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Diagnosis and Treatment of Chronic Ankle Instability

Yanyu Chen

Abstract

Ankle sprains involve up to 30% of all sport injuries. About 30% of patients may develop chronic ankle instability (CAI), which significantly limits their professional or recreational activities. The diagnosis of CAI relies on the understanding of anatomy and a thorough assessment of the patient. Imaging studies, including plain radiographs, sonography, MRI, and arthroscopic examinations, are beneficial in evaluating the extent and structures involved. Once conservative treatment has failed, surgery is indicated to restore ankle joint stability. Suture repair is sufficient, whether open or arthroscopically, if the remnant ligament quality is acceptable. Anatomical graft reconstruction is used for poor remnant quality or revision.

Keywords: ankle instability, ankle sprain, arthroscopy, Broström, reconstruction

1. Introduction

Ankle sprains are among the most common of sports injuries, and lateral ankle sprains comprise more than 80% of these [1]. Even though most of them heal well with conservative treatment, a 56–74% recurrence rate has been reported [2]. Up to 30% of patients with lateral ankle sprains end up having chronic ankle instability (CAI) [3]. The predictors of patients with single or repeated ankle sprains who may develop CAI include a grade II–III sprain [4], postural instability [5], lower limb muscle weakness or imbalance [6], and decreased ankle dorsiflexion [7].

1.1 Pathophysiology

The pathophysiology of CAI includes anatomical and/or functional deficiencies. Anatomical factors consist of pathological laxity of ankle ligaments and problematic bony structures such as hindfoot varus [8, 9]. Functional factors include neuromuscular and proprioception impairments [6, 10].

The traditional spectrum of CAI is divided to mechanical instability, which means a structurally unstable ankle and functional instability, which means a perceptionally unstable ankle. Mechanical instability of the ankle can be demonstrated manually or subjectively. Functional instability is much more difficult to evaluate; a comprehensive questionnaire is usually needed for better communication and understanding [11].

1.2 Functional anatomy

1.2.1 Bony structure

The ankle joint consists of the ankle mortise and talus. The tibial plafond forms the ankle mortise, together with the distal fibula through syndesmosis ligaments. The width of the talar dome is wider in the anterior aspect. Hence, the ankle joint is more stable in dorsiflexion position than in plantarflexion.

The stability of ankle joint will be at risk if the mortise is relatively less constrained. A posteriorly positioned fibula, either congenital or post-traumatic, may increase the anterior opening of ankle mortise and cause instability [12, 13]. The length of the fibula does not affect the stability of the ankle [14]. A decreased talar dome coverage of the tibia plafond, evaluated from plain, weight-bearing, and lateral view radiographs as well as an increased lateral radius of the talus, is linked to the development of lateral ankle instability (LAI) [13, 15].

Medial ankle instability (MAI) is less discussed in the literature. It has been reported that during arthroscopic exploration for lateral ankle instability, 20% of patients show a concomitant injury of the deltoid [16]. MAI involves the dysfunction of the deltoid ligament complex, which may cause valgus deformity of the ankle, and, vice versa, hindfoot valgus deformity carries a higher risk of developing MAI.

1.2.2 Ligamentous structure

The lateral ankle ligaments comprise of the anterior talofibular ligament (ATFL), the calcaneofibular ligament (CFL), and the posterior talofibular ligament (PTFL). The ATFL is taut when the ankle is in plantarflexion position, whereas the PTFL and CFL are taut when the ankle is in dorsiflexion position (**Figure 1**) [17].

Broström surgically opened 105 sprained ankles and reported ATFL injury in two-thirds and combined ATFL and CFL injuries in one-fourth of patients [18]. This finding suggested that the ATFL is the first-line structure against supination. The ATFL has two fascicles; the superior fascicle is positioned intra-articularly, which suggests a poor healing potential and becomes stretched in ankle plantarflexion. The inferior fascicle, on the other hand, is extra-articular and shares a common insertion with the CFL in the fibula and is not stretched in ankle plantarflexion [19].

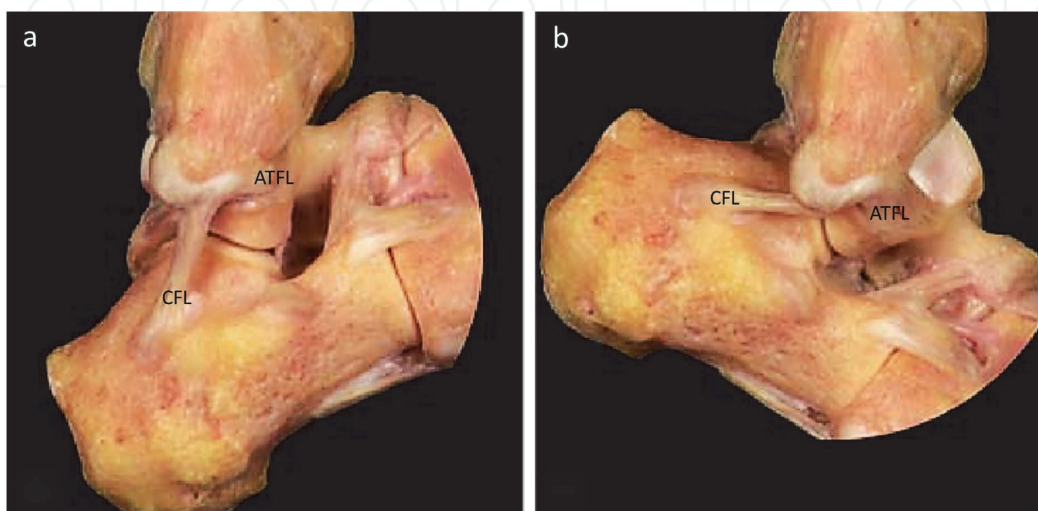


Figure 1. Lateral view of the right ankle. The tension of the ATFL and CFL can be observed in different ankle positions: (a) dorsiflexion, (b) plantar flexion (with kind permission from Vega et al. [68]).

If the ATFL does not heal well after rupture, its laxity will result in excessive plantarflexion and supination of the ankle, which decreases the stability of the joint, increases the compensative burden of peroneal muscles, and increases the wearing of articular cartilage. Even after healing, some patients may still have lateral ankle pain and swelling despite their return of full pre-injury activity. The presence of local painful scarring, synovitis, post-traumatic weakness of peroneal muscles, and injury to the proprioception afferent fibers inside the ATFL may be the causative reasons of these residual symptoms.

The deltoid ligament is composed of a superficial layer and a deep layer. The superficial layer, which is positioned across the ankle and subtalar joint, consists of four components: the tibionavicular ligament, the tibiospring ligament, the tibiocalcaneal ligament, and the superficial posterior tibiotalar ligament [20]. The deep layer, which is thicker and positioned across the ankle joint only, consists of two components: the anterior tibiotalar ligament and the deep posterior tibiotalar ligament (**Figure 2**).

The deltoid ligament complex is composed of the deltoid ligament and the spring ligament (the calcaneonavicular ligament). The spring ligament helps not only to maintain the supination of midfoot but also to support the medial ankle structure through its connection with the deltoid ligament by the tibiospring ligament. A patient with MAI often presented with dysfunction of these two structures.

1.2.3 Neuromuscular structure

The peroneal musculature is the dynamic stabilizer of the lateral ankle joint. Lateral ankle sprains may cause injury to the ATFL as well as to the peroneal muscles. Not only can the muscular fibers be injured, the neuromuscular function can also be affected. It has been reported that the reaction time of the peroneal muscles may be delayed in patients with a history of repeated sprains, which may increase the risk of another lateral ankle sprain when the ankle lands in a supinated position [21]. This delay may be related to the deafferentation of receptors in the muscle tendon and ligaments around the ankle joint after a sprain injury [22].

Proprioception deficits are frequently encountered in patients with CAI. The dysfunction of proprioception will result in poor joint position sense, which means

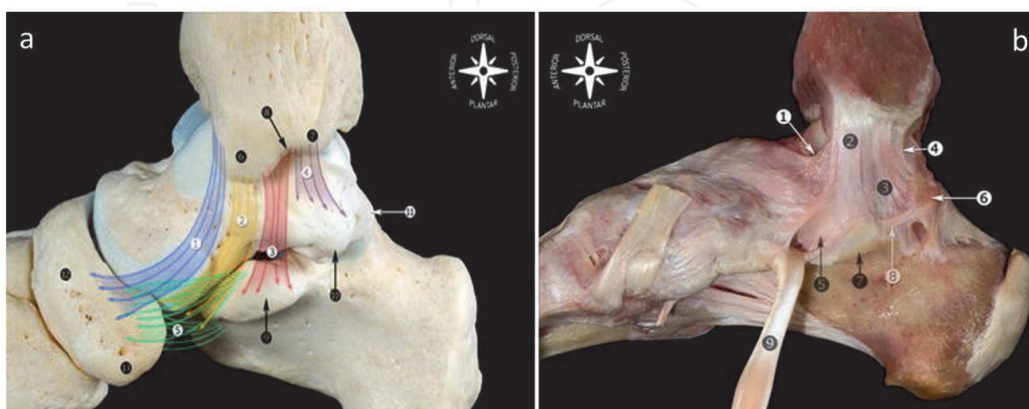


Figure 2. Superficial and deep layers of deltoid ligament. (a) Superficial deltoid ligament. (1) Tibionavicular ligament, (2) tibiospring ligament, (3) tibiocalcaneal ligament, (4) deep posterior tibiotalar ligament, (5) spring ligament complex (plantar and superomedial calcaneonavicular ligaments), (6) anterior colliculus, (7) posterior colliculus, (8) intercollicular groove, (9) sustentaculum tali, (10) medial talar process, (11) lateral talar process, (12) navicular, (13) navicular tuberosity. (b) Deep deltoid ligament. (1) Tibionavicular ligament, (2) tibiospring ligament, (3) tibiocalcaneal ligament, (4) deep posterior tibiotalar ligament, (5) spring ligament complex (superomedial calcaneonavicular ligament), (6) medial talar process, (7) sustentaculum tali, (8) medial talocalcaneal ligament, (9) tibialis posterior tendon (from Vega et al. [68]).

in a patient with CAI that the actual ankle joint position may be much more inverted than perceived by the patient [23]. This error in joint position sense may increase the risk of lateral ankle sprains.

2. Diagnosis of chronic ankle instability

The diagnosis of CAI is mostly a clinically based diagnosis. There is no generally accepted standard of “how much laxity” is true unstable. The key idea is trying to determine whether the condition of instability could be the leading cause of the symptoms of the patient.

2.1 Presenting symptoms

The symptoms of CAI may be vague and nonspecific. Typical complaints are “insecurity” and “giving way” when running or walking on uneven ground. Patients may also complain of recurrent pain, swelling, and tenderness over medial or lateral ankle after prolonged standing or walking. Repeated ankle sprains are also a common complaint.

It should be noted that about 30% of the patients with CAI may be asymptomatic between sprains, which makes it an easily missed diagnosis [24]. Symptoms related to tendinitis, osteochondral lesion of talus, and even arthrosis of ankle joint may also be presented in patients with CAI.

2.2 Physical examinations

A comprehensive examination to check for tender points, alignment, stability, calf tension, muscle power and balance, and joint range of motion is essential for patients with potential CAI.

2.2.1 Tender points

A thorough palpation of the ankle/foot is essential in the initial evaluation of patients with CAI. An understanding of the surface anatomy is crucial for the assessment of the involved structures.

The presence of tenderness just anterior to the fibula tip indicates inflammation of the ATFL. Tenderness on the anterolateral ankle mortise that could be elicited by passive dorsiflexion of the ankle indicates possible anterolateral ankle impingement of the Bassett's ligament frequently seen in patients with CAI [25]. Bony spurs secondary to ankle arthrosis could also be a cause of anterior ankle impingement.

Tenderness on the anteromedial aspect of the ankle could indicate an osteochondral lesion of the talus or coexisting deltoid ligament injury. Tenderness on the posterolateral ankle may point to peroneal tendinitis, whereas medial foot tenderness along the posterior tibia tendon or the spring ligament is prevalent in patients with MAI.

A posteromedial ankle tenderness located anterior to the Achilles tendon indicates a possible posterior ankle impingement. A recent study showed that CAI may increase the likelihood for surgery in athletes with os trigonum syndrome [26].

2.2.2 Stress tests

Manual stress tests such as anterior drawer test and talar tilt can be positive in patients with ligament laxity, but the reliability of these tests is doubted [27].

Several modifications of the stress tests have been postulated such as the varus talar tilt test combined with an internal rotation pivot stress (VTTT with IR) and the anterior talar palpation (ATP) test [28, 29]. The VTTT with IR adds an internal rotational stress on the hindfoot with varus stress, which may better detect the rotational instability in ATFL deficiency judging from its orientation [28]. The ATP test increases the sensitivity of traditional anterior drawer test by pressing the examiner's thumb on the anterolateral ridge of the talus to better detect the anterior talar translation during the anterior draw [29].

The superficial deltoid ligament can be evaluated using the external rotation test. With the sitting patient's leg relaxed and hanging free, the degree of ankle external rotation of both legs can be compared manually. The eversion stress test can be used to assess the deep deltoid ligament by similar manner [30].

2.3 Image studies

2.3.1 Plain radiographs and dynamic radiographs

Plain weight-bearing radiographs of the ankle and foot are essential in the evaluation of patients with CAI to exclude any bony lesions and malalignment. Osseous fragments on the medial or lateral malleolar tip may indicate ligamentous or retinacular avulsion.

Dynamic radiographs can be performed manually, intraoperatively, or using a Telos stress device to demonstrate the anterior drawer test, the talar inversion, and the eversion test (**Figure 3**). For lateral ankle ligaments, a stress radiograph is considered positive when more than 5° difference compared with normal ankle or more than 10° absolute varus tilt is observed [31].

Dynamic radiographs are useful for determining the extent of instability objectively and for documentation purposes. The reported specificity of dynamic radiographs is high, but their sensitivity is low [32]. A recent study showed that preoperative stress radiographic findings do not affect the clinical outcomes of CAI after surgical treatment [33]. Therefore, the dynamic radiographs are better suited for follow-up than for diagnosis.

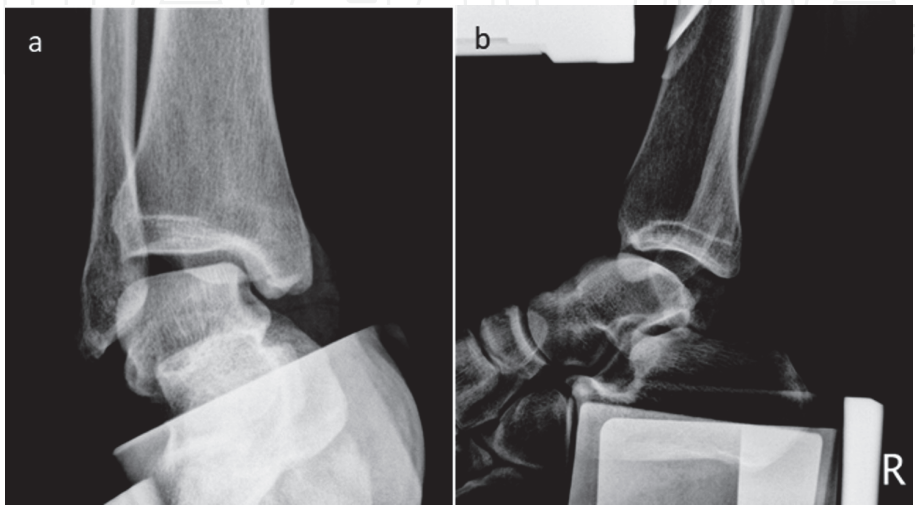


Figure 3.
Dynamic radiographs. A dynamic test using the Telos stress device showing marked varus tilt and anterior subluxation of the talus.

2.3.2 Musculoskeletal sonography

Musculoskeletal sonography allows real-time evaluation of the integrity and laxity of ligaments. It can also be used to check for tenosynovitis and periarticular synovitis of the ankle.

Evidence of an acute sprain is found when the compact fibrillar pattern of the ligament is disrupted by edema or adjacent hematoma [34]. The accuracy of sonography for an acute sprain of the ATFL and CFL is reported to be 95 and 90%, respectively [35]. Ultrasound is also highly accurate for the assessment of deltoid ligament injury after supination-external rotation fractures of the ankle [36].

In patients with CAI, the sonogram may show loss of compact fibrillar pattern and complete disorganization of the ligamentous tissue or even non-visualization (**Figure 4**) [34]. It can be used to detect small avulsion fractures in the malleolus frequently seen in patient with CAI. Stress ultrasound, either done in real-time or in combination with the drawer test, has been proposed. One study compared the relative diagnostic values of the anterior drawer test, stress radiography, stress ultrasound, and magnetic resonance imaging (MRI) using arthroscopic finding as the reference standard. The results showed 78.6% sensitivity of the anterior drawer test, 86% of the stress radiographs, and 100% of both stress ultrasound and MRI [37]. In view of the clinical availability and cost, sonography may well be the imaging tool of choice for the diagnosis of CAI [38].

The major drawback of sonography is its operator dependency and its lack of standards in the communication with other health-care professionals.

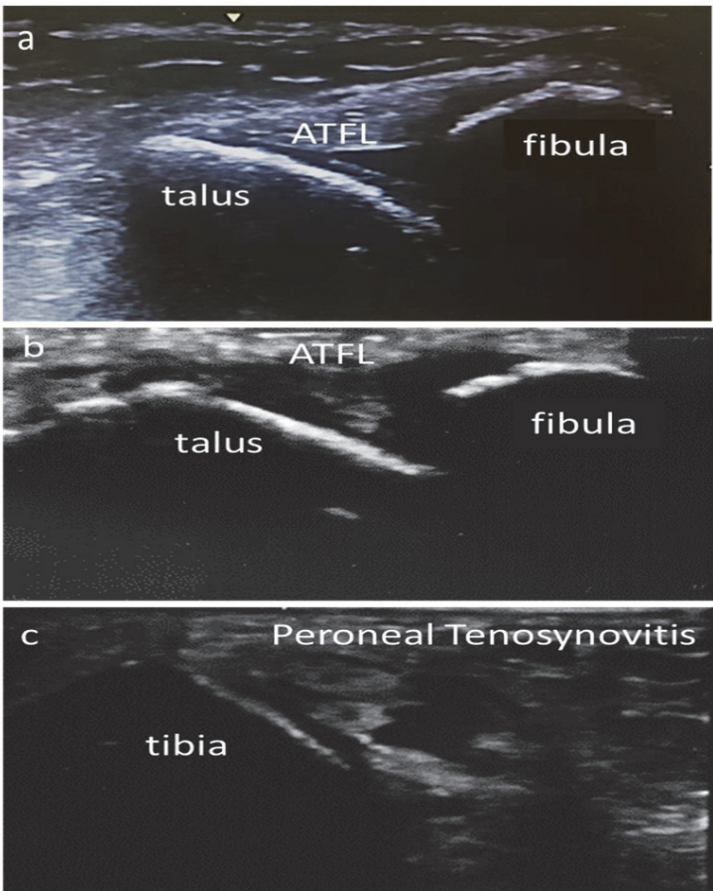


Figure 4.
Sonogram of the ATFL. (a) Normal ATFL. (b) Rupture ATFL. (c) Peroneal tendon tenosynovitis.

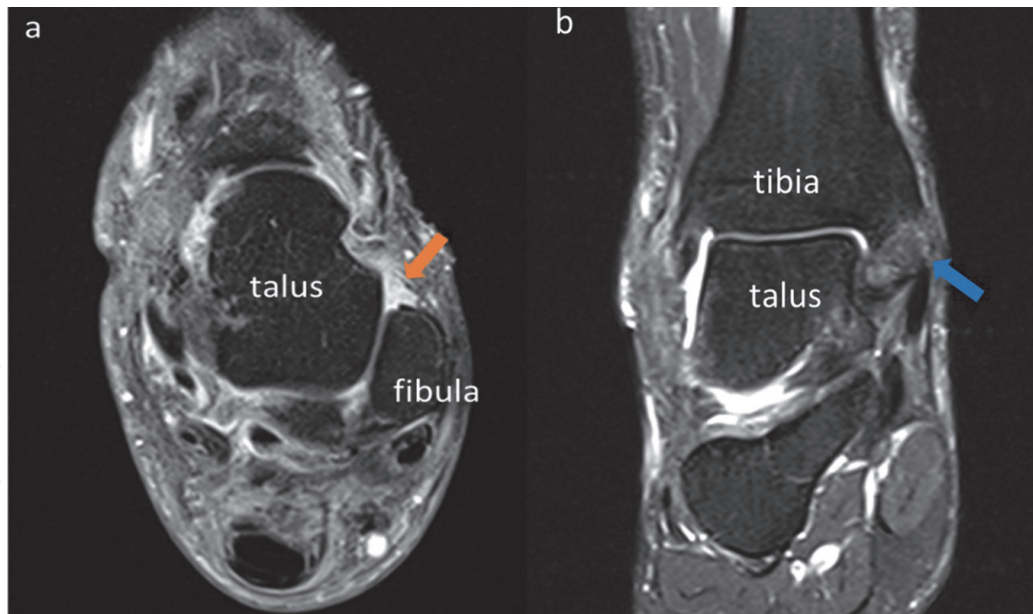


Figure 5.
MRI of injured ankle ligaments. (a) Axial view of the left ankle. The arrow points to the absent ATFL. (b) Coronal view of the right ankle. The arrow points to the injured deep deltoid ligament along with bone marrow edema in the medial malleolus.

2.3.3 MRI

MRI is useful for the evaluation of ligament integrity, thickness, and bony attachment. Normal ligaments appear as low-signal-intensity structures often surrounded by high-signal-intensity fatty tissue [39]. The ATFL is best seen in the axial plane, while the CFL and the deltoid are best seen in the coronal plane. Chronic ligament injury usually presents with morphological changes on MRI such as heterogeneous, intra-substance signals, wavy contour, thinning or elongation, and poor visualization or absence of ligament (**Figure 5**). The surrounding fatty tissue may show fibrosis with medium-signal-intensity or may show a synovitis with a high-signal-intensity [40].

The diagnostic sensitivity of MRI without contrast for ATFL rupture is reported to be 100%, whereas the specificity is only 50% [41]. MRI in combination with arthrography may improve the accuracy for diagnosing ATFL rupture to 100% [42].

MRI can also show the presence of concomitant intra- and periarticular pathologies such as osteochondral lesions, articular degeneration, bone marrow edema, tendon injury or tenosynovitis, and ankle impingement syndrome. However, MRI cannot be used to evaluate the mechanical stability of the ankle.

2.3.4 Arthroscopic examination

In the United States, nearly one-half of the patients undergo arthroscopic evaluation before ligament reconstruction [43]. Ankle arthroscopy can be performed under regional anesthesia without traction in an outpatient setting. It can provide information on the integrity, thickness, attachment, and laxity of the ligaments around the ankle joint. It can also aid in the detection of intra-articular lesions such as injuries to the articular cartilage, bony or soft tissue impingement, and syndesmosis [16, 44–47]. In ATFL and deltoid ligament injuries, the most common site of avulsion is found at the proximal insertion at the anterior aspect of fibula. The

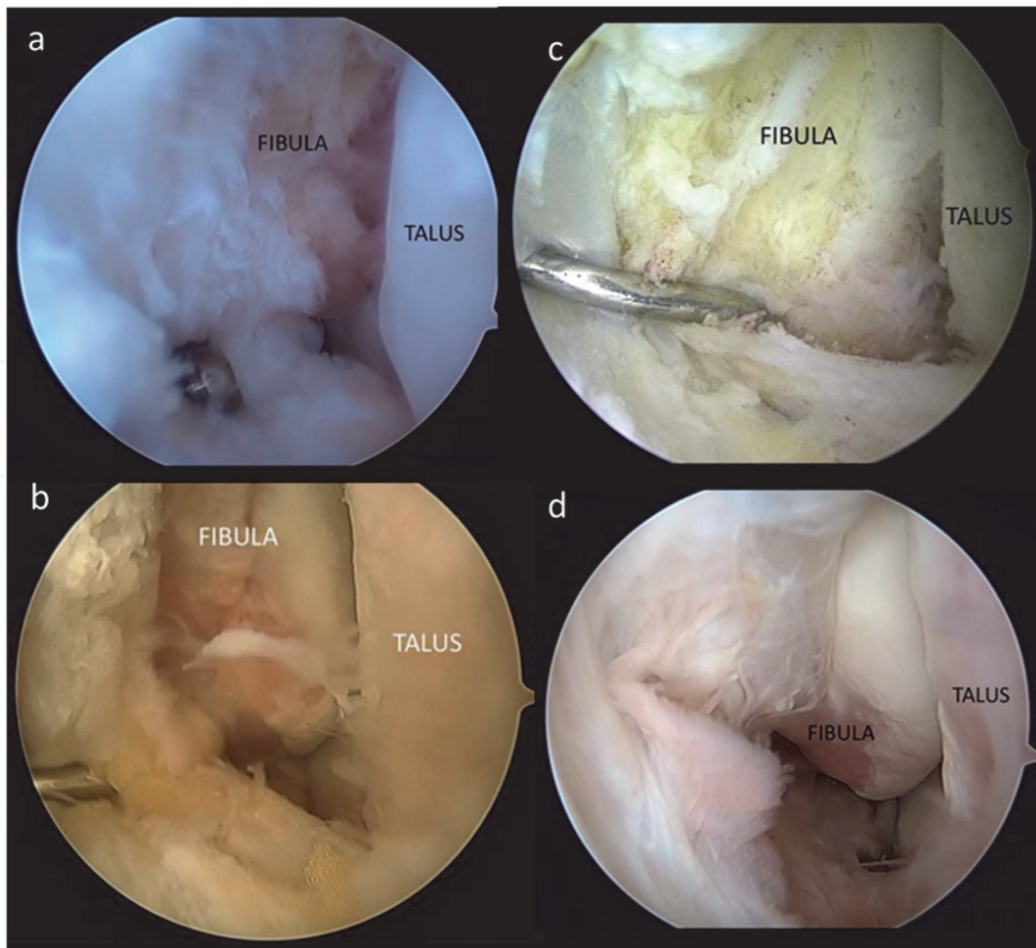


Figure 6. Arthroscopic classification of chronic ATFL injury. (a) Grade I, distended ATFL. (b) Grade II, avulsion from fibula with decreased tension. (c) Grade III, tear and thinning with no mechanical resistance. (d) Grade IV, bald fibula (with kind permission of Thomas Bauer and the French Society of Arthroscopy [50]).

examiner can often see a bare patch of the periosteum normally covered by ligament insertion on the medial or lateral malleolus. Many authors recommended a functional arthroscopic test, which includes axial traction to quantify the tibiotalar opening, anterior drawer test, and varus and valgus tilt test [48, 49].

Using visual inspection and probe testing, injury to the ATFL can be classified in four grades (**Figure 6**) [50]:

- Grade 0, which represents a normal and continuous ligament with normal thickness and tautness
- Grade 1, a distended ligament with normal thickness but decreased tension by hook palpation
- Grade 2, a fibular or talar avulsion (with fibrous tissue) of the ATFL, normal thickness, but decreased tension by hook palpation
- Grade 3, a thin ATFL ligament with no mechanical resistance by hook palpation, with or without scar tissue
- Grade 4, which shows as scar tissue with no residual ligament and leaving a bald malleolus

The author also postulated different surgical strategies according to different grading. Surgical repair and reconstruction techniques are still under debate as will be discussed later.

3. Treatment of CAI

3.1 Conservative treatment

Conservative treatment is usually reserved for the correction of proprioception deficits, balance deficits, and any static disorders. A meta-analysis showed rehabilitation attempts, including balance training, manipulation, and muscle stretch/training, which are beneficial by health-related quality of life standards in patients with CAI [51]. It has also been reported that patients with primarily functional instability are more likely to benefit from rehabilitation than patients with primarily mechanical instability [52].

3.2 Operative treatment

Operative treatment is indicated when conservative treatment failed to resolve the patients' symptoms. Patients with higher physical demands are less likely to become asymptomatic with conservative measures. Patients with mechanical instability, repeated ankle sprains, osseous fragments in the malleolar region, and limitations in on-demand activities may benefit most from operative treatment. It has been reported that patients who received surgical repair showed better muscle endurance and postural stability than patients who had conservative treatment [53].

The goals of surgery are to reestablish ankle joint stability with reduced risk of future sprains in the short term and of articular degeneration in the long term.

Several surgical techniques to reestablish ankle joint stability have been reported either by open or arthroscopic approach. These techniques can be roughly divided into two categories: suture repair and graft reconstruction.

3.2.1 Suture repair

The Broström procedure is the gold standard for patients with CAI and comes with several modifications [24]. After exposure of the remnant ligaments, the ligaments are either folded (if elongated) or reattached (if detached) back to the distal fibula using suture anchors or transosseous sutures [54]. If the quality of the remnant ligament is poor or the quality of the repaired structure is unsatisfactory, the repair can be reinforced using the nearby inferior extensor retinaculum [55]. A complication of using inferior extensor retinaculum as augmentation is that it may cause a decrease in ankle plantarflexion or pain on plantarflexion after the surgery.

Osseous fragments in the lateral malleolar region should be removed if they cause pain or are detached. However, if the fragment size is large, removal may cause a considerable soft tissue defect, which may complicate later repair [56]. Therefore, screw fixation should be considered in cases of large-sized osseous fragments.

In patients with MAI, similar procedures are used to expose, fold, and reattach the remnant ligament to the medial malleolus. If the remnant tissue quality is poor, a periosteal flap reflected from medial malleolus can be used as augmentation. The key to repair the deltoid ligament is, first, to tie the sutures with the ankle in plantigrade position and, second, to avoid sutures through the deep and superficial deltoid ligaments [27]. Sutures across both layers of deltoid ligament may cause a decrease in ankle plantarflexion or pain on plantarflexion after the surgery.

Techniques for arthroscopy-assisted or all-inside repair of both medial and lateral ankle ligaments have been proposed over many years (**Figure 7**) [57–59]. In a recent review, the postoperative functional scores, patient's satisfaction, and surgery-related complications of open and arthroscopic lateral ankle ligament repair

have been compared. Excellent results were shown for both open and arthroscopic surgical procedures in the treatment of the chronic ankle instability. The higher complication rate of arthroscopic procedures relative to open ones represents a major issue; however, this does not seem to affect the patient’s satisfaction [60].

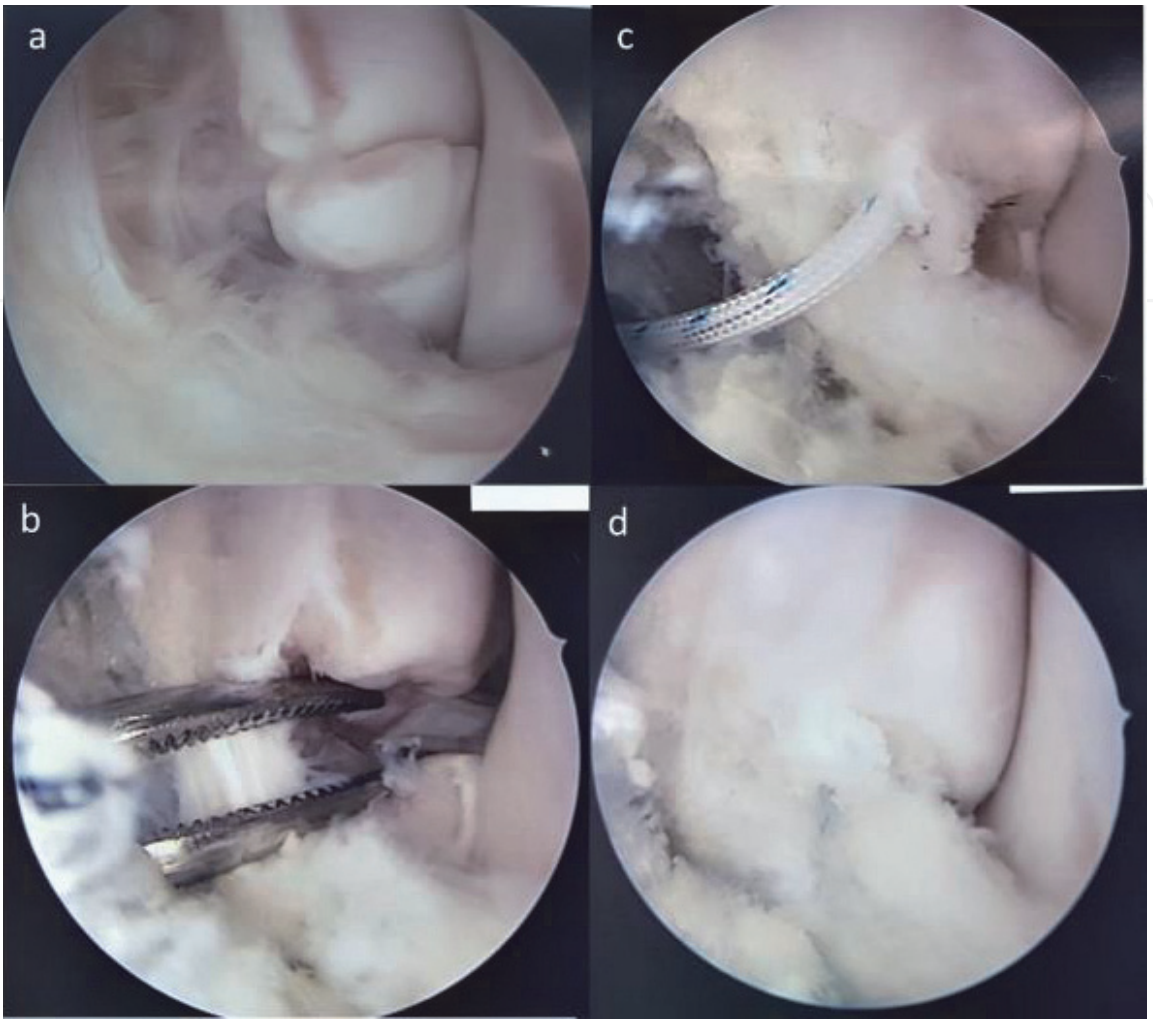


Figure 7. Arthroscopic all-inside repair of the ATFL using suture anchor. (a) Detached ATFL and periosteum from distal fibula along with an osseous fragment. (b) Complete detachment of an osseous fragment from the fibula. (c) Application of suture anchor to fibula tip after excision of osseous fragment. (d) Reattachment of the ATFL using a suture anchor.

Weeks	Patient Mobilization	Physiotherapy
1–2	Rest, Ice, Compression and Elevation (RICE) Orthosis Walker	Lymphatic drainage
3–6	Walker Weight bearing as tolerated	ROM max PF/DF 20°/0°/10 No inversion/eversion Proprioceptive training
7–12	Orthosis if needed	Unrestricted ROM, proprioceptive training, coordination training and force

Table 1. Postoperative treatment protocol.

3.2.2 Graft reconstruction

Using tendon grafts to reconstruct the medial or lateral ligaments is indicated when local tissue quality is poor or in case of revision surgery.

Numerous graft reconstruction techniques have been reported. They can be divided into roughly two types: anatomical and nonanatomical reconstruction.

Anatomical reconstruction is intended to reproduce the course of the ATFL and CFL as anatomically as possible. The nonanatomical reconstruction, also called peroneus tenodesis, leads to nonphysiological intra-articular pressure peaks, sacrifices a dynamic stabilizer, and causes movement restrictions. It should therefore only be used when all other treatment options have failed [61]. Recent meta-analysis concluded that nonanatomical reconstruction may abnormally increase the inversion stiffness at the subtalar level [62].

Numerous graft options have been reported including the plantaris longus tendon, hamstrings tendon, and bone-tendon-bone grafts [63–66]. These tendon grafts are fixed to the malleolus, talus, and calcaneus in various ways including the suture anchor, interference screw, and endo-button. The remnant ligaments are debrided or left in situ. There is still a lack of consensus as to which technique is biomechanically stronger or gives better functional results.

3.2.3 Postoperative treatment

Postoperative treatments of both suture repair and graft reconstruction are similar to that of acute ankle sprain. Recommendations according to the Cochrane review are listed in **Table 1** [67].

4. Conclusions

Ankle sprains are involved in up to 30% of all sport injuries with 30% of patients likely to develop CAI. These traumas can limit their professional or recreational activities significantly. The diagnosis of CAI is mainly clinically based. Sonography is cost-effective and allows real-time assessment of ligament integrity and laxity. Arthroscopic examination has the highest accuracy rate and allows direct visualization of both ligaments and intra-articular lesions.

Once conservative treatment has failed, surgery is indicated to restore ankle joint stability. Suture repair is satisfactory, whether performed open or arthroscopically if the remnant ligament quality is acceptable. Anatomical graft reconstruction is used if remnant quality is poor or a revision is required.

Conflict of interest

The authors declare no conflict of interest.

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References

- [1] Woods C, Hawkins R, Hulse M, Hodson A. The football association medical research programme: An audit of injuries in professional football: An analysis of ankle sprains. *British Journal of Sports Medicine*. 2003;**37**(3):233-238. DOI: 10.1136/bjsm.37.3.233
- [2] Swenson DM, Yard EE, Fields SK, Comstock RD. Patterns of recurrent injuries among US high school athletes, 2005-2008. *The American Journal of Sports Medicine*. 2009;**37**:1586-1593. DOI: 10.1177/0363546509332500
- [3] van Rijn RM, van Os AG, Bernsen RM, Luijsterburg PA, Koes BW, Bierma-Zeinstra SM. What is the clinical course of acute ankle sprains? A systematic literature review. *The American Journal of Medicine*. 2008; **121**:324-331. DOI: 10.1016/j.amjmed.2007.11.018
- [4] Pourkazemi F, Hiller CE, Raymond J, Nightingale EJ, Refshauge KM. Predictors of chronic ankle instability after an index lateral ankle sprain: A systematic review. *Journal of Science and Medicine in Sport*. 2014;**17**:568-573. DOI: 10.1016/j.jsams.2014.01.005
- [5] Munn J, Sullivan SJ, Schneiders AG. Evidence of sensorimotor deficits in functional ankle instability: A systematic review with meta-analysis. *Journal of Science and Medicine in Sport*. 2010;**13**(1):2-12. DOI: 10.1016/j.jsams.2009.03.004
- [6] Hubbard TJ, Kramer LC, Denegar CR. Contributing factors to chronic ankle instability. *Foot & Ankle International*. 2007;**28**(3):343-354. DOI: 10.3113/FAI.2007.0343
- [7] de Noronha M, Refshauge KM, Herbert RD, Kilbreath SL, Hertel J. *British Journal of Sports Medicine*. 2006;**40**(10):824-828. DOI: 10.1136/bjsm.2006.029645
- [8] Crim JR, Beals TC, Nickisch F, Schannen A, Saltzman CL. Deltoid ligament abnormalities in chronic lateral ankle instability. *Foot & Ankle International*. 2011;**32**:873-878. DOI: 10.3113/FAI.2011.0873
- [9] Morrison KE, Hudson DJ, Davis IS, Richards JG, Royer TD, Dierks TA, et al. Plantar pressure during running in subjects with chronic ankle instability. *Foot & Ankle International*. 2010;**31**: 994-1000. DOI: 10.3113/FAI.2010.0994
- [10] Hoch MC, Staton GS, Medina McKeon JM, Mattacola CG, McKeon PO. Dorsiflexion and dynamic postural control deficits are present in those with chronic ankle instability. *Journal of Science and Medicine in Sport*. 2012;**15**(6):574-579. DOI: 10.1016/j.jsams.2012.02.009
- [11] Gribble PA, Delahunt E, Bleakley C, Caulfield B, Docherty CL, Fourchet F, et al. Selection criteria for patients with chronic ankle instability in controlled research: A position statement of the International Ankle Consortium. *JOSPT*. 2013;**43**(8):585-591. DOI: 10.2519/jospt.2013.0303
- [12] Scranton PE Jr, McDermott JE, Rogers JV. The relationship between chronic ankle instability and variations in mortise anatomy and impingement spurs. *Foot & Ankle International*. 2000;**21**(8):657-664. DOI: 10.1177/107110070002100805
- [13] Bonnel F, Toullec E, Mabit C, Tourné Y. Sofcot: Chronic ankle instability: Biomechanics and pathomechanics of ligaments injury and associated lesions. *Orthopaedics & Traumatology, Surgery & Research*. 2010;**96**(4):424-432. DOI: 10.1016/j.otsr.2010.04.003
- [14] Frigg A, Magerkurth O, Valderrabano V, Ledermann HP,

Hintermann B. The effect of osseous ankle configuration on chronic ankle instability. *British Journal of Sports Medicine*. 2007;**41**:420-424. DOI: 10.1136/bjsm.2006.032672

[15] Frigg A, Frigg R, Hintermann B, Barg A, Valderrabano V. The biomechanical influence of tibio-talar containment on stability of the ankle joint. *Knee Surgery, Sports Traumatology, Arthroscopy*. 2007;**15**(11):1355-1362. DOI: 10.1007/s00167-007-0372-2

[16] Hintermann B, Boss A, Schäfer D. Arthroscopic findings in patients with chronic ankle instability. *The American Journal of Sports Medicine*. 2002;**30**(3): 402-409. DOI: 10.1177/03635465020300031601

[17] Colville MR, Marder RA, Boyle JJ, Zarins B. Strain measurement in lateral ankle ligaments. *The American Journal of Sports Medicine*. 1990;**18**:196-200. DOI: 10.1177/036354659001800214

[18] Attarian DE, McCrackin HJ, DeVito DP, McElhaney JH, Garrett WE Jr. Biomechanical characteristics of human ankle ligaments. *Foot & Ankle*. 1985;**6**(2):54-58

[19] Vega J, Malagelada F, Manzanares Céspedes MC, Dalmau-Pastor M. The lateral fibulotalocalcaneal ligament complex: An ankle stabilizing isometric structure. *Knee Surgery, Sports Traumatology, Arthroscopy*. DOI: 10.1007/s00167-018-5188-8

[20] Milner CE, Soames RW. The medial collateral ligaments of the human ankle joint: Anatomical variations. *Foot & Ankle International*. 1998;**19**(5): 289-292. DOI: 10.1177/107110079801900504

[21] Hoch MC, McKeon PO. Peroneal reaction time after ankle sprain: A systematic review and meta-analysis. *Medicine & Science in Sports &*

Exercise. 2014;**46**(3):546-556. DOI: 1249/MSS.0b013e3182a6a93b

[22] Hertel J. Sensorimotor deficits with ankle sprains and chronic ankle instability. *Clinics in Sports Medicine*. 2008;**27**(3):353-370. DOI: 10.1016/j.csm.2008.03.006

[23] Willems T, Witvrouw E, Verstuyft J, Vaes P, De Clercq D. Proprioception and muscle strength in subjects with a history of ankle sprains and chronic instability. *Journal of Athletic Training*. 2002;**37**(4): 487-493

[24] Brostrom L. Sprained ankles. VI. Surgical treatment of "chronic" ligament ruptures. *Acta Chirurgica Scandinavica*. 1966;**132**(5):551-565

[25] Nikolopoulos CE, Tsirikos AI, Sourmelis S, Papachristou G. The accessory anteroinferior tibiofibular ligament as a cause of talar impingement: A cadaveric study. *The American Journal of Sports Medicine*. 2004;**32**(2):389-395. DOI: 10.1177/0095399703258697

[26] D'Hooghe P, Alkhelaifi K, Almusa E, Tabben M, Wilson MG, Kaux JF. Chronic lateral ankle instability increases the likelihood for surgery in athletes with os trigonum syndrome. *Knee Surgery, Sports Traumatology, Arthroscopy*. 2018. DOI: 10.1007/s00167-018-5183-0

[27] Alshalawi S, Galhoum AE, Alrashidi Y, Wiewiorski M, Herrera M, Barg A, et al. Medial ankle instability: The deltoid dilemma. *Foot and Ankle Clinics*. 2018;**23**(4):639-657. DOI: 10.1016/j.fcl.2018.07.008

[28] Guerra-Pinto F, Côrte-Real N, Gomes TM, Consciência JG, Glazebrook M, Oliva XM. Varus talar tilt combined with an internal rotation pivot stress assesses the supination instability vector in lateral ankle

ligaments' injury—Cadaver study. *Foot and Ankle Surgery*. 2019; pii: S1268-7731. DOI: 10.1016/j.fas.2019.03.007

[29] Gomes JLE, Soares AF, Bastiani CE, de Castro JV. Anterolateral talar palpation: A complementary test for ankle instability. *Foot and Ankle Surgery*. 2018;24(6):486-489. DOI: 10.1016/j.fas.2017.05.006

[30] Hintermann B. Medial ankle instability. *Foot and Ankle Clinics*. 2003;8:723-738

[31] Chan KW, Ding BC, Mroczek KJ. Acute and chronic lateral ankle instability in the athlete. *Bulletin of the NYU Hospital for Joint Diseases*. 2011; 69:17-26

[32] Cordova ML, Sefton JM, Hubbard TJ. Mechanical joint laxity associated with chronic ankle instability: A systematic review. *Sports Health*. 2010;2:452-459. DOI: 10.1177/1941738110382392

[33] Jeong BO, Kim TY, Song WJ. Effect of preoperative stress radiographic findings on radiographic and clinical outcomes of the modified Broström procedure for chronic ankle instability. *The Journal of Foot and Ankle Surgery*. 2016;55(1):125-128. DOI: 10.1053/j.jfas.2015.08.010

[34] Girish G, Finlay K, Landry D, O'Neill J, Popowich T, Jacobson J, et al. Musculoskeletal disorders of the lower limb—Ultrasound and magnetic resonance imaging correlation. *Canadian Association of Radiologists Journal*. 2007;58(3):152-166

[35] Peetrans P, Creteur V, Bacq C. Sonography of ankle ligaments. *Journal of Clinical Ultrasound*. 2004;32: 491-499. DOI: 10.1002/jcu.20068

[36] Henari S, Banks LN, Radovanovic I, Queally J, Morris S. Ultrasonography as

a diagnostic tool in assessing deltoid ligament injury in supination external rotation fractures of the ankle. *Orthopedics*. 2011;34(10):e639-e643. DOI: 10.3928/01477447-20110826-11

[37] Cho JH, Lee DH, Song HK, Bang JY, Lee KT, Park YU. Value of stress ultrasound for the diagnosis of chronic ankle instability compared to manual anterior drawer test, stress radiography, magnetic resonance imaging, and arthroscopy. *Knee Surgery, Sports Traumatology, Arthroscopy*. 2016; 24(4):1022-1028. DOI: 10.1007/s00167-015-3828-9

[38] Lee SH, Yun SJ. The feasibility of point-of-care ankle ultrasound examination in patients with recurrent ankle sprain and chronic ankle instability: Comparison with magnetic resonance imaging. *Injury*. 2017;48(10): 2323-2328. DOI: 10.1016/j.injury.2017.07.015

[39] Muhle C, Frank LR, Rand T, Yeh L, Wong EC, Skaf A, et al. Collateral ligaments of the ankle: High-resolution MR imaging with a local gradient coil and anatomic correlation in cadavers. *Radiographics*. 1999;19(3):673-683. DOI: 10.1148/radiographics.19.3.g99ma06673

[40] Salat P, Le V, Veljkovic A, Cresswell ME. Imaging in foot and ankle instability. *Foot and Ankle Clinics*. 2018; 23(4):499-522.e28. DOI: 10.1016/j.fcl.2018.07.011

[41] Verhaven EF, Shahabpour M, Handelberg FW, Vaes PH, Opdecam PJ. The accuracy of three-dimensional magnetic resonance imaging in the diagnosis of ruptures of the lateral ligaments of the ankle. *The American Journal of Sports Medicine*. 1991;19(6): 583-587. DOI: 10.1177/036354659101900605

[42] Chandnani VP, Harper MT, Ficke JR, Gagliardi JA, Rolling L,

- Christensen KP, et al. Chronic ankle instability: Evaluation with MR arthrography, MR imaging, and stress radiography. *Radiology*. 1994;**192**(1): 189-194. DOI: 10.1148/radiology.192.1.8208935
- [43] Werner BC, Burrus MT, Park JS, Perumal V, Gwathmey FW. Trends in ankle arthroscopy and its use in the management of pathologic conditions of the lateral ankle in the United States: A National Database Study. *Arthroscopy*. 2015;**31**(7):1330-1337. DOI: 10.1016/j.arthro.2015.01.020
- [44] Takao M, Ochi M, Oae K, Naito K, Uchio Y. Diagnosis of a tear of the tibiofibular syndesmosis. The role of arthroscopy of the ankle. *Journal of Bone and Joint Surgery. British Volume (London)*. 2003;**85**(3):324-329
- [45] Komenda GA, Ferkel RD. Arthroscopic findings associated with the unstable ankle. *Foot & Ankle International*. 1999;**20**:708-713. DOI: 10.1177/107110079902001106
- [46] DiGiovanni BF, Fraga CJ, Cohen BE, Shereff MJ. Associated injuries found in chronic lateral ankle instability. *Foot & Ankle International*. 2000;**21**(10):809-815. DOI: 10.1177/107110070002101003
- [47] Choi WJ, Lee JW, Han SH, Kim BS, Lee SK. Chronic lateral ankle instability: The effect of intra-articular lesions on clinical outcome. *The American Journal of Sports Medicine*. 2008;**36**(11): 2167-2172. DOI: 10.1177/0363546508319050
- [48] Kerr HL, Bayley E, Jackson R, Kothari P. The role of arthroscopy in the treatment of functional instability of the ankle. *Foot and Ankle Surgery*. 2013; **19**(4):273-275. DOI: 10.1016/j.fas.2013.06.008
- [49] Guillo S, Bauer T, Lee JW, Takao M, Kong SW, Stone JW, et al. Consensus in chronic ankle instability: Aetiology, assessment, surgical indications and place for arthroscopy. *Orthopaedics & Traumatology, Surgery & Research*. 2013;**99**(8 Suppl):S411-S419. DOI: 10.1016/j.otsr.2013.10.009
- [50] Thès A, Odagiri H, Elkaïm M, Lopes R, Andrieu M, Cordier G, et al. Arthroscopic classification of chronic anterior talo-fibular ligament lesions in chronic ankle instability. *Orthopaedics & Traumatology, Surgery & Research*. 2018;**104**(8S):S207-S211. DOI: 10.1016/j.otsr.2018.09.004
- [51] Powden CJ, Hoch JM, Hoch MC. Rehabilitation and improvement of health-related quality-of-life detriments in individuals with chronic ankle instability: A meta-analysis. *Journal of Athletic Training*. 2017;**52**(8):753-765. DOI: 10.4085/1062-6050-52.5.01
- [52] Ajis A, Maffulli N. Conservative management of chronic ankle instability. *Foot and Ankle Clinics*. 2006;**11**:531-537. DOI: 10.1016/j.fcl.2006.07.004
- [53] Lee JH, Lee SH, Jung HW, Jang WY. Modified Broström procedure in patients with chronic ankle instability is superior to conservative treatment in terms of muscle endurance and postural stability. *Knee Surgery, Sports Traumatology, Arthroscopy*. 2019. DOI: 10.1007/s00167-019-05582-4
- [54] Cho BK, Kim YM, Kim DS, Choi ES, Shon HC, Park KJ. Comparison between suture anchor and transosseous suture for the modified-Broström procedure. *Foot & Ankle International*. 2012;**33**(6): 462-468. DOI: 10.3113/FAI.2012.0462
- [55] Gould N, Seligson D, Gassman J. Early and late repair of lateral ligament of the ankle. *Foot & Ankle*. 1980;**1**: 84-89
- [56] Kim BS, Choi WJ, Kim YS, Lee JW. The effect of an ossicle of the lateral

malleolus on ligament reconstruction of chronic lateral ankle instability. *Foot & Ankle International*. 2010;**31**(3): 191-196. DOI: 10.3113/FAI.2010.0191

[57] Nery C, Raduan F, Del Buono A, Asaumi ID, Cohen M, Maffulli N. Arthroscopic-assisted brostrom-gould for chronic ankle instability: A long-term follow-up. *The American Journal of Sports Medicine*. 2011;**39**:2381-2388. DOI: 10.1177/0363546511416069

[58] Vega J, Golanó P, Pellegrino A, Rabat E, Peña F. All-inside arthroscopic lateral collateral ligament repair for ankle instability with a knotless suture anchor technique. *Foot & Ankle International*. 2013;**34**:1701-1709. DOI: 10.1177/1071100713502322

[59] Cottom JM, Rigby RB. The “all inside” arthroscopic brostrom procedure: A prospective study of 40 consecutive patients. *The Journal of Foot and Ankle Surgery*. 2013;**52**: 568-574. DOI: 10.1053/j.jfas.2013.02.022

[60] Guelfi M, Zamperetti M, Pantalone A, Usuelli FG, Salini V, Oliva XM. Open and arthroscopic lateral ligament repair for treatment of chronic ankle instability: A systematic review. *Foot and Ankle Surgery*. 2018;**24**(1): 11-18. DOI: 10.1016/j.fas.2016.05.315

[61] Knupp M, Lang TH, Zwicky L, Lötscher P, Hintermann B. Chronic ankle instability (medial and lateral). *Clinics in Sports Medicine*. 2015;**34**(4): 679-688. DOI: 10.1016/j.csm.2015.06.004

[62] Cao Y, Hong Y, Xu Y, Zhu Y, Xu X. Surgical management of chronic lateral ankle instability: A meta-analysis. *Journal of Orthopaedic Surgery and Research*. 2018;**13**(1):159. DOI: 10.1186/s13018-018-0870-6

[63] Hintermann B, Renggli P. Anatomische Rekonstruktion der lateralen Sprunggelenkbänder mit der

Plantarissehne zur Behandlung der chronischen Instabilität. *Orthopäde*. 1999;**28**:778-784. DOI: 10.1007/PL00003667

[64] Richter J, Volz R, Immendörfer M, Schulz M. Reconstruction of the lateral ankle ligaments with hamstring tendon autograft in patients with chronic ankle instability. *Operative Orthopädie und Traumatologie*. 2012;**24**:50-60. DOI: 10.1007/s00064-011-0126-7

[65] Coughlin MJ, Matt V, Schenck RC. Augmented lateral ankle reconstruction using a free gracilis graft. *Orthopedics*. 2002;**25**:31-35

[66] Sugimoto K, Takakura Y, Kumai T, Iwai M, Tanaka Y. Reconstruction of the lateral ankle ligaments with bone-patellar tendon graft in patients with chronic ankle instability: A preliminary report. *The American Journal of Sports Medicine*. 2002;**30**:340-346. DOI: 10.1177/03635465020300030701

[67] de Vries JS, Krips R, Sierevelt IN, Blankevoort L, van Dijk CN. Interventions for treating chronic ankle instability. *Cochrane Database of Systematic Reviews*. 2011;(8): CD004124. DOI: 10.1002/14651858.CD004124

[68] Golanó P, Vega J, de Leeuw PA, Malagelada F, Manzanares MC, Götzens V, et al. Anatomy of the ankle ligaments: A pictorial essay. *Knee Surgery, Sports Traumatology, Arthroscopy*. 2010;**18**(5):557-569. DOI: 10.1007/s00167-010-1100-x