Review

DELTOID LIGAMENT REPAIR IN ANKLE FRACTURES: ANATOMY, BIOMECHANICS, INJURY MECHANISMS, AND TREATMENT APPROACHES

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ABSTRACT

The deltoid ligament (DL) is a complex structure that provides medial stability to the ankle joint. Injuries to the DL, particularly in association with ankle fractures such as Weber B and C fractures, are often challenging to manage. The presence of a DL sprain generally worsens the prognosis, requiring thorough clinical and radiographic evaluation to determine whether surgical intervention is necessary to restore stability. A combination of clinical and radiographic methods is often employed to evaluate DL injuries in the context of ankle fractures. Plain radiographs are primarily used to exclude fractures or other bony abnormalities, while weight-bearing radiographs help assess any deformities, particularly in chronic cases. The surgical management of bimalleolar equivalent ankle fractures typically begins with open reduction and internal fixation (ORIF) of the fibula, performed through a lateral or posterolateral approach. However, in cases where the DL or posterior tibial tendon becomes entrapped between the talus and the medial malleolus, it can prevent proper closure of the medial clear space or obstruct fibular reduction. The common aspect of surgical techniques for DL repair is the use of suture anchors to reattach ligament fibers to their anatomic origin on the medial malleolus or medial tibia. However, variations exist regarding the location of the incision, whether both the superficial and deep fibers of the deltoid are repaired, and how avulsions (particularly from the talus or from calcaneus) are managed. The purpose of this narrative review is to provide a comprehensive overview of the ligament's anatomy, mechanics, common injury patterns, and treatment options, focusing on the surgical repair of the ligament in ankle fractures.

KEYWORDS: *deltoid ligament, ankle joint, fracture, Weber B and C fractures, ligament repair*

INTRODUCTION

The deltoid ligament (DL) is a complex structure that provides medial stability to the ankle joint. Injuries to the DL, particularly in association with ankle fractures such as Weber B and C fractures, are often challenging to manage. (1).

Understanding the anatomical structure and biomechanical role of the DL is essential for the accurate diagnosis and appropriate treatment of these injuries (2). The purpose of this narrative review is to provide a comprehensive

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overview of the ligament's anatomy, mechanics, common injury patterns, and treatment options, with a focus on the surgical repair of the ligament in ankle fractures.

Anatomy of the DL

The DL is a strong, broad ligament with a complex fascicular arrangement. It spans from the medial malleolus to the calcaneus, navicular, and talus bones, creating a triangular shape on the medial side of the ankle (1,3).

DL complex consists of two layers: a superficial and a deep layer. The superficial layer is composed of four distinct components, including the talonavicular (TN), talocalcaneal (TC), and the anterior and posterior tibiotalar (TT) ligaments. Functionally, this layer restricts the talus from moving into the valgus position and resists the eversion of the hindfoot (4). The deep layer primarily consists of the deep TT ligament, which is the principal restraint of the talus against external rotation. Together, the superficial and deep fibers of the DL provide medial stability, resisting external forces that could lead to ankle dislocation or misalignment (4).

Biomechanics and the role of the DL

The DL stabilizes the ankle joint during weight-bearing and prevents excessive eversion and valgus stress. With all lateral structures removed, the intact DL allows only 2 mm of separation between the talus and medial malleolus. When the deep DL is released, the talus can be separated from the medial malleolus by 3.7 mm (4, 5).

The superficial layers of the DL primarily limit talar abduction or negative talar tilt. The TC ligament specifically restricts talar pronation. In contrast, the deep layers of the DL rupture during external rotation, with the superficial portion remaining unaffected. The DL is the primary restraint against pronation of the talus, with the superficial and deep components equally effective.

Injury mechanisms and associated fractures

DL injuries are often linked to ankle fractures, particularly in Weber B and Weber C fractures, where the fibula is fractured at or above the syndesmosis (1, 6).

The Weber classification is a system that categorizes fibular fractures based on their relationship to the syndesmosis (7, 8). Weber B fractures occur at the level of the syndesmosis, while Weber C fractures happen above it and are typically more severe. In both types, there is a risk of DL injury, which can lead to significant instability. In Weber B fractures, the DL may be sprained or torn if there is a widening of the medial clear space, signaling ligamentous injury. In Weber C fractures, DL disruption is more often associated with severe syndesmotic injury and potential ankle dislocation. Although DL sprains are less common than lateral and syndesmotic sprains, they can lead to considerable ankle instability.

The presence of a DL sprain generally worsens the prognosis, requiring thorough clinical and radiographic evaluation to determine whether surgical intervention is necessary to restore stability (Fig. 1).

Fig. 1. *An example of X-ray antero-posterior (**A**) and lateral (**B**) view of ankle fracture dislocation with disruption of the syndesmotic distal tibio-peroneal ligaments and DL rupture.*

Clinical presentation of incompetence of the DL

Acute injuries to the DL must be suspected after an eversion and/or pronation injury (1, 4, 5). Typically, the foot is firm on the ground when an eversion force causes valgus stress to the ankle or an internal rotation force causes pronation stress to the hindfoot.

Acute injuries to the DL can also occur in association with lateral ankle fractures (6, 9). Chronic injuries typically cause medial ankle instability. This must be suspected if the patient feels the ankle “give way,” especially medially, when walking on even ground, downhill, or downstairs, or if the patient experiences pain at the anteromedial or lateral aspect of the ankle, especially on dorsiflexion of the foot (10). Accurate diagnosis of DL injury is essential for determining the appropriate treatment.

Clinical findings

Acute DL injuries often present with tenderness and hematoma along the ligament. In chronic cases, a key finding is pain in the medial gutter, typically elicited by palpation of the anterior border of the medial malleolus. When the patient is weight-bearing, excessive valgus of the hindfoot and pronation of the affected foot indicate laxity on the medial side of the ankle (4). This valgus deformity and pronation usually disappear when the patient activates the posterior tibial muscle. Similarly, the valgus of the hindfoot and foot pronation resolve when the patient rises onto their tiptoes. Significantly, because there is no flattening of the medial longitudinal arch, the hindfoot valgus and forefoot abduction are not corrected by the single heel rise test, allowing clinicians to quickly rule out posterior tibial dysfunction (2-5).

A reliable clinical test involves the patient seated on an examination table with their feet hanging freely. The examiner grasps the heel of the affected ankle with one hand and the tibia with the other, applying first a varus and then a valgus tilt to the heel, comparing the results with the contralateral side. An anterior drawer test is also performed, and the findings are again compared with the unaffected ankle (10).

Imaging

To evaluate DL injuries in the context of ankle fractures, a combination of clinical and radiographic methods is often employed.

Plain radiographs are primarily used to exclude fractures or other bony abnormalities, while weight-bearing radiographs help assess any deformities, particularly in chronic cases. In cases of severe medial ligament incompetence, valgus deformity of the hindfoot may be evident (11). Additionally, stress radiographs provide indirect evidence of DL lesions in acute fractures, with a widened medial clear space, defined as greater than 4 mm and at least 1 mm more than the superior tibiotalar clear space, strongly suggesting deltoid disruption, particularly when accompanied by a fibular fracture (6, 9, 11). This often warrants surgical intervention. However, a normal medial clear space in static imaging does not necessarily exclude deltoid injury, as some cases may show widening only under stress, such as during an external rotation stress test (12).

Studies have shown that a medial clear space of 5 mm or more under external rotation and dorsiflexion is a reliable predictor of deep DL injury (11-13). In some cases, gravity stress radiographs, where the patient lies laterally and gravity induces external rotation stress, are also employed. These stress tests are typically more sensitive than simple weight-bearing radiographs for evaluating deltoid and syndesmotic integrity (11, 12).

Magnetic resonance imaging (MRI) can detect acute DL injuries, including partial tears or edema. However, it is not routinely recommended for deciding between surgical and non-surgical treatment in acute settings (13). This is due to variability in medial clear space widening even with similar MRI findings and the higher inter-rater reliability of stress test results over MRI in such cases. In rare instances, the "medial malleolus fleck sign," which indicates a small bone avulsion, may be present in bimalleolar equivalent fractures (13).

SURGICAL MANAGEMENT

Surgical sequence and indications for DL repair

The surgical management of bimalleolar equivalent ankle fractures typically begins with open reduction and internal fixation (ORIF) of the fibula, performed through a lateral or posterolateral approach (14). However, in cases where the DL or posterior tibial tendon becomes entrapped between the talus and the medial malleolus, it can prevent proper closure of the medial clear space or obstruct fibular reduction. In such instances, clearing the medial gutter via a separate medial incision is recommended (15).

Following fibular fixation, syndesmotic integrity should be assessed using the Cotton test or hook test, which involves applying lateral distraction to the fibula and evaluating for dynamic widening of the syndesmosis on a mortise view. If widening is observed, syndesmotic reduction and trans-syndesmotic fixation are required (16).

After addressing the fibula and syndesmosis, the need for DL repair remains controversial. Some surgeons advocate for routine deltoid repair in all patients with bimalleolar equivalent fractures, arguing that if the DL is incompetent enough to destabilize the fracture, it should be repaired to restore the medial tether and improve tibiotalar mechanics. Others only repair the DL if medial exposure is necessary to clear soft tissue from the medial gutter or if the patient is an athlete or shows signs of complete deltoid rupture during arthroscopy (17).

Intraoperative stress radiography is another method used to evaluate the stability of the medial ankle following ORIF. This typically involves applying an external rotation or eversion stress test to assess for persistent medial-sided instability. If the medial clear space widens by more than 4 mm and 1 mm more than the superior tibiotalar clear space, this is considered a positive result, indicating medial instability (10, 11). Additionally, talar tilt during eversion stress, greater than 7 degrees, suggests a complete rupture of both the deep and superficial DL, warranting ligament repair (6, 9).

While the exact threshold for talar tilt or medial clear space widening necessitating deltoid repair is debated, studies suggest that talar tilt occurs in around half of patients even after proper fibular and syndesmotic fixation. DL repair is indicated in patients with positive intraoperative stress radiographs, as it helps to address persistent instability (6).

However, further research is needed to establish standardized thresholds for when DL repair should be performed during surgery.

Techniques for DL repair

DL repair techniques in ankle fractures have been extensively described by multiple authors, each proposing variations in the surgical approach (18, 19). Despite these differences, direct comparisons of these methods are lacking in the literature.

The common aspect of surgical techniques is the use of suture anchors to reattach the DL fibers to their anatomic origin on the medial malleolus or medial tibia (10, 18, 19). However, variations exist regarding the location of the incision, whether both the superficial and deep fibers of the deltoid are repaired, and how avulsions (particularly from the talus or calcaneus) are managed.

One of the first steps in the deltoid repair involves making a 5-cm curvilinear incision over the medial malleolus, after which the skin flaps are mobilized to provide adequate visualization. Often, horizontal clefts in the ligament or joint capsule are visible (18). If osteochondral lesions are present in the talus or tibia, they are treated either with traditional drilling or, more commonly, with a microfracture technique using an awl, which avoids excessive heating of the bone (20).

In cases where the DL avulses from the medial malleolus (the most frequent scenario), the malleolus is prepped for repair by drilling appropriately sized holes for suture anchor placement. Typically, one or two anchors are inserted, allowing for fixation with braided nonabsorbable sutures. The ligament is repaired using a "vest-over-pants" imbrication technique, which secures the superficial and deep fibers to the malleolus, alongside repairing any capsular disruption. The ankle is then stress-tested to confirm stability under external rotation and eversion forces (17, 18).

For less common cases of distal avulsion from the talus, the repair requires a more distal exposure, taking care to avoid injury to neurovascular structures. Two anchors are inserted on the medial aspect of the talus at the insertion sites of the deep anterior and posterior tibiotalar ligaments, and the deltoid fibers are then sutured back in place. Depending on the avulsion site, superficial deltoid repairs may also require an anchor placed into the fibula (21).

From a clinical standpoint, the decision to repair the DL remains somewhat controversial (22, 23). Some surgeons advocate routine repair in all bimalleolar equivalent fractures, reasoning that a damaged DL should be restored to optimize tibiotalar kinematics and stability (19). Others prefer to reserve deltoid repair for high-level athletes or when medial exposure is already required to clear soft tissue (6, 9, 23).

Recent studies emphasize that DL repair can optimize outcomes, especially when combined with syndesmotic fixation. A meta-analysis by Guo et al. (24) demonstrated that deltoid repair could reduce complications and improve long-term clinical outcomes associated with ankle instability. Conversely, research by Sun et al. (25) suggested that there is no indication of routine exposure and repair of the injured DL, advocating a more selective approach based on intraoperative findings and patient activity level. More work is required to establish standardized guidelines for when to repair the deltoid. Still, current techniques, especially those using suture anchors and stress radiographs, have proven effective in restoring ankle function (Fig. 2).

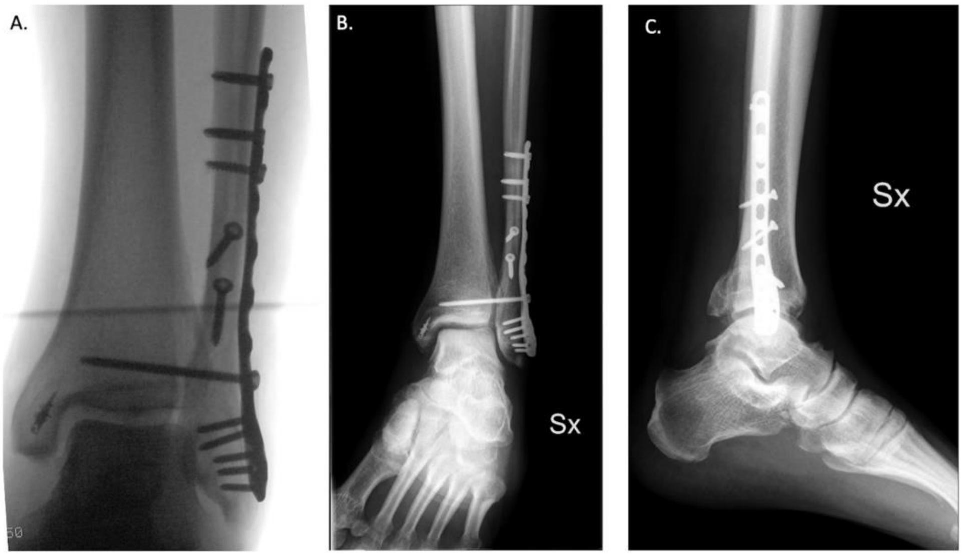

Fig 2. *Intra-operative fluoroscopic anteroposterior view (**A**) of the left ankle after open reduction internal fixation with plate and screws, trans-syndesmotic fixation, and DL repair with 5 mm anchor. The 1-month X-ray anteroposterior (**B**) and lateral (**C**) views show excellent mortise anatomy reduction and restoration.*

Outcomes of surgical repair

Early retrospective studies from the 1980s suggested that ORIF of bimalleolar-equivalent ankle fractures without repairing the DL yields acceptable long-term results (22). The theory behind this approach is that by restoring the anatomical alignment of the ankle mortise through fibular and syndesmotic ORIF, the DL would scar in and heal without the need for direct repair. For example, Zeegers and van der Werken (22) studied 28 patients with lateral malleolar fractures and associated DL ruptures who underwent lateral malleolar ORIF without DL repair. After an average follow-up of 18 months, none of the patients showed medial instability on clinical exams or stress testing, although seven showed early signs of osteoarthritis. Notably, 5 of these patients had anatomically restored mortises at the time of surgery, leading the authors to conclude that direct deltoid repair may not be necessary if the mortise is restored correctly.

Later studies with improved designs, such as comparative studies, reinforced these findings. Maynou et al. (26) compared 34 patients with bimalleolar-equivalent fractures, 18 of whom underwent deltoid repair and 17 did not. The study found no significant differences in subjective or objective outcomes, including medial instability, between the two groups, with only one patient in the non-repair group developing posttraumatic osteoarthritis. The authors concluded that repair of the DL is necessary in case of medial incongruency greater than 3 mm after the internal fixation of the fibula.

In 1995, Strömsöe et al. (27) conducted the first randomized controlled trial, comparing 50 patients with Weber B and C fractures. Half of the patients underwent deltoid repair, while the other half did not. After a mean follow-up of 17 months, there were no significant differences in functional outcomes between the groups, though deltoid repair resulted in longer surgical times. The study concluded that deltoid repair was unnecessary if the talus was adequately reduced to the medial malleolus and fibular anatomy restored. However, the study lacked a power analysis and did not assess medial instability, limiting the strength of its conclusions.

Despite the positive outcomes in most studies without deltoid repair, there have been reports of suboptimal results in some patient subgroups, including persistent medial instability, medial gutter pain, and early-onset posttraumatic arthritis (22-27). These poor outcomes have been attributed to the failure of the DL to heal anatomically. Consequently, some surgeons decide on deltoid repair in select cases, particularly in high-demand athletes or when intraoperative stress tests reveal medial instability (25-27).

Some authors strongly support the DL repair. Hsu et al. (28) reported excellent outcomes in 14 National Football League (NFL) players who underwent DL repair and ORIF for bimalleolar equivalent fractures. Eighty-six percent returned to play, and no medial pain or instability was observed at the final follow-up.

Woo et al. (29) retrospectively studied 78 patients with bimalleolar equivalent fractures over a 15-year period. The study found that those who underwent deltoid repair had significantly smaller medial clear space on final radiographs compared to those who did not have deltoid repair (3.2 mm vs. 3.7 mm). A subgroup analysis of patients who also had syndesmotic injuries revealed that the deltoid repair group had superior clinical outcomes, including better American Orthopedic Foot and Ankle (AOFAS) scores, lower pain levels, and less medial-sided pain. This suggests that deltoid repair may be particularly beneficial in cases with combined syndesmotic injuries, as the two repairs may reinforce each other (Fig. 3).

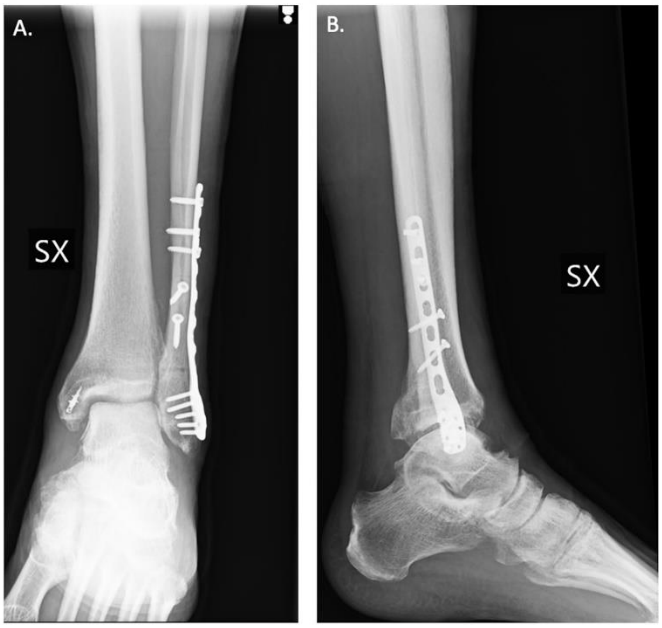

Fig. 3. One-*year follow-up X-ray assessment with anteroposterior (A) and lateral (B) view of the left ankle after open reduction internal fixation and DL repair with 5 mm anchor. Imaging demonstrated no development of ankle osteoarthritis and excellent mortise restoration.*

Early studies (22, 26, 27) suggested that DL repair might not be necessary for all bimalleolar equivalent ankle fractures, whereas recent research (23, 25, 28, 29) highlights specific groups, such as those with syndesmotic injuries or high physical demands, that may benefit from primary deltoid repair.

DISCUSSION

Proper reduction of the fibula and syndesmosis could allow the DL to heal without direct intervention. Patients with confirmed syndesmotic injury or high functional demands may benefit from DL repair when combined with syndesmotic fixation, which enhances medial stability and functional outcomes. Improved radiographic results, such as reduced medial clear space and decreased instances of posttraumatic arthritis, suggest that combining these repairs strengthens ankle stability and reduces complications like talar tilt and arthritis.

The decision to repair the DL remains controversial and is not universally accepted for all bimalleolar equivalent fractures. Some surgeons continue to reserve deltoid repair for cases where medial-sided instability persists following fibular and syndesmotic fixation. Others use it routinely in patients with combined deltoid and syndesmotic injuries, as their combined repair may enhance recovery and stability.

The lack of large-scale, randomized, controlled trials comparing outcomes with and without DL repair highlights the need for further investigation. Future research should focus on establishing clear clinical guidelines and decision-making criteria for when DL repair should be performed. Such studies could clarify which subgroups of patients, such as athletes, those with high physical demands, or individuals with syndesmotic injury, are most likely to benefit from this additional intervention.

Ultimately, the goal is to optimize treatment protocols that lead to the best possible functional, clinical, and radiographic outcomes, reducing long-term complications like arthritis and instability while facilitating rapid return to normal activity.

CONCLUSIONS

In conclusion, the DL plays a critical role in ankle stability, especially in the context of ankle fractures. While early research downplayed the necessity of its repair, evolving evidence suggests that DL repair, particularly when combined with syndesmotic fixation, may be beneficial for specific patient groups. As understanding of this topic continues to grow, surgeons must consider the individual patient's needs, activity level, and the presence of additional injuries when deciding whether DL repair is indicated. Further research will help refine these indications and improve long-term outcomes for patients with ankle fractures.

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