Acta orthop. scand. *54*, 36–44, 1983

DELTOID LIGAMENT

Functional Analysis of the Medial Collateral Ligamentous Apparatus of the Ankle Joint

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On 34 osteoligamentous ankle preparations the function of the various components of the deltoid ligament has been elucidated by tracing mobility patterns after successive transection of the components in varying sequence. The anterior and posterior talofibular ligaments were included in the study to investigate the interaction between these structures and the deltoid ligament. The tibiocalcaneal and the intermediate tibiotalar ligaments control abduction of the talus. The anterior tibiotalar and talofibular ligaments control plantar flexion, while dorsiflexion is inhibited by the posterior tibiotalar and talofibular ligaments, and partly by the anterior talofibular ligament as well. In combination, the anterior and intermediate tibiotalar ligaments control external rotation, while the intermediate and posterior tibiotalar ligaments control both external and, together with the anterior talofibular ligament, internal rotation of the talus. Isolated, neither the anterior nor the posterior tibiotalar ligament appears to play any major role in ankle stability.

Key words: ankle instability; ankle joint; deltoid ligament; ligament injuries

Accepted 25.vi.82

The ankle is a hinge joint enabling dorsiflexion and plantar flexion of the ankle. Since the talus can be looked upon as a badly mounted wheel (Wyller 1963), minor movements in the horizontal plane (Close 1956, Laughman et al. 1980, McCullough & Burge 1980) and in the frontal plane (Rubin & Witten 1960, Sedlin 1960, Quellet et al. 1968) are also possible.

The mobility of the joint is restricted by the collateral ligaments which secure reasonable stability. The role of the lateral ligaments has been fairly well elucidated (Dias 1979, Johnson et al. 1981, Rasmussen & Tovborg-Jensen 1982). Less work has been done on the function of the deltoid ligament, perhaps because there are often fractures of the medial malleolus instead of rupture in the ligamentous substance. Such fractures, however, are usually avulsion fractures, due to traction by the deltoid ligament (Lauge-Hansen 1942).

The present study was designed to investigate the function of the various components of the deltoid ligament and the traumatic mechanisms which may cause their rupture.

ANATOMY

Anatomical descriptions of the deltoid ligament vary within wide limits, as its individual components are only vaguely differentiated. The most detailed description is by Pankovich & Shivaram (1979) who made a distinction between a superficial part, comprising the tibionavicular ligament,

Aided by grants from the Danish Medical Research Council, project No. 12-2109, and from the Foundation for Classical Clinical Research in the Århus University.

the tibiocalcaneal ligament, and the superficial tibiotalar ligament, and a profound part, composed of the anterior and posterior tibiotalar ligaments. They admit, however, that it is difficult to distinguish the various components. For analysing the function of the medial ligamentous apparatus, we found another classification to be more expedient. The deep structures of the deltoid ligament form a broad ligamentous plate, the fibres of which irradiate from the medial malleolus. Both anatomically and functionally it can be divided into three parts, and in the following text the deltoid ligament will be considered to comprise a superficial part, the tibiocalcaneal ligament (TCL), and a profound part, a) the tibionavicular ligament + the anterior tibiotalar ligament (ATTL), b) the intermediate tibiotalar ligament (ITTL) lying deep to the TCL and making up the central part of the deep fibres, and c) the posterior tibiotalar ligament (PTTL) forming the posterior one-third of the profound part (Figure 1).

MATERIAL AND METHOD

The mobility of the ankle joint was measured by an apparatus which renders it possible to record rotatory movements in two planes simultaneously when acting upon the talus by a well-defined torque. In previous papers (Rasmussen et al. 1982, Rasmussen & Andersen 1982) the method has been described in detail.

An osteoligamentous preparation is fixed in a stand and a nail is inserted into the talus, either in the postero-anterior direction to record mobility in the sagittal and horizontal planes or from below, through the calcaneous and into the talus, to record mobility in the sagittal and frontal planes. On the nail a lever is mounted, provided with strain gauges and connected with potentiometers for recording of torque and rotation respectively. The lever is manually moved so that the talus is submitted to a torque of 1.5 nm in the dorsal, medial, plantar, and lateral directions and the ap-

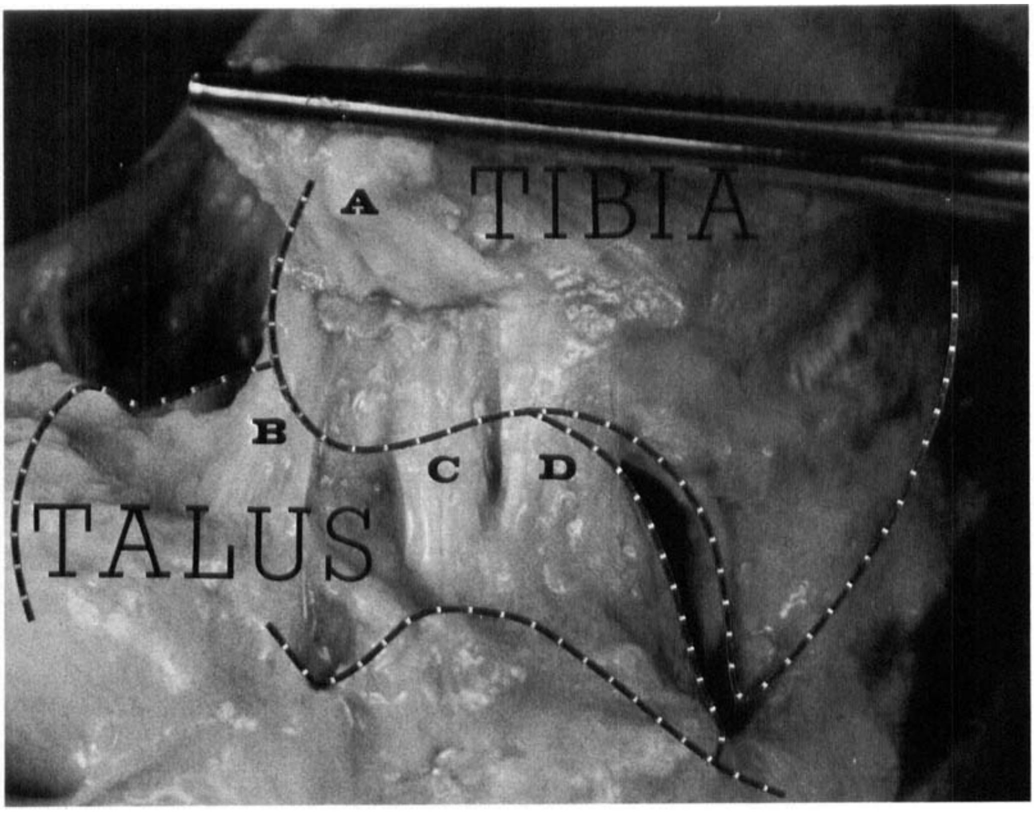

Figure 1. Infero-postero-medial view of the deltoid ligament. a: tibiocalcaneal ligament loosened distally and elevated; b: anterior tibiotalar ligament; c: intermediate tibiotalar ligament; d: posterior tibiotalar ligament.

Table 1. Sequence of ligament transection

Groups	Sequence of ligament transection	No. of ankles examined in sagittal and horizontal planes	No. of ankles examined in sagittal and frontal planes
1	TCL-ATTL-ITTL-PTTL	3	3
2	TCL-PTTL-ITTL-ATTL	3	3
3	TCL-ITTL	3	3
4	TCL-ATaFL-ATTL-ITTL-PTTL	3	1
5	TCL-ATaFL-PTTL-ITTL ATTL	3	1
6	TCL-PTaFL-ATTL-ITTL-PTTL	3	1
7	TCL-PTaFL-PTTL-ITTL-ATTL	3	1

purtenant rotation is depicted as a mobility pattern consisting of a dorsal, medial, plantar, and lateral curve. The resolution for the values of torque and rotation is 0.023 nm and about 0.7°, respectively, so even small alterations in a pattern should be conclusive.

Mobility patterns were traced for 34 osteoligamentous preparations, partly at intact ligaments and partly after successive cutting of the ligaments in the sequence shown in Table 1. Mobility was investigated also after simultaneous transection of anterior talofibular ligament (ATaFL) or the posterior talofibular ligament (PTaFL). On the patterns a movement into the dorsal and plantar direction indicates dorsal and plantar flexion respectively. In the horizontal plane a movement into the medial and lateral direction means internal and external rotation of the talus respectively – in the frontal plane adduction and abduction. Central in each figure is the mobility pattern at intact ligaments.

RESULTS

In all cases the superficial TCL was cut first. This hardly affected the mobility pattern in the sagittal and horizontal planes (Figure 2a), while in the frontal plane it consistently caused a slight increased abduction (Figure 2b).

Below, the seven groups from Table 1 will be presented separately. As mentioned, the TCL has already been cut.

Group 1 (Figure 3a and b)

Transection of the ATTL caused practically no alteration in the patterns in the horizontal and frontal planes, but it slightly increased plantar flexion. After cutting of the ITTL, as well, external rotation, plantar flexion and abduction increased, and after further cutting of the PTTL the ankle joint was so unstable that a mobility pattern could seldom be traced at the chosen torque.

Group 2 (Figure 4a and b)

Transection of the PTTL resulted in only a minimal increase in dorsiflexion. Further cutting of the ITTL again increased dorsiflexion as well as internal and external rotation and, on a dorsiflexed ankle, also abduction. After transection of the ATTL, too, the ankle was completely loose.

Group 3 (Figure 5a and b)

Transection of the ITTL did not essentially affect mobility in the sagittal or horizontal planes, but caused some increase in abduction.

Group 4 (Figure 6)

Transection of the ATaFL entailed increased internal rotation and slightly increased plantar flexion and abduction. There also occurred a minimal increase in dorsiflexion. Further cutting of the ATTL did not essentially alter the pattern in any plane, except that plantar flexion increased a bit. After cutting of the ITTL mobility in all directions increased a little, and after total cutting of the deltoid ligament the joint was utterly unstable. The mobility pattern in the frontal plane is not illustrated, since owing to the anatomical

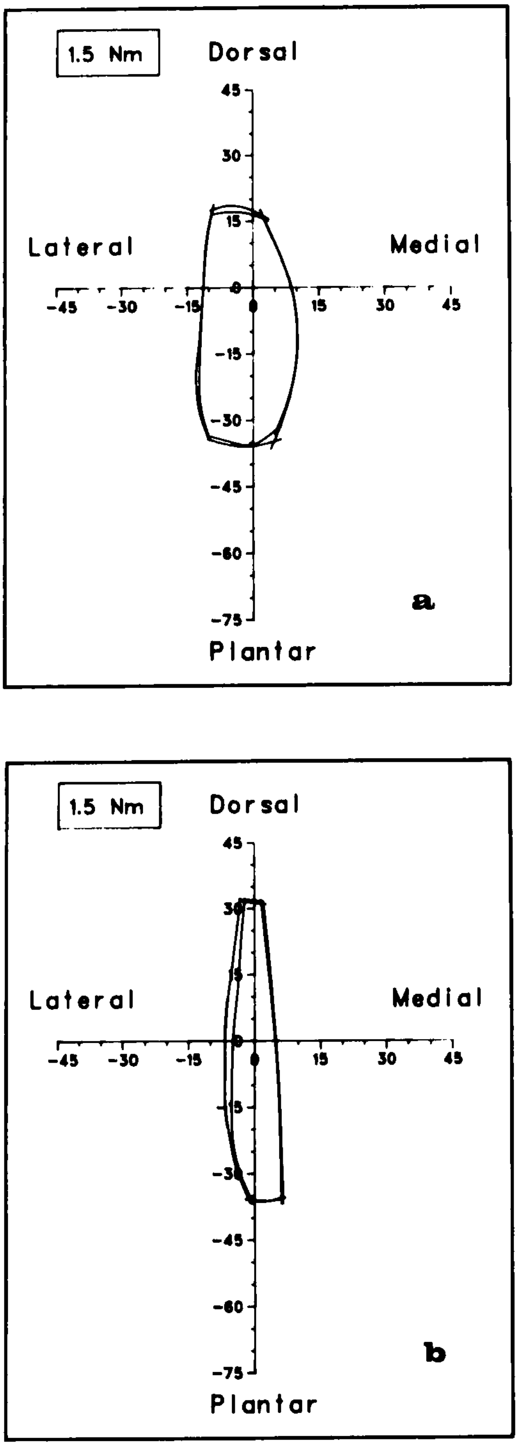

Figure 2. Mobility patterns at intact ligaments and after transection of the TCL – a: in the sagittal and horizontal planes and b: in the sagittal and frontal planes.

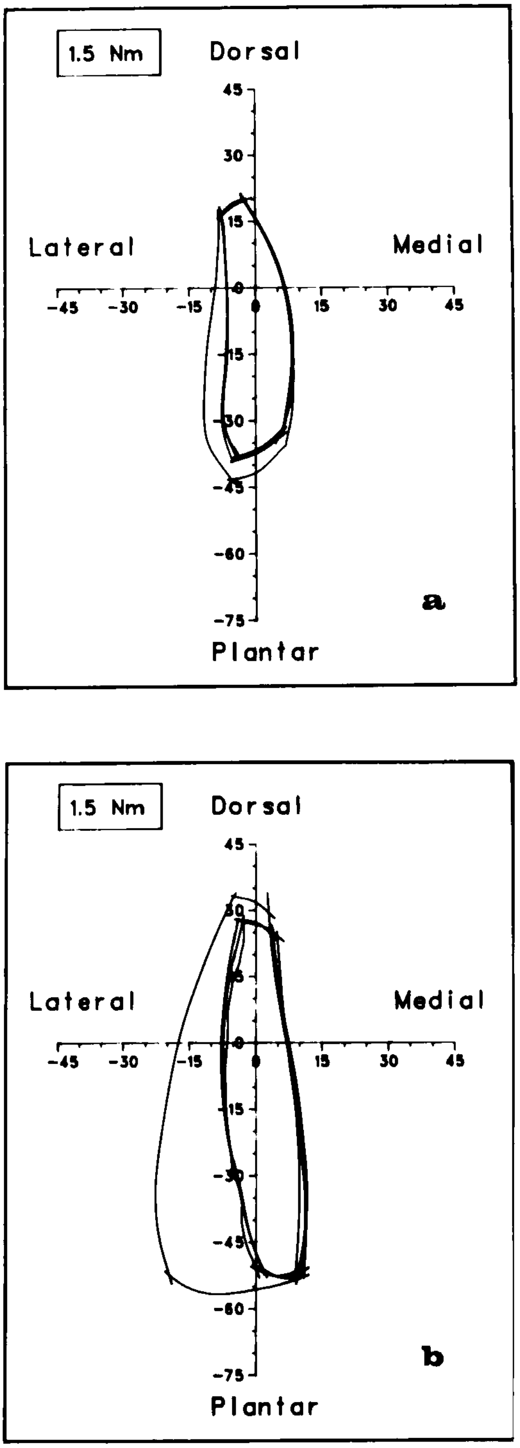

Figure 3. Mobility patterns from group 1. a: sagittal + horizontal plane. b: sagittal + frontal plane.

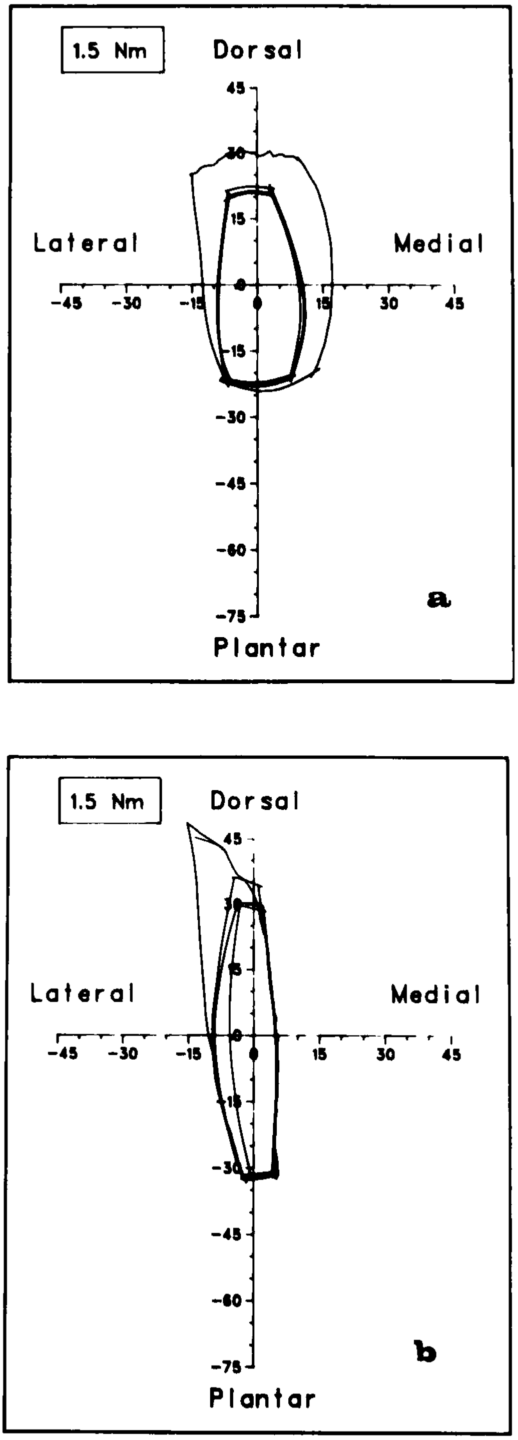

Figure 4. Mobility patterns from group 2. a: sagittal + horizontal plane. b: sagittal + frontal plane.

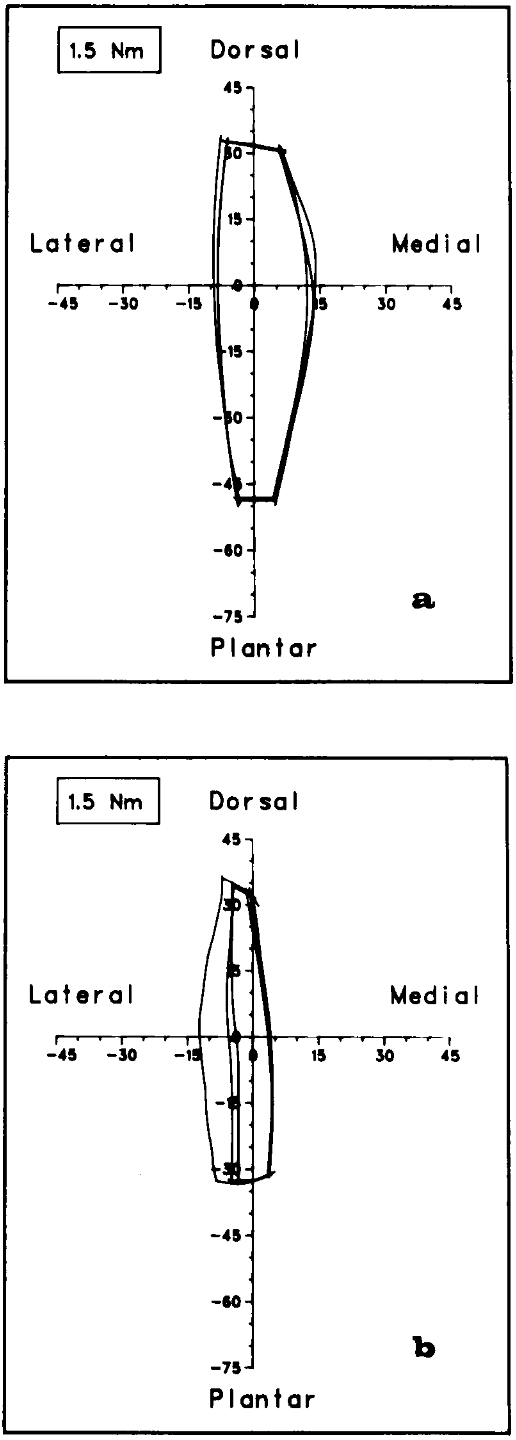

Figure 5. Mobility patterns from group 3. a: sagittal + horizontal plane. b: sagittal + frontal plane.

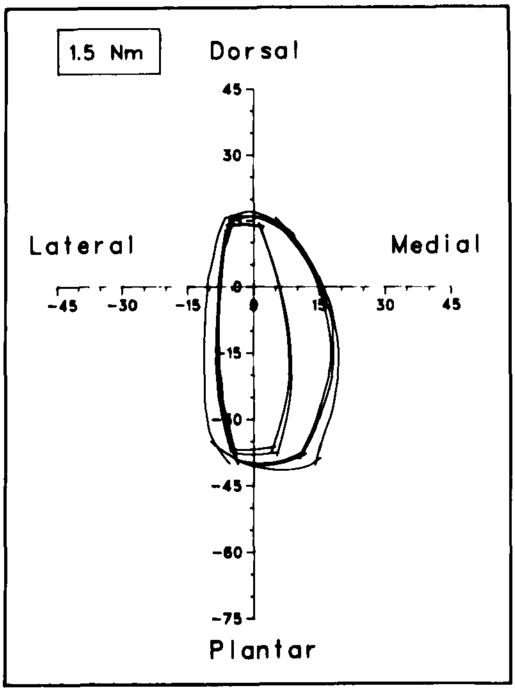

Figure 6. Mobility pattern from group 4. Sagittal + horizontal plane.

conditions the collateral medial and lateral ligaments cannot cooperate in this plane.

Group 5 (Figure 7)

Transection of the ATaFL entailed increased internal rotation which again increased a bit on further cutting of the PTTL. Subsequent cutting of the ITTL caused a massive increase in dorsiflexion simultaneously with a certain abduction, and internal rotation increased a great deal. In the frontal plane transection of the ATaFL did not affect the function of the medial ligaments.

Group 6 (Figure 8)

Transection of the PTaFL did not change the pattern except for a minimal increase in dorsiflexion. Cutting of the ATTL also did not essentially alter the mobility. After the ITTL had been cut, there was an increase in internal rotation on plantar flesion and of external rotation on dor-

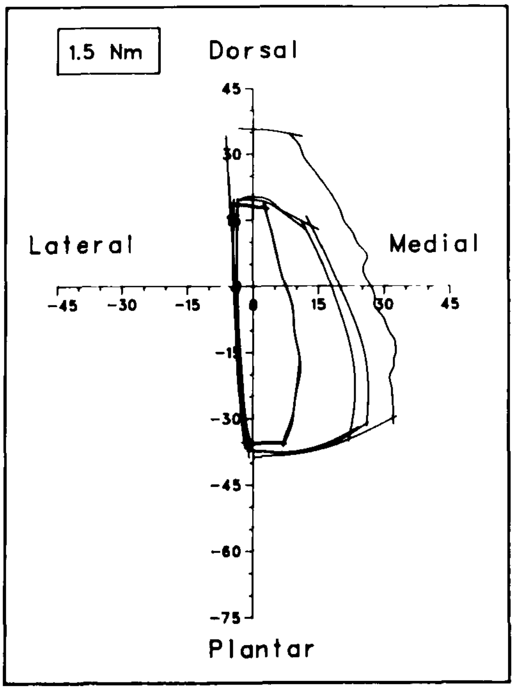

Figure 7. Mobility pattern from group 5. Sagittal + horizontal plane.

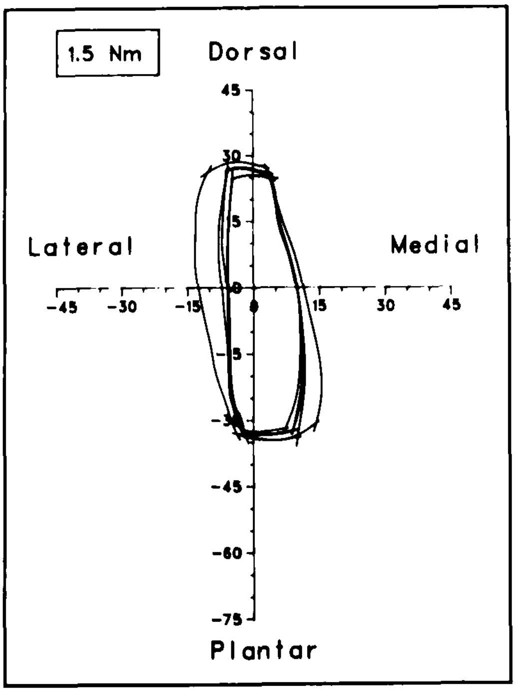

Figure 8. Mobility pattern from group 6. Sagittal + horizontal plane.

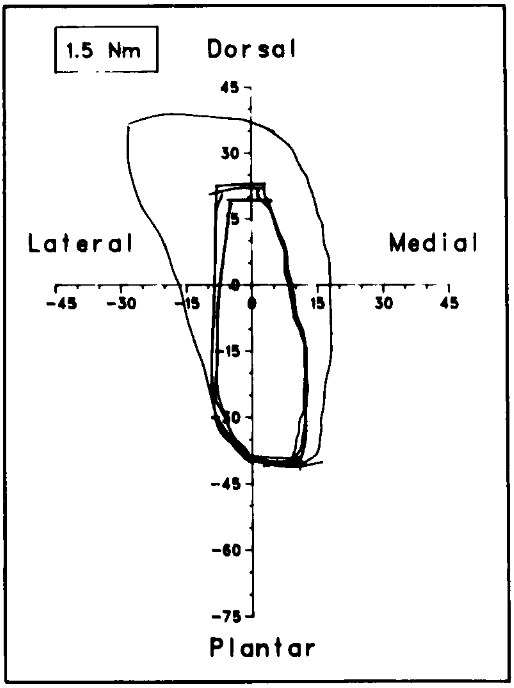

Figure 9, Mobility pattern from group 7. Sagittal + horizontal plane.

siflexion. As might be expected, abduction in the frontal plane also increased. Further cutting of the PTTL made the joint completely unstable.

Group 7 (Figure 9)

Transection of the PTaFL slightly increased dorsiflexion and external rotation. Cutting of the PTTL further increased dorsiflexion, but not essentially the mobility in the horizontal plane. After the ITTL had been cut, dorsiflexion, internal rotation, external rotation and, in the frontal plane, abduction increased.

Table 2 shows which medial ligamentous components primarily control the various movements of the ankle joint. In the course of the present investigation it was observed that absolute mobility in the various preparations varied a great deal, but the changes found after ligament transections were consistent.

DISCUSSION

Grath (1960) stated that the superficial part of the deltoid ligament is of no account in ankle stability. Padovani (1975) found that transection of this structure led to an increased external rotation, and Wirth (1978) found that the TCL grew tense on dorsiflexion and accordingly inhibited this movement. Our findings are contrary to those mentioned, as we found that the TCL restricts no other movement than abduction.

Combined rupture of the ATTL and ATaFL has been described by Broström (1964), who, however, did not discuss the mechanism of trauma. Our studies showed that this lesion may occur as a result of a plantar flexion trauma. Isolated rupture of the ATTL is claimed by Berridge & Bonnin (1944) to result in an abduction of 10° in the ankle joint, and Kleiger (1956) found the ATTl to be the first structure to burst on external rotation. Finding no changes in the mobility patterns after cutting of the ATTL, we cannot agree with them.

Combined rupture of the ATTL and PTaFL

Table 2. The function of the deltoid ligament in motion control

Motion	Motion controlling structures
Dorsiflexion	PTTL (+ PTaFL + part of ATaFL)
Plantar flexion	ATTL (+ ATaFL)
Anterolateral rotation	Deltoid ligament not involved
Posteromedial rotation	ITTL + PTTL
External rotation	ATTL + ITTL or ITTL + PTTL
Adduction	Deltoid ligament not involved
Abduction	TCL + ITTL

might be expected, considering the course of their fibres, from an external rotation trauma, but this was not confirmed by the investigation. However, external rotation becomes particularly marked in the presence of a simultaneous rupture of the syndesmosis between the tibia and fibula (Rasmussen et al. 1982). So, it is not likely that a simultaneous rupture of the ATTL and PTaFL can arise without the tibiofibular ligaments being involved in the injury.

Isolated rupture of the PTTL is described by Cedell (1974) who reports that this lesion may arise from abduction of the dorsiflexed ankle. We found increased dorsiflexion on isolated cutting of the PTTL, but no increase in abduction, and we can merely deduce that such an injury may occur after a dorsiflexion trauma. We also found, unexpectedly, a slight increase in dorsiflexion after transection of the ATaFL, but this accords with de Vogel's observation (1970) that the most plantar fibres of the ATaFL tighten during dorsiflexion. The increased dorsiflexion after transection of the ITTL + PTTL is possible only in the presence of talar abduction, and ITTL is hardly a limiting factor in dorsiflexion of the intact ankle joint.

Isolated cutting of the ATaFL results in an increased internal rotation, viz. an anterolateral rotation of the talus (Rasmussen & Tovborg-Jensen 1982). Transection of the PTTL might be expected to result in an increased internal rotation too, in the form of a posteromedial rotation, but this was not found, until the ITTL had also been cut. As the ATaFL is by far the weakest structure, internal rotation traumas will probably result in a rupture of the ATaFL first.

Cutting of the ITTL did not affect the mobility in the sagittal and horizontal planes, but caused a marked increase in abduction. Thus, the ITTL primarily stabilizes the ankle in the frontal plane.

Rupture of the TCL and ITTL appears to be possible on abduction of the talus. Rupture of the ATTL, possibly together with the ATaFL, may occur on plantar flexion. Rupture of the PTTL, possibly together with the PTaFL, may arise in a dorsiflexion trauma which may also cause a partial rupture of the ATaFL. Combined injury of the ATTL and ITTL may occur on forced external rotation, abduction, and plantar flexion, while rupture of the PTTL together with the ITTL arises on forced dorsiflexion, abduction, external rotation and, presumably after rupture of the weaker ATaFL, on internal rotation. It must be mentioned, however, that the named mechanisms of trauma may easily cause avulsion fractures in the medial malleolus instead of ruptures of the ligamentous substance.

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