Science Letters ISSN 2345-5463

DOI: https://doi.org/10.47262/SL/13.1.132025170

Review article

2025 | Volume 13 | Issue 1 | Article ID 1325170sl

ARTICLE INFO

Received
December 11, 2024
Revised
February 19, 2025
Accepted
February 23, 2025
Published
March 22, 2025

***Corresponding author**
Jianchao Gui
E-mail
gui1997@126.com

Keywords
Deltoid ligament
Ankle instability
Arthroscopy
Regenerative medicine
Biomechanics

How to Cite
Khan AA, Ali MJ, Zhang K, Li Y, Tao T, Gui JC. Arthroscopic deltoid ligament surgery in ankle disorders: a review. Science Letters 2025; 13(1):1324370sl

Open Access

Arthroscopic Deltoid Ligament Surgery in Ankle Disorders: A Review

Abdul Aleem Khan[1]*, Mohammed Junaid Ali[2], Kaibin Zhang[1], Yang Li[1], Tianqi Tao[1], Jianchao Gui[1]

[1]Department of Orthopedics, Department of Sports Medicine, Nanjing First Hospital, Nanjing Medical University, Changle Road 68, 210000, Nanjing, Jiangsu, China

[2]Department of Orthopedics, Sir Run Run Hospital, Nanjing Medical University, Longmian Road 109, 211100, Nanjing, Jiangsu, China

Abstract

Medial ankle stability relies heavily on deltoid ligaments and failure to treat these injuries could result in chronic instability, degenerative disease, or osteoarthritis. This article discusses deltoid ligament biomechanics, recent advancements in arthroscopic surgical techniques, clinical outcomes and emerging treatment trends. Biomechanics of the deltoid ligament is relevant for ankle stability and is influenced by age and sex. Injuries are also more common in women, particularly as they age. Recent studies have demonstrated that the ligament's superficial and deep layers are critical for sustaining ankle function and that supplementary ligament structures are hindering surgical repair attempts. The advent of arthroscopic techniques revolutionized deltoid ligament repair due to its minimally invasive nature, causing less blood loss, shorter hospital stays and fewer complications. These techniques facilitate accurate visualization of the ligament, further helping speed up recovery and decrease postoperative pain while addressing concomitant intra-articular pathologies. Clinical outcomes following arthroscopic repairs have been favorable, with marked improvements in pain relief, functional recovery and shortened return to activity. Any complications, such as recurrent instability or graft issues, remain relatively rare. Concerns about long-term complications, including osteoarthritis, remain, especially in severe cases. Advanced techniques, including biologic augmentation and robotic-assisted surgery, are improving ligament repair and rehabilitation. Biomechanical and regenerative medicine developments are set to propel deltoid ligament repair forward as well. Overall, arthroscopic deltoid ligament repair is a promising development that should yield a symptomatic and functional advantage over an open alternative, and further study will undoubtedly advance recovery and long-term outcome for patients.

SCAN ME

This work is licensed under the Creative Commons Attribution-Non-Commercial 4.0 International License.

Introduction

The ankle joint is responsible for bearing mechanical stress and it takes more stress per square centimeter than any other joint. In some cases, the ankle is prone to injury during impactful activities. However, ankle arthritis is much rarer than knee or hip arthritis, with ankle arthritis being approximately nine times less common [1]. While arthritis is generally considered a primary condition in the case of the knee and hip, it is mostly secondary in the ankle after traumatic injuries like fractures, ligament sprains, or osteochondral lesions [2]. Fractures such as Weber A to C, pilon fractures and osteochondral lesions of the talus are associated with an increased rate of post-traumatic ankle arthritis. Fourteen percent of ankle fractures develop arthritis; the risk increases when it is associated with ligamentous injury or includes the posterior malleolus [2]. The deltoid ligament is important for medial ankle stability. Damage or chronic instability in the ligament can decrease the contact area of the joint by 15% to 20%, markedly increasing joint stress and causing degenerative changes [3].

High-energy fractures (*e.g.*, pilon fractures) can lead to significant cartilage damage and degenerative changes that can occur within twenty years even with impeccable reduction and fixation [1, 5]. Most commonly, fractures of the talar neck result in tibiotalar arthritis in 47% to 97% of cases [8]. The deltoid ligament plays an important role in the kinematics of the ankle joint and its deficiency leads to increased wear and tear of the talocrural joint in cases of chronic instability and concomitant osteochondral lesions [9, 10]. The Visual Analogue Scale (VAS) for pain demonstrated dramatic improvement after surgical intervention, emphasizing the need for early treatment [9, 10]. Improved arthroscopic methods provide minimally invasive repair with precise results, fast recovery and lower complication rates compared to open repair [13, 14]. However, such repairs demand significant surgical expertise concerning the complexity of the anatomy surrounding the ankle and access to the joint space. The rising incidence of ankle injuries in the active population necessitates effective surgical techniques to restore joint stability and function. Recent developments in ankle biomechanics and arthroscopic techniques for deltoid ligament repair provide promising outcomes for these injuries [17, 18]. This review highlights recent arthroscopic approaches to deltoid ligament repair, evaluates clinical results, and considers future directions in the management of ankle pathology associated with deltoid ligament disease. This study was approved by the Institutional Review Board of Nanjing First Hospital and written informed consent was obtained from all the subjects involved in the study.

Ankle Anatomy and Mechanics Relevant to Deltoid Ligament Surgery

Ankle anatomy

Detailed knowledge of ankle anatomy and biomechanics is the key factor in the success of deltoid ligament surgery. The ankle joint is a complex structure consisting of bones, ligaments, tendons and muscles, which work together to provide stability and movement through a wide range of motion. The numeric impression visuals of the joint are important, but the summary of the numeric impact on surgery is what surgeons need to successfully navigate the joint [20]. The ankle is made up of important joints that facilitate motion and weight bearing: the subtalar joint (STJ), tibiotalar (talocrural) joint, and the transverse-tarsal (Chopart's) joint. Subtalar (STJ) is found between the talus and calcaneus and allows the foot to conform to uneven ground surfaces to produce inversion and eversion actions, which help in adapting the foot to the surface [21-24]. The tibiotalar (Talocrural) joint makes a connection between the tibia, fibula and talus, and it allows dorsiflexion and plantarflexion. In the ankle, the talus plays the role of a mortise, adapted to a space surrounded by the tibia and fibula, forming a stable and permissive hinge for body weight with considerable degrees of freedom of motion [20, 26-27]. Transverse-Tarsal Joint (Chopart's Joint) comprising the talonavicular and calcaneocuboid joints, is essential for converting the foot from a flexible to a rigid structure for propulsion in walking, particularly the pre-propulsive phase [24, 28].

Biomechanics related to deltoid ligament surgery

Extrinsic muscles, that come from the lower leg and intrinsic muscles within the foot control movement of the ankle. These muscles are set up in functional compartments. Anterior compartment muscles of this compartment include the tibialis anterior, extensor digitorum longus, extensor hallucis longus and peroneus tertius, which allow for dorsiflexion and inversion. The tibialis anterior is important for stabilizing the ankle during locomotion [20, 29]. The lateral compartment contains the peroneus longus and brevis, which assist with eversion and plantar flexion and contribute to the stabilization of the lateral ankle in use during side-to-side activities [20, 29]. The posterior compartment contains the superficial muscles (gastrocnemius, soleus and plantaris) that integrate to form the Achilles tendon and execute plantar flexion, while the deep group (tibialis posterior, flexor digitorum longus, and flexor hallucis longus) performs plantar flexion and inversion [20, 29]. The biomechanics of the ankle involve some simple but essential movements that facilitate both mobility and stability. At the tibiotalar joint, plantar flexion refers to the downward movement of the foot compared to dorsiflexion, which causes the upward movement of the foot, both are essential for the stance and push-off phases of walking [26]. Inversion and eversion occur around both the subtalar and transverse-tarsal joints, these allow for proper adaption of the foot on uneven surfaces to keep balance [26]. Supination is a triad of plantarflexion, inversion and adduction whereas pronation is a triad of dorsiflexion, eversion and abduction. This is highly important for dynamic stability, especially in rapid directional changes [26]. Anatomy and biomechanics of the ankle are critical to the success of deltoid ligament management. The deltoid ligament, or the medial ligament of the ankle, reinforces the subtalar and tibiotalar joints. Injuries to this ligament lead to instability and must be surgically repaired. Moreover, recent studies indicate that the deltoid ligament acts as an indirect stabilizer of the syndesmosis, which is crucial for the ankle track [30-35].

Imaging Modalities in Pre-Surgical Evaluation of Deltoid Ligament Pathologies

Deltoid ligament injuries and long-term fixed talar alignment are best visualized with accurate imaging for diagnosis and potential surgical considerations. Due to the complex anatomy of the ankle, there are multiple imaging modalities employed to ensure thorough investigation. Plain radiography or weight-bearing X-rays (anteroposterior, mortise and lateral views) are the preliminary investigation and provide baseline information on the bone structures as well as evidence of fractures, dislocation, or joint space narrowing that may support the diagnosis of ligament injury [36]. After surgery, radiographic assessment of the medial clear space (MCS) is frequently used to monitor the repair of the deltoid ligament; a decreased MCS suggests a successful intervention (Fig. 1) [6].

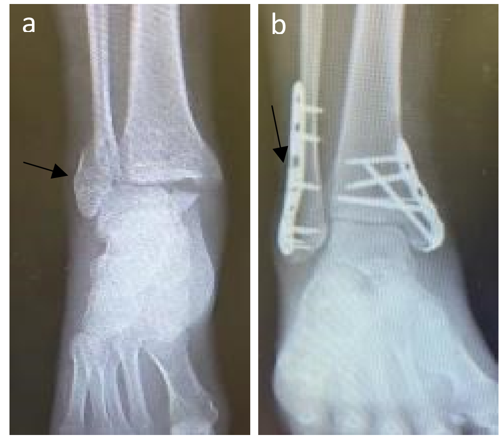

Fig. 1 An X-Ray for a patient (a) before and (b) after surgery with plating and screw fixation.

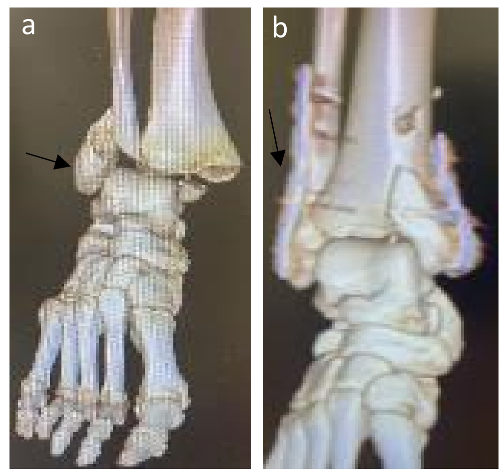

Fig. 2 A CT for a patient (a) before and (b) after surgery with plating and screws fixation.

Fig. 3 An MRI for our patient (a) before and (b) after surgery removal for plating and screws fixation can be seen on MRI with good recovery.

Advanced imaging techniques

CT-SCANS: Important for evaluating bony anatomy, especially complex fractures or the presence of hardware from past surgery. CT is less prone to metal artifacts than MRI and is thus useful in patients with implants (Fig. 2) [38-39].

Magnetic resonance imaging (MRI)

The gold standard for soft tissue assessment of the deltoid ligament and surrounding structures. The role of MRI is more useful in chronic cases to demonstrate ligament tears and degeneration in detail, as well as examine associated structures, such as the tibialis posterior tendon [40]. It assists in confirming clinical and radiological diagnoses, especially in complex cases (Fig. 3) [42].

Techniques for imaging specialized situations

Understanding ankle biomechanics requires the assessment of the *rotational axis* that passes through the tibiotalar and subtalar joints [12, 43]. Rotation about this axis needs to be evaluated both for ligament repair as well as for surgical purposes. *Functional imaging and gait analysis* can be utilized to evaluate the impact of deltoid ligament injuries on rachial biomechanics, which may assist in surgical planning by quantifying motion and muscle activation abnormalities [26]. Another imaging technique serving as a dynamic test is *ultrasound provides real-time imaging* during activity, but its specificity is inferior to that of MRI and thus it should be considered supplementary for confirming the diagnosis along with other modalities [47, 48].

Surgical Techniques of the Arthroscopic Deltoid Ligament Surgery

The deltoid ligament on the medial side of the ankle is important for joint stabilization. Acute or chronic injuries can render joints unstable and painful, requiring a surgical fix when non-operative management fails. Due to the advantageous nature of this approach, including relatively low morbidity and the avoidance of non-weight-bearing post-operatively [20, 48, 49], arthroscopic deltoid ligament repair has emerged as a more desirable method of repair.

Arthroscopic methods

During arthroscopic surgery, small incisions (portals) are made on the medial ankle and an arthroscope is inserted so that the ligaments and surrounding tissue can be visualized. This technique allows for limited soft tissue insult and accurate repairs [17, 50, 51]. Effective repair requires accurate placement of the portal. Usually, two or three portals while the medial ankle is exposed for better access. This aids the surgeon in evaluating the condition of ligaments and other paths of pathologies, so accurate dissection can be performed and he/she will be better prepared for repair [32, 50, 54]. Suture anchors (placed at the ligament's anatomic origin [usually the medial malleolus and talus]) are the basis of arthroscopic repair. The ligament is fixed by threading sutures through its body and reattaching it to the bone finalizing the restoration of stability to the ankle [9, 25, 50]. This technique provides a secure repair and encourages good healing [34]. In case of deep-seated ligament damage, graft reconstruction is done. (The surgeon can use autografts (like a hamstring tendon) or allografts (donor tissue). These are anchored to the medial malleolus and talus to re-establish ankle stability [17, 55-57]. This technique offers persistent relief and functional enhancement [63, 65].

Technological development

Newer treatments, such as bioabsorbable suture anchors, dissolve in the body once healing has occurred to reduce the need for hardware removal [66]. Further innovations in surgical tools and suture materials have improved the precision and durability of repairs, enabling more complex cases [17, 39, 71]. In more extreme circumstances of difficulties and postoperative management, issues with accurate portal placement and promoting graft integration can present challenges. Afterward, the toe must be immobilized, and the foot must be gradually conditioned to bear weight. Physical therapy restoring strength, range of motion and proprioception [11, 18, 64]. Scientists are still developing techniques and better outcomes. New biological augmentations (growth factors, stem cells) and new imaging technologies are likely to enhance the quality and reliability of arthroscopic repairs [17, 39, 66].

Clinical Outcomes and Complications of Arthroscopic Deltoid Ligament Surgery

Using arthroscopic deltoid ligament surgery is an efficient approach to restore ankle stability and functional stability after traumatic acute ligament injury or in cases of chronic instability. Many studies have reported good clinical outcomes in terms of pain relief, functional improvement, and high satisfaction rates from patients.

Pain relief and functional improvement

The main purpose of arthroscopic deltoid ligament repair is to relieve pain and restore mechanical stability. It demonstrates again from previous research that patients get significant pain relief and improvement in function. The goal of being able to restore ligament integrity leads to reduced joint "giving way" (an unstable joint) after any type of reconstructive procedure for those with chronic instability, in addition to enhanced confidence in daily activities and sports [74 -76]. Many patients, especially athletes, can return soon to near pre-injury activity levels after arthroscopic repair. Evidence has shown that much of the function and activity is preserved with this surgical approach as many patients return to competition six months after their surgery [44, 65, 74, 77-79]. Long-term follow-up shows that most patients have the significantly improved function of the ankle with low rates of recurrence of instability. However, individuals may develop osteoarthritis, particularly if degenerative conditions existed before surgical intervention [74-76]. While the success rate is high, there are potential complications. It is uncommon for complications to occur postoperatively, blood or seroma accumulation, wound healing issues, peripheral nerve irritation and infection can occur. Irritation of the superficial peroneal nerve may result in transient numbness or pain surrounding the ankle [80]. When ligaments are reconstructed with grafts, there are other risks. Three-dimensional culture retains the native structure of the tissue and prevents the boilerplate formation of fibrotic tissue seen for autografts, which leads to donor site morbidity and allografts, which carry the risk of immune response or introducing infection. Whereas rare, these complications should be counselled on pre-operatively [72]. If the graft does not heal sufficiently or integrate properly, instability may worsen, necessitating additional procedures. Some patients will develop osteoarthritis over the years, especially in the subtalar joint due to altered biomechanics that the surgery has brought [75]. Complex cases that involve multi-ligament injuries may need more invasive procedures and result in less predictable (Table 1) [83].

Table 1 Summary of clinical outcomes and complications of arthroscopic deltoid ligament surgery.

Category	Details
Pain relief and functional improvement	Significant reduction of pain and improved functional outcome of chronic instability cases [74, 75, 76].
Return to activity	Quick recovery, with athletes returning to competitive sports in 6 months [44, 65,74, 77-79].
Long-term stability and duration	Sustained ankle stability, low rates of recurrent instability, and risk of osteoarthritis in some cases [34, 74, 75, 76].
Postoperative complications	Wound healing problems, nerve irritation, and infection are generally rare due to minimally invasive.
Graft-related complication	Autograft risks: donor site morbidity. Allograft risks: infection, immune response [41, 72].
Recurrent instability and mechanical failure	Recurrent instability may require further intervention and rare mechanical failure linked to pre-existing joint degeneration [81, 82].
Long-term complications	Risk of osteoarthritic changes in the ankle, especially in patients with significant ligament damage [75].
Considerations for complex cases	Unpredictable outcomes in complex cases may require open repair [83].

Comparative Evaluation of Treatment Modalities for Deltoid Ligament Disorders

Management of deltoid ligament injuries should be individualized depending on the grade of injury and the needs of the patient. Next, this section compares this arthroscopic deltoid ligament procedure with other surgical and nonsurgical treatment options.

History of present illness and examination

A complete history is crucial to recognize deltoid ligament injuries. Clinicians should assess for a history of prior ankle injury, chronic instability, or pain with activities, such as walking on uneven surfaces [86, 87]. Physical examination Gait analysis is used to assess stability and gait analysis of the turning table for the cost associated with the cost of the deltoid ligament and other up to the spring phase. X-rays and imaging are also important in diagnosing associated conditions such as osteochondral lesions or medial ankle instability [88, 89].

Table 2 Comparative evaluation of treatment modalities for deltoid ligament disorders.

Treatment modalities	Advantages	Disadvantages
Conservative management	Non-invasive, cost-effective, and fewer risks. Restores function and alleviates pain [88,90, 91].	Limited effectiveness in severe ligament damage, higher chance of recurrence [90, 91].
Arthroscopic repair	Minimally invasive, less soft tissue damage, enhanced joint visualization, quicker recovery [94, 95].	Technically challenging, limited long-term data on durability, not suitable for complex injuries [97, 98].
Open deltoid ligament reconstruction	Durable repair for severe injuries, tendon graft provides long-term stability [99, 100].	Longer recovery time increases the risk of complications such as infection, scarring, and prolonged pain [101-103].
Comparative evaluation (arthroscopic vs open surgery)	Arthroscopy offers a shorter recovery, with fewer complications, open surgery is durable for severe injuries [102, 103, 105].	Open surgery provides more durability but has a longer recovery and more risks [104, 105].

Non-invasive treatment options

For mild or early-stage injuries, conservative treatments are the mainstay of management. Functional braces stabilize and orthotics correct misalignments [88, 89]. Recurrent instability risks decrease through strength and proprioception exercises [90, 91]. Intra-articular steroid injections provide short-term pain relief but should be used judiciously [90, 91]. Non-surgical procedures provide benefits such as lower risk and cost. However, they may not work in severe or chronic cases and recurrence can occur [56, 92].

Surgical treatment modalities

Arthroscopic deltoid ligament repair is minimally invasive, meaning that it requires fewer and smaller incisions and uses specialized tools to repair the ligament. Its benefits include less injury to soft tissues, less pain, faster recovery and better visualization [95, 96]. The drawbacks include technically complex and limited long-term data [97- 99]. In more severe cases, open deltoid ligament reconstruction surgery with tendon grafts is necessary for a more thorough and durable repair. This technique is durable for severe injuries [99, 100], but with increased recovery time and complication risks [101-103]. Arthroscopic repair (AT) provides can achieve rehabilitation (rehab) as compared to open repair (OR) [102, 103].

Invasiveness and durability

Compared to open surgery, arthroscopy is less invasive, resulting in fewer complications [104]. For severe cases, open surgery is more durable, yet has a greater risk antioncogenes of complications and long recovery [105]. In cases of unstable fibula fractures, the outcomes of arthroscopic repair are comparable to those of open surgery, albeit less invasive with quicker recovery time (Table 2) [65].

Surgical Management of Ankle Instability with Deltoid Ligament Reconstruction

Patients with deltoid ligament disorders may benefit from improved outcomes due to advances in the repair of ligaments, biologic and imaging technologies. It reviews recent advances and future perspectives in deltoid ligament repair.

Biologic augmentation and biologic tissue engineering

Biologic augmentation, which envelops the use of growth factors, stem cells and bioactive scaffolds, is one such domain that has shown promise to enhance ligament healing and provide durability to repairs. The growth factors like platelet-rich plasma (PRP) and bone marrow aspirate concentrate (BMAC) promote healing and decrease recovery time [110, 111]. Stem cell therapy is known for regenerative properties, mesenchymal stem cells (MSCs) play a role in collagen formation and ligament regeneration [112]. Bioactive scaffolds are scaffolds impregnated with growth factors or stem cells that can aid in tissue regeneration and help in some cases in which there would be requirements for autografts or allografts [113].

Minimally invasive and robotic-assisted solutions

The advantages of robotic-assisted surgery include greater accuracy, better dexterity and enhanced visualization. This technology ensures precise repairs with minimum disruption of the tissue [114, 115].

Arthroscopic tools such as 3D imaging and augmented reality (AR) are also evolving to enhance precision [116]

Biomechanical modelling and customized surgical planning

Preoperative 3D modelling and AI revolutionize surgical planning with accurate patient-specific modelling of the ankle. This permits surgeons to test different approaches and choose the best strategy [117-120] Similarly, AI algorithms can also contribute to predicting prognosis based on patient data. Argued for Gene Therapy and Regenerative Medicine CRISPR and other types of gene therapy are being investigated for their potential to improve ligament healing by altering gene expression associated with collagen biosynthesis. Regenerative implants that can release growth factors or genetic material might accelerate tissue regeneration even further [121-123]. Smart wearables and real-time motion tracking enable clinicians to track patient progress and adjust rehabilitation plans. VR/AR systems are also being integrated into rehabilitation programs for an immersive and interactive patient experience [124-126].

Future research directions

In particular, future investigations in biologic therapy refinement, robotics and AI integration in surgical and rehabilitative efforts and biomarker-driven biomechanical and genetic analysis for personalized treatment protocol initiatives will drive these efforts. The repair of deltoid ligament will continue to improve with improvements and refinements of these technologies (Table 3).

Biomechanics of the Ankle and Clinical Relevance in Deltoid Ligament Pathologies

The deltoid ligament plays a key role in medial ankle stability; its injury can lead to instability and post-traumatic osteoarthritis (PTOA). Management of medial ankle instability requires an understanding of ankle biomechanics, particularly the role of the deltoid ligament. Ankle ROM is influenced by age and gender [133], where decreases in joint stability seem more skewed toward females, especially as they get older [134]. This loss of ROM contributes to instability, and functioning, in combination with degenerative changes, to impair the ligament. Evaluation of surgical outcomes includes gait analysis, as patients with deltoid ligament injuries demonstrate altered ambulation and reduced range of motion (ROM). Recent evidence shows that the superficial and deep portions of the ligament are

Table 3 Ankle instability through deltoid ligament surgery.

Surgical method	description	advantages	disadvantages
Anatomical tendon reconstruction	Restores ankle and subtalar biomechanics, uses periosteal flaps, autografts, [81, 83, 108]	Beneficial when direct anatomic repair is not feasible, superius mechanical properties, [81, 83]	Autografts can lead to donor site morbidity, and allografts carry the risk of infection [74,107].
Medial ankle instability	Often occurs with fracture or dislocations, causes medial instability, requires conservative treatment [110],	A comprehensive approach then includes lateral ligament injury management [115].	Isolated medial ligament injuries are rare and challenging to manage [110-115].
Chronic lateral ankle instability	Caused by ligament laxity and impaired proprioception treatment with arthroscopy or ligament repair [117].	Restores joint stability and improves talar tilt and talar slide [55,121].	Intra-articular pathologies complicate treatment, such as chondral injuries or tendon tears [118].
Neuromuscular training	Strengthens balance and postural control through exercises used for functional instability [119, 120].	It improves functional stability and enhances strength and balance [119, 120].	Conservative treatments might not be effective in chronic instability cases [121].
Nonanatomic tenodesis reconstruction	Historically used procedures, like Waston-Jones and Evans techniques, may lead to complications [122,129,130].	It offers stability but complications such as restricted motion and anterior bone impingement [119].	Leads to chronic pain, restricted motion, and higher revision surgery rates [121].
Anatomic ligament repair	Brostrom technique for ATFL and CFL repair, refined to yield excellent long-term results [83,123,131].	Excellent long-term results, minimally invasive, offer faster recovery [123,131,132].	Limited long-term data on outcomes may require open surgery for CFL injuries [132].

critical to stability, contradicting previous theories that only deep ligaments if injured, would provide instability [6]. The presence of an accessory bundle [140] also adds complexity to the biomechanics of the deltoid ligament and highlights its role in preserving function at the ankle. The introduction of arthroscopic techniques has led to more precise repairs of the LHB but complete restoration of biomechanics is a challenge; therefore, the procedure is sometimes augmented with other stabilizing procedures to optimize outcomes.

Arthroscopic repair of the deltoid ligament has gained popularity as a minimally invasive and precision tool at our disposal. A recent meta-analysis of studies comparing arthroscopy versus open surgery noted benefits with arthroscopy in terms of decreased blood loss, length of stay, and complication rates [141]. Direct visualization and repair of the ligament provide a precision alignment, particularly in complex presentations or concurrent injuries. Arthroscopy leaves surrounding structures and soft tissue intact, minimizing postoperative pain and speeding recovery. Moreover, it enables concurrent management of intra-articular abnormalities that frequently accompany patients with chronic instability. Research indicates that arthroscopic ligamentoplasty of the deltoid and lateral ligaments is possible with good recovery times and patient satisfaction [9, 25, 76]. However, new research must continue to improve our benefit from these methods and success rates. Long-term studies are necessary to assess the durability of these repairs and to investigate whether they restore normal ankle function.

Conclusions

Arthroscopic deltoid ligament reconstruction is an established, minimally invasive option for the treatment of foot and ankle pathology characterized by ligamentous instability. Key benefits of arthroscopic surgery are smaller incisions, shorter recovery times, and less postoperative pain than open surgical procedures. The procedure, however, is limited by the restricted working area around the ankle and the necessity for requires a high level of proficiency. More complex deformities such as marked varus or valgus malalignment may benefit from open surgical repair owing to restoring alignment complexities. Arthroscopic methods have shown encouraging clinical results. However, these techniques should be assessed in the light of the other surgical and non-surgical procedures, based on individual patient anatomy and pathology. Further expectations of better instrumentation and techniques in arthroscopy should enable its role in the management of deltoid ligament injuries and ankle instability in the future.

Acknowledgments

The authors would like to thank all the personnel who were involved in the treatment of the patients.

Conflict of Interest

The authors have no conflicts of interest.

References

[1] Thomas RH, Daniels TR. Ankle arthritis. J Bone Joint Surg Am 2003; 85:923-36.

[2] Lindsjö U. Operative treatment of ankle fracture-dislocations. A follow-up study of 306/321 consecutive cases. Clin Orthop Relat Res 1985; 199:28-38.

[3] Pitakveerakul A, Kungwan S, Arunakul P, Arunakul M. Radiographic parameters in gravity stress view of the ankle: Normative data. Foot Ankle Surg 2019; 25:819-825.

[4] Daniels TR, Smith JW. Talar neck fractures. Foot Ankle 1993; 14:225-34.

[5] Huch K, Kuettner KE, Dieppe P. Osteoarthritis in ankle and knee joints. Semin Arthritis Rheum 1997; 26:667-74.

[6] Gu G, Yu J, Huo Y, Xu G, Yin Z, Yu J, et al.. Efficacy of deltoid ligament reconstruction on the curative effect, complication and long-term prognosis in ankle fracture-dislocation with deltoid ligament injury. Int J Clin Exp Med 2017; 10:13778-13783.

[7] Acevedo JI, Kreulen C, Cedeno AA, Baumfeld D, Nery C, Mangone PG. Technique for arthroscopic deltoid ligament repair with description of safe zones. Foot Ankle Int 2020; 41:605-611.

[8] Shepherd DE, Seedhom BB. Thickness of human articular cartilage in joints of the lower limb. Ann Rheum Dis 1999; 58:27-34.

[9] Feng SM, Sun QQ, Wang AG, Chang BQ,Cheng J. Arthroscopic Anatomical Repair of Anterior Talofibular Ligament for chronic lateral instability of the ankle: medium- and long-term functional follow-up. Orthop Surg 2020; 12:505-514.

[10] Feng SM, Maffulli N, Oliva F, Wang AG,Sun QQ. Arthroscopic remnant-preserving anterior talofibular ligament reconstruction does not improve mid-term function in chronic ankle instability. Injury 2020; 51:1899-1904.

[11] Michels F, Pereira H, Calder J, Matricali G, Glazebrook M, Guillo S, et al.. Searching for consensus in the approach to patients with chronic lateral ankle instability: ask the expert. Knee Surg Sports Traumatol Arthrosc 2018; 26:2095-2102.

[12] Feger MA, Glaviano NR, Donovan L, Hart JM, Saliba SA, Park JS, et al.. Current trends in the management of lateral ankle sprain in the united states. Clin J Sport Med 2017; 27:145-152.

[13] Ismail Sr EE, Al Saffar RA, Motawei K, Hiware SD, Moizuddin K, Shaikh SA, et al.. Defining the components of the deltoid ligament (dl): a cadaveric study. Cureus 2022; 14: e23051.

[14] Sogbein OA, Yi J, Sanders DW, Lawendy AR, MacLeod M,Del Balso C. Early radiographic outcomes following deltoid ligament repair in bimalleolar equivalent ankle fractures. Foot Ankle Surg 2022; 28: 720-725.

[15] Pisanu F, Ortu S, Corda M, Andreozzi M, Caggiari G, Manunta AF, et al. Deltoid ligament reconstruction with autologous gracilis tendon in chronic medial ankle instability after ankle fracture surgery: A case report. Foot (Edinb) 2021; 49:101714.

[16] James M, Dodd A. Management of deltoid ligament injuries in acute ankle fracture: a systematic review. Can J Surg 2022; 65:E9-e15.

[17] Vega J, Allmendinger J, Malagelada F, Guelfi M,Dalmau-Pastor M. Combined arthroscopic all-inside repair of lateral and medial ankle ligaments is an effective treatment for rotational ankle instability. Knee Surg Sports Traumatol Arthrosc 2020; 28:132-140.

[18] Shoji H, Teramoto A, Sakakibara Y, Kamiya T, Watanabe K, Fujie H, et al. Kinematics and laxity of the ankle joint in anatomic and nonanatomic anterior talofibular ligament repair: a biomechanical cadaveric study. Am J Sports Med 2019; 47:667-673.

[19] Salameh M, Alhammoud A, Alkhatib N, Attia AK, Mekhaimar MM, D'Hooghe P, et al. Outcome of primary deltoid ligament repair in acute ankle fractures: a meta-analysis of comparative studies. Int Orthop 2020; 44:341-347.

[20] Gray H. Gray's Anatomy: With original illustrations by Henry Carter. Arcturus Publishing; 2009.

[21] Basmajian JV. Surface anatomy: an instructional manual. Baltimore: Williams & Wilkins; 1983.

[22] Viladot A, Lorenzo JC, Salazar J,Rodríguez A. The subtalar joint: embryology and morphology. Foot Ankle 1984; 5:54-66.

[23] Hicks JH. The mechanics of the foot. I. The joints. J Anat 1953; 87:345-57.

[24] Sarrafian SK. Biomechanics of the subtalar joint complex. Clin Orthop Relat Res 1993; 290:17-26.

[25] Mococain P, Bejarano-Pineda L, Glisson R, Kadakia RJ, Akoh CC, Chen J, et al. Biomechanical effect on joint stability of including deltoid ligament repair in an ankle fracture soft tissue injury model with deltoid and syndesmotic disruption. Foot Ankle Int 2020; 41:1158-1164.

[26] Nordin M, Frankel VH. Basic biomechanics of the musculoskeletal system Lippincott Williams & Wilkins; 2001.

[27] Nordin JS, Olsson O, Lunsjö K. The gracilis tendon autograft is a safe choice for orthopedic reconstructive procedures: a consecutive case series studying the effects of tendon harvesting. BMC Musculoskelet Disord 2019; 20:138.

[28] Sarrafian SK. Anatomy of the foot and ankle: descriptive, topographic, functional. Lippincott Williams & Wilkins, 1993.

[29] Procter P, Paul JP. Ankle joint biomechanics. J Biomech 1982; 15:627-34.

[30] Massri-Pugin J, Lubberts B, Vopat BG, Wolf JC, DiGiovanni CW,Guss D. Role of the deltoid ligament in syndesmotic instability. Foot Ankle Int 2018; 39:598-603.

[31] Lubberts B, Massri-Pugin J, Guss D, Wolf JC, Bhimani R, Waryasz GR, et al. Arthroscopic assessment of syndesmotic instability in the sagittal plane in a cadaveric model. Foot Ankle Int 2020; 41:237-243.

[32] Warner SJ, Garner MR, Fabricant PD, Schottel PC, Loftus ML, Hentel KD, et al. The diagnostic accuracy of radiographs and magnetic resonance imaging in predicting deltoid ligament ruptures in ankle fractures. Hss j 2019; 15:115-121.

[33] Vega J, Malagelada F, Dalmau-Pastor M. Ankle microinstability: arthroscopic findings reveal four types of lesion to the anterior talofibular ligament's superior fascicle. Knee Surg Sports Traumatol Arthrosc 2021; 29:1294-1303.

[34] Hempen EC, Butler BA, Barbosa M, Muriuki M, Havey RM,Kadakia AR. Superficial deltoid ligament and deep deltoid ligament play equally important roles in the stability of isolated lateral malleolus (OTA/AO 44-B1) fractures: a biomechanical study. J Orthop Trauma 2022; 36:73-79.

[35] Longo UG, Loppini M, Fumo C, Lanotte A, Trovato U, Risi Ambrogioni L, et al. Deep deltoid ligament injury is related to rotational instability of the ankle joint: a biomechanical study. Knee Surg Sports Traumatol Arthrosc 2021; 29:1577-1583.

[36] Coughlin M, Mann R, Saltzman C. Imaging of the foot and ankle. Surgery of the foot and ankle. 8th ed. Philadelphia: Mosby. 2007; pp. 71-131.

[37] Saltzman CL, Salamon ML, Blanchard GM, Huff T, Hayes A, Buckwalter JA, et al. Epidemiology of ankle arthritis: report of a consecutive series of 639 patients from a tertiary orthopaedic center. Iowa Orthop J 2005; 25:44-6.

[38] Reilingh ML, Beimers L, Tuijthof GJ, Stufkens SA, Maas M,van Dijk CN. Measuring hindfoot alignment radiographically: the long axial view is more reliable than the hindfoot alignment view. Skeletal Radiol 2010; 39:1103-8.

[39] Acevedo JI, Palmer RC, Mangone PG. Arthroscopic Treatment of Ankle Instability: Brostrom. Foot Ankle Clin 2018; 23:555-570.

[40] Kavanagh EC, Zoga AC. MRI of trauma to the foot and ankle. Semin Musculoskelet Radiol 2006; 10:308-27.

[41] Goetz JE, Vasseenon T, Tochigi Y, Amendola A,Femino JE. 3D talar kinematics during external rotation stress testing in hindfoot varus and valgus using a model of syndesmotic and deep deltoid instability. Foot Ankle Int 2019; 40:826-835.

[42] Jeong BO, Kim TY, Baek JH, Song SH,Park JS. Assessment of ankle mortise instability after isolated supination-external rotation lateral malleolar fractures. J Bone Joint Surg Am 2018; 100:1557-1562.

[43] Dalmau-Pastor M, Malagelada F, Kerkhoffs GM, Karlsson J, Guelfi M,Vega J. Redefining anterior ankle arthroscopic anatomy: medial and lateral ankle collateral ligaments are visible through dorsiflexion and non-distraction anterior ankle arthroscopy. Knee Surg Sports Traumatol Arthrosc 2020; 28:18-23.

[44] Zhao HM, Lu J, Zhang F, Wen XD, Li Y, Hao DJ, et al.. Surgical treatment of ankle fracture with or without deltoid ligament repair: a comparative study. BMC Musculoskelet Disord 2017; 18:543.

[45] Stauffer RN, Chao EY, Brewster RC. Force and motion analysis of the normal, diseased, and prosthetic ankle joint. Clin Orthop Relat Res 1977; 127:189-96.

[46] Grimston SK, Nigg BM, Hanley DA,Engsberg JR. Differences in ankle joint complex range of motion as a function of age. Foot Ankle 1993; 14:215-22.

[47] Hosseinian SHS, Aminzadeh B, Rezaeian A, Jarahi L, Naeini AK,Jangjui P. Diagnostic Value of ultrasound in ankle sprain. J Foot Ankle Surg 2022; 61: 305-309.

[48] Saengsin J, Hagemeijer NC, Ho Chang S, Lubberts B, Waryasz G, Guss D, et al. Medial Ankle stability evaluation with dynamic ultrasound: establishing natural variations in the healthy cohort. J Am Acad Orthop Surg 2021; 29:703-713.

[49] Guo W, Lin W, Chen W, Pan Y, Zhuang R. Comparison of deltoid ligament repair and non-repair in acute ankle fracture: A meta-analysis of comparative studies. PLoS One 2021; 16:e0258785.

[50] Thordarson DB. Fusion in posttraumatic foot and ankle reconstruction. J Am Acad Orthop Surg 2004; 12:322-33.

[51] O'Brien TS, Hart TS, Shereff MJ, Stone J, Johnson J. Open versus arthroscopic ankle arthrodesis: a comparative study. Foot Ankle Int 1999; 20:368-74.

[52] Myerson MS, Quill G. Ankle arthrodesis. A comparison of an arthroscopic and an open method of treatment. Clin Orthop Relat Res 1991; 268:84-95.

[53] Baumfeld D, Baumfeld T, Cangussú J, Macedo B, Silva TAA, Raduan F, et al. Does foot position and location of measurement influence Ankle Medial Clear Space? Foot Ankle Spec 2018; 11:32-36.

[54] Woo BJ, Lai MC, Koo K. Arthroscopic versus open broström-gould repair for chronic ankle instability. Foot Ankle Int 2020; 41:647-653.

[55] Xiao K, Xie W, An Y. Anatomic Repair of Deltoid Ligaments in Acute Injury With Suture Anchor Technique. Orthopedics 2022; 45:e168-e173.

[56] Mansur NSB, Lemos A, Baumfeld DS, Baumfeld TS, do Prado MP, Raduan FC, et al.. Medial and Lateral Combined Ligament Arthroscopic Repair for Multidirectional Ankle Instability. Foot Ankle Orthop 2021; 6:2473011420986150.

[57] Mansur NSB, Raduan FC, Lemos A, Baumfeld DS, Sanchez GT, do Prado MP, et al. Deltoid ligament arthroscopic repair in ankle fractures: Case series. Injury 2021; 52:3156-3160.

[58] Thomas R, Daniels TR, Parker K. Gait analysis and functional outcomes following ankle arthrodesis for isolated ankle arthritis. J Bone Joint Surg Am 2006; 88:526-35.

[59] Sheridan BD, Robinson DE, Hubble MJ,Winson IG. Ankle arthrodesis and its relationship to ipsilateral arthritis of the hind- and mid-foot. J Bone Joint Surg Br 2006; 88:206-7.

[60] Fuchs S, Sandmann C, Skwara A,Chylarecki C. Quality of life 20 years after arthrodesis of the ankle. A study of adjacent joints. J Bone Joint Surg Br 2003; 85:994-8.

[61] Frey C, Halikus NM, Vu-Rose T,Ebramzadeh E. A review of ankle arthrodesis: predisposing factors to nonunion. Foot Ankle Int 1994; 15:581-4.

[62] Coester LM, Saltzman CL, Leupold J,Pontarelli W. Long-term results following ankle arthrodesis for post-traumatic arthritis. J Bone Joint Surg Am 2001; 83:219-28.

[63] Pellegrini MJ, Torres N, Cuchacovich NR, Huertas P, Muñoz G,Carcuro GM. Chronic deltoid ligament insufficiency repair with Internal Brace™ augmentation. Foot Ankle Surg 2019; 25:812-818.

[64] Alshalawi S, Galhoum AE, Alrashidi Y, Wiewiorski M, Herrera M, Barg A, et al.. Medial Ankle Instability: The Deltoid Dilemma. Foot Ankle Clin 2018; 23:639-657.

[65] Woo SH, Bae SY, Chung HJ. Short-Term Results of a Ruptured Deltoid Ligament Repair During an Acute Ankle Fracture Fixation. Foot Ankle Int 2018; 39:35-45.

[66] Schneider D. Arthroscopic ankle fusion. Arth Video 1983; 3.

[67] Winson IG, Robinson DE, Allen PE. Arthroscopic ankle arthrodesis. J Bone Joint Surg Br 2005; 87:343-7.

[68] Morgan CD, Henke JA, Bailey RW,Kaufer H. Long-term results of tibiotalar arthrodesis. J Bone Joint Surg Am 1985; 67:546-50.

[69] Buck P, Morrey BF, Chao EY. The optimum position of arthrodesis of the ankle. A gait study of the knee and ankle. J Bone Joint Surg Am 1987; 69:1052-62.

[70] Abdo RV, Wasilewski SA. Ankle arthrodesis: a long-term study. Foot Ankle 1992; 13:307-12.

[71] Fonseca LF, Baumfeld D, Mansur N,Nery C,. Deltoid insufficiency and flatfoot—oh gosh, i'm losing the ankle! what now? Techniques in Foot & Ankle Surgery 2019; 18:202-207.

[72] Vega J, Malagelada F, Dalmau-Pastor M. Arthroscopic all-inside ATFL and CFL repair is feasible and provides excellent results in patients with chronic ankle instability. Knee Surg Sports Traumatol Arthrosc 2020; 28:116-123.

[73] Higashiyama R, Sekiguchi H, Takata K, Endo T, Takamori Y,Takaso M. Arthroscopic Reconstruction of the Anterior Tibiotalar Ligament Using a Free Tendon Graft. Arthrosc Tech 2020; 9:e541-e547.

[74] Caprio A, Oliva F, Treia F,Maffulli N. Reconstruction of the lateral ankle ligaments with allograft in patients with chronic ankle instability. Foot Ankle Clin 2006; 11:597-605.

[75] Harrington KD. Degenerative arthritis of the ankle secondary to long-standing lateral ligament instability. J Bone Joint Surg Am 1979; 61:354-61.

[76] Guelfi M, Vega J, Malagelada F,Dalmau-Pastor M. The arthroscopic all-inside ankle lateral collateral ligament repair is a safe and reproducible technique. Knee Surg Sports Traumatol Arthrosc 2020; 28:63-69.

[77] Kitaoka HB, Luo ZP, An KN. Reconstruction operations for acquired flatfoot: biomechanical evaluation. Foot Ankle Int 1998; 19:203-7.

[78] Hintermann B, Valderrabano V, Kundert HP. Lengthening of the lateral column and reconstruction of the medial soft tissue for treatment of acquired flatfoot deformity associated with insufficiency of the posterior tibial tendon. Foot Ankle Int 1999; 20: 622-9.

[79] Deland JT, de Asla RJ, Sung IH, Ernberg LA,Potter HG. Posterior tibial tendon insufficiency: which ligaments are involved? Foot Ankle Int 2005; 26:427-35.

[80] Bozkurt M, Doral MN. Anatomic factors and biomechanics in ankle instability. Foot Ankle Clin 2006; 11: 451-63.

[81] Coughlin MJ, Schenck RC, Jr., Grebing BR,Treme G. Comprehensive reconstruction of the lateral ankle for chronic instability using a free gracilis graft. Foot Ankle Int 2004; 25: 231-41.

[82] Van Dijk CN, Bossuyt PM, Marti RK. Medial ankle pain after lateral ligament rupture. J Bone Joint Surg Br 1996; 78:562-7.

[83] Broström L. Sprained ankles. VI. Surgical treatment of "chronic" ligament ruptures. Acta Chir Scand 1966; 132:551-65.

[84] Sun X, Li T, Sun Z, Li Y, Yang M, Li S, et al. Does routinely repairing deltoid ligament injuries in type B ankle joint fractures influence long term outcomes? Injury 2018; 49:2312-2317.

[85] Butler BA, Hempen EC, Barbosa M, Muriuki M, Havey RM, Nicolay RW, et al. Deltoid ligament repair reduces and stabilizes the talus in unstable ankle fractures. J Orthop 2020; 17:87-90.

[86] Taruc-Uy RL, Lynch SA. Diagnosis and treatment of osteoarthritis. Prim Care 2013; 40:821-36.

[87] Sacitharan PK. Ageing and Osteoarthritis. Subcell Biochem 2019; 91:123-159.

[88] McInnes IB, Schett G. The pathogenesis of rheumatoid arthritis. N Engl J Med 2011; 365: 2205-19.

[89] Lee DM, Weinblatt ME. Rheumatoid arthritis. Lancet 2001; 358:903-11.

[90] Weatherall JM, Mroczek K, McLaurin T, Ding B, Tejwani N. Post-traumatic ankle arthritis. Bull Hosp Jt Dis 2013; 71: 104-12.

[91] Stephens AR, Grujic L. Post-Traumatic Hindfoot Arthritis. J Orthop Trauma 2020; 34 Suppl 1: S32-s37.

[92] Wu K, Lin J, Huang J,Wang Q. Evaluation of transsyndesmotic fixation and primary deltoid ligament repair in ankle fractures with suspected combined deltoid ligament injury. J Foot Ankle Surg 2018; 57:694-700.

[93] Sun Y, Wang H, Tang Y, Zhao H, Qin S, Xu L, et al. Incidence and risk factors for surgical site infection after open reduction and internal fixation of ankle fracture: A retrospective multicenter study. Medicine (Baltimore) 2018; 97:e9901.

[94] Burkhart KJ, HollingerB. [Post-traumatic arthritis in the young patient: Treatment options before the endoprosthesis]. Orthopade 2016; 45:832-43.

[95] Parekh SG, Kadakia RK. Avascular necrosis of the talus. J Am Acad Orthop Surg 2021; 29:e267-e278.

[96] [96] Large TM, Adams MR, Loeffler BJ, Gardner MJ. Posttraumatic avascular necrosis after proximal femur, proximal humerus, talar neck, and scaphoid fractures. J Am Acad Orthop Surg 2019; 27:794-805.

[97] Lee C, Brodke D, Perdue PW, Jr.,Patel T. Talus fractures: evaluation and treatment. J Am Acad Orthop Surg 2020; 28:e878-e887.

[98] Lachman JR, Adams SB. Tibiotalocalcaneal arthrodesis for severe talar avascular necrosis. Foot Ankle Clin 2019; 24:143-161.

[99] Schachter AK, Chen AL, Reddy PD,Tejwani NC. Osteochondral lesions of the talus. J Am Acad Orthop Surg 2005; 13:152-8.

[100] Reilingh ML, van Dijk CN. Comments on: "osteochondral lesions of the talus: current concept" by O. Laffenêtre published in Orthop Traumatol Surg Res 2010;96: 554-66. Orthop Traumatol Surg Res 2011; 97:461-2; author reply 463.

[101] Beltran J, Shankman S. MR imaging of bone lesions of the ankle and foot. Magn Reson Imaging Clin N Am 2001; 9:553-66, xi.

[102] Mu MD, Yang QD, Chen W, Tao X, Zhang CK, Zhang X, et al. Three dimension printing talar prostheses for total replacement in talar necrosis and collapse. Int Orthop 2021; 45:2313-2321.

[103] Backus JD, Ocel DL. Ankle Arthrodesis for Talar Avascular Necrosis and Arthrodesis Nonunion. Foot Ankle Clin 2019; 24:131-142.

[104] Cameron MH, Monroe L. Physical Rehabilitation-E-Book: Evidence-based examination, evaluation, and intervention. 2007: Elsevier Health Sciences.

[105] Rosskopf AB, Loupatatzis C, Pfirrmann CWA, Böni T,Berli MC. The Charcot foot: a pictorial review. Insights Imaging 2019; 10: 77.

[106] Whitlock KG, LaRose M, Barber H, Fletcher A, Cunningham D, Menken L, et al. Deltoid ligament repair versus trans-syndesmotic fixation for bimalleolar equivalent ankle fractures. Injury 2022; 53:2292-2296.

[107] Järvelä T, Weitz H, Järvelä K,Alavaikko A. A novel reconstruction technique for chronic lateral ankle instability: comparison to primary repair. Int Orthop 2002; 26:314-7.

[108] Pagenstert GI, Hintermann B, Knupp M. Operative management of chronic ankle instability: plantaris graft. Foot Ankle Clin 2006; 11:567-83.

[109] de Vries JS, Krips R, Sierevelt IN,Blankevoort L. Interventions for treating chronic ankle instability. Cochrane Database Syst Rev2006; Cd004124.

[110] Ferran NA, Maffulli N. Epidemiology of sprains of the lateral ankle ligament complex. Foot Ankle Clin 2006; 11:659-62.

[111] Krips R, De Vries JS, Van Dijk CN. Ankle instability. Foot Ankle Clin 2006; 11: 311-29.

[112] Harper MC. The deltoid ligament. An evaluation of need for surgical repair. Clin Orthop Relat Res 1988; 226:156-68.

[113] Hintermann B, Valderrabano V, Boss A, Trouillier HH,Dick W. Medial ankle instability: an exploratory, prospective study of fifty-two cases. Am J Sports Med 2004; 32:183-90.

[114] Hintermann B. Medial ankle instability. Foot Ankle Clin 2003; 8:723-38.

[115] [115] Chorley JN, Hergenroeder AC. Management of ankle sprains. Pediatr Ann 1997; 26: 56-64.

[116] [116] Ruiz R, Hintermann B. Clinical Appearance of Medial Ankle Instability. Foot Ankle Clin 2021; 26:291-304.

[117] Hertel J. Functional Anatomy, Pathomechanics, and Pathophysiology of Lateral Ankle Instability. J Athl Train 2002; 37:364-375.

[118] Griffith JF, Brockwell J. Diagnosis and imaging of ankle instability. Foot Ankle Clin 2006; 11:475-96.

[119] Robbins S, Waked E, Rappel R. Ankle taping improves proprioception before and after exercise in young men. Br J Sports Med 1995; 29:242-7.
[120] Baier M, Hopf T. Ankle orthoses effect on single-limb standing balance in athletes with functional ankle instability. Arch Phys Med Rehabil 1998; 79:939-44.
[121] Komenda GA, Ferkel RD. Arthroscopic findings associated with the unstable ankle. Foot Ankle Int 1999; 20:708-13.
[122] Watson-Jones R. Recurrent forward dislocation of the ankle joint. J. Bone Joint Surg B 1952; 34:519.
[123] Karlsson J, Bergsten T, Lansinger O, Peterson L. Reconstruction of the lateral ligaments of the ankle for chronic lateral instability. J Bone Joint Surg Am 1988; 70:581-8.
[124] Gould N, Seligson D, Gassman J. Early and late repair of lateral ligament of the ankle. Foot Ankle 1980; 1:84-9.
[125] Evans DL. Recurrent instability of the ankle; a method of surgical treatment. Proc R Soc Med 1953; 46:343-4.
[126] Chrisman OD, Snook GA. Reconstruction of lateral ligament tears of the ankle. An experimental study and clinical evaluation of seven patients treated by a new modification of the Elmslie procedure. J Bone Joint Surg Am 1969; 51:904-12.
[127] Boyer DS, Younger AS. Anatomic reconstruction of the lateral ligament complex of the ankle using a gracilis autograft. Foot Ankle Clin 2006; 11:585-95.
[128] DiGiovanni CW, Brodsky A. Current concepts: lateral ankle instability. Foot Ankle Int 2006; 27:854-66.
[129] Sugimoto K, Takakura Y, Akiyama K, Kamei S, Kitada C,Kumai T. Long-term results of Watson-Jones tenodesis of the ankle. Clinical and radiographic findings after ten to eighteen years of follow-up. J Bone Joint Surg Am 1998; 80:1587-96.
[130] Snook GA, Chrisman OD, Wilson TC. Long-term results of the Chrisman-Snook operation for reconstruction of the lateral ligaments of the ankle. J Bone Joint Surg Am 1985; 67:1-7.
[131] Hawkins RB. Arthroscopic stapling repair for chronic lateral instability. Clin Podiatr Med Surg 1987; 4:875-83.
[132] Lee KT, Lee JI, Sung KS, Kim JY, Kim ES, Lee SH, et al. Biomechanical evaluation against calcaneofibular ligament repair in the Brostrom procedure: a cadaveric study. Knee Surg Sports Traumatol Arthrosc 2008; 16:781-6.
[133] Nigg B, Fisher V, Ronsky J. Gait characteristics as a function of age and gender. Gait & posture 1994; 2:213-220.
[134] Singer S, Klejman S, Pinsker E, Houck J,Daniels T. Ankle arthroplasty and ankle arthrodesis: gait analysis compared with normal controls. J Bone Joint Surg Am 2013; 95:e191(1-10).
[135] Rouhani H, Favre J, Aminian K, Crevoisier X. Multi-segment foot kinematics after total ankle replacement and ankle arthrodesis during relatively long-distance gait. Gait Posture 2012; 36:561-6.
[136] Queen RM, De Biassio JC, Butler RJ, DeOrio JK, Easley ME,Nunley JA. J. Leonard Goldner Award 2011: changes in pain, function, and gait mechanics two years following total ankle arthroplasty performed with two modern fixed-bearing prostheses. Foot Ankle Int 2012; 33:535-42.
[137] Queen RM, Butler RJ, Adams SB, Jr., DeOrio JK, Easley ME,Nunley JA. Bilateral differences in gait mechanics following total ankle replacement: a two year longitudinal study. Clin Biomech (Bristol, Avon) 2014; 29:418-22.
[138] Hahn ME, Wright ES, Segal AD, Orendurff MS, Ledoux WR,Sangeorzan BJ. Comparative gait analysis of ankle arthrodesis and arthroplasty: initial findings of a prospective study. Foot Ankle Int 2012; 33:282-9.
[139] Brodsky JW, Polo FE, Coleman SC, Bruck N. Changes in gait following the Scandinavian Total Ankle Replacement. J Bone Joint Surg Am 2011; 93:1890-6.
[140] Zamperetti M, Guelfi M, Biz C, Pantalone A, Salini V, Oliva XM, et al. The undefined anatomical variations of the deltoid ligament bundles: a cadaveric study. Muscles Ligaments Tendons J 2018; 8:163-171.
[141] Bai Z, Yang Y, Chen S, Dong Y, Cao X, Qin W, et al Clinical effectiveness of arthroscopic vs open ankle arthrodesis for advanced ankle arthritis: A systematic review and meta-analysis. Medicine (Baltimore) 2021; 100:e24998.