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An Anatomical Overview on Deltoid Ligament of the Ankle and its Biomechanics

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Abstract:

The foot being a complex biomechanical structure has crucial functions to maintain stability and ensure the proper transfer of force through the lower limb. The ankle joint connects the leg and the foot to establish lower limb stability, is an important joint in relation to movement. The ankle joint is usually stabilized by several structures and trauma to the ankle joint is very common. So understanding the anatomy and biomechanics of the ankle is important for choosing treatment approach and preventing nerve injuries, poor healing or dysfunction. One structure of interest is the deltoid ligament complex, also known as the medial stabilizer of the ankle from eversion. Repeated episodes of ankle sprain can cause laxity of lateral dual-ligament hence leading to chronic ankle instability. The deltoid ligament complex consists of the tibiotalar joint whose function prevents and limits the tilting of the joint. Deltoid ligament complex has six different parts divided into two layers; one superficial layer consisting of four bands and one deep layer consisting of two bands. However, studies have been debating about heterogeneity of the size and prevalence of the deltoid ligament components. Studying and

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understanding the anatomy and biomechanics of the deltoid ligament and its components is very helpful in regards to the guidance of the anatomical placement of repair or the reconstruction in case of ligament injury or instability.

Key words: anterior tibiotalar ligaments(ATTL) , deep fibres of the posterior tibiotalar ligament (dPTTL) tibiocalcaneal ligaments(TCL), tibionavicular (TNL), tibiospring (TSL) , tibiotalar ligament (TTL), posterior tibial tendon (PTT), flexor digitorum longus (FDL)

INTRODUCTION

Due to having an episode or repeated episodes of ankle sprain, this can lead to chronic ankle instability which is an important subset of complication (estimates vary from 0% to 40%)[1,2,3] .in United States, ankle sprain is common with occurrence of over 27,000 cases daily [4]. Among all this, the majority are injuries involving the lateral ankle ligaments and some authors estimated that deltoid ligament of the ankle are involved in about 5% [5]. The commonly seen symptoms in patients are recurrent "giving way" and lateral-sided ankle pain. Severe limitations to patients activities as a result of chronic ankle instability have been implicated as an important cause of ankle osteoarthritis [6,7] in chronic ankle instability. Injuries to the ATFL alone are seen in minority of patients whereas injuries to both the ATFL and CFL are seen in majority of patients [8,9,10,11,12,13].

One study reported [14] in acute ankle sprain that the cervical and interosseous talocalcaneal ligaments have high incidence of injuries but this has not been documented in chronic ankle instability. Weber B type fractures, also called Supination–external rotation (SE) fractures, is known to be the most common ankle fractures and account for as many as 80% of all ankle fractures [15, 16, 17, 18, 19, 20, 21].

Depending on the stability of the ankle, decision are made whether to use surgical or non-surgical treatment approach and as for the unstable fractures surgical management had better outcome than those with conservative treatment [22, 23, 24, 25, 26,27]._The ankle is composed of superficial and deep components that form deltoid ligament complex. The superficial fascicles is demonstrated to maintain the primary restraint of tibiotalar valgus angulation whereas on the other hand, deep ligament act to prevent axial rotation of the talus within the mortise.[28,29,30] Regarding superficial deltoid ligament, its components variation have been described in different publication[31,32,33,34,35]

Tibiocalcaneal ligament is known to be a component of the superficial layer nearly by all of the groups. The origination of the distal medial malleolus fascicle inserts upon the sustentaculum tali and it was found by Pankovich and Shivaram that this fascicle was strongest when compared to superficial deltoid. [33].

Anatomy

Deltoid ligament, in our opinion is composed of six different parts depending on different functional properties; Superficial and anterior are the tibionavicular (TNL), the tibiospring (TSL) and the tibiocalcaneal (TCL) ligaments.[36]. The superior posterior (sPTTl), deep posterior (dPTTl) and anterior tibiotalar (ATTL) ligaments made up the deep layer of the deltoid ligament [37, 38, 39]. There can be differed opinions among individuals as some consider the TNL to be a fibrous thick part of the anterior capsule instead of being another ligament [37]. The ankle joint of the bony anatomy is generally well known as the groove dividing into two colliculi from medial malleolus. The posterior tibial tendon (PTT) and the flexor digitorum longus (FDL) pass on the posterolateral side.[36]

Both colliculi are attached to deltoid ligament proximally and has several insertions distally on to the talus , navicular, and calcaneus and onto the spring ligament. The typical shape and name of the ligaments came to be due to its narrow proximal anchoring and multiple distal attachments. The first division anatomically separates the ligament into superficial and deep layers. [36] At the anterior colliculus superficial fibers originate and cross two joints (talocalcaneal and tibiotalar), as for the deep part which just bridges the tibiotalar joints emerging from between and on the posterior colliculu. Historically, three to six different form of anatomical divisions have been described by the other authors [37, 40, 38, 41, 42, 43].

MRI and dissection in anatomy showed deep fibres of the posterior tibiotalar ligament (dPTTL) to be the thickest ligament and it connects the posterior colliculus to the medial tubercle of the talus. Another component of the deltoid ligament is the tibiospring (TSL) which do not have the two bony attachments. It takes origin from the anterior colliculus and spread out to the planter calcaneonavicular or spring ligament to form a functional unit with it [own paper reff modle]. It is seen to be the second largest of the components on MRI [41]. However, the TCL through anatomical procedures is viewed to be comparable in thickness to the deep fibres of the posterior tibiotalar ligament (dPTTL) [37]. The deep fibres of the posterior tibiotalar ligament (dPTTL) and tibiospring (TSL) were never present when Mengiardi et al. [37, 44] studied the deltoid ligament about the visibility and signal characteristic on MRI of asymptomatic patients.

In only 50% of subjects were the anterior tibiotalar ligaments(ATTL) and tibionavicular (TNL) visible [36].The medial collateral ligament also known as the deltoid ligament is a strong and broad ligament that has a multifascicular appearance spanning out of the medial malleolus to the talus, calcaneus and navicular bones forming a delta shape to which the name of the deltoid ligament is originated from.

The fibrous sheaths of the posterior tibial tendon and flexor digitorum tendons share a contiguous relation with the components of the ligament making it hard to differentiate. Over the years this has caused confusion in describing the ligament and its composition anatomically [45]. Quoting Barclay-Smith, 'the anatomist is apt to blindly follow the accepted description and methods of dissection, and thereby, often unconsciously, to fashion the structure dissected to the mould of the description […] and of all structures in the body, the ligaments are the most plastic in this respect' [46] Through literature, it shows that most authors found common ground for a fact that a fad pad divides the deltoid ligament into two layers (superficial and deep) with both of them formed by several components.

Rasmussen, Pankovichand and Shivaram vouched in independent anatomical studies about the anatomy of deltoid ligament with its components still not clear [47, 48, 49]. The description of the deltoid ligament most commonly accepted was proposed by Milner and Soames [36], which was supported later by Boss and Hintermann [50]. They differentiate the ligament into six components which got their name according to their attachments, with four belonging to the superficial and the other two conformed to the deep layer.

(a)Superficial layer

Four components or fascicles made up the superficial layer and out of these the only two which are seen in all cases are the tibionavicular (TNL), and tibionavicular ligaments(TNL).

It may vary for the other two superficial fascicles, which are the tibiotalar(TTL) and tibiocalceneal ligaments(TCL). The functions of these fibers are to help maintaining the talus and medial malleolus in alignment and also for the talus to resist external rotation through stress of the tibia and valgus [52].

(b)Deep layer

Fibers emerging from the tibia towards the talus form the deep layer which consist of two components; the ever present deep posterior tibiotalar ligament (TTL)and the non-constant tibiotalar ligament[36].. The fibers of the ligaments is arranged in such a way to prevent not only lateral displacement but also external rotation of the talus.

Biomechanics of the deltoid ligament

The deltoid ligament is believed to have two functions; firstly to provide medial stability to the tibiotalar joint and secondly to transfer forces between tibia and tarsus [53, 54, 55].

The main function of the deltoid ligament is to hold the tibia firmly above the talus and prevent the talus from moving into a valgus position, moving anterolaterally or rotating externally. Even if the lateral structures are out of place, the intact deltoid ligament do not allow any lateral movement of more than 2mm [56, 57,58,59,60].

The Talus in the mortise is capable to move normally in all three planes and this have various descriptions: with plantar flexion exceeding by 4-5 times or as far as 80% of the dorsiflexion [61,62,63,60]; the talus shows an internal rotation of 1.9 when the foot is at maximum plantar flexion, contrarily it shows an external of 7.2 at maximum dorsiflexion [64]. It is widely argued that the intact ligaments have a symmetrical adduction and abduction range from 5 to some extreme values [65, 66, 60, 67].

Internal and external rotation have been noted to have a range of 14-24 [68,69,60]. Severe instability is noted when the whole ligament is cut off but a good degree of stability still remains when only the superficial part of the deltoid ligament is removed. It was possible for the talus to have just 4-7 external rotation with the remaining deep layer intact [69,60]. Without a medial injury, a complete fibular osteotomy allowed the ankle to have normal motion[64,70]. It is thought that both the anterior tibiotalar ligaments(ATTL) and the anterior talofibular ligament on the lateral side cause restriction in the forward translation of the talus. Some authors said that the anterior tibiotalar ligaments(ATTL) lack independent function with the lateral ligament predominantly limiting plantar flexion [60].

Dehne and Dias [71, 72] mentioned that the deep fibres of the posterior tibiotalar ligament (dPTTL) alone restrict internal rotation of the talus, but they did not do isolated dissection studies of these fibres.

Rasmussen while studying injuries to different ankle ligaments found that the talar movement in any direction was barely affected when both the tibiocalcaneal ligaments(TCL) and anterior tibiotalar ligaments(ATTL) were cut [60]. Both radiological and anatomic studies found common ground in regard to the strength of the different components of the deltoid ligament. The dPTTL seems to be the strongest with the TSL being next and the tibiocalcaneal ligaments(TCL) and tibionavicular (TNL) being the weakest [73, 74, 60, 75]. Moreover the interlacing of the tibiospring (TSL) with tibionavicular (TNL) form the spring ligament complex that medially supports the talar head and provide stability to the whole talocalcaneonavicular joint. According to Hintermann there is a relationship between the medial ankle instability and the looseness of the spring ligament complex [76]. The downside of in-vitro studies by many authors is when non-standardized forces are used to start movement of the isolated structures in the ankle joint. Cautions are to be taken when interpreting results of these biomechanical studies as the ligaments may have a different behavior in-vivo compared to in-vitro as a cadaver exerts no force[36].

CONCLUSION:

The deltoid ligament is a complex structure that needs further studies to better understand the different components and their functions. Understanding the anatomy and biomechanics of the deltoid ligament and its components is useful in regards to the guidance of the anatomical placement of repair or the reconstruction in case of ligament injury or instability.

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