, the tibia and all overlying soft tissue were removed to visually verify and meticulously isolate the surgical repair. Testing was performed in accordance with previously described techniques.[35,36] Specimens were secured to the steel base of a custom clamping fixture via a metal strap over the dorsal aspect of the foot with the foot positioned in 20 degrees of inversion and 10 degrees of plantarflexion to replicate the position of tension of the ATFL and provide a worst-case scenario for biomechanical testing (Figure 3).[36] Additional fixation was achieved with a 6-mm pin placed through the back of the testing fixture and into the posterior aspect of the calcaneus. The subtalar joint was rigidly fixed using a superior- to inferior-directed screw through the dorsal aspect of the talus into the calcaneus. Finally, a lateral- to medial-directed 6-mm fibular tunnel was reamed approximately 1.5 cm distal from the proximal fibular cut.

A custom loading fixture was mounted to the load actuator of a dynamic tensile testing machine (ElectroPuls E10000, Instron Systems, Norwood, Massachusetts). The steel base of the clamping fixture was oriented in 20 degrees of inversion and 10 degrees of plantarflexion relative to the vertical fibula, which was secured to the actuator via a 6-mm-diameter pin placed lateral to medial through the previously reamed fibular tunnel (Figure 3). Specimens were pulled to failure at a rate of 20 mm/min. Maximum load (N), stiffness (N/mm), displacement at maximum load (mm), and mechanism of failure were recorded.

Statistical Analysis

Paired t tests were chosen to compare groups with respect to each of the 3 measurements as it was assumed a priori that

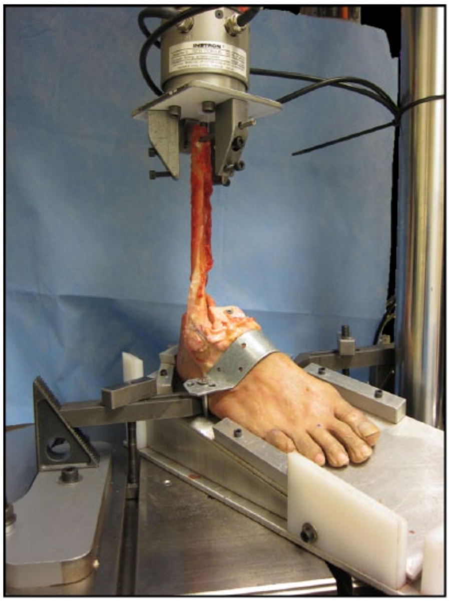

Figure 3. Right foot and ankle specimen secured to the load actuator of the dynamic tensile testing machine via a 6-mm-diameter pin placed lateral to medial through a reamed fibular tunnel. The specimen was secured to the base via a custom jig that positioned the specimen in 20 degrees of inversion and 10 degrees of plantarflexion relative to the vertical fibula.

interspecimen variability would be larger than intraspecimen variability (contralateral ankles). Differences between groups were deemed significant for *P* values less than .05 (alpha = 0.05). We opted to conduct these tests without *P* value adjustments because it is conceptually intuitive to compare max load, displacement, and stiffness separately and for their own merit. Statistical analyses were performed using SPSS Statistics, version 20 (IBM, Armonk, New York).

Results

The standard and augmented arthroscopic Broström repairs had similar mean stiffness, maximum load, and displacement at maximum load (Table 1). There were no significant differences between groups (*P* = .685, *P* = .222, *P* = .306). Biomechanically, there were no notable differences in the mechanism of failure between groups, all of which occurred by suture cut-out at the ligament-suture interface.

Discussion

In this cadaveric model, the ultimate strength and stiffness of the standard and suture anchor–augmented arthroscopic Broström repair techniques were not significantly different. Although the mean strength of augmented repairs trended toward improved strength, differences were not statistically significant; therefore, we were not able to confirm our hypothesis given the present sample. Despite a lack of statistical significance, this study provides important insights that could lead to improvements in the arthroscopic surgical treatment of lateral ankle ligament injuries. Most notably, arthroscopic repairs compared favorably to biomechanical properties of similarly tested open techniques and supported the results of prior research.[6,35,36]

Previous comparison of open and arthroscopic Broström repairs at time zero reported no significant differences in biomechanical properties.[15] Giza et al[15] demonstrated comparable strength and stiffness using an ankle-inversion testing protocol. Comparison of construct stiffness, torque to failure, and rotation (degrees) to failure in their study revealed no significant differences between techniques.[15]

In addition, the present study utilized a testing methodology and loading protocol identical to previous literature techniques used to assess the biomechanical properties of the intact, Broström-repaired, and allograft-reconstructed ATFL.[6,35,36] In one such study, Waldrop et al[36] reported a mean strength and stiffness of 68.2 ± 27.8 N and 6.0 ± 2.5 N/mm, respectively, for the open suture-only Broström repair of the ATFL. Waldrop et al[36] additionally reported corresponding values of 79.2 ± 34.3 N and 6.8 ± 2.7 N/mm and 75.3 ± 45.6 N and 6.6 ± 4.0 N/mm for fibular and talar suture anchor–based repairs, respectively. All of these are lower than the corresponding values for both testing groups in the current study; however, the present study utilized 2 suture anchors to reestablish the ATFL and CFL fibular footprints, while Waldrop et al[36] compared repairs using suture-only, a single fibular suture anchor, or a single talar suture anchor for isolated repair of the ATFL. Although not directly comparable, these results suggest that increasing the number of suture anchors and suture limbs used to reapproximate fibular footprints may be a viable option for augmenting repair strength.

Subsequently, Viens et al[35] and Clanton et al[6] analyzed suture tape–augmented Broström repairs and allograft reconstructions of the ATFL and reported respective ultimate loads to failure of 250.8 ± 122.7 N and 170.7 ± 54.8 N and stiffness values of 21.1 ± 9.1 N/mm and 23.1 ± 9.3 N/mm compared to the intact ATFL (154.0 ± 63.7 N, 14.5 ± 4.4 N/mm). Arthroscopic repairs in the present study demonstrated similar mean maximum loads but were notably less stiff. However, arthroscopic repairs overall were more variable than open repairs and reconstructions. In part, this may be attributed to the limited visualization of the arthroscopic approach leading to more variability in the complete capture of the torn ligament remnants or incorporation of the inferior extensor retinaculum into the repair. Clinically, consistency is likely to be influenced by and improved with surgeon experience with the arthroscopic

Table 1. Maximum Load, Stiffness, and Displacement at Maximum Load of the Standard and Augmented Arthroscopic Broström Repair.

Technique	Maximum Load, N	Stiffness, N/mm	Displacement at Maximum Load, mm
Standard, mean ± SD	154.4 ± 60.3	9.8 ± 2.6	17.3 ± 7.5
Suture anchor augmentation, mean ± SD	194.2 ± 157.7	10.5 ± 4.7	22.6 ± 12.6
Δ (Δ%)	39.8 (+25.8)	0.7 (+7.1)	5.3 (+30.6)
P value	.222	.685	.306

approach and technique. Regardless, comparison of biomechanical properties of the presently described arthroscopic repairs to previous biomechanical analysis of the intact ATFL, open Broström repairs, and allograft reconstructions at time zero suggests that arthroscopic repairs are a viable alternative to open repairs and reconstructions and could be treated with similar mobilizing rehabilitation protocols demonstrated to be beneficial in the postoperative period.[12,22,23,25,30]

Although we believe that the present study adequately assessed the time zero strength of the 2 arthroscopic Broström variations, certain limitations must be considered when interpreting the results. Foremost, we recognize the sample size as a limitation. The sample size per group exceeds several previous similar investigations[6,15,35,36]; yet, given the significant variability of the biomechanical properties of the repairs, differences between techniques were not found to be statistically significant. Second, the conclusions of this study are restricted by the inherent limitations of an in vitro time zero cadaveric model. We anecdotally noted qualitative differences in appearance between techniques, including possibly more complete approximation and restoration of the lateral ligament footprints with augmentation. However, such differences were not quantified in the present study. It is possible that significant biomechanical differences between techniques may occur following differences in biological healing in the postoperative period; however, this does not lie within the scope of the present study. We also acknowledge other confounding factors, including the variability in specimen age. However, attempts to minimize these affects and control for bone quality were made by utilizing younger, male, and matched-paired specimens.

In conclusion, the arthroscopic Broström compared favorably at time zero with other open techniques described in the literature, including repairs and reconstructions. Augmented repairs, however, did not confer a significantly higher mean strength and stiffness at time zero when compared to the nonaugmented arthroscopic repair. Future research is required to determine if significant biomechanical differences between techniques arise later in the postoperative period following biologic healing.

Editor's Note

One additional weakness of the study is that no fatigue failure testing was performed. However, since the greatest concern with ankle ligament repair failure is catastrophic failure, the data presented here are still of value in evaluating this clinical problem.

Declaration of Conflicting Interests

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