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FOOT AND ANKLE SPORTS MEDICINE (M DRAKOS, SECTION EDITOR)

Operative treatment of lateral ligament instability

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Abstract
Purpose of review Ankle sprains, which account for 40% of sports injuries in the USA, can lead to chronic ankle instability. Chronic ankle instability can be classified as functional, mechanical, or a combination of both and is diagnosed using a combination of a physical exam, an MRI, and stress radiographs. This review focuses on different approaches to treatment, including non-operative and operative techniques, of chronic ankle instability, including reviewing traditional procedures as well as more novel and newer techniques.
Recent findings Based on existing literature, non-operative treatment should always precede operative treatment of chronic ankle instability. If rehabilitation fails, Brostrom-Gould type ankle stabilization has been the preferred surgical option. Recent literature suggests that arthroscopic repair might reduce recovery time and improve outcomes in certain populations; however, there are higher rates of complication following these surgeries. In more high-risk populations, some literature reports that ligament repair with peroneus brevis transfer could be a more effective treatment option.
Summary Currently, varying surgical techniques exist for the treatment of chronic ankle instability. While the more recently reported techniques show promise, it is important to note that there is little evidence showing they are more successful than traditional techniques. It is imperative that future studies focus on outcomes and complication rates of these newer procedures.

Keywords Ankle instability · Brostrom · Lateral ligament reconstruction · ATFL · Ankle sprain

Introduction

In the USA, there are approximately 30,000 ankle sprains per day [1] and 2 million per year [2]. Furthermore, 20–40% of all sports-related injuries in the USA are ankle sprains [3]. An ankle sprain is defined as any tear to the ligament in the ankle and can vary in severity, including microscopic, partial, or complete [4]. Eighty-five percent of all ankle sprains involve the lateral ligaments, most notably the anterior talofibular ligament (ATFL) [5]. Recovery from an ankle sprain is dependent on the severity of the injury and concomitant pathology [6]. While most sprains recover uneventfully, there is a high rate of re-injury after an initial sprain; up to 34% of patients will suffer a second sprain within 3 years following the initial injury [6].

Repeated ankle sprains can lead to attenuation of the ATFL and lateral ligamentous complex. This may render those tissues incompetent and chronic ankle instability may ensue in 10–20% of cases [7]. Patients may have a subjective sense of instability where an innocuous misstep may lead to another ankle injury [8]. Recurrent ankle sprains may alter the biomechanics at the ankle joint which can potentially lead to cartilage degeneration over time [9–13]. Up to 93% of patients with ankle instability have associated intra-articular pathology [14–16]. Varus instability of the ankle shifts the contact pressure medially and can lead to osteochondral lesions of the ankle particularly in the central medial talar region [17].

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There are varied treatment options for ankle instability including conservative and surgical methods. In this review, we will present the current options for work-up and treatment and a potential treatment algorithm based on current literature.

Anatomy

The ATFL, calcaneofibular ligament (CFL), and the posterior talofibular ligament (PTFL) are the three ligaments that make up the lateral ankle ligament. When they are torn or stretched, the result can be ankle instability. These ligaments are extra-articular and frequently heal with scar tissue. This tissue may ultimately compromise the stability of the ankle. The ATFL and CFL are primarily affected in patients with ankle instability [1]. The ATFL, which originates at the anterior border of the distal fibula and inserts into the lateral portion of the talar neck, anterior to the lateral malleolar surface, is a capsular thickening which functions to prevent both inversion and anterior displacement of the talus [18]. The CFL, which plays a role in subtalar stability, extends across the tibiotalar and subtalar joints [18]. It originates on the anterior border of the lateral malleolus, adjacent to the ATFL, and extends in a posterior and oblique direction along the lateral aspect of the calcaneal tuberosity. It runs deep to the peroneal tendons which function as the dynamic stabilizers of the ankle. As the ankle is dorsiflexed, the CFL is tensioned, and the CFL works to stabilize the ankle joint in this position [19]. The PTFL originates on the lateral malleolus and inserts on the posterolateral aspect of the talus [8]. It functions to prevent internal rotation as well as inversion and is not as commonly sprained [20]. The anatomy of the inferior extensor retinaculum (IER) is variable with a superolateral band present in only about 25% of cases; some assert that the true IER is only used as the Gould modification in cases with this anatomic variant and that the sural fascia is more likely incorporated [21].

Classification

Injuries to the lateral ligaments vary in degree, from grade I to grade III. A grade I injury is the least severe and is defined as stretching of the ligaments. A grade II injury is classified as a partial tear and can affect either just one of the ligaments of several of the ligaments. The most severe type of injury involves complete rupture of the lateral ligament complex and is considered grade III [22] (see Fig. 1).

Mechanism of injury

Lateral ligament injury usually involves an inversion and plantarflexion injury, with increasing rotation leading to sequential injury of the ATFL, CFL, and then rarely the PTFL [23]. It is also possible to rupture the CFL independent of the other two lateral ligaments when a dorsiflexed ankle is subject to supination force [24, 25]. This can lead to subtalar instability in addition to ankle instability.

Fig. 1 Severe talar tilt on stress radiographs

Risk factors

A major risk factor for lateral ankle sprains and eventual chronic ankle instability is past sprain(s) of the ankle [26–28]. Various physical features are associated with increased risk of ankle sprains, including elevated BMI, midfoot or hindfoot malalignment, and generalized ligamentous laxity [29, 2]. Deformities that increase the risk of ankle sprain and ankle instability include first ray plantarflexion, midfoot cavus, and hindfoot varus [30]. Females between the ages 30 and 99 and males between the ages of 15 and 24 are most likely to experience ankle sprains [29]. Females are also at a greater risk of ankle sprains than males in general because they have been shown to have greater ligamentous laxity in the ankle [31]. Tarsal coalitions have also been associated with ankle sprains. Jumping sports particularly basketball and volleyball also pose an increased risk.

History and physical examination

A thorough history and physical exam are crucial when a patient presents with complaints of ankle instability. History of past ankle sprains, duration of symptoms, and presence of pain should be key features in the history. When pain is a component of the patient's presentation, it is important to identify whether pain results from or precipitates an instability event. This can help determine whether other associated injuries may be present such as cartilage lesions, peroneal tendon pathology, or loose bodies [29].

A standard physical exam should be conducted paying particular attention to the ankle stability assessment, peroneal tendons, neurovascular status, and the presence of deformity. All tests should be compared to the contralateral side, which serves as an internal control. The anterior drawer test for the ATFL involves applying force anteriorly to the foot in approximately 15° of plantarflexion while applying posterior force to the tibia, as well as a small inversion moment [32]. The talar tilt test is also performed, which involves inverting the calcaneus and stabilizing the tibia while maintaining the foot in neutral position and then determining the degree of varus instability [32]. The talar tilt test also helps determine CFL competence. The sensitivity of these tests is variable and ranges from 74 to 96% [33–37]. Regardless, performing a manual physical exam is an important part of assessing a patient presenting with ankle instability.

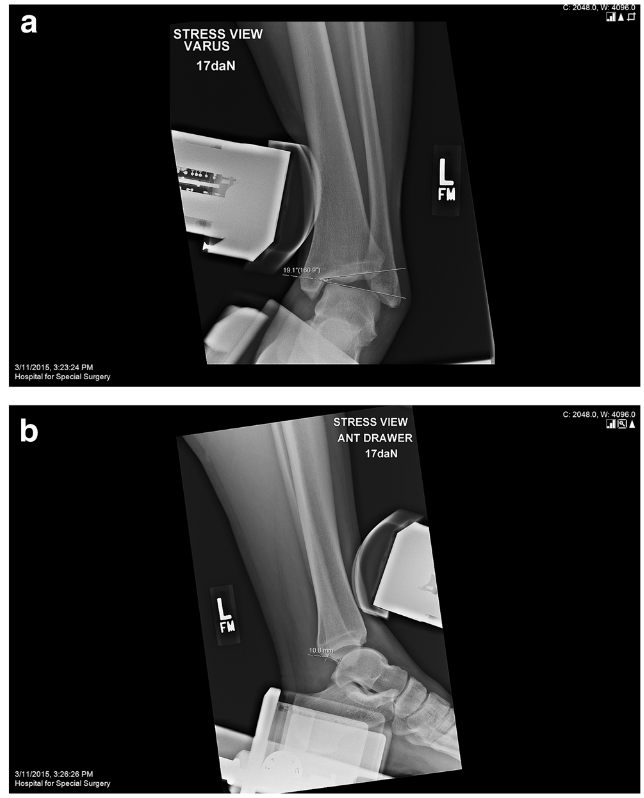

Fig. 2 Lateral talar tilt (**a**) and anterior drawer stress (**b**) demonstrate instability of the ATFL and CFL. Example of angle measurements is shown

Imaging

Stress radiographs

Standard weight-bearing radiographs should be performed to assess for alignment, evaluate for arthritis, as well as osteophytes and other osseous pathology. Stress radiographs are extremely useful and can be used in either in isolation or compared to the uninvolved side (see Fig. 2). While there should be no hard cutoff, pathologic instability is often diagnosed with greater than 10 degrees of varus tilt or 10 mm of anterior translation or 5 degrees of 5 mm more than the contralateral side [38]. However, asymptomatic ankles may actually have a much narrower range of normal with less than 4 degrees of varus tilt and less than 2 mm anterior drawer seen in a series of normal volunteers [39]. This is an inexpensive, non-invasive test that can aid in diagnosis, although it may underestimate instability due to patient guarding, the unique morphology of the talus, and difficulty quantifying rotational moments on 2-D radiographs [40, 38]. However, stress x-rays are invaluable in helping to determine the degree of instability and differentiating a mechanical instability from a functional one.

Magnetic resonance imaging

Magnetic resonance imaging (MRI) in the setting of ankle instability is important for determining whether there is any associated pathology such as talar osteochondral lesions and peroneal tendon injury. Symptoms from these areas can sometimes be ascertained from patient history and physical examination; however, an MRI can be extremely useful for preoperative planning. We routinely use it to identify talar osteochondral lesions (OCLs) and then we can counsel patients as the treatment of these lesions often changes the post-operative protocol in addition to the surgical plan. MRI sensitivity for concomitant lesions is high, especially when evaluating for osteochondral lesions [41–44]. However, the utility in diagnosing symptomatic lateral ankle instability is limited because it is a static study. Up to 60% of ATFLs may appear attenuated or torn in an asymptomatic population [45]. Moreover, the ATFL rarely appears normal after an ankle sprain. MRI is limited in its ability to determine whether or not the tissues are competent. Therefore, we are using MRI primarily to identify concomitant pathology rather than determine functionality of the ATFL and CFL.

Non-operative management

There are generally two categories of chronic instability: mechanical instability, in which ankle joint motion is greater than normal physiologic limits, and functional instability, in which motion is physiologic but no longer under voluntary control

[46]. Patients with functional instability may have proprioceptive and strength deficits and are thought to improve with physical therapy [47]. Studies show that there is increased peroneal tendon latency after ankle sprains [48].

Some theorize that patients with mechanical instability may be more likely to need surgical treatment [49]. Unfortunately, the two types of instability are not mutually exclusive and categorizing a patient is not simple. A course of physical therapy is indicated as the first line of treatment to treat chronic lateral ligament instability, whether functional or mechanical. Patients should attempt this treatment for at least 3 months before considering surgical intervention.

Operative management

Evolution of surgical treatment

Surgical treatment of lateral ligament instability was first described in 1932 involving a non-anatomic peroneus brevis transfer based on the work of Gallie in 1913 in the paralytic clubfoot [50, 51]. Many iterations of peroneal tendon-sacrificing procedures were described including the Watson-Jones, Evans, and Chrisman-Snook procedures; however, patient outcomes were generally suboptimal with unresolved pain, stiffness, subtalar arthritis, or recurrent instability [52–62]. In 1966, Broström described direct ligament repair which was anatomic and preserved the peroneal tendons [63]. The Gould modification incorporated the inferior extensor retinaculum, which has been shown to improve biomechanical strength of the repair by 60% [64, 65]. This procedure was popularized after the presentation of successful outcomes in professional ballet dancers by Hamilton in 1993 and is presently the gold standard of surgical treatment of chronic ankle instability [66].

Arthroscopic ligament repair

Arthroscopy is commonly performed at the time of lateral ligament repair to assess for intra-articular pathology given that up to 92% of patients have intra-articular lesions [67, 15]. However, in the patient without pain and a negative MRI, arthroscopy may not be necessary [29].

Open lateral ligament repair is widely performed, but the development of arthroscopic techniques have become more common with newer technologies. The potential benefits of performing ligament repair arthroscopically include quicker recovery, decreased morbidity, and the ability to address intra-articular pathology with one approach. Arthroscopic lateral ligament repair is biomechanically successful compared to an open technique when evaluated in cadaver studies [69–71]. Clinical outcomes have also been positive, although there may be a high complication rate due to the risk of nerve injury. One study showed an AOFAS score of 85 with a 2-year follow-up in 28 patients after arthroscopic lateral ligament repair; there was a 29% complication rate including wound issues, nerve injuries, and deep venous thrombosis [7]. A more recent study demonstrated 95% good and excellent outcomes and AOFAS score of 90 after 9 years in a series of 38 patients; there were no reported nerve or wound complications [72•]. Another study using an all-inside technique and knotless anchors in 16 patients resulted in an AOFAS score of 97 at 2 years with a 13% complication rate consisting of superficial wound issues that resolved with conservative treatment [73]. When compared to open ligament repair, arthroscopic repair using two suture anchors was associated with faster surgical time, similar functional scores, and similar radiographic stability; time to return to sports was not shown to be significantly different and averaged around 17 weeks [74•]. In terms of neurologic injury in this study, temporary numbness of the superficial nerve was seen in 2 of 19 patients in the arthroscopic group and 1 of 18 patients in the open group. A systematic review found an overall complication rate of 15% after arthroscopic ligament repair as compared to 8% when the procedure was performed open [75•]. In performing arthroscopic lateral ligament repair, care should be taken to avoid injuring nearby structures. In a cadaver study, 16% of sutures traversed another structure and a specific safe zone was defined [76]. Arthroscopic lateral ligament repair has been shown to be successful in these clinical series, but indications are still evolving. In the author's opinion, arthroscopic stabilization can be indicated for patients with mild to moderate instability and is contraindicated in patients with generalized ligamentous laxity, greater than 20 degrees of varus tilt or 15 mm of anterior translation on stress radiographs, and in revision cases. New techniques have been described involving the use of a lasso stitch, including or excluding the inferior extensor retinaculum, and using one to two suture anchors [77, 78]. There is also a published technique to perform an arthroscopic ligament reconstruction using gracilis autograft which could be used in patients with moderate to severe ankle instability [79]. A cadaver study demonstrated that tunnels could realistically be placed within 4 mm of the true ATFL and CFL footprints [80]. Despite positive results published in the literature, the highest recommendation in a systematic review on minimally invasive surgical techniques for chronic lateral ankle instability was grade C (poor-quality evidence) [81].

Anatomic ligament reconstruction

Patients with generalized ligamentous laxity have been noted to have inferior results after ligament repair prompting further investigation into alternate procedures offering more robust stability [68]. Anatomic ligament reconstruction has become popular in certain subgroups such as heavier athletes, revision cases, and patients with ligamentous laxity, hindfoot varus, or inadequate residual ligament for direct repair [82]. Objective indications include greater than 20 degrees of varus or 15-mm translation on stress radiographs. There are many ligament reconstruction procedures in the literature with a wide variety of auto- and allograft types, graft fixation methods, and technical points [83–87]. The procedure typically involves weaving and fixating a graft in the talus, fibula, and calcaneus in order to reconstruct the ATFL and CFL in a nearly anatomic fashion (see Fig. 3). The residual ligament tissue is repaired for additional strength and improved proprioception. Clinical and radiographic success has been demonstrated in multiple studies with up to 100% excellent and good outcomes at 2 years post-operatively [85, 88•]. The procedure can also be performed percutaneously using a single tunnel in the fibula for a "Y" configuration reconstructing the ATFL and CFL [89]. When anatomic allograft reconstruction was compared to direct ligament repair in a retrospective cohort study, similar functional outcomes at 2 years post-operatively were seen; no revision stabilization procedures were required, although 4 out of 21 patients (19%) in the reconstruction cohort required arthroscopy for arthrofibrosis [88•]. Implanting the graft near

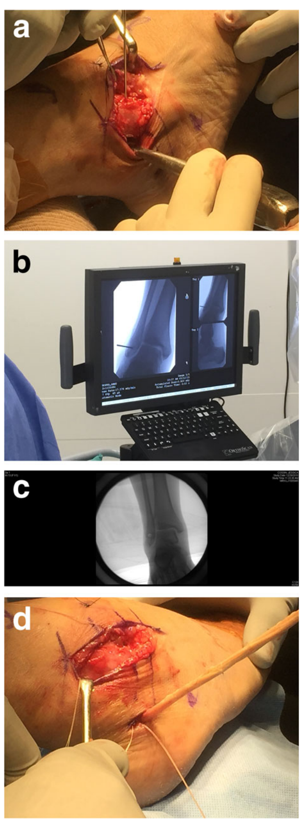

Fig. 3 Example of tunnel placement in distal fibula during anatomic ligament reconstruction (**a**). Guide-wire placement should be checked on fluoroscopy (**b**) to ensure that tunnel placement is appropriate (**c**) and limit risk of iatrogenic fracture. The graft can be docked in the calcaneus using an interference screw and percutaneous technique (**d**)

the anatomic footprints of the ligaments is crucial to reestablishing normal mechanics of the ankle and care should be taken when making drill holes in the fibula to avoid iatrogenic fracture. One group created custom templates based on CT scan to guide the placement of fibular drill holes to the appropriate positions [90]. Fifteen patients that underwent this procedure had significant improvement in post-op functional scores and radiographic stability on par with other ligament reconstruction methods. The benefit of using custom jigs has not been demonstrated and the added cost and radiation exposure to the patient may not be indicated without further study.

Ankle ligament laxity in patients with generalized joint hypermobility (as defined by Beighton score of greater than or equal to 4 has recently been called into question [91]. In a case series of 32 patients with generalized joint hypermobility and normal stress radiographs on the uninvolved ankle, excellent post-operative functional scores were attained after treatment with a modified Broström [92•]. Nine patients went on to reinjure their ankles, and 3 of these were unstable on stress radiographs. Nonetheless, the patients were satisfied and no reoperations were required. Slightly lower functional scores were seen in those patients with Beighton score of 8 and higher. The authors note that patients with generalized laxity along with radiographic instability demonstrated on the uninvolved ankle were treated with anatomic reconstruction. The decision-making process in patients with ligamentous laxity certainly requires further study. Furthermore, the determination of optimal graft type (autograft versus allograft) in this patient population has yet to be determined.

Anatomic ligament repair

Multiple studies demonstrated satisfaction rate of over 90% after modified Broström procedure [66, 68, 93]. Although the Broström procedure is generally considered a highly successful operation, the recovery typically involves a prolonged period of immobilization and rehabilitation. There has been a drive to accelerate the recovery process by augmenting the repair using a suture tape and interference screw construct called an InternalBraceTM (Arthrex, Naples, FL) [94]. Use of this device in cadaver models has been shown to increase the mean ultimate load to failure as compared to a Broström with suture or suture anchors or even the native ATFL [95–97]. However, it does not improve proprioception in a similar manner as imbricating the ligaments. The accelerated post-operative regimen can allow patients to return to cycling at 2 weeks and running at 8 weeks [94]. A case series published by one of the implant designers does show good patient improvement with all 15 athletes returning to running within 12 weeks, although many standard rehab protocols after simple ligament repair involve return to running by that time point [94]. Earlier return to function is desirable although increased cost and limited geography on the distal fibula are disadvantages of this device. Furthermore, it is possible that accelerated rehab after a standard ligament repair procedure could be associated with equivalent outcomes; immediate weight-bearing as tolerated has been shown to have acceptable results [98].

Cartilage injury

Surgical treatment for ankle instability is generally successful, but associate cartilage lesions may be associated with different outcomes. One study with a subgroup of 10 out of 38 patients with cartilage lesions found higher AOFAS scores as compared to patients with no cartilage injury, although this was not statistically significant [72•]. Symptomatic cartilage lesions in patients with associated instability may have greater potential to improve because stabilization alone can reduce pain related to the cartilage injury.

Treatment algorithm

Post-operative rehabilitation

Traditional post-operative protocol involves 6 weeks of protected weight-bearing followed by gradual return to activity in a physical therapy program. However, immediate weight-bearing as tolerated after modified Broström may be possible with a 94% rate of return to sports and a 6% failure rate in one study [98]. Early range of motion is also thought to be beneficial with improved range of motion and earlier return to sport [99].

Prevention

Although patients do well after surgical treatment for ankle instability, the best way to avoid time lost from sport or work due to injury is prevention. Prophylactic proprioception training was shown to reduce injuries in a prospective randomized study of 900 high school basketball players [100]. In patients with frequent ankle sprains, proprioception training was associated with a decreased risk of recurrent ankle instability when compared to use of an orthosis [101]. Prophylactic bracing may be useful as was shown in a prospective study of female volleyball players [102].

Conclusion

Ankle instability remains a common problem encountered by many athletes after ankle sprains. Conservative management with an early functional rehabilitation program remains the most important intervention. In those patients who fail conservative management, surgical intervention can be employed successfully with high, predictable rates of return to sport. Newer, less invasive techniques may provide quicker recovery times and less morbidity. However, there remain patients such as those with sever instability or generalized ligamentous laxity who may benefit from a tissue augmenting type procedure. Specific indications for which patients may benefit from each of these procedures are an area of ongoing study.

Compliance with ethical standards

Conflict of interest None of the authors has a financial or proprietary interest in the subject matter or materials discussed in the manuscript, including, but not limited to, employment, consultancies, stock ownership, honoraria, and paid expert testimony.

Human and animal rights This article does not contain any studies with human or animal subjects performed by any of the authors.

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