C. Schäffeler

Medial Collateral Ligament

Introduction • Epidemiology • Biomechanical Overview • Clinical Considerations • MR Examination • MR-Imaging of Deltoid Ligament Injury

Introduction

The medial collateral ligament of the ankle joint is a multibanded complex which is also referred to as the deltoid ligament. Although variation in the presence of its ligamentous parts has been reported, it is accepted that the deltoid ligament is composed by a separated superficial and a deep portion. The superficial layer consists of the tibiospring (TSL), tibionavicular (TNL), and tibiocalcaneal (TCL)[1] ligaments. The anterior (ATTL) and the posterior (PTTL) tibiotalar ligaments comprise the deep fibers and are covered by a synovial layer due to their intracapsular but extrasynovial course (Fig. 1).[2] However, up to 13 different ligamentous parts of the deltoid ligament complex have been described.[3]

Epidemiology

Trauma to the ankle joint accounts for 10–30 % of all sports injuries and the ankle is the second most common joint involved in sports injuries after the knee.[4,5] The incidence of ankle sprains is reported between 2–7/1000 persons per year with adolescent males being subject to the highest risks.[6,7] Fifty percent of ankle sprains occur during athletic activity, mostly in sports such as basketball, soccer, or indoor volleyball. Regarding the frequency of ankle sprains during sports, isolated injury to the deltoid ligament is extremely rare. It has been reported in up to 4 % of cases involving athletes.[8,9] However, case studies exist that did not find any isolated injury of the deltoid ligament complex.[10] Predominantly, deltoid ligament injuries occur in combination with lateral or syndesmotic ligament injuries, lateral ankle fractures, or both.[11,12] Amongst these combined injuries, medial ligament injuries are more common than generally believed.[13]

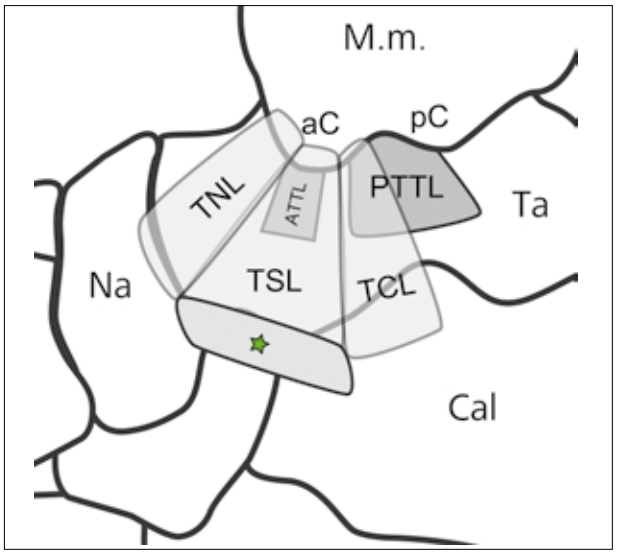

Fig. 1: *Schematic drawing of the medial collateral ligament complex of the ankle. The anterior tibiotalar ligament (ATTL) originates at the anterior colliculus (aC) of the medial malleolus (M.m.) with the posterior tibiotalar ligament (PTTL) originating at the intercollicular groove and the posterior colliculus (pC) of M. Both ligaments run deep to the superficial deltoid ligament formed by the tibionavicular (TNL), tibiospring (TSL), and the tibiocalcaneal ligament (TCL). Distally, the TSL blends with the fiber superomedial calcaneonavicular ligament (asterisk) fibers. (Cal=calcaneus, Na=navicular, Ta=talus).*

Biomechanical Overview

The deltoid ligament provides medial stability to the ankle joint and transfers forces between the tibia and the tarsus. [14, 15] It is a major stabilizer of the ankle joint against valgus (eversion) forces and abduction of the talus within the ankle mortise. [8] The biomechanical function of the various components of the deltoid ligament complex is not known in detail. However, it is assumed that the superficial and deep layers contribute equally to resist valgus stress, with the PTTL considered to be the strongest part followed by the TSL. [16–19] Furthermore, it is supposed that the deep layer of the deltoid ligament complex is the strongest restraint limiting talar abduction and lateral talar excursion. Therefore, an intact deltoid ligament prevents lateral talar shifting of more than 2 mm, even if the lateral ligamentous structures are dissected. [20] On the other side, the deep layer of the ligament is weaker in resisting external rotation forces than the superficial layer, therefore isolated deep deltoid ligament ruptures may occur in external rotation injuries. [21] However, it requires a considerable amount of force for the deltoid ligament to be ruptured.

When it comes to ankle fractures, the integrity of the deltoid ligament plays a major role in the setting of end-stage supination-external rotation (SER, Weber type B) and pronation-external rotation (PER, Weber Type C) fractures of the ankle. [11] The stability of the medial collateral ligament is an indicator in the decision between conservative and surgical therapy of SER injuries. [10, 11, 22] A recent study showed a high frequency of partial deltoid ligament injuries in SER detected by MR-imaging, even if the medial clear space was normal on stress radiographs. [23] However, the authors did not recommend further MR-imaging evaluation in SER ankle fractures if the ankle is functionally stable within the scope of the external rotation stress test.

Clinical Considerations

The main mechanism of injury to the deltoid ligament is a pronation and/or eversion trauma to the ankle joint under dorsiflexion. This can occur through landing on uneven surfaces, missteps of the foot, for example when running downstairs, or external rotation of the foot opposed to an internal rotation of the body. However, the patients often do not exactly remember the mechanism of injury after sustaining an ankle sprain. Patients´ complaints in an acute injury are swelling, hematoma, ecchymosis, and pain of the ankle joint from a medical aspect. [24] Furthermore, the patients are often unable to bear weight. In the acute stage, the clinical eversion stress testing of deltoid ligament insufficiency may be of limited value. [25] However, about 5 days after the trauma, the accuracy of clinical evaluation in the detection of deltoid ligament injury increases to a sensitivity and specificity of 96 % and 84 % respectively. [13, 26]

In chronic injury, weight-bearing reveals hindfoot valgus and pronation of the ankle joint. This malposition disappears when the patient activates the posterior tibialis muscle, for example when going on tiptoes, under the assumption that the posterior tibial tendon is preserved. [27] The clinical criteria for medial instability of the ankle are a feeling of "giving way", pain at the anteromedial gutter of the ankle, and a valgus/pronation deformity that can be corrected by action of the posterior tibialis muscle. Chronic ankle instability limits patient activity, is an important risk factor for osteoarthritis development, and may lead to an elongated posterior tibial tendon with consecutive tendon insufficiency and flatfoot deformity. [28, 29] Apart from a sequel of a traumatic injury, other causes of chronic deltoid ligament insufficiency include posterior tibial tendon insufficiency, triple arthrodesis, and arthroplasty. [30]

MR Examination

As isolated deltoid ligament injuries are extremely rare, MR-imaging protocols have to be universally applicable to detect associated injuries after ankle traumata. Positioning of the foot in mild plantar flexion of about 20° has been suggested to decrease magic angle artifacts. Use of dedicated extremity coils is recommended. [31] The protocol should comprise at least one T1-weighted MR sequence without fat-suppression to allow depiction of bone marrow abnormalities. Furthermore, a combination of intermediate-weighted and T2-weighted MR-imaging sequences with and without fat-suppression should be applied in all three standard imaging planes. Usually an ankle MR protocol consists of coronal T1-weighted TSE and intermediate-weighted Dixon TSE sequences, a sagittal intermediate-weighted MR sequence with fat-suppression, and a T2-weighted Dixon TSE sequence in the transverse plane. In case of gradient field inhomogeneity, spectral fat suppression may be problematic. In such a case, the alternative for fat-suppression can be use of techniques such as STIR or Dixon's. Thin slices, no more than 3 mm (if possible even smaller; about 2 to 3 mm) are required to visualize the detailed ligamentous anatomy.

Normally, the deltoid ligament can be evaluated on coronal and transverse standard imaging planes of the ankle joint. [31] However, with respect to the oblique orientation of the TNL, coronal oblique reformations of standard sequences or direct coronal-oblique acquisition of images have been suggested (Fig. 2). [17, 31]

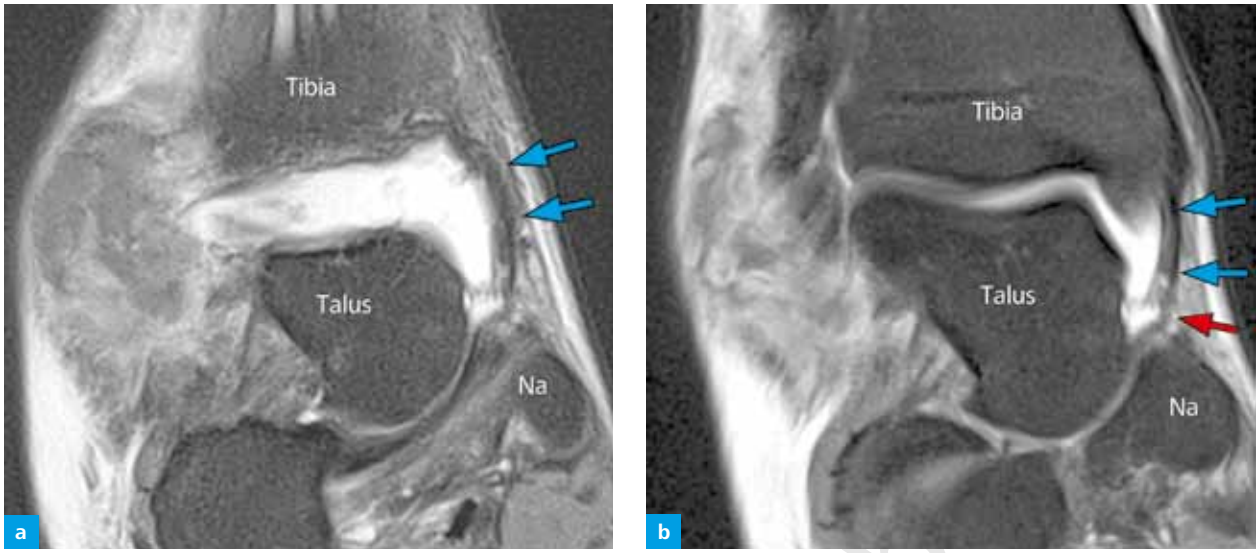

Fig. 2: MR-imaging of tibionavicular ligament (TNL). (a) Standard coronal intermediate-weighted MR image with fat-suppression of a 21-year-old hockey player after ankle trauma. The arrows mark the course of the TNL. Due to the partial volume effect, the TNL is not clearly demonstrated. (b) Corresponding secondary reformations of the standard images in Fig. 2a in a 20° coronal-oblique plane along the course of the TNL. The reformations were performed on a standard PACS work station. The blue arrows show the course of the whole TNL from the origin at the anterior tibia to the insertion at the navicular bone (Na). In this reformation, the distal partial tear is obvious (red arrow).

There is no evidence that intravenous contrast increases the diagnostic potential of MR-imaging in the evaluation of chronic deltoid ligament tears. However, in MR-imaging of anteromedial impingement, intravenous contrast administration has been suggested to potentially detect focal capsular enhancement and synovitis. [32] In this rare cases, even MR arthrography may play a role in the evaluation of capsular thickening and scarring in the anteromedial joint recess. [33]

MR-Imaging of Deltoid Ligament Injury

MR-imaging has the possibility to easily depict normal deltoid ligament anatomy, best evaluated on coronal images. [34] Normal ligaments are structures of homogenous low-signal intensity on all pulse sequences connecting two bones and are sharply outlined by fatty tissue (Fig. 3a). [35] Only the PTTL, occasionally the ATTL as well, show a striated appearance on T1-weighted and intermediate-weighted images without fat-suppression due to interposed fatty tissue between the ligamentous fascicles (Fig. 3b). [31, 34]

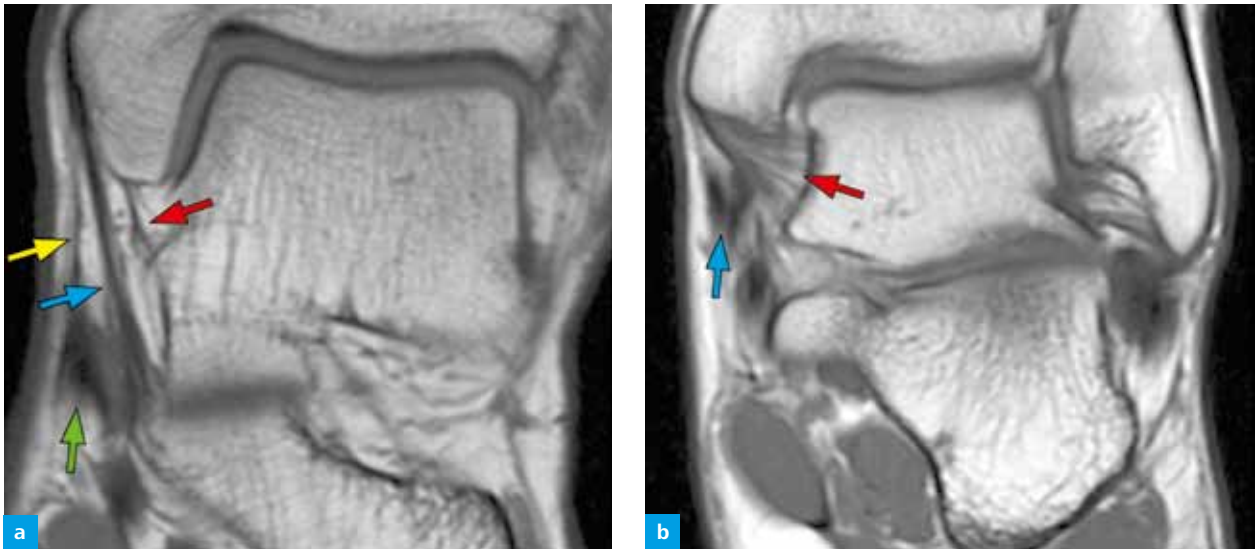

Fig. 3: Normal anatomy of the deltoid ligament on MR-imaging. (a) T1-weighted coronal MR image shows the deep anterior tibiotalar ligament (red arrow), superficial tibiospring ligament (blue arrow), and flexor retinaculum (yellow arrow) at the level of the anterior colliculus of the medial malleolus. The tibialis posterior muscle tendon (PTT) is seen (green arrow) between the flexor retinaculum and the superficial deltoid ligament. (b) Intermediate-weighted coronal MR image at the posterior colliculus of the medial malleolus demonstrates the typical conical shape and striated appearance of the deep posterior tibiotalar ligament (red arrow) in close proximity to the PTT.

There is little evidence regarding the diagnosis of deltoid ligament tears with MR-imaging in the literature. However, classification of the severity of injury of the deltoid ligament can be performed similarly to at other anatomical locations.[30] A grade I sprain represents the appearance of edema and hemorrhage on fluid-sensitive sequences around the ligament without disruption of the ligament itself (Fig. 4a). At the PTTL, loss of its striated imaging appearance in an acute trauma without discontinuity of fibers can be considered as a grade I injury (Fig. 4b). Caution is warranted in individuals older than 45 years, in whom loss of striation can be frequently found without acute trauma.[34] Partial disruption, thinning, increased ligamentous signal, or contour irregularity of ligamentous fibers, can be classified as grade II partial tear (Fig. 5).

Complete discontinuity or bony detachment with a fluid-filled gap on T2-weighted images can be considered as a grade III complete tear of the ligament (Fig. 6).[31] Proximal bony avulsions are frequently seen in PTTL injury.[17] Furthermore, it is reported that if either the PTTL or the TSL were torn, both the TCL and the TNL were also affected.[17] Lateral talar shift or widening of the medial clear space may occasionally be seen in high-grade injuries. As on MR-imaging, the TNL or the ATTL may only be visible in about 55 % of the cases in asymptomatic volunteers on a 1.5 T scanner, non-visibility may not necessarily represent a sign of a complete rupture.[34] However, increased field strength on MR-imaging may also improve the depiction of these ligaments.

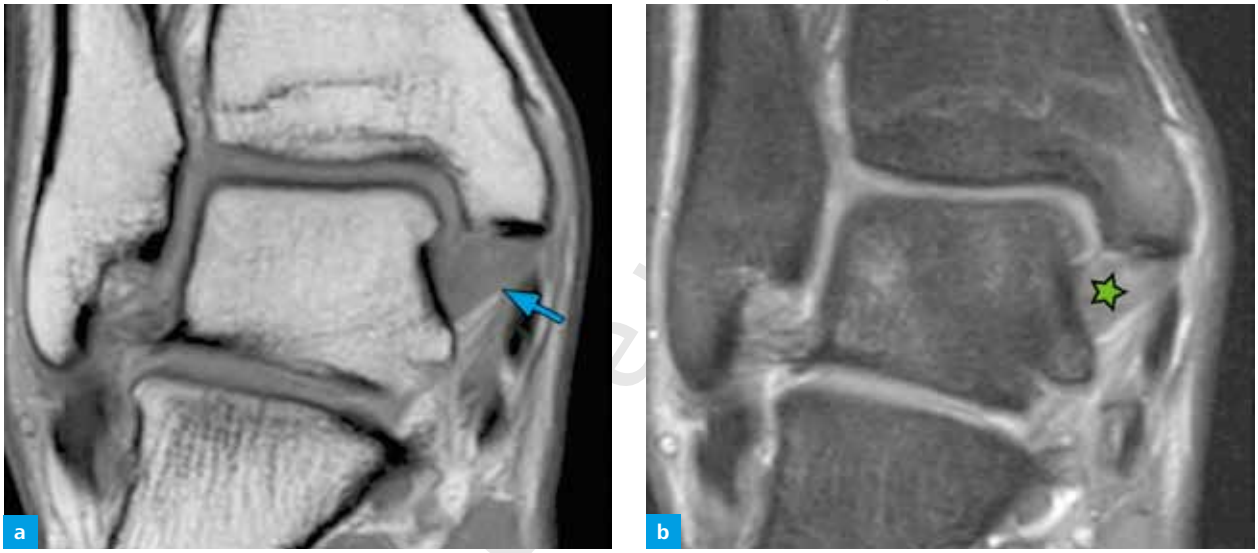

Fig. 4: Grade I strain of posterior tibiotalar ligament (PTTL). Coronal MR images of a 22-year-old unihockey player after sustaining an ankle sprain with lateral collateral ligament tears. (a) T1-weighted MR image of the ankle shows loss of normal striation of the PTTL in a grade I strain (arrow). (b) Corresponding intermediate-weighted MR image with fat-suppression demonstrating hyperintense signal around the PTTL and the medial collateral ligament representing edema and hemorrhage (asterisk).

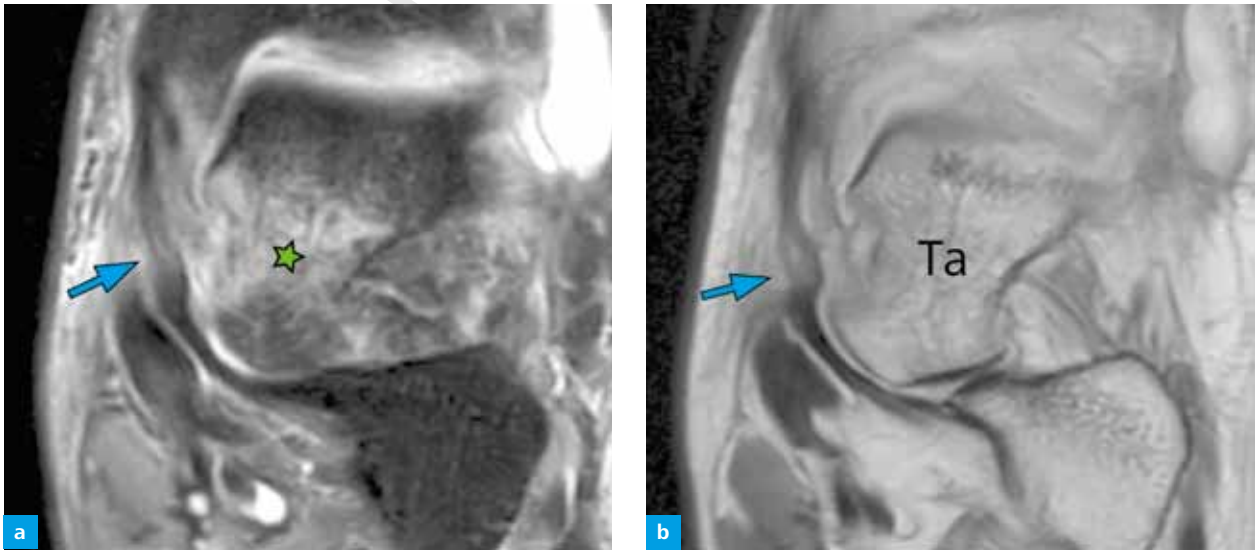

Fig. 5: Grade II partial tear of the tibiospring ligament. Coronal MR images of a 33-year-old-female after ankle sprain. (a) Intermediate-weighted MR image with fat suppression demonstrating irregular thickening and increase of signal intensity within the TSL (arrow) with surrounding hemorrhage. Note extensive bone marrow edema within the talar head (asterisk). (b) The corresponding intermediate-weighted MR image shows thickening and increased signal of the TSL (arrow) without complete discontinuity representing a partial tear.

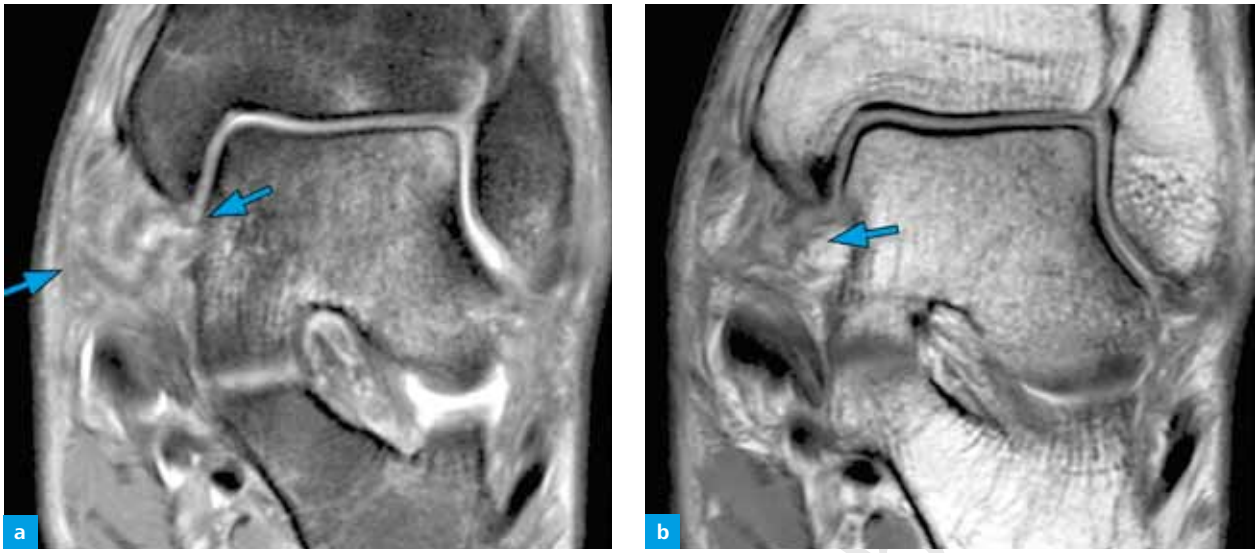

Fig. 6: Grade III complete tear of deltoid ligament. Coronal MR images of a 21-year-old hockey goalie after acute ankle trauma. (a) Intermediate-weighted MR image with fat suppression of the ankle showing complete disruption of the ligamentous fibers at the anterior deltoid ligament (arrows). (b) No intact ligamentous fibers can be seen bridging the ankle joint (arrow) in a complete grade III injury of the deltoid ligament.

Recently, the evaluation of the proximal attachment of the superficial layer of the medial collateral ligament after acute trauma was emphasized in a study.[36] All cases with deltoid ligament tears included in this study showed a tear of the proximal origin of the superficial deltoid ligament at time of surgery and diagnostic criteria for the detection of a proximal tear of the superficial components have been described: (1) focal discontinuity of the ligament at the anteromedial malleolus; (2) detachment of a sheet of fibrous tissue from the bone in the anteroposterior orientation at the superficial aspect of the medial malleolus (Fig. 7).

This so-called "fascial sleeve of the medial malleolus" refers to a combined structure of the superficial origin of the deltoid ligament, the periosteum of the medial malleolus, and the flexor retinaculum. A thin hyperintense signal layer, isointense to fluid on T2-weighted MR images should be considered as stripping off the fascial sleeve of the medial malleolus representing an injury which has been described in orthopedic literature (Fig. 8).[27] In this retrospective study, the sensitivity of MR-imaging in the detection of deltoid ligament tears using these criteria was 83.3 % with a corresponding specificity of 93.9 %.

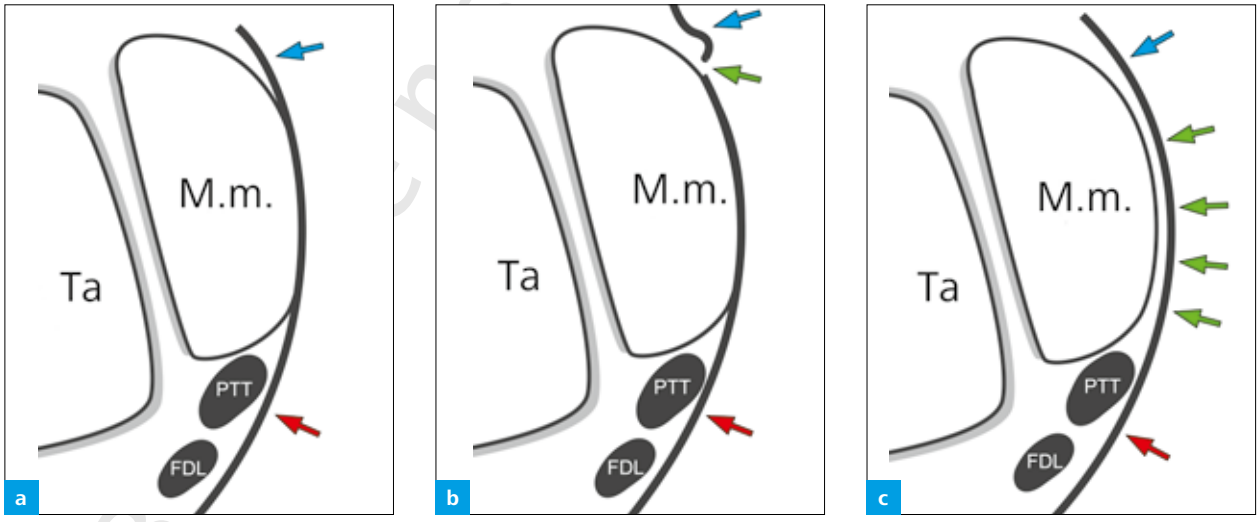

Fig. 7: Schematic drawing of the fascial sleeve of the medial malleolus (adopted from[36]). (a) Normal anatomic situation. The anterior part of the superficial deltoid ligament (blue arrow) inserts at the anteromedial portion of the medial malleolus (M.m.). The fibers blend with the medial periosteum as well as the fibers of the flexor retinaculum (red arrow). (b) Proximal grade III tear (green arrow) of the superficial fibers of the deltoid ligament (blue arrow) at the anteromedial malleolus (M.m.). (c) Complete proximal detachment of the fascial sleeve including the proximal superficial fibers of the deltoid ligament (blue arrow), the medial periosteum of M.m. (green arrows), and the origin of the flexor retinaculum (red arrow). (Ta=talus, PTT=posterior tibial tendon, FDL=flexor digitorum longus tendon).