

Proximity of Arthroscopic Ankle Stabilization Procedures to Surrounding Structures: An Anatomic Study

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Purpose: To examine the anatomy of the lateral ankle after arthroscopic repair of the lateral ligament complex (anterior talofibular ligament [ATFL] and calcaneofibular ligament [CFL]) with regard to structures at risk. **Methods:** Ten lower extremity cadaveric specimens were obtained and were screened for gross anatomic defects and pre-existing ankle laxity. The ATFL and CFL were sectioned from the fibula by an open technique. Standard anterolateral and anteromedial arthroscopy portals were made. An additional portal was created 2 cm distal to the anterolateral portal. The articular surface of the fibula was identified, and the ATFL and CFL were freed from the superficial and deeper tissues. Suture anchors were placed in the fibula at the ATFL and CFL origins and were used to repair the origin of the lateral collateral structures. The distance from the suture knot to several local anatomic structures was measured. Measurements were taken by 2 separate observers, and the results were averaged. **Results:** Several anatomic structures lie in close proximity to the ATFL and CFL sutures. The ATFL sutures entrapped 9 of 55 structures, and no anatomic structures were inadvertently entrapped by the CFL sutures. The proximity of the peroneus tertius and the extensor tendons to the ATFL makes them at highest risk of entrapment, but the proximity of the intermediate branch of the superficial peroneal nerve (when present) is a risk with significant morbidity. **Conclusions:** Our results indicate that the peroneus tertius and extensor tendons have the highest risk for entrapment and show the smallest mean distances from the anchor knot to the identified structure. Careful attention to these structures, as well as the superficial peroneal nerve, is mandatory to prevent entrapment of tendons and nerves when one is attempting arthroscopic lateral ankle ligament reconstruction. **Clinical Relevance:** Defining the anatomic location and proximity of the intervening structures adjacent to the lateral ligament complex of the ankle may help clarify the anatomic safe zone through which arthroscopic repair of the lateral ligament complex can be safely performed.

Ankle sprains are an exceedingly common injury and usually involve the lateral ligament complex, consisting of the anterior talofibular ligament (ATFL), calcaneofibular ligament (CFL), and posterior talofibular ligament.¹ Although most patients recover well with conservative treatment, 10% to 40% have persistent symptoms and may have chronic ankle instability develop, requiring surgery.¹⁻⁵

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Although there are many potential open reconstructive techniques, the Broström procedure with the Gould modification is considered the gold standard for surgical management of chronic lateral ankle instability.⁶⁻⁹ The Broström-Gould procedure consists of midsubstance repair of the ATFL with additional reinforcement with the lateral talocalcaneal ligament, CFL, and inferior extensor retinaculum.¹ Although the Broström-Gould procedure is considered the gold standard, its use may be limited in patients with longstanding ligamentous laxity or with poor tissue quality.¹⁰

The high prevalence of intra-articular lesions in these patients suggests that intra-articular examination of the ankle may be prudent to address all pathology. Furthermore, the use of arthroscopic techniques may allow surgeons to address both the intra-articular lesions and the lateral instability concomitantly. Given that arthroscopic ankle stabilization is in its infancy, this study sought to examine the superficial and deep anatomy of the lateral ankle after arthroscopic repair of the lateral ligament complex (ATFL and CFL) with

regard to structures at risk. We hypothesized that several important anatomic structures are at risk of entrapment during an arthroscopic approach, and that by defining the proximity of these structures, an anatomic safe zone may be found, through which placement of arthroscopic suture repairs would pose minimal patient morbidity.

Methods

Ten lower extremity cadaveric specimens from the level of the knee joint distal to the toes were obtained from 10 fresh cadavers (mean age, 40 ± 12 years) and were screened for gross anatomic defects and pre-existing ankle laxity. A stress test performed on each of the specimens confirmed that less than 10° of laxity was present before testing. The other 10 lower extremity cadaveric specimens from these cadavers were used for a separate study. A 5- to 7-cm curved incision was made over the lateral aspect of the fibula. The lateral ligamentous structures were identified, and an arthrotomy was performed. The ATFL and CFL were completely detached from the fibula by an open technique.¹¹ The transection was carried out to the level of the peroneal tendons, which were not violated. The skin and subcutaneous tissues were then sutured. The proximal aspect of the tibia was dissected so that the metaphyseal flare was exposed. The specimens were secured to a vice at the level of the proximal tibia. The distal aspect of the tibia was not fixed; thus gravity was used for distraction of the tibiotalar joint. Standard anterolateral and anteromedial portals were established.¹² Diagnostic arthroscopy was performed. The lateral portal was created in the standard position, in the anterolateral corner of the ankle joint. The open incision was located slightly posterior to this. Specimens were screened for underlying osseous or articular defects. An additional portal was created 2 cm distal to the anterolateral portal. The articular surface of the fibula and sectioned ATFL and CFL remnants were identified. Electrocautery was used to debride the ATFL and CFL remnants from the fibula to expose their footprints. This was performed with a 2.7-mm-diameter 30° arthroscope. Occasionally, a 4.0-mm-diameter 70° arthroscope was used to improve visualization of the CFL footprint. Two metal 3.5-mm-diameter double-loaded Corkscrew anchors (Arthrex, Naples, FL) were placed arthroscopically on the fibula at the ATFL and CFL origins. The ATFL anchor was placed through the standard anterolateral portal, and the CFL anchor was placed under arthroscopic visualization through the accessory portal. A suture lasso was used to pierce each ligament 7 to 10 mm from its origin, exiting at the origin site.¹¹ No. 2 FiberWire sutures (Arthrex) were then shuttled sequentially from inferior to superior. The ankle was reduced by placing a posteriorly directed force at the tibiotalar joint, as well as an eversion

moment. With the ankle in a neutral position, sutures were then tied arthroscopically from inferior to superior. Each suture was tied with 2 half-hitches in the same direction and then 3 additional half-hitches in alternating directions, completing the reconstruction. The ATFL and CFL were imbricated with the ankle in a position of maximum posterior translation and eversion. The peroneal tendons were not violated in this procedure. All open procedures and arthroscopic reconstructions were performed by a foot and ankle fellowship-trained surgeon who was also fellowship trained in sports medicine and proficient in arthroscopic stabilization techniques.

After the repair, the lateral side of the ankle was completely exposed and dissected. The knots were left in the position in which they were tied. We then dissected the following structures, taking care to avoid displacement of native anatomy: extensor tendons, peroneus tertius, superficial peroneal nerve (SPN), peroneal tendons, sural nerve, and intermediate branch of the SPN. With the ankle in a neutral position, the shortest distance from the suture knot to the following structures was measured: extensor tendons, peroneus tertius, SPN, peroneal tendons, sural nerve, and intermediate branch of the SPN. Measurements were taken by 2 separate orthopaedic surgeons using a Vernier caliper with a calibrated uncertainty of ± 0.015 mm (Mitutoyo America, Aurora, IL).

A χ^2 test was used to determine whether the number of entrapped anatomic locations varied statistically between anchors in the ATFL and those in the CFL. A 2-factor analysis of variance (anchor location and structure to be entrapped) was used to determine whether any statistically significant differences existed between the mean distances from the identified structure and the suture knot. In all instances, statistical significance was set at $P < .05$ a priori. The interobserver error between the 2 surgeons' identifications of the various structures was also calculated.

Results

Our results indicate that several anatomic structures lie in close proximity to the ATFL and CFL sutures. The ATFL sutures entrapped significantly more structures compared with sutures in the CFL: 9 of 55 structures compared with 0 of 55 structures ($P = .0017$). The ATFL sutures entrapped 2 different structures in 3 of the specimens, so a total of 6 of 10 specimens had entrapped structures. The ATFL sutures entrapped the extensor tendons (2 specimens), peroneus tertius (5 specimens), intermediate branch of the SPN (1 specimen), and main trunk of the SPN (1 specimen) (Table 1, Figs 1-3). The proximity of the ATFL to the peroneus tertius, the extensor tendons, and the intermediate branch of the SPN, when present, increased the risk of entrapment. The intermediate branch of the

Table 1. Mean Distance \pm Standard Deviation From Suture Knot to Important Local Anatomic Structures

Structure	Mean Measured Distance (mm)		P Value
	ATFL Anchor	CFL Anchor	
Extensor tendons	6.0 \pm 4.8 (range, 0-15)	13.9 \pm 4.0 (range, 7-23)	<.001*
Peroneus tertius	2.6 \pm 2.9 (range, 0-8)	9.4 \pm 3.5 (range, 5-18)	<.001*
Main branch of SPN	15.2 \pm 8.3 (range, 0-28)	25.8 \pm 7.0 (range, 10-37)	<.001*
Intermediate branch of SPN	10.1 \pm 9.5 (range, 0-24)	18.3 \pm 4.3 (range, 11-24)	.004*
Peroneal tendon	33.7 \pm 4.5 (range, 26-42)	24.2 \pm 5.6 (range, 13-35)	<.001*
Sural nerve	47.5 \pm 7.5 (range, 36-60)	34.7 \pm 7.8 (range, 20-50)	<.001*

NOTE. Entrapment of a structure was recorded as 0 mm. The *P* values show that the distance from the ATFL suture knot to certain structures is statistically different from the distance between the CFL suture knot and those structures, meaning that we are significantly "safer" when dealing with the CFL with regard to that structure than we are in dealing with the ATFL.

*Statistically significant difference.

SPN was not located in 5 of 10 samples. Our results found mean distances between the ATFL and the peroneus tertius, extensor tendons, intermediate branch of the SPN, and main branch of the SPN of 2.6 mm, 6.0 mm, 10.1 mm, and 15.2 mm, respectively. Significantly decreased distances between these structures and the ATFL compared with the CFL suggest a higher risk of entrapment.

Table 1 reports the mean distances calculated between the identified structures and the respective suture anchor knot. Table 2 reports the calculated interobserver error for each measurement group.

Discussion

Prevention of lateral ankle instability is paramount, given the risk of late sequelae, including degenerative

arthritis.¹³ Many techniques have been described, including anatomic,^{6,14,15} nonanatomic,^{4,16-20} and graft reconstruction—type procedures.^{16,21} There are several advantages of an anatomic repair, such as restoring normal ankle anatomy and joint kinematics while maintaining motion of the ankle and subtalar joints.^{6,14,22} Relying on poor-quality tissue for lateral ligamentous repair is touted as the main disadvantage of anatomic reconstruction.²³ Tenodesis procedures (e.g., Evans and Chrisman-Snook), without direct repair of the lateral ankle ligaments, are often used during nonanatomic reconstructions. These procedures fail to restore normal ankle kinematics, and they commonly lead to a reduction in subtalar motion.^{16,18,20}

Surgical management of chronic lateral ankle instability has evolved considerably over the past 30 years.

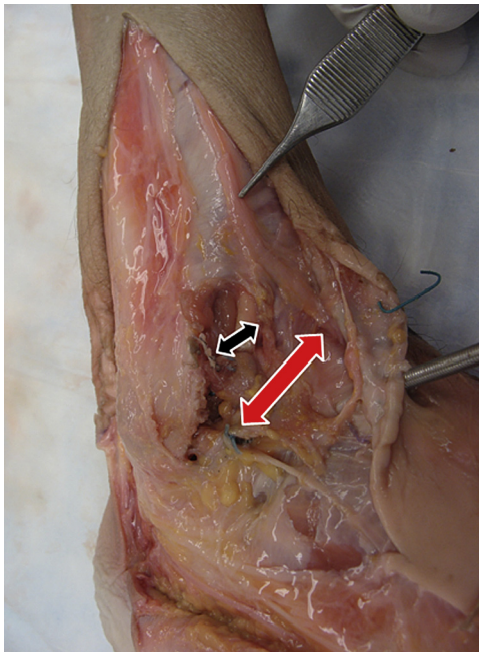


Fig 1. Structures at risk during arthroscopic lateral ankle ligament repair, showing distance from ATFL anchor to intermediate branch of SPN (black arrow) and distance from CFL anchor to main branch of SPN (red arrow).

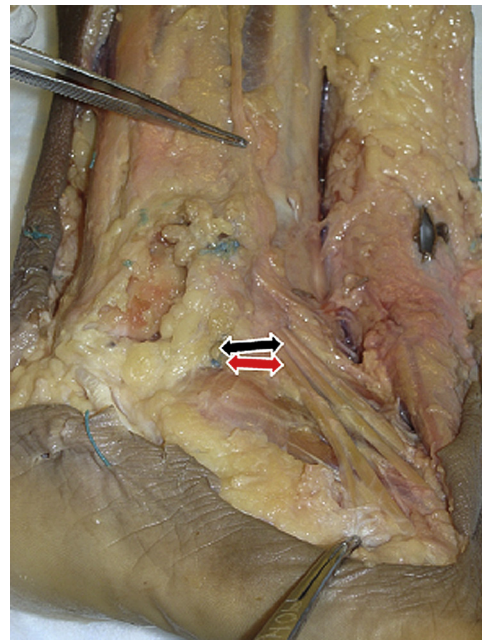


Fig 2. Structures at risk during arthroscopic lateral ankle ligament repair, showing distance from CFL anchor to extensor tendons (black arrow) and distance from CFL anchor to peroneus tertius (red arrow).

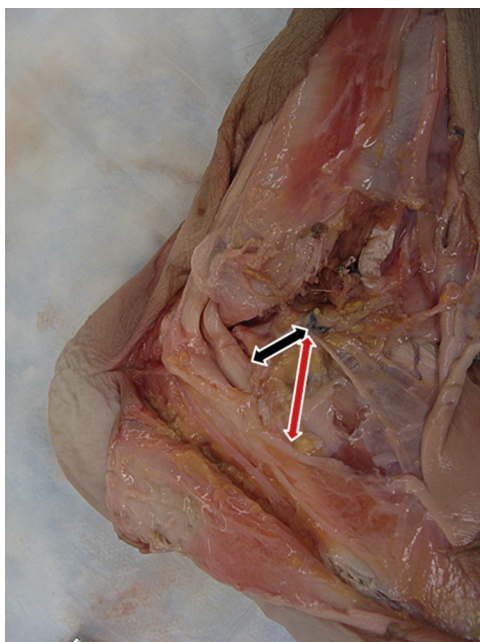


Fig 3. Structures at risk during arthroscopic lateral ankle ligament repair, showing distance from CFL anchor to peroneal tendons (black arrow) and distance from CFL anchor to sural nerve (red arrow).

Currently, many surgeons perform an ankle arthroscopy to evaluate and treat associated intra-articular lesions, followed by an open repair of the lateral ligamentous complex.^{9,24-26} Arthroscopic advancements have enabled more procedures to be performed arthroscopically. Specifically, arthroscopic stabilization procedures of the shoulder and knee have been performed safely and routinely now for over a decade.²⁷ Arthroscopic ankle stabilizations have been slow to evolve because of the smaller dimensions of the ankle joint, need for distraction, and surgeon unfamiliarity with arthroscopic techniques. In addition, open techniques have highly successful outcomes and allow for the ability to add a Gould modification. However, more specialized equipment and improved arthroscopic resolution have enabled many arthroscopic procedures to be performed on small joints such as the ankle.²⁸

The role of ankle arthroscopy in the management of chronic lateral ankle instability has not been well

defined. Several studies describe the presence of osteochondral fractures of the talus and other articular abnormalities after acute ankle sprains or chronic lateral ankle instability.^{26,29,30} In 1999 Komenda and Ferkel²⁹ noted a 25% incidence of articular chondral injury in 54 patients undergoing ankle arthroscopy before open lateral ligament stabilization. They concluded that patients with chronic lateral ankle instability often have articular cartilage injuries that can be addressed with ankle arthroscopy followed by open ligament repair. In addition, in 2010 Hua et al.³¹ found that of 85 patients with chronic ankle instability and intra-articular symptoms, 91% had intra-articular lesions on arthroscopy. The ankle joint is not as clearly visualized with open procedures as it is during ankle arthroscopy.

There are few reports of arthroscopic lateral ligamentous repairs in the literature. Kashuk et al.³² used an arthroscopic technique to repair the ATFL by using a suture anchor placed on the fibula. In 2009 Corte-Real and Moreira³³ performed a diagnostic ankle arthroscopy in 31 patients and confirmed lateral ankle instability under direct visualization. The lateral ankle ligamentous complex was then repaired with a suture anchor placed on the anterior aspect of the fibula. The anchor was introduced through the accessory anterolateral portal, which was then extended to a length of approximately 1 cm to place a deep stitch in the lateral ligaments. Corte-Real and Moreira reported results that are comparable to those obtained with the Broström procedure. Nine patients had complications, including 3 patients with some numbness of the SPN. This shows the need to take great care in placing the arthroscopic portals to minimize damage to local anatomic structures.¹² However, to date, there are no biomechanical or anatomic data that have evaluated the efficacy and safety of these procedures.

This study helps to identify anatomic structures that are at risk of entrapment during arthroscopic placement of suture anchors for repair of the ATFL and CFL in patients with chronic ankle instability. There are numerous potential complications associated with ankle arthroscopy, many of which can be avoided by familiarity with the local surface anatomy.^{12,34} Ferkel et al.³⁵ found an overall complication rate of 9%, with neurologic complications being most common (49%). The SPN was involved in 15 of the 27 cases with neurologic injury (56%). During placement of anchors at the ATFL and CFL origins, tissue capture is of concern because of the proximity of several anatomic structures. Awareness of these structures may enable surgeons to use an arthroscopic approach to ankle instability while minimizing the risk of injury to important local anatomic structures. Several anatomic structures including the extensor tendons, peroneus tertius, intermediate branch of the SPN, and main trunk of the SPN are at risk of entrapment during arthroscopic repair

Table 2. Calculated Interobserver Error for Measured Distance From Suture Anchor to Important Local Anatomic Structures

Structure	Interobserver Error (mm)	
	ATFL Anchor	CFL Anchor
Extensor tendons	2.1	2.9
Peroneus tertius	1.1	3.5
Main branch of SPN	3.1	5.0
Intermediate branch of SPN	3.0	1.5
Peroneal tendon	3.5	4.3
Sural nerve	6.7	5.5

of the ATFL and CFL. In our experience, entrapment was significantly more common with the sutures used to repair the ATFL compared with those for the CFL.

Care can be taken specifically with the ATFL suture to avoid entrapment of nearby structures. This can be accomplished by paying careful attention to the amount of tissue captured. Specifically, the sutures should only traverse the deeper tissue layers of the capsule and ligament. These tissues can usually be separated easily with an open approach. This can also be accomplished arthroscopically with meticulous attention to detail. The tissues superficial to the capsule contain the anatomic structures at risk of entrapment (SPN, peroneus tertius, and so on) with arthroscopic reconstruction of the lateral ankle ligament complex. The tissue capture with the ATFL anchor should be deep enough to advance the capsule without crossing the superficial tissues. Knowledge of the proximity of these tissues can allow for safe passage of sutures and tissue advancement without concomitant adjacent structure injury.

Limitations

We recognize that the use of cadaveric samples and the measurement techniques have several limitations. First, our study was limited by the small sample size of 10 cadavers, which was especially limiting given the high variability in the course of the SPN. Second, in many instances the interobserver error was large, depending on the structure to be identified. However, the intention of this experiment was to recognize which structures were at highest risk for entrapment. There was no disparity with regard to the identification of an "entrapped" structure between investigators. Third, we acknowledge that our method of detaching the ATFL and CFL from the fibula does not replicate the in vivo method and that if we were to replicate midsubstance repairs rather than avulsions, other structures may be at higher risk of entrapment; however, our method is widely accepted in cadaveric analysis.^{6,19,36} Finally, the removal of skin and soft tissue during the initial open procedure and subsequent reattachment may affect the relation of the skin to the anatomic structures and, consequently, the accuracy of the measurements.

Conclusions

In the model studied, the sutures at the location of the ATFL entrapped significantly more structures than the sutures from the CFL anchor. Our results indicate that the peroneus tertius and extensor tendons have the highest risk for entrapment and show the smallest mean distances from the anchor knot to the identified structure. Careful attention to these structures, as well as the SPN, is mandatory to prevent entrapment of tendons and nerves when one is attempting arthroscopic lateral ankle ligament reconstruction.

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