CHAPTER IV

MATERIAL

4.1 PREPARATIONS

The material for this study consisted of 10 skeleto-ligamentous lower leg-foot preparations from the collection of the Laboratory for Anatomy and Embryology. The preparations were taken from cadavers preserved in toto (intravascular fixation) using the socalled 'vin d'Alsace', composition:

chloral hydrate 300 g, sol. Carolinum facticium 500 g, formalin 36% 0.75 l, alcohol 96% 0.50 l, glycerin 100 ml, phenol 100 ml; add water to 10 l.

The foot-lower leg preparations were obtained by exarticulation at knee level. The skin and subcutaneous tissue were removed, after which the musculature of the lower leg was detached from the foot by severing the tendons at the level of the ankle joint. Good care was taken to ensure that during these manipulations, the capsule and ligaments of the ankle joint should not be damaged. The proximal tibiofibular joint was left in situ.
The subcutaneous tissue and the fatty mass below the plantar surface of the calcaneus were removed.
The 10 preparations were listed under a socalled catalogue number, in this study they will be referred to by numbers 1 to 10 inclusive. The catalogue numbers and the data regarding sex, age and left- or right-sided preparation are shown in Table 4-1.

4.2 MARKING BALLS

The marking pins were perspex rods, approx 18 mm long with a diameter of approx 3 mm, into which were pressed 2 marking balls and a variable number (1 to 3) identification balls.
Both ends of a pin contained the steel marking balls (Ø approx 2 mm). Between them, but closer to one end, they contained 1, 2 or 3 identification balls so that in all we had three types of pins (Figure 4-1). The identification balls were required for the identification in the X-ray film of juxtaposed pairs of marking balls. The

positions of each marking ball in the successive X-rays had to be measured each time in the same sequence, in order to feed them into the computing programme.

Table 4-1. Data anatomical specimen.

Number of specimen	Sex	Age (yrs)	L/R	Catalogue number
1 R	M	79	R	WK 4056
2 R	V	80	R	WK 5186
3 R	V	84	R	WK 4656
4 R	V	76	R	WK 5218
5 R	M	76	R	WK 5185
6 R	V	88	R	WK 4754
7 R	V	64	R	WK 4528
8 L	M	91	L	WK 5165
9 L	M	65	L	WK 1963
10 L	M	59	L	WK 4123

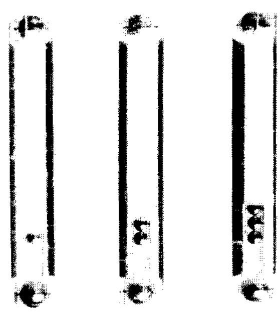

Figure 4-1. Marking pins with marking balls and identification balls.

4.3 EXPERIMENTAL SET-UP

The test cage, specially designed for our experiments, consisted of a rigid steel frame with an internal construction and a construction on top (see Figure 4-2).

The internal construction of the cage (see Figure 4-3) consisted of two plates of duralumin placed at right angles: one horizontal and one vertical. Attached to each of these plates were film cassettes (make ENRAF). The vertical cassette lay in the XZ plane and the horizontal cassette in the XY plane. The X-axis pointed in the direction of the longitudinal axis of the foot.

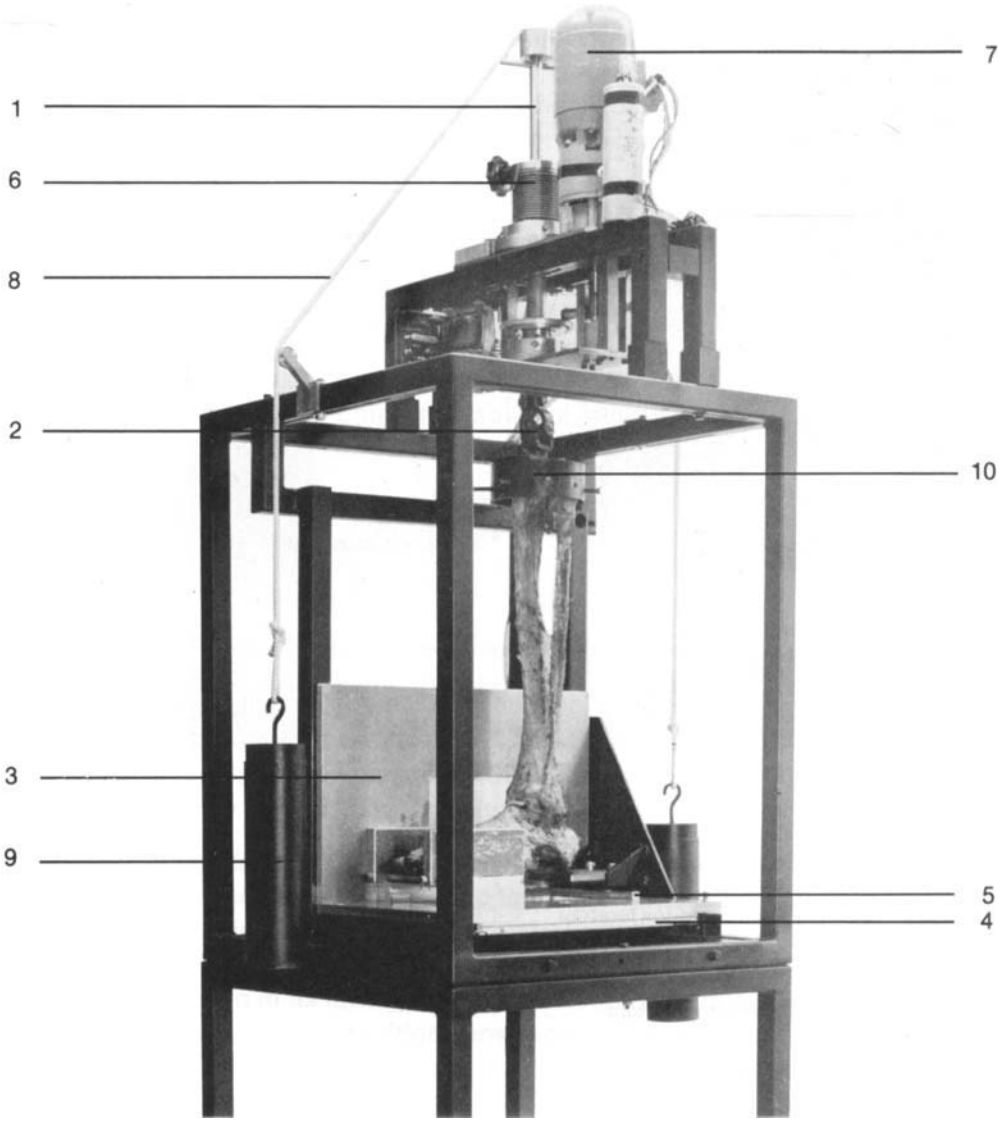

Figure 4-2. Experimental cage for a kinematical analysis of the tarsus moved by external rotation of the tibia.

1. central axis
2. universal joint
3. vertical X-ray cassette
4. horizontal X-ray cassette
5. one bar of reference system
6. bellows
7. electromotor
8. yoke
9. weight
10. locking ring

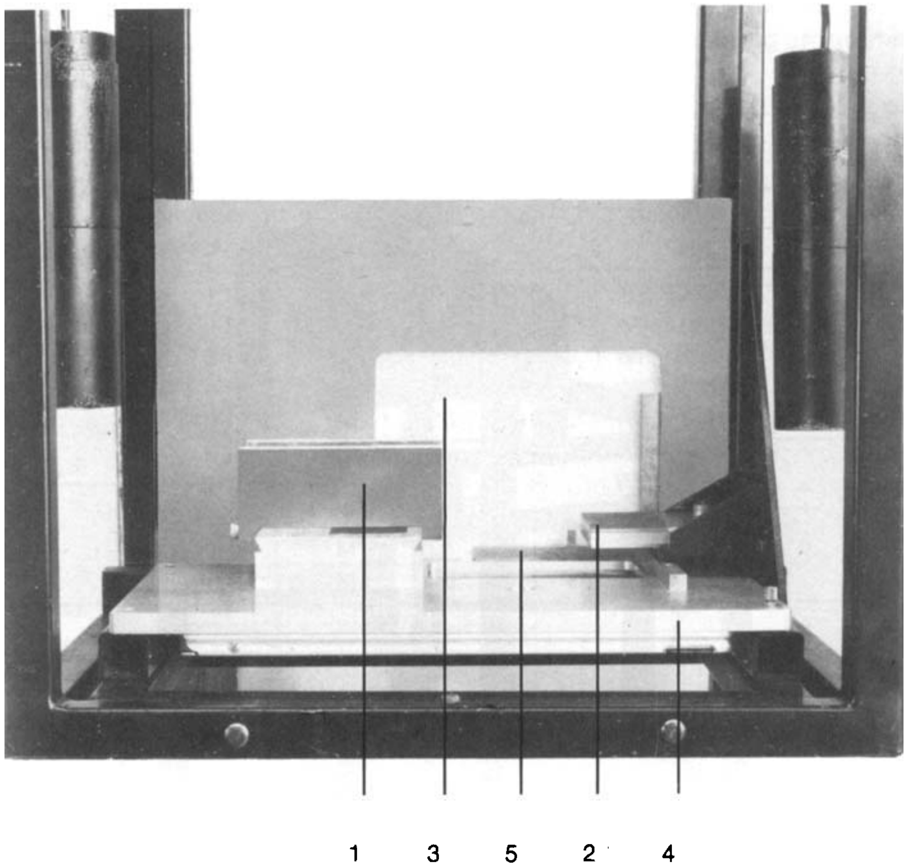

Figure 4-3. Internal construction of the cage.

1. vertical supports for forefoot
2. heel platform
3. vertical X-ray cassette
4. horizontal X-ray cassette
5. bar of reference system

The aluminium cassettes are rather flexible, but by fitting them against the duralumin plates, we ensured good flattening. This was necessary because for the computing procedure the X-ray films have to lie perfectly flat. In the areas where the horizontal and vertical projections, respectively, of the tarsal bones appear in the X-ray films, two small windows were cut out. Copper strips were attached on the horizontal and vertical film cassettes; these strips supply a reference system with origin O_S, formed by certain selected axes of the strips. These strips in their turn carried small steel marking strips at regular distances from the origin.

The copper strips as well as the small steel marking strips appear in the X-rays. With the aid of the steel marking strips, projectional distortions in the X-rays may be calculated (see Chapter 5). Above the level of the axial strips, a horizontal support was constructed on which the heel (calcaneus) of a foot-lower leg preparation could rest. This support was constructed in such a manner that when the foot-lower leg preparation was loaded axially, no measurable deformation of the axial strips occurred. Attached to the surface of this horizontal plane was waterproof emery paper preventing slipping over the lower plane during movement of the heel c.q. calcaneus. The calcaneus, in other words, was not fixed in place. This rendered it possible for the calcaneus to perform its own tilting motion during tibial rotation.
In addition, the internal construction of the cage includes a flat support for the forefoot on which are mounted two adjustable vertical lateral supports. These prevent an abduction of the foot as a whole during exorotation of the tibia.

The reason why the calcaneus is placed in this manner and the lateral supports are fitted is that owing to introduction of two endorotation moments (at the forefoot and friction of the calcaneus), exorotation of the tibia may lead to movements *in* the foot and not to movement of the foot as a whole. This also occurs in the in-vivo situation due to a moment brought about by friction forces between the sole of the foot and the floor. In the experimental set-up there is an axial load on the tibia and there is friction between the calcaneus and the surface of the ankle support. Strictly speaking, therefore, it is not correct to state that the calcaneus is not fixed. We have tried to fix the calcaneus as little as possible, in order to optimally approximate the situation in vivo.

The construction on top of the cage consists of a steel bridge constructed in such a manner that it can move in relation to the cage itself (in the X-direction). It also contains the bearing housing for the central rotation axis. This is a solid steel axis, 1 cm in diameter, with a double bearing in the top structure. This central axis with its suspension in its turn can be shifted over the bridge construction (in the Y-direction). By moving the bridge construction and the axis in directions X and Y, respectively, it is possible for each subsequent experiment to re-position the central rotation axis in relation to the initial position of the tibia of a foot-lower leg preparation (see Chapter 5.3). At the lower end of this central axis there is a steel locking ring in which the proximal part of the tibia can be fixed by means of eight screws. This ring is connected to the central rotation axis by a universal joint coupling. Thus, a rotation of the central rotation axis can be transmitted to the tibia without the necessity of prescribing a single immobile axis of rotation for the tibia which would be an extension of the central axis of rotation of the cage. This does imply, however, that the discrete axis of rotation of the tibia will always pass through the centre of the universal joint and will always intersect with the central axis of the cage. Supination of the tarsus is associated with an elevation of the medial arch of the foot and with an upward movement of the tibia (cf. Huson, 1961, Ambagtsheer, 1978). In order to permit the tibia to undergo this axial translation during rotation, a bellows mechanism is mounted on the central axis of rotation for the transmission of the rotation. This bellows consists of a compressible system of lamellae with a high resistance to torsion.

To recapitulate, the locking ring accordingly has a 4° freedom of movement: firstly, a translation in the vertical direction, secondly, a rotation around this vertical axis and thirdly and fourthly, the rotation around the two axes of the universal joint.

For our experiments, the central axis of rotation had to be rotated in steps of 5° each. For this purpose, the lower part of the central axis of rotation has been fitted with a ratchet mechanism and a graduation in degrees. At every 5°, a pawl can be engaged with the ratchet mechanism to block the axis in that position. In order to avoid excessive 'wear and tear' by the loading due to the rotating moment of the axially loaded foot-lower leg preparation, the central axis of rotation was further fitted with a clamping screw capable of fixing the central axis of rotation in any foot-lower leg position.
The central axis of rotation could also be connected by a cogwheel transmission to an electromotor mounted on the bridge construction. By this electric propulsion, a continuous rotation could be transmitted, at adjustable speed, to the central axis of rotation or to the tibia. This continuous motion was used for the positioning of the preparation in the experimental set-up (Chapter 5.3). The electric propulsion has also been used to study the continuous motion (Benink, 1977).
Fitted on top of the central axis of rotation there is a yoke carrying two weights of 7 kg each, allowing axial loading of the preparation. Via cables and pulleys these weights exerted a vertical force of approx 120 N on the central axis of rotation or the tibia.

4.4 X-RAY EQUIPMENT

The experimental set-up included two roentgen tubes. One tube, type Philips Practix, focus 2 sq.mm was installed beside the cage for the lateral projection of the tarsus (focus B_1). In relation to the coordinate origin O in the cage, this roentgen tube was positioned at approx 140 cm distance in the Y-direction and approx 5 cm above the level of the XY-plane. For the dorsoplantar projection, use was made of the second roentgen tube, type Philips Standard, focus 1 sq.mm (focus B_2).
The X-ray film used was Kodak Definix Polyester 18 x 24 cm (pochettes). These films were left in their special wrappings. The X-ray cassettes in our cage were used only to keep the X-ray films pressed as flatly as possible against the aluminium wall panel of the cassette.