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MOBILITY OF THE ANKLE JOINT

Recording of Rotatory Movements in the Talocrural Joint in vitro with and without the Lateral Collateral Ligaments of the Ankle

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A method for graphic recording of rotatory movements in osteoligamentous ankle preparations is described. By this method it is possible to record characteristic mobility patterns in two planes at the same time. The ankle is affected by a known torque, so that the individual mobility patterns are reproducible with unchanged condition of the ligaments. Six amputated legs were investigated in the sagittal and horizontal planes and another six in the sagittal and frontal planes. Mobility patterns were recorded with intact ligaments and after successive cutting of the lateral collateral ligaments of the ankle in the anteroposterior direction. In the sagittal plane increased dorsiflexion was observed after total cutting of the lateral ligaments, while plantar flexion remained unchanged. In the horizontal plane the internal rotation of the talus increased in step with increasing injury to the ligament, particularly when the ankle was plantar flexed. When all collateral ligaments had been cut, an increase in external rotation occurred, especially in dorsiflexion. In the frontal plane the talar tilt increased gradually with increasing injury to the ligaments. Talar tilt was at a maximum in the neutral position of the ankle or in plantar flexion. After total severing of the collateral ligaments, however, talar tilt was most marked in dorsiflexion of the ankle.

Key words: ankle joint; anterolateral rotatory instability; lateral ligament injuries; mobility patterns; talar tilt

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Traditionally, the talocrural joint is considered to be a hinge joint allowing rotation in the sagittal plane, so that the foot can be dorsal and plantar flexed. Joint stability is provided mainly by the surrounding ligaments. Owing to a certain incongruence between the talus and the ankle mortise (Inman 1976) and because of a certain laxity in the ligaments, however, small movements can occur in the horizontal and frontal planes.

The present study was undertaken in an attempt to elucidate the rotatory movements that can occur in the joint when the ligaments are intact as well as after successive cutting of the anterior talofibular ligament (ATaFL), the calcaneofibular ligament (CFL), and the posterior talofibular ligament (PTaFL), in that order. The order of cutting was chosen as it has been reported (Broström 1964) that in general *in vivo* ruptures start anteriorly and spread backwards.

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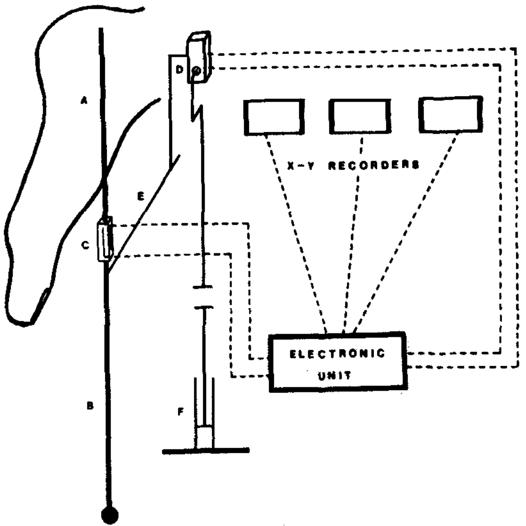

Figure 1. Schematic diagram of the experimental set-up. A: steel nail through the talus, B: lever, C: strain gauges, D: potentiometers, E: connecting arm to potentiometers, F: guiding aggregate for potentiometer arm.

METHODS AND MATERIAL

An apparatus was developed to measure and record rotatory movements in the ankle joint at a given torque.

The apparatus (Figure 1) consists of a lever provided with strain gauges in two planes at right angles to each other, enabling torque measurements in both planes simultaneously. The lever is mechanically connected to two potentiometers which measure rotatory movements in the same two planes. By means of an amplifier unit the signals are transferred to X–Y recorders, one recording the torque and the others the rotation of the talus.

From an amputated leg the ankle region is dissected free. All tendons, major vessels, and nerves that pass the joint are cut. A steel nail is inserted, either postero-anteriorly through the talus and out at the dorsum of the foot (Figure 2a) to measure torque and rotation in the sagittal and horizontal planes, or from below through the calcaneus up into the talus (Figure 2b) to measure motion in the sagittal and frontal planes. The osteo-ligamentous preparation with the inserted nail is placed in a fixture with the ankle joint in its neutral position when no torque is exerted. The preparation and the measuring apparatus are connected, the lever being fastened end-to-end to the inserted nail.

A defined torque will rotate the talus to some degree, or – reversely – rotating the talus to a defined degree will demand some torque. We preferred to keep the torque at a defined magnitude and to record the corresponding talar rotation.

When no torque is exerted, the torque recorder pen will be at the centre of the torque circle (Figure 3). In this situation the ankle joint is in its neutral position. The torque recorder is calibrated to make the magnitude in Nm (Newton metres) of the torque correspond to the radius of the torque circle, i.e. M_0 Nm. The lever, and thereby the talus, can be moved manually in any direction. The torque recorder depicts the magnitude and direction of the torque and the rotation recorder the magnitude and direction of the corresponding talar rotation. When the lever is moved so that the torque recorder follows the periphery of the torque circle, the magnitude of the torque is constant, but its direction alters 360° as the circumduction of the lever continues. Simultaneously the rotation recorder depicts the rotatory movements of the talus by drawing a mobility pattern.

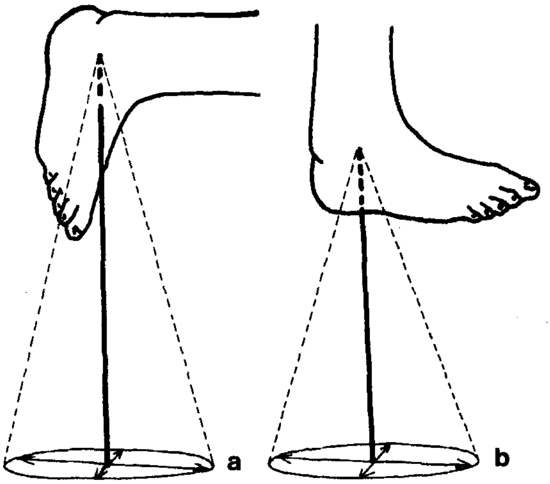

Figure 2. Placement of lever, a: in place for investigation in the sagittal and horizontal planes, and b: in place for investigation in the sagittal and frontal planes.

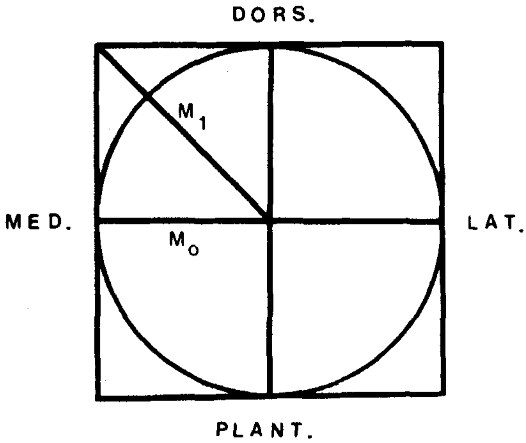

Figure 3. Torque circle with radius M_0 Nm and torque square indicating constant transverse vector at M_0 Nm.

The mobility pattern achieved in this way is well defined and reproducible, but gives no information about the maximum internal or external rotation or the maximum tilting of the talus when the ankle joint is in a dorsal flexed or plantar flexed position. When the torque recorder pen is positioned dorsally, the whole torque, viz. the radius of the circle = M_0 Nm, is directed dorsally, thus bringing the ankle joint into dorsiflexion. In this situation there is no torque in the transverse direction, and accordingly no transverse rotation occurs. In order to record the maximum transverse rotation in any degree of dorsal or plantar flexion the transverse vector causing this motion should be kept constant and at a magnitude of M_0 Nm. This is achieved by letting the torque recorder follow a square, the sides of which are $2 \times M_0$ Nm (Figure 3). The total torque then ranges from M_0 Nm to M_1 Nm, M_1 being $M_0 \times \sqrt{2}$ Nm.

In this study we set M_0 at 1.5 Nm. At a constant transverse vector of 1.5 Nm, then the total torque varies between 1.5 Nm and $1.5 \times \sqrt{2}$ Nm = about 2.12 Nm. We have depicted the mobility patterns at a constant radial torque on one recorder and the patterns at a constant transverse vector on another.

The investigations were performed on 12 amputated legs, recording for 6 legs movements in the sagittal and horizontal planes (Figure 2a) and for the other 6 movements in the sagittal and frontal planes (Figure 2b).

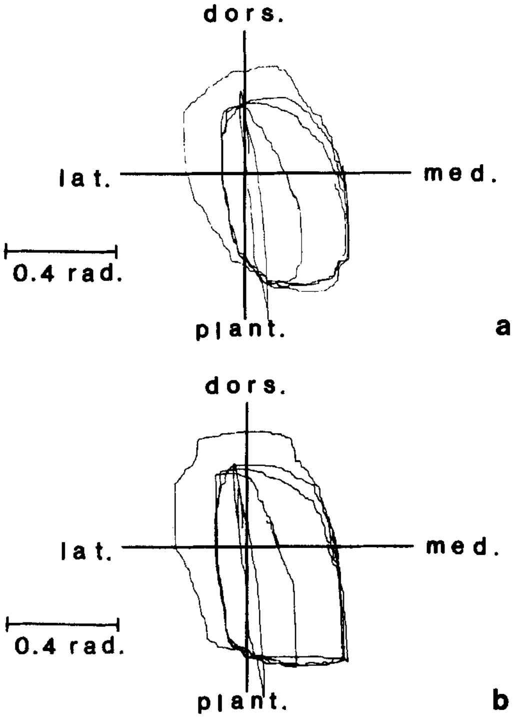

Figure 4. Mobility pattern in the sagittal and horizontal planes, a: at a constant radial torque and b: at a constant transverse vector.

RESULTS

Figures 4a and b give examples of the mobility patterns recorded in the sagittal and horizontal planes. Movement in the medial direction expresses internal rotation of the talus, and in the lateral direction external rotation. The narrow tracing is produced without transverse torque, and it will be seen that a certain spontaneous horizontal rotation occurs during dorsi-plantar flexion. The extent and direction of this movement varied individually and in an inconsistent manner. The innermost, approximately oval tracing represents the mobility with intact ligaments. The next shows what happens after the ATaFL has been cut. Then follows a tracing after cutting ATaFL + CFL, and most externally the situation after cutting all three ligaments.

Dorsiflexion with intact ligaments was found to be 18° (10°–29°), while after transection of all the ligaments it was 28° (13°–38°). There was no increase in dorsiflexion until all ligaments had been cut. Plantar flexion with intact ligaments was 32° (22°–45°). After total severing of the ligaments it averaged 34° (24°–45°); in other words it was practically unchanged.

In the horizontal plane internal rotation of the talus with the ligaments intact averaged 7°, and increased to 18° after cutting of the ATaFL, to 21° after cutting of the ATaFL + CFL, and to 26° after cutting of all three ligaments. Internal rotation was most pronounced when the ankle was plantar flexed, until all ligaments had been cut. Thereafter, it was most marked around the neutral position or in slight plantar flexion. In the same plane the external rotation of the talus averaged 10°. Not until all ligaments had been cut did it increase to an average of 19°, and was then most pronounced when the ankle was dorsiflexed. In other words, external rotation was greatly increased after total cutting of the ligaments.

Figures 5a and b show characteristic mobility patterns in the sagittal and frontal planes. Movement in the medial direction represents talar tilt,

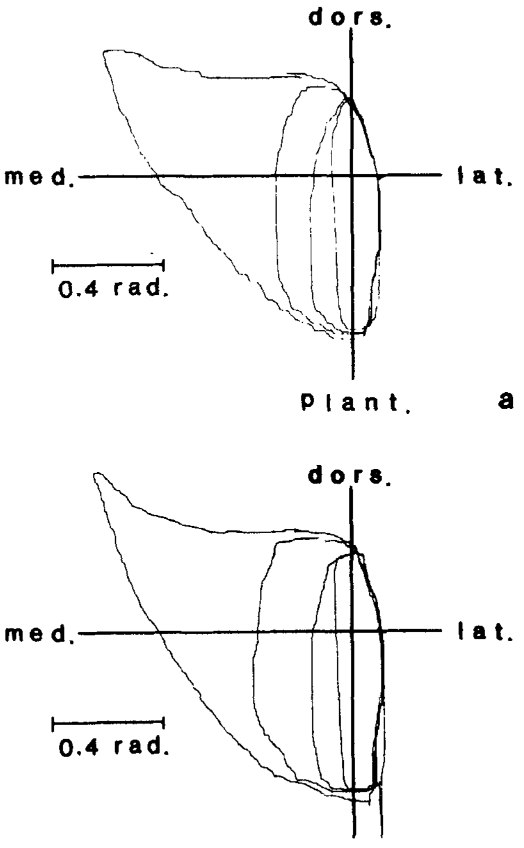

Figure 5. Mobility pattern in the sagittal and frontal planes, a: at a constant radial torque and b: at a constant transverse vector.

while movement in the lateral direction is evidence of a negative or lateral tilt. The narrowest tracing indicates the mobility when the ligaments were intact. The next tracing shows the appearance after cutting of the ATaFL. Outside this is the mobility after cutting of the ATaFL + CFL, and most externally the situation after total severing of all of the ligaments.

When the ligaments were intact dorsiflexion was 17° (9°–22°). After cutting of all lateral ligaments dorsiflexion increased to 22° (11°–28°). Plantar flexion was 30° (19°–38°) with intact ligaments, and after they were cut it was 31° (21°–39°, i.e. unchanged.)

The talus could be tilted an average of 5° laterally, and this was not altered by transection of the ligaments. The true talar tilt was 6° (2°–10°), and it increased to an average of 11°, 19°, and 46° in step with the extent of ligament cutting. After the ATaFL and the ATaFL + CFL had been cut, talar tilt was most marked around the neutral position of the ankle or in plantar flexion, while after total cutting of the ligaments it was most marked in dorsiflexion.

DISCUSSION

Translatory movements which occur in the talocrural joint are not recorded by the present method. Thus, the dorsi-plantar flexion axis of the ankle alters during movement (Barnett & Napier 1952, Hicks 1953). The centre of rotation changes continuously, and several authors have mapped this phenomenon by calculating instant centres (Sammarco et al. 1973, D'Ambrosia et al. 1976, Parlasca et al. 1979).

Nevertheless, we believe that our method of recording is more reliable than previous ones which are based mainly on radiographic technique (Leonard 1949, Weseley et al. 1969, Sammarco et al. 1973) or on goniometric studies *in vivo* (Glanville & Kreezer 1937, Boone & Azen 1979). In particular, we consider it important that the method permits the use of an accurately defined torque, and thereby renders it possible to reproduce the mobility pattern of an ankle as long as the condition of the ligaments is unchanged.

The extent of mobility in the ankle joint earlier reported varies within wide limits. The values for dorsiflexion range from 10° to 51°, and for plantar flexion from 15° to 56° (Glanville & Kreezer 1937, Bonnin 1950, Weseley et al. 1969, Sammarco et al. 1973, Boone & Azen 1979).

In our study the mean dorsiflexion was 18° and the mean plantar flexion 32°. At the same time, we found dorsiflexion to be increased after total severing of the ligaments.

As early as 1934, Dehne stated that injury to the lateral collateral ligaments of the ankle affords a possibility of increased internal rotation of the talus, and this was later confirmed by others (Anderson et al. 1952, Broström 1964). Cedell (1967) has demonstrated the internal rotation radiologically by asymmetry in the joint between the talus and the lateral malleolus, and Lindstrand et al. (1978) have tried to diagnose lateral ligament rupture by demonstrating this incongruence. They found, however, that the method was unreliable. In a previous study we have measured radiologically the abnormal internal rotation which may be induced after injuries to the lateral ligaments, but by that method it was not possible to maintain a defined torque (Rasmussen & Tovborg-Jensen 1981).

In the present study we found the greatest increase in internal rotation to occur already when the ATaFL had been cut. Thus, the corresponding instability – anterolateral rotatory instability – is marked also in injuries affecting only the ATaFL. The marked increase in external rotation of the talus, which we found only after total cutting of the ligaments, has not been described previously. The corresponding instability – posterolateral rotatory instability – is manifest only after extensive injuries to the lateral ligamentous apparatus.

Talar tilt in the intact ankle is generally reported to be from 0° to 10°, although several authors have found values exceeding 20° (Bonnin 1950, Rubin & Witten 1960, Sedlin 1960, Quellet et al. 1968, Duquennoy et al. 1975, Edeiken & Cotler 1978, Cox & Hewes 1979). We found the talar tilt to average 6°, range 2°–10°. In rupture of the ATaFL the talar tilt has been found to be between 5° and 21° (Broström 1965, Fordyce & Horn. 1972, Duquennoy et al. 1975) and after cutting the ligament on osteo-ligamentous preparations the tilt ranges from 0° to 25° (Leonard 1949, Anderson et al. 1962, Pascoët et al. 1972, Duquennoy et al. 1975).

Correspondingly, after cutting the ATaFL, we found a mean talar tilt of 11°, range 9° to 18°. Unlike Glasgow et al. (1980), we did not find the talar tilt to be quite devoid of value in isolated ruptures of the ATaFL, although a mild degree of tilt is hardly conclusive.

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