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ANATOMICAL BASIS OF VARIABILITY IN INJURIES OF THE MEDIAL MALLEOLUS AND THE DELTOID LIGAMENT

I. Anatomical Studies

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An anatomical study of the medial malleolus and the deltoid ligament of the ankle on fresh and formalin preserved legs of cadavera and amputation specimens has been carried out.

The anterior and posterior colliculi, and the intercollicular groove of the medial malleolus were described. The deltoid ligament was found to have two layers: the superficial, attached primarily to the anterior colliculus, consisted of the naviculotibial, calcaneotibial, and superficial talotibial ligaments; the deep layer consisted of the deep anterior and posterior talotibial ligaments and was attached primarily to the posterior colliculus and the intercollicular groove. These findings are at variance with previous descriptions of the deltoid ligament.

Key words: ankle anatomy; deltoid ligament; medial malleolus

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It has been established that only section or rupture of the deep portion of the deltoid ligament allows for a significant displacement of the talus (Close 1956, Grath 1960). The role, if any, of the superficial portion of the deltoid ligament in a normal ankle or in an injury of the ankle is not clear from the literature. Furthermore, the morphology of the medial malleolus and its colliculi has not been previously described in detail, and in particular the relationship to the various parts of the deltoid ligament. Finally, it is generally assumed that in order for the talus to be displaced and rotated laterally, either the deltoid ligament must first rupture, or instead a fracture of the medial malleolus must occur. The existence of concurrent injuries of the medial malleolus and the deltoid ligament thus appear impossible, and yet such cases have been presented in the literature (Close 1956, Burwell & Charnley 1965, Mendelsohn 1965, Solonen & Lauttamus 1965, Coonrad 1970), although never clearly described nor their mechanism of injury explained.

Therefore the aim of this investigation was: 1) to make a detailed study of the morphology of the medial malleolus and the deltoid ligament, and their spacial relationship, and 2) to apply the findings of the anatomical studies to actual cases, in order to gain further understanding of variations of injuries of the deltoid ligament and the medial malleolus. This latter part of the study will be reported separately.

MATERIAL AND METHODS

A total of 16 specimens were available for dissection. Each specimen consisted of the entire leg

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amputated just below the knee joint. Ten specimens were fresh: two were obtained following above-knee amputations for lesions in the femur and eight at autopsy. These specimens were kept frozen, and were thawed for 12 hours before dissection. Four specimens were preserved in formalin.

All specimens were carefully dissected and all structures photographed. The relationships of the deltoid ligament and the overlying and surrounding structures were recorded. Particular care was exercised in dissecting the tendon sheaths overlying the deltoid ligament. In order to demonstrate the articular side of the deep deltoid ligament, all tendons and ligaments along the fibula as well as the joint capsule were sectioned, and the tibia and fibula tilted medially. Each ligament was carefully dissected and its bony attachments and relations to the adjoining structures were recorded and photographed.

PREVIOUS DESCRIPTIONS OF THE DELTOID LIGAMENT

Essentially five different descriptions were found in the literature:

1. Bonnin (1950) and Dziob (1956) considered the deltoid ligament to be a single layer ligament consisting of three parts: the anterior and posterior talotibial, and the calcaneotibial ligaments. Dziob stated that the deltoid ligament originates from the entire border of the medial malleolus and inserts into the anterior side of the talus, the sustentaculum tali, and the medial tubercle of the talus.

2. Toldt (1921) and Grath (1960) (citing Rauber-Kopsch's Textbook of Anatomy, 1932 Edition) described two layers of the deltoid ligament: the superficial layer composed of the tibionavicular and calcaneotibial ligaments, and the deep portion of the anterior and posterior talotibial ligaments. The smaller anterior talotibial ligament originates on the anterior edge of the medial malleolus and is inserted into the neck of the talus (Grath) or into the anterior part of the medial surface of the talus (Toldt). The posterior talotibial ligament originates on the posterior border of the medial malleolus and is inserted into the posterior part of the medial surface of the talus.

3. In the 29th Edition of Gray's Anatomy (1973) the deltoid ligament is described as having two layers. In the superficial layer there are three ligaments: tibionavicular, calcaneotibial, and posterior talotibial. They originate on the medial malleolus and are inserted into the navicular, the sustentaculum tali, and the medial tubercle of the talus. In the deep layer there is only the anterior talotibial ligament which is attached to the tip of the medial malleolus and the medial surface of the talus.

4. Close (1956) described the superficial fibers of the deltoid ligament as taking origin on the anterior colliculus of the medial malleolus and being inserted into the navicular, the neck of the talus, the spring ligament, and the sustentaculum tali. The deep portion originates in the groove between the colliculi and is inserted into the medial surface of the talus.

5. Wilson (1975) described superficial and deep fibers of the deltoid ligament. The superficial fibers originate at the tip of the medial malleolus and are inserted into the navicular, the sustentaculum tali, and the talus. The deep fibers run from the intercollicular notch of the medial malleolus to the medial surface of the talus.

FINDINGS IN THE ANATOMICAL STUDIES

The following structures were studied in each specimen: the medial malleolus, the medial surface of the talus, calcaneus, and tarsal navicular, the deltoid ligament, and the relationship of the medial tendons, their sheaths, and the crural fascia to the deltoid ligament.

A. Medial malleolus is the medial process of the distal tibia. It has a wide base proximally, a convex medial surface, a slightly concave articular surface which is continuous with the articular surface of the tibial plafond, and an anterior and a posterior

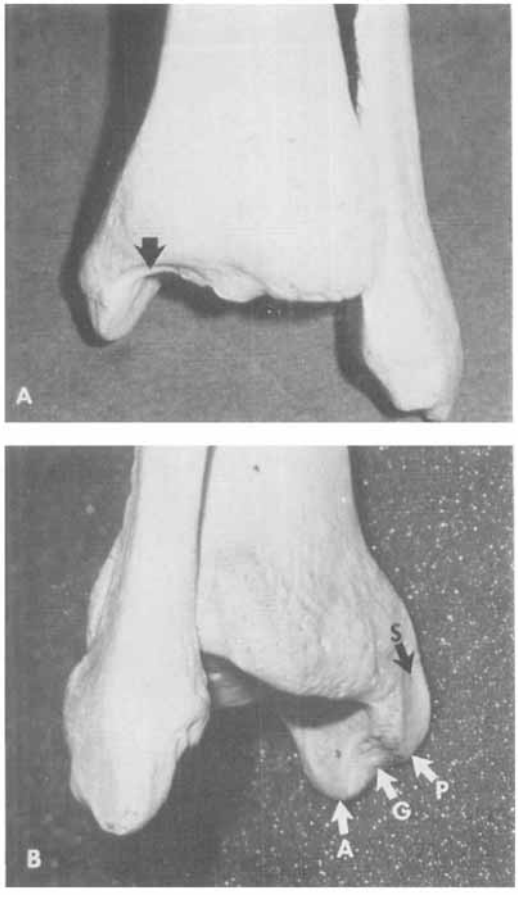

Figure 1. Two views of the medial malleolus and its colliculi. A. Anterolateral view of the anterior colliculus showing the articular surface and the anterior ridge. The arrow indicates the anteromedial corner of the plafond where a great many fractures of the medial malleolus occur. B. Posterolateral view of the medial malleolus. The intercollicular groove (G) and the distal and posterior surfaces of the posterior colliculus (P) are clearly seen along with the sulcus for the tendons of tibialis posterior and flexor digitorum longus (S) and the anterior colliculus (A).

colliculus which are separated from each other by the intercollicular groove (Figure 1A and B).

The anterior colliculus is the narrower, slender, anterior portion of the medial malleolus which extends distally below the level of the posterior colliculus. It forms a ridge anteriorly and inferiorly, and its convex medial surface serves for attachment of the superficial portion of the deltoid ligament. The articular surface of the anterior colliculus is easily distinguishable from and is continuous with the articular surface of the posterior colliculus.

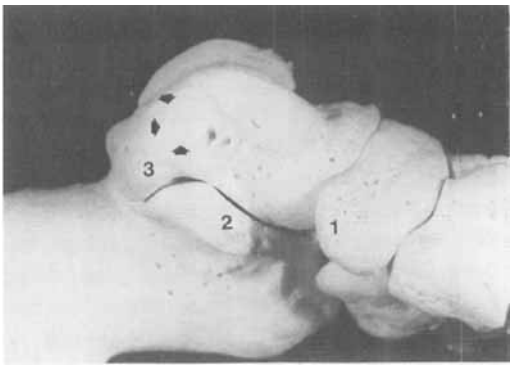

Figure 2. Medial surfaces of the talus, calcaneus, and tarsal navicular showing: navicular tuberosity (1), sustentaculum tali (2), medial tubercle of the talus (3), and the surface for attachment of the deep posterior talotibial ligament (arrows).

The posterior colliculus is the broader, solid, posterior portion of the medial malleolus. It is convex medially and posteriorly, and contains the smaller posterior portion of the articular surface of the medial malleolus. A shallow sulcus on its posterior surface serves for attachment of the tendon sheaths of the tibialis posterior and flexor digitorum longus.

The intercollicular groove extends from the anterior border of the articular surface of the posterior colliculus in an anteromedial direction, and ends on the medial surface at the base of the anterior colliculus. The entire surface of the intercollicular groove, and the distal surface of the posterior colliculus, serve for attachment of the deep posterior talotibial ligament.

B. The medial surface of the talus, calcaneus, and tarsal navicular serve for attachments of various parts of the deltoid ligament (Figure 2).

The medial surface of the talus has at its anterior and upper part a triangular articular facet which articulates with the medial malleolus. Below the posterior part of this facet, there is a surface for attachment of the

deep posterior talotibial ligament. Anterior to this surface, a number of small perforations serve for entrance of the talar vessels, and anterior to that starts the neck of the talus. Posterior and distal to this surface, the medial tubercle overhangs the posterior articular facet of the talus. It is located just posterior and proximal to the sustentaculum tali of the calcaneus. It is important to distinguish these two bony prominences when dissecting the superficial portion of the deltoid ligament in order to deliniate the calcaneotibial and superficial talotibial ligaments which are in most instances contiguous with each other. The concave, medial surface of the calcaneus, below the sustentaculum tali, serves for passage of the tendon of the flexor hallucis longus and plantar vessels and nerves into the foot. The plantar calcaneonavicular ("spring") ligament takes origin from the anterior margin of the sustentaculum tali and is inserted into the medial and plantar surfaces of the navicular and its tubercle. On the dorsomedial surface of this ligament is attached the naviculotibial ligament.

C. The deltoid ligament was found to have two portions: deep and superficial.

Deep portion of the deltoid ligament.

Two ligaments, the smaller deep anterior and the deep posterior talotibial ligament, were discerned in the deep portion of the deltoid ligament and found to be practically intraarticular structures (Figure 3A and B).

Deep anterior talotibial ligament. This is a small and short band which is covered by the calcaneotibial ligament. The two ligaments blend with each other and may be confused during dissection for a single calcaneotibial ligament, although each of them has a separate insertion on the talus and the calcaneus. The origin of the ligament is on the intercollicular groove and the adjoining anterior colliculus, and is contiguous with the deep posterior talotibial ligament. It descends in a distal and slightly anterior direction, and is inserted on the medial surface of the talus near its neck. This ligament was found to be of variable size in different specimens, sometimes hardly discernible, and in some cases completely absent.

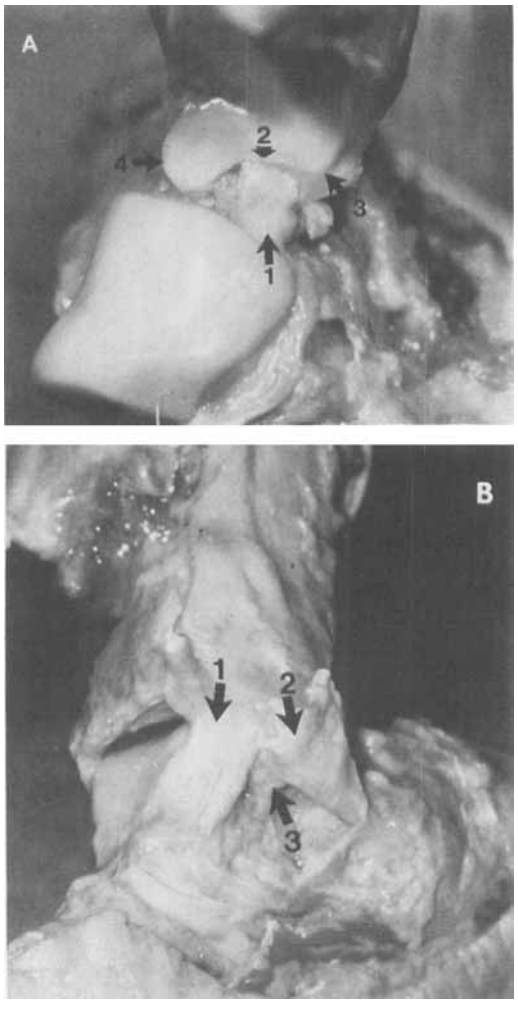

Figure 3. The deep portion of the deltoid ligament. A. Lateral (intraarticular) view of the deep posterior talotibial ligament and its attachments to the talus (1), the intercollicular groove (2), and the posterior colliculus (3). The anterior colliculus (4) has a few ligamentous attachments. B. Medial view of the deep posterior talotibial ligament (1) and its attachments to the posterior colliculus and talus. Superficial deltoid ligaments (2) were detached and reflected in order to show the deep anterior talotibial ligament (3).

Deep posterior talotibial ligament. This is a strong and thick ligament which takes origin

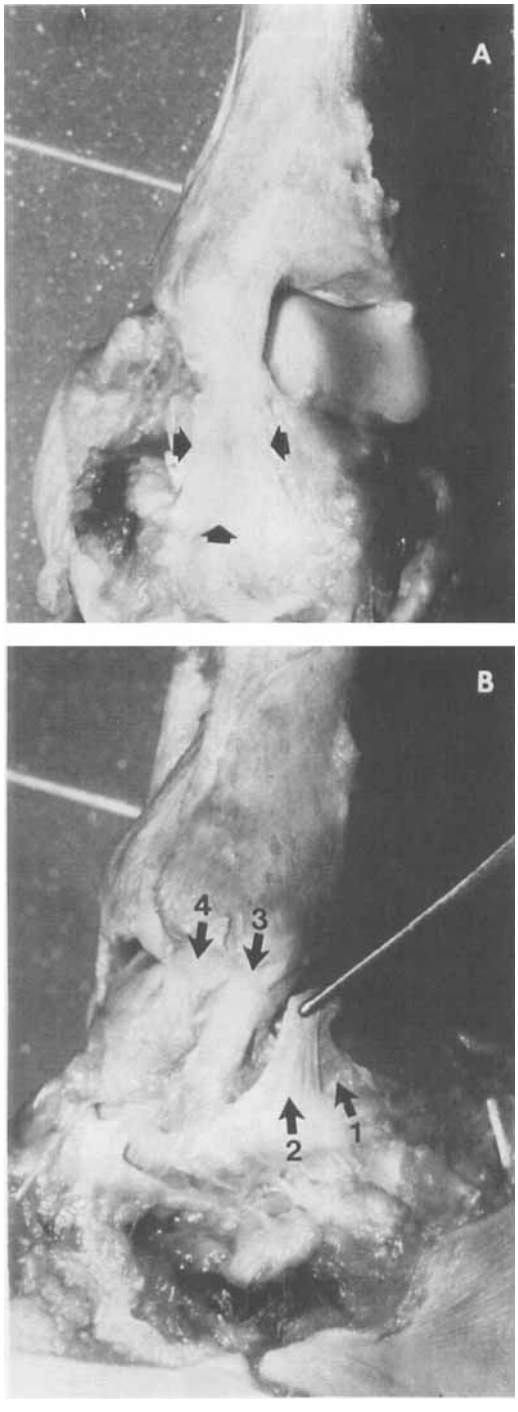

Figure 4. The superficial portion of the deltoid ligament takes origin from the anterior colliculus. A. The naviculotibial ligament (arrows). B. Detached from the anterior colliculus are: naviculotibial (1) and calcaneotibial (2) ligaments; still attached is the superficial talotibial ligament (3). In view is also the deep posterior talotibial ligament (4).

on the area bordered by the articular surface of the posterior colliculus, the posterior sulcus, the medial surface of the posterior colliculus, and the entire anterior margin of the intercollicular groove. A few fibers of the ligament take origin also from the adjoining anterior colliculus. The ligament extends in a posterior, lateral, and distal direction and inserts into the medial surface of the talus, in an area extending from the medial tubercle to the edge of the posterior third of the articular surface of the talar trochlea. The intraarticular surface of the ligament is covered with a layer of synovium.

Superficial portion of the deltoid ligament

Three ligamentous parts or bands were discerned in the superficial portion of the deltoid ligament which originate on the medial surface and the anterior ridge of the anterior colliculus and partially on the medial surface of the posterior colliculus of the medial malleolus. Their origins are contiguous with each other as are these ligaments in most parts (Figure 4A and B).

Naviculotibial ligament. This band originates from the anterior colliculus. It extends in a fan-shaped fashion and forms a triangular ligament which is inserted into the dorsomedial surface of the navicular and along the dorsomedial surface of the plantar calcaneonavicular ("spring") ligament. This is the largest and widest, yet the weakest portion of the deltoid ligament. It blends with the joint capsule anterolaterally, and with the calcaneotibial ligament posteriorly.

Calcaneotibial ligament. This is the middle band. It originates from the mid portion of the medial surface of the anterior colliculus. It extends distally in an almost perpendicular plane and inserts along the medial border of

the sustentaculum tali of the calcaneus. This is the strongest of the three bands.

Superficial talotibial ligament. This band originates from the posterior part of the medial surface of the anterior colliculus and the adjacent small part of the posterior colliculus. It takes a postero-distal course and inserts into the anterior portion of the medial tubercle of the talus. In some specimens the ligament was separated from the adjoining calcaneotibial ligament and in others the two structures were contiguous and indistinguishable; in the latter cases their separate insertions into the medial tubercle of the talus and the sustentaculum tali of the calcaneus had to be carefully dissected and differentiated. In one specimen, the ligament was absent.

It was also observed that the deep anterior talotibial and naviculotibial ligaments, and most fibers of the calcaneotibial ligament, became taut when the foot is plantar flexed. Conversely, with the foot in dorsiflexion, the superficial talotibial and the deep posterior talotibial ligaments, and the posterior fibers of the calcaneotibial ligament, are taut.

D. Relations of the deltoid ligament to the overlying structures.

Superficial portion of the deltoid ligament is almost completely covered by the sheaths and tendons of the tibialis posterior and flexor digitorum longus. The tendon sheaths are firmly attached to the calcaneotibial and superficial talotibial ligaments, and are quite difficult to dissect. The only part of the deltoid ligament which is readily dissectable, on a specimen or exposed at surgery, is the anterior portion of the naviculotibial ligament which lies under the fascia. The tendons and the neurovascular bundle are covered by the crural fascia which is reinforced with the laciniate ligament at the level of the ankle joint (Figure 5A and B).

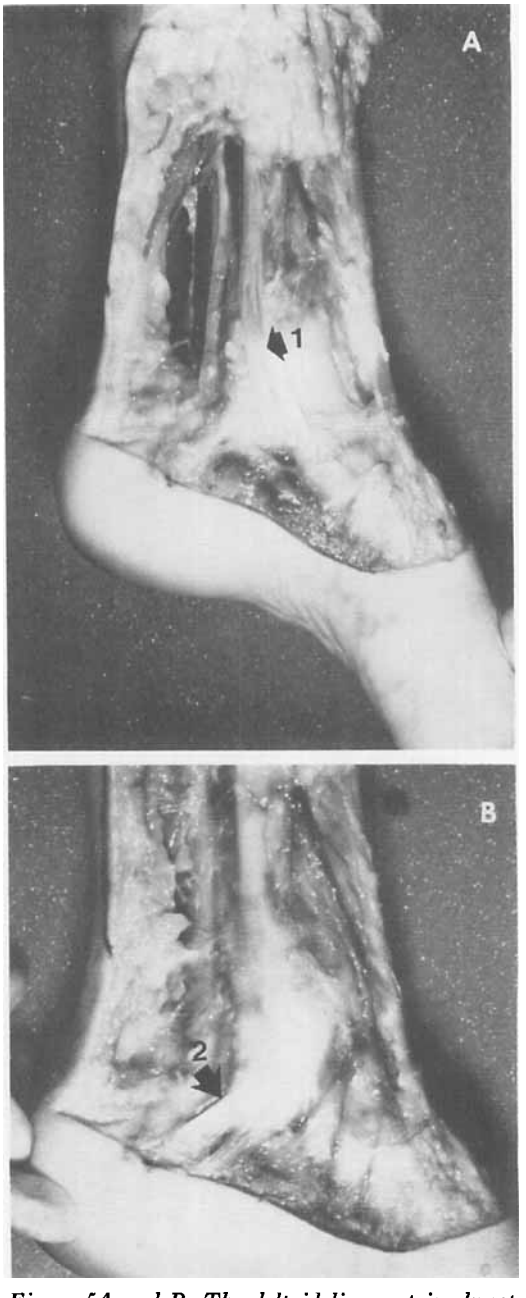

Figure 5A and B. The deltoid ligament is almost completely covered by the tendons of the tibialis posterior and flexor digitorum longus (1), crural fascia, and the laciniate ligament (2).

DISCUSSION

Review of the literature revealed differences among descriptions of the deltoid ligament, its component parts, and their attachments to the medial malleolus and the talar bones. At least five descriptions varying from each other exist in the literature. Some authors consider

the deltoid ligament to be a single layer structure, and others described two layers: superficial and deep. Variations also exist in regard to the number of ligaments in each layer and their bony attachments.

Description of the deltoid ligament by Close (1956) is similar to the findings in the present study, the main difference being his failure to recognize the superficial talotibial ligament, and inclusion of the anterior talotibial ligament in the superficial group. Grath (1960) and Toldt (1921) consider the deep anterior and posterior talotibial ligaments as the deep portion of the deltoid ligament but do not recognize the superficial talotibial ligament. The description in Gray's Anatomy is clearly inaccurate because the anterior talotibial ligament does not represent the principal deep portion of the deltoid ligament. Finally, Wilson (1975) does not recognize the anterior talotibial ligament and its relation to the calcaneotibial ligament. Otherwise, his description is very similar to the present one.

Since it was found in the present study that the deep anterior talotibial and the superficial talotibial ligaments may be less developed or even absent in some specimens, it is possible that the description by other authors reflected these variations in the deltoid anatomy.

Findings in the present study demonstrated that the ligaments of the superficial deltoid layer take origin primarily from the anterior colliculus, and its three bands insert into the navicular and the plantar calcaneonavicular ("spring") ligament, the sustentaculum tali, and the medial tubercle of the talus. The deep deltoid ligaments take origin primarily from the posterior colliculus and the intercollicular groove and are inserted into the medial surface of the talus. Only a very small portion of the deep anterior and posterior talotibial ligaments are attached to the anterior colliculus. These findings of separate attachments of the superficial and the deep portions of the deltoid ligament to the anterior and posterior colliculi, respectively, are essential in the understanding and recognition of various singular and concurrent lesions of the medial malleolus and the deltoid ligament. These lesions will be described in a separate communication.

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