On the surgical treatment of chronic anterolateral ankle instability

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Chapter II

DOES A LIGAMENT INJURY OF THE ANKLE JOINT LEAD TO STRAIGHT OR ROTATIONAL INSTABILITY? A CADAVERIC STUDY

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Abstract
The aim of this experimental study was to determine the amount and centre of rotation that occurs when performing an anterior drawer test on a stable and unstable ankle joint. The anterior drawer test was evaluated in 15 fresh human ankle specimens using computed tomography. The specimens were held in a specially-designed testing apparatus in which an anterior translation force of 150 N could be applied in a controlled manner. Testing was performed with intact ligaments and was repeated after sectioning of the anterior talo-fibular ligament and thereafter sectioning of the deltoid ligament.
Both anterior translation and internal rotation of the talus relative to the tibia increased significantly after sectioning of the anterior talo-fibular ligament. The centre of rotation was located at the deltoid ligament/medial malleolus. Sectioning of the deltoid ligament caused the internal rotational component to disappear, producing a straight forward movement of the talus.

We conclude that the anterior drawer test does not produce a straight forward translation of the talus in relation to the tibia, but it is rather a rotatory movement. This rotation is caused by the intact deltoid ligament. This rotational component of the anterior drawer has important implications for the method of testing in the clinical setting.
Introduction
An inversion trauma of the ankle is a combination of four mechanically linked movements in more than one joint; movement of the hindfoot in varus, movement of the forefoot in supination, movement of the forefoot in adduction and movement of the foot and tarsal joints in plantar flexion. Thereby the movements of the talus are; in the coronal plane; varus tilt, in the sagittal plane; anterior translation and plantar flexion, in the transversal or horizontal plane; probably slight internal rotation. Clinical tests for evaluation of acute or chronic ankle laxity can be divided into the talar tilt test and anterior drawer test.

The talar tilt test is clinically impracticable and most often unreliable. The anterior talo-fibular ligament is the most important stabilisator of the ankle joint. It is also the first ligament to rupture during an inversion trauma. Therefore, the anterior drawer test is the most important test for evaluation of acute and chronic ankle laxity.

There are several ways of performing an anterior drawer test. In most test situations, the foot is moved anteriorly relative to the tibia. The foot thereby is placed in 10° to 20° of plantar flexion. It has been postulated that the anterior drawer test does not produce a straight forward translation of the talus in relation to the tibia, but it is rather a rotatory movement of the talus upon the tibia (comparable to the anterolateral rotatory instability of the knee in case of an anterior cruciate ligament rupture). The rotation is caused by the intact deltoid ligament which prevents the talus to move forward on the medial side of the joint. This rotatory instability has been reported by several authors, but the cause of this rotatory instability has never been objectified by experimental studies. The clinical tests known for the evaluation of lateral ligament laxity are only aimed at instability in the sagittal and coronal plane. If a lateral ankle ligament injury causes also a rotatory instability, this has important implications for the method of testing.

The aim of this experimental study was to determine the amount of rotation that occurs when performing an anterior drawer test using standardized evaluation methods. Furthermore, we wanted to determine the centre of rotation during the performance of an anterior drawer test. Our hypothesis was that in case of chronic ankle instability, the anterior displacement of the talus relative to the tibia is a rotational displacement, whereby the deltoid ligament represents the axis of rotation.
Material and methods
The experimental protocol in this study involved measurement of anterior talar translation, internal rotation and talar tilt during a standardized application of an anterior translation force of 150 N. The ankle specimens were held in a specially-designed non-radioopaque testing apparatus in which an anterior translation force could be applied in a controlled manner (Figure 1). Movements of the talus were measured by computed tomography imaging.

Specimens
Fifteen above-the-knee amputated fresh human ankle specimens (mean donor age, 63 years; range, 52 to 75) were harvested soon after death, frozen at -20°C, and thawed at room temperature directly before testing. Specimens with signs of degenerative disease or ligamentous injury were excluded from the study.

Experimental setup
The specimens were transsected with one-third of the distal femoral shaft remaining. To prevent any rotation and axial movement and translation of the tibia and fibula, both were firmly fixed in the testing apparatus by a 5-mm Steinmann pin at the level of the proximal tibiofibular syndesmosis and a 5-mm Steinmann pin just proximally to the distal tibiofibular syndesmosis. At the same levels, two 4-mm cortical screws were passed antero-posteriorly through the tibia. The foot was fixed in 15° of plantarflexion to the footplate of the testing apparatus by a cable tie tightened across the metatarsal heads distally. This allowed rigid fixation of the foot to the footplate, yet, at the same time permitted normal adjustment of the arch of the foot to the anterior translation force. The footplate was attached to a torque wrench that could be adjusted to and locked at any desired anterior translation force (Figure 2). The whole testing apparatus was placed on a standard which tilted the apparatus in an angle of 15°. In this way, the ankle joint which is in 15° of plantar flexion, could be scanned perpendicularly in the transversal plane. The CT-scans (Elscint Twin Flash Spiral) were performed using axial slices of 0.5 mm with the acquisition of coronal and sagittal 2 mm reconstructions. The scanning range was from the distal tibiofibular joint to the level of the subtalar joint.

Testing sequence and procedure
Before testing, the anterolateral joint capsule, the anterior talo-fibular ligament and the superficial fibres of the deltoid ligament on the medial side were exposed. The first CT-scan
was performed without application of the anterior translation force. Thereafter, the torque wrench was locked at a torque of 9 Nm corresponding to an anterior translation force of 150 N to the footplate. In this setting the scan was repeated. After performing the testing sequence with the ligaments intact, the torque wrench was unlocked and the anterior talo-fibular ligament with the surrounding capsular tissue was sectioned. Again, the torque wrench was locked at 9 Nm and the scan was repeated. Finally, the same testing sequence was repeated after sectioning of the superficial and deep fibers of the deltoid ligament.

**Measurement of displacement of the talus**

Movement of the talus was recorded from the axial CT-slices and the coronal and sagittal reconstructions. In this way, talar movement could be measured in three dimensions. For each testing sequence the same CT-slice was chosen to measure the movement of the talus. Anterior talar translation was measured from the sagittal CT reconstructions using Lindstrand’s method which takes the opposing joint surfaces of the talus and tibia as parts of concentric circles in consideration (Figure 3).\(^5\)
Figure 2: Adjustment of the torque wrench at any desired translation force
Figure 3. Anterior drawer measurement according to Lindstrand (1977). The joint surfaces of the tibia and talus run parallel and describe parts of concentric circles. Lines are drawn through the centre of each circle parallel to the axis of the lower leg. Changes in the perpendicular distance between the two lines indicate the anterior displacement of the talus.
When an anterior translation force is applied, the distance is measured between a line passing through the centre of the ‘talus circle’ and a line passing through the centre of the ‘tibia circle.’ Using this method, the starting point is 0 mm of anterior shift. Talar tilt was recorded from the coronal CT reconstructions by measuring the angle subtended by two lines drawn on the tibial and talar articular surfaces. Rotational movement of the talus was recorded from the axial slices. A line along the posterior process of the talar body (A) and a line along posterior rim of the tibia (B) were drawn (Figure 4).

![Figure 4: Transversal plane; line A along the posterior talar process; line B along the posterior rim of the tibia](image)

The angle ($\angle AB$) represents the amount of rotation. In the first testing sequence (i.e. without an anterior translation force and intact ligaments) the amount of rotation is set at 0°. In the following testing sequences line A is projected onto the new slice, in which line A’ is drawn along the posterior process of the rotated talar body. The angle between the projected line A and the new line A’($\angle AA'$) represents the increase of rotation of the talar body after application of an anterior translation force. The point of intersection of line A and A’ represents the centre of rotation of the talus (Figure 5).
Figure 5: transversal plane

Left picture: line A along the posterior talar process; line B along the posterior rim of the tibia; the anterior translation force is applied with intact lateral ankle ligaments.

Right picture: the anterior translation force is applied with dissected lateral ankle ligaments. The angle AA’ represents the increase in internal rotation. The point of intersection of AA’ represents the center of rotation (see text).
In the next testing sequence the deltoid ligament is dissected and the anterior translation force is applied. Line $A''$ represents the new line along the posterior talar process. The angle between the projected line $A$ and the new line $A''$ ($\angle AA''$) represents the amount of rotation of the talar body after dissection of both the lateral ankle ligaments and the deltoid ligament (Figure 6).

Figure 6: transversal plane
Left picture: line $A$ is the line along the posterior talar process when the anterior translation force was applied with intact lateral ankle ligaments; line $A'$ is the line along the posterior talar process when the anterior translation force was applied with dissected lateral ankle ligaments.

Right picture: in this situation the deltoid ligament is dissected. Line $A$ is the line along the posterior talar process when the anterior translation force was applied with intact lateral ligaments. Line $A''$ is the line along the posterior talar process with both the lateral ankle ligaments and the deltoid ligament dissected. Internal rotation ($\angle AA''$) is significantly reduced when compared with the situation with an intact deltoid ligament ($\angle AA'$) as in the left picture.
Data analysis

The motion data of each testing sequence were analyzed and compared using a paired samples t-test. An alpha level of 0.05 was considered significant. Results are presented as means ± standard error of the mean (SEM) unless otherwise noted.
Results

Anterior talar translation
The mean values for anterior talar translation in the different testing sequences are shown in Table I. Sectioning of the anterior talo-fibular ligament resulted in a significant mean increase of anterior talar translation when compared with the intact ankle. The mean difference (SEM) between both test sequences was 4.5 mm (0.49) (p<0.001). When the deltoid ligament also was sectioned, the mean difference (SEM) increased to 8.1 mm (0.78) (p<0.001).

Rotation
The mean values for rotation in the different testing sequences are shown in Table I. After application of an anterior translation force to the intact ankle, we found a mean (SEM) internal rotation of the talar body of 2.03° (0.94) (p=0.048). When the anterior talo-fibular ligament was sectioned, internal rotation of the talar body increased to a mean value (SEM) of 14.2° (1.4) (p<0.001). When the deltoid ligament was sectioned, internal rotation of the talar body decreased to a mean value (SEM) of 0.40° (1.4) (p<0.001).

In all specimens, the talar body rotated around the medial malleolus. Thus, the centre of rotation was located on the medial side in all cases.

Talar tilt
The mean value for talar tilt during the testing sequences varied between 0° and 4°. No significant alterations in talar tilt between the testing sequences could be observed.
Discussion

The principal finding of this study was that during application of a standardized anterior drawer stress, internal rotation of the talus occurs. Internal rotation of the talus increased significantly after sectioning the anterior talofibular ligament. Internal rotation of the talus dissipated after sectioning the deltoid ligament.

The study was designed to assess displacement of the talus during application of a standardized anterior drawer stress torque. Our hypothesis was that in patients with a lesion of the anterior talo-fibular ligament, when performing an anterior drawer test, the anterior displacement of the talus relative to the tibia is a rotational displacement whereby the deltoid ligament represents the axis of rotation. The amount of rotation determined was to be an average of 14.2°. The centre of rotation was the deltoid ligament.

The methods used in this study to measure displacement of the talus have some limitations. As Siegler et al. demonstrated, the ankle has coupled three-dimensional flexibility characteristics. We observed that the foot had a tendency to rotate internally when anterior drawer stress was applied. However, rotational freedom of the foot was not entirely permitted during application of the anterior translation force. Despite this limitation, we still found a significant increase of internal rotation of the talus after application of an anterior translation force. This suggests that there is a certain degree of freedom of rotational movement of the talus in relation to the calcaneus. Another limitation is that the CT-slices may not be taken in exact the same plane during the different testing sequences due to small differences in the testing conditions (i.e. displacement of the testing apparatus in the CT-tube). As we compared the CT-slices from the from the different testing sequences, this might have caused some deviations in our measurements.

The anterior talo-fibular ligament is regarded as the most important ligament of the ankle joint. Investigation of its integrity after trauma or in a chronic condition, therefore, has priority. Numerous authors have reported internal rotatory laxity following rupture of the anterior talo-fibular ligament, often in association with a anterior drawer sign. Rasmussen found that with intact ligaments approximately 8° of internal rotation was possible. After sectioning of the anterior talofibular ligament this increased to about 18°. He concluded that internal rotation of the talus was primarily inhibited by the anterior talofibular ligament. We
found under anterior drawer stress a mean internal rotation of the talus of 2° with intact ligaments and 14° after sectioning the anterior talo-fibular ligament.

In the clinical situation, the physician must evaluate the integrity of the anterior talo-fibular ligament with the anterior drawer in the presence of active contraction of the muscles that bridge the ankle and act to stabilize the joint. Several experimental studies indicate that the anterior drawer test should be performed with the foot between 10° and 20° of plantar flexion for the clinician to detect the largest magnitude of displacement. This is the reason that we chose 15° of plantar flexion of the foot in our cadaveric study.

The findings of our study have important implications for the method of testing the integrity of the anterior talo-fibular ligament. The value of the anterior drawer test has been evaluated in numerous studies. Van Dijk found that the anterior drawer test had, in comparison with arthrography, stress radiography and ultrasonography, the highest sensitivity (96%) and specificity (84%) for detection of a lesion of the anterior talofibular ligament.

As mentioned above, a large increase in internal rotation was observed after sectioning the anterior talofibular ligament during anterior drawer testing. Presumably, a testing technique which limits internal rotation would reduce the sensitivity of the anterior drawer test in detecting a lesion of the anterior talofibular ligament. Therefore, the technique proposed by van Dijk (1994), where the foot is pulled anteriorly and medially, using the deltoid ligament as a center of rotation, may be preferable to a technique where the foot is pulled straight forward (Figure 7).
Figure 7: the technique proposed by van Dijk (1994), where the foot is pulled anteriorly and medially, using the deltoid ligament as a center of rotation.

Conclusion

The anterior drawer test does not only produce straight forward translation, but also significant internal rotation of the talus in relation to the tibia. Internal rotation of the talus is caused by the intact deltoid ligament, which acts as the center of rotation. This rotational component of the talus during the anterior drawer test has important implications for the method of testing in the clinical setting.
Table I. ATT: anterior talar translation
IR: internal rotation
TT: talar tilt
I: anterior drawer with intact ligaments
II: anterior drawer with sectioned anterior talo-fibular ligament
III: anterior drawer with sectioned anterior talo-fibular ligament and sectioned deltid ligament.

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Mean(SEM) 4.4 (0.4) 8.9 (0.5) 12.5 (0.7) 2.0 (0.9) 14.2 (1.3) 0.4 (0.9) 1.8 (0.3) 2.4 (0.4) 2.5 (0.4)
References
