LATERAL ANKLE LIGAMENT INJURY

An experimental and clinical study

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Lateral Ankle Ligament Injury

An experimental and clinical study

PROEFSCHRIFT

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To Igna
and our children
Sanne, Jorn and Meike.
To my parents.

LATERAL ANKLE LIGAMENT INJURY
AN EXPERIMENTAL AND CLINICAL STUDY

CONTENTS

INTRODUCTION AND MOTIVATION

Sport has become one of the most popular methods of spending freetime and consequently is of great social importance.
In recent studies concerning sports injuries in the Netherlands (Boersma-Slütter et al. - 1979, v.Rens - 1982) it was estimated that about 20% of all registered sportsmen sustain a sports injury every year, resulting in about 800.000 sports injuries in one year.
Ankle sprain was found to be the most frequent injury, accounting for 18-21% of all sports injuries. Accordingly, ankle sprain is diagnosed in about 150.000 sportsmen every jear.

The medical consequences of this finding were already clearly recognized in 1975 by Cedell as he stated: "Ankle injuries constitute a quantitative therapeutic problem that must be solved in the best way considering the available economic and medical resources. However, the demand for higher quality in the treatment must not be omitted."

A reliable diagnostic procedure, providing an accurately specified diagnosis would enable an appropriate therapy for ankle sprains. Consequently, all kinds of sequelae, like chronic sprain, ankle instability, damage to the articular cartilage and osteo-arthrosis, resulting from misdiagnosis and mistreatment, can be prevented (O'Donoghue - 1958, Blain et al. - 1962, Grond - 1973, Tonino - 1973, v.Barth - 1975, Fulp - 1975, Kooyman and Ponsen - 1976, McCluskey et al. - 1976, Seiler and Holzrichter - 1977, Stepanuk -1977, Speeckaert - 1978, Jungmichel - 1978, Tausch - 1978).

The study presented in this thesis was set up to evaluate the diagnostic significance of arthrography in diagnosing recent ankle ligament ruptures and to assess the value of early surgical repair of ruptured lateral ankle ligaments as a method of treatment, with the above-mentioned considerations in mind.

The two suppositions underlying this study are:

1. The value of the anterior talofibular ligament in stabilizing the ankle joint is generally underestimated.
2. Early surgical repair can improve the process of ligament healing by providing adequate coaptation of ligament ends, thereby leading to early functional recovery.

The investigations were prompted by the promising results of surgical repair lateral ankle ligament ruptures, obtained in 63 patients within a pilot study, carried out in the period of May 1977 until April 1979 at the surgical department of the Zeeweg Hospital IJmuiden (Head: F. Schreuder M.D.).

The results of a prospective clinical study, carried out at the surgical department of the St. Hippolytus Hospital Delft (Head: W.M. Oosterwijk M.D. Ph.D.) will be compared to the results of other therapeutic modalities as found in literature and will be combined with the findings of an experimental study on the process of ligament healing, carried out at the Laboratory of Experimental Surgery at the Erasmus University Rotterdam, under the supervision of Prof. D.L. Westbroek M.D.

PART I LITERATURE REVIEW

CHAPTER 1 ANATOMY

1.1 Introduction

In the first part of this chapter the normal anatomy of the talocrural and subtalar joints, as found in anatomy textbooks and related surgical literature, is described.

The various osseous and soft tissue components are discussed. Functional anatomy with its biomechanical aspects is the subject of the second part, while in the third part the pathological anatomy, as seen in the case of trauma to the above-mentioned structures, is discussed.

1.2 Descriptive anatomy

1.2.1 Osseous structures

The talocrural joint

The talocrural joint involves the articulation of the dome and both the medial and lateral faces of the talus with the inferior surface of the tibia and the articular surfaces of the tibial and fibular malleoli. It is generally considered as a complex hinge joint. The distal ends of both tibia and fibula form a mortise, bounded on each side by the malleoli of which the fibular malleolus projects more posteriorly and inferiorly than does the tibial malleolus. The talar trochlea fits closely in this ankle mortise. The inferior articular surface of the tibia articulates with the superior surface of the talus, which is wedge-shaped, being wider anteriorly than posteriorly (fig. 1).

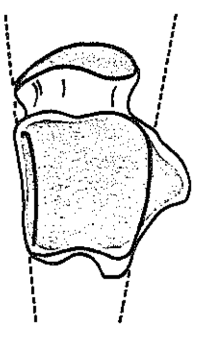


fig. 1
The wedge-shaped configuration of the talus.

On the medial side the articular surface of the medial malleolus is orientated nearly in a sagittal plane and corresponds with the medial articular surface of the talar trochlea.

In the frontal plane the superior surface of the talus is concave. Riede et al. (1971) found a clear correlation between the degree of concavity and age, the talar trochlea of younger people being more concave than of older people. Correlation with other factors like sex, weight, length or profession could not be established.

In the sagittal plane the superior surface of the talus is convex, being more pronounced in younger people.

However, the talar profile flattens to some degree already in the first and second decade, after which it appears fairly constant (Riede et al. - 1973).

The subtalar joints

The subtalar joints consist of two joints: the posterior talocalcaneal joint and the talocalcaneonavicular joint, their joint cavities respectively lying posteriorly and anteriorly of the tarsal sinus, separated by the interosseus talocalcaneal ligament.

The posterior talocalcaneal joint, formed by the posterior inferior articular surface of the talus and the posterior superior articular surface of the calcaneus has a convex-concave saddle-shaped aspect. The talocalcaneonavicular joint can be described as a ball and socket joint. The head of the talus with its convex navicular articular surface articulates with the concave articular surface of the navicular bone, whereas the convex inferior anterior articular surface of the talus articulates with the concave anterior superior articular surface of the calcaneus.

On the medial side the plantar calcaneonavicular ligament shows a fibrocartilagenous part which participates as a functional part of the talocalcaneonavicular joint.

Considerable variation exists in the shape and contour of the subtalar joints which has an important effect on the range of movements in the subtalar joints (Staples - 1965).

The interosseous talocalcaneal ligament is a very strong ligament which, together with fatty tissue and frequently a bursa, occupies the complete tarsal sinus. Its fibers run obliquely from a craniomedial position on the talus to a caudolateral position on the calcaneus, holding the talus and calcaneus firmly together, assisted by the other ligamentous structures of the hind foot.

1.2.2 Joint capsule

The capsule of the talocrural joint is proximally attached to the bone cartilage border of the tibia and the malleoli. Distally it is attached to the talar neck around its superior articular surface. The outer (fibrous) layer is continuous with the fibrous layer of the periosteum of these bones. In accordance with the requirements of free movements in dorsiflexion and plantar flexion the capsule is lax and capacious anteriorly and posteriorly. On the medial and lateral side the capsule is reinforced by distinct ligaments. Between the tibia and the fibula the synovial cavity extends upwards in the tibiofibular recessus, of about 2-2½ cm.

The sensory innervation of the capsule is supplied by the tibial nerve, the sural nerve, the peroneal nerve and the saphenous nerve (Prins - 1978).

1.2.3 Fascia cruris

The fascia cruris covers the muscles of the lower limb and the ankle region and continues distally in the fascia dorsalis pedis. Just proximally to the malleoli, the crural fascia is reinforced by a band of transverse fibers, the superior extensor retinaculum (lig. transversum cruris). A second reinforcement, the inferior extensor retinaculum (lig. cruciforme), is found at the level of the talocrural joint. It covers the long extensors of the foot and consists of two bands: one well-developed band runs from the calcaneus to the medial malleolus, whereas a less well-developed band extends from the lateral malleolus to the tuberositi of the navicular bone (Hafferl - 1969).

On the dorsolateral side, the crural fascia shows a reinforcement running from the tip of the lateral malleolus to the calcaneus. This superior peroneal retinaculum covers the two peroneal tendons. More distally the crural fascia forms the inferior peroneal retinaculum which fixates the peroneal tendon sheath at the level of the calcaneal trochlea.

On the dorsomedial side the crural fascia continues into the flexor retinaculum (lig. laciniatum) which covers the tendon sheaths of the posterior tibial, the flexor digitorum longus and the flexor hallucis longus muscle.

1.2.4 Vascular supply

The lateral malleolar region is supplied arterially by branches of two main arteries. Anteriorly the anterior lateral malleolar artery derives from the anterior tibial artery and supplies the malleolar region by its rete malleolare laterale, a network of small arterial branches. Posteriorly, the peroneal artery derives from the posterior tibial artery and branches into the rete calcaneum laterale.

At the level of the interosseous membrane both arterial networks communicate by the ramus perforans of the peroneal artery.

The venous drainage is provided by a subcutaneous network which communicates superficially with the great and small saphenous veins and furthermore with the peroneal vein and the deep anterior and posterior tibial veins.

1.2.5 Muscular support

The talus has no mobility of its own, it is moved passively by the contiguous bones because all the long foot muscles insert on the metatarsal bones, bridging the talocrural as well as the subtalar joints. These muscles can be classified in four groups, on the basis of their function in relation to the axes of rotation of both ankle and subtalar joints (Wirth et al. - 1978), as shown in fig. 2.

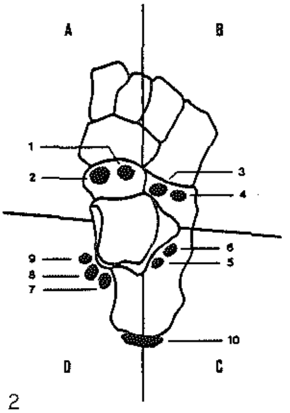


fig. 2
Muscular support of the ankle joint.
(After:Wirth et al.1978)

A. Dorsiflexion, adduction and supination is provided by the extensor hallucis longus muscle (1) and the anterior tibial muscle (2).

B. Dorsiflexion, abduction and pronation is provided by the peroneus tertius muscle (3) and the extensor digitorum longus and brevis muscle (4).

C. Plantar flexion, abduction and pronation is provided by the peroneus longus (5) and brevis (6) muscle.

D. Plantar flexion, adduction and supination is provided by the flexor hallucis longus muscle (7), flexor digitorum longus muscle (8) and the posterior tibial muscle (9).

The main plantar flexion function is provided by the triceps surae muscle (10).

Joint stability among others is based on dynamic stability provided by the muscles of the lower leg. They control and limit the movements of the foot, thus protecting the ankle from stressed positions. Weakness of these muscles can contribute to ankle disability.

As shown in fig. 2 the muscular support on the anterolateral side of the ankle joint is provided only by the small inconstant muscle of the peroneus tertius and by the extensor digitorum muscles. Thus, the muscular support on this anterolateral side is rather weak and provides only minimal protection against non-physiological stressed positions of the ankle joint.

1.2.6 Anatomy of the lateral ankle ligaments

The lateral ligamentous apparatus is composed of three ligaments, each being quite distinct from the other, and each serving a different functional role. The space between the different lateral ligaments is occupied by the thin anterolateral capsule and by the lateral talocalcaneal ligament anterolaterally (fig. 3).

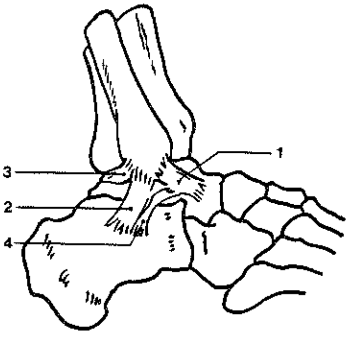


fig. 3
The lateral ankle ligaments:
anterior talofibular ligament (1), calcaneofibular ligament (2), posterior talofibular ligament (3) and lateral talocalcaneal ligament (4).

Anterior talofibular ligament

The anterior talofibular ligament is a distinct and sizable ligament incorporated in the joint capsule, extending from the anterior margin of the lateral malleolus to the neck of the talus, just anteriorly to its lateral articular facet. It is 6-8 mm wide, 12-20 mm long and 2-2½ mm in thickness. The inner surface is covered with a thin synovial membrane. In its course it passes anteriorly and medially and corresponds in this direction with the long axis of the foot. De Vogel (1970) distinguished a superior part, originating from the anterior margin of the lateral malleolus and an inferior part, originating from a more distal point of the anterolateral malleolus. This description was confirmed by Müller (1978). Sosna et al. (1975) studied the lateral ligaments in 80 cadaver specimen and found the anterior talofibular ligament in most cases (81%) to be single, only in a minority of cases to be doubled. Prins (1978), who confirmed the anatomical distinction made by De Vogel in most of his operative cases, described that both parts are usually divided by a small arterial branch.

In the neutral position of the ankle (90° dorsiflexion) the anterior talofibular ligament runs almost horizontally and is relaxed. It is generally agreed that it becomes tightened in plantar flexion and most authors mention that it is relaxed in dorsiflexion, but Broström (1964) and Wirth et al. (1978) stated that this ligament is tense in all flexion positions of the talocrural joint.

De Vogel (1970) concluded that in plantar flexion both parts of the ligament were tightened whereas in dorsiflexion only the inferior part tightens, the superior part being relaxed.

In pathological stress positions, when plantar and dorsiflexion are associated with rotational stress, the anterior talofibular ligament stays quite relaxed in neutral position but is stressed maximally in plantar flexion combined with endorotational force on the talus (Wirth et al. - 1978).

The calcaneofibular ligament

The calcaneofibular ligament is an isolated ligament, anatomically separated from the joint capsule but intimately associated with the posteromedial part of the peroneal tendon sheath. It originates from the anterior surface of the fibular tip, just inferior to the attachment of the anterior talofibular ligament and passes posteriorly, slightly medially and inferiorly to insert on the posterolateral aspect of the calcaneus, bridging the talocrural as well as the subtalar joints. Sometimes its insertion on the calcaneus is marked by a tubercle.
The calcaneofibular ligament is a strong rounded cordlike structure, generally described as about 20 mm long and 6-8 mm in diameter, but it can show considerable variations in size, shape and direction.
Ruth (1961) described his anatomical findings in 75 ankles of which 45 were operated on, the remaining 30 ankles being cadaver specimen, and found the long axis of the calcaneofibular ligament usually (75%) angled from 10-45° posteriorly from the long axis of the fibula. In about 18% this angle was less, and in 4% the angle was found to be more than 45°, extending to 80-90° posteriorly. In the remaining 3% the calcaneofibular ligament was fan-shaped.
Kaye and Bohne (1977) opacified the lateral ligaments of cadaver specimen by means of a special "paint" and visualized them on plain radiographs. By using this technique they demonstrated that the anterior talofibular, calcaneofibular and posterior talofibular ligaments form an almost straight line in a nearly horizontal plane.
V. Moppes and v.d. Hoogenband (1982) concluded on the basis of 20 cadaver dissections that the calcaneofibular ligament is not a distinct extracapsular ligament but has to be regarded as a continuous structure of collagenous fibers inseparable from the joint capsule.
In plantar flexion the calcaneofibular ligament is completely relaxed. In neutral position it is relaxed or may be slightly tensed. It is tightened only by supination of the calcaneus (Broström - 1964, Padovani - 1975, Kooyman and Ponsen - 1976, Speeckaert - 1978) or in dorsiflexion (De Vogel - 1970, Prins - 1978, Wirth et al. - 1978).
In pathological stress positions the calcaneofibular ligament is especially tensed in dorsiflexion-exorotation movements.

The posterior talofibular ligament

The posterior talofibular ligament, like the anterior talofibular ligament, is incorporated in the joint capsule and is considered to be the strongest of the three lateral ankle ligaments. It originates from the medial and posterior aspect of the distal fibula and passes medially and almost horizontally to the

posterolateral aspect of the talus where it has a broad insertion extending from the lateral tubercle of the posterior process to the lateral process of the talus.
In transverse section this ligament is triangular, the top of the triangle anteriorly (de Vogel - 1970), its diameter being approximately 6 mm. As described by Prins (1978) this ligament consists of short fibers running from the lateral malleolar fossa straight to the lateral process of the talus and long fibers passing to the posterior process of the talus.
In plantar flexion and neutral position this ligament is relaxed, except for the short fibers who become tensed in plantar flexion (de Vogel - 1970). In dorsiflexion it is tightened, especially when this is associated with endo-rotation (Wirth et al. - 1978).

The lateral talocalcaneal ligament

The lateral talocalcaneal ligament, together with the anterolateral capsule, occupies the space between the anterior talofibular ligament and the calcaneofibular ligament (Anderson et al. - 1952). Its fibers run from their calcaneal attachment parallel with the fibers of the calcaneofibular ligament to the lateral malleolus, where they separate (fig. 3). A part of this ligament then inserts on the fibula, the remaining fibers blend with the anterior talofibular ligament (Prins - 1978, Stewart and Hutchins - 1978) passing to the lateral articular facet of the talus. Ruth (1961) found the lateral talocalcaneal ligament attached low on the talus in 92% of the examined ankles. Staples (1975) called this ligament "the talar extension of the calcaneofibular ligament".

1.2.7 The medial ligaments

The medial collateral ligament or deltoid ligament is a fan-shaped strong ligamentous structure, irradiating from the medial malleolus to the talus, the calcaneus and the navicular bone. In the midregion the superficial layer is composed of the fairly long fibers of the tibiocalcaneal ligament while a deeper layer consists of the tibionavicular ligament and the short anterior and posterior tibiotalar fibers, intimately associated with the joint capsule (Close - 1956, Den Herder - 1961, Broström - 1964. Staples - 1965, Gerbert - 1975, Rasmussen et al. - 1983).
The middle and posterior part of the deltoid ligament is covered by the tendon sheath of the posterior tibial muscle in much the same way as the peroneal tendon sheath is associated with the calcaneofibular ligament on the lateral side.

1.2.8 The inferior tibiofibular ligaments

The distal tibiofibular ligaments belong to the syndesmosis group, which includes those joints in which contiguous bony surfaces are united by an interosseus membrane, allowing a slightly movable articulation (Outland - 1943). The distal tibiofibular syndesmosis is formed by the convex surface of the medial side of the fibula and the concave surface of the lateral side of the tibia, which is generally referred to as the peroneal groove. This groove is bounded anteriorly and posteriorly by the distal tibial tubercles and its depth can show great individual variations (Bonnin - 1950).

In relation to this joint, the following four ligaments secure the fibula against the tibia in the peroneal groove:

1. The anterior tibiofibular ligament.

This ligament passes downwards laterally and posteriorly, angling 45° with the sagittal plane (de Vogel - 1970) from the anterolateral margin of the tibia to the anterior margin of the lateral malleolus. It is a strong oblique band, about 2 cm wide and almost 5 mm thick.

2. The posterior tibiofibular ligament.

This ligament passes from the posterolateral border of the tibia downwards in anterolateral direction to the posteromedial border of the lateral malleolus.

3. The inferior transverse ligament.

This ligament is composed of the most inferior fibers of the posterior tibiofibular ligament, which are stronger and thicker than the upper and are attached more medially along the posterior edge of the tibial articular surface.

4. The interosseus tibiofibular ligament.

This ligament is generally considered to be the largest and strongest of the tibiofibular ligaments and consists of short, thick fibers from the lateral aspect of the distal tibia downwards to the adjacent medial surface of the lower fibula. These fibers form the limitation of the tibiofibular recessus and are continuous with the interosseus membrane proximally.

The strength of the interosseus ligaments varies individually (Monk - 1969).

In literature it is generally stated that both the anterior and posterior tibiofibular ligaments are tensed in dorsiflexion and relaxed in plantar flexion (de Vogel - 1970, Padovani - 1975).

In contrast, Wirth et al. (1978) found that under these physiological conditions the posterior tibiofibular ligament was relaxed in both plantar flexion and dorsiflexion and slightly tightened in neutral position. In circumstances with pathological stress both tibiofibular ligaments are tightened by outward rotation of the talus in the ankle mortise (Close -1956, Menelaus - 1961, Broström- 1964, Wirth et al. - 1978).

1.3 Functional anatomy

1.3.1 The talocrural joint

As mentioned in chapter 1.2.1 the talocrural joint is usually described as a complex hinge joint or ginglymus. Normally it allows only dorsiflexion and plantar flexion, but owing to a certain incongruence between the talus and the ankle mortise and because of a minor laxity in the ligaments, small movements in the horizontal and frontal planes are possible. The normal range of movements in the talocrural joint shows a wide interindividual variation. Sammarco et al. (1973) studied the range of motion in both weightbearing and non-weightbearing conditions, using 22 ankles of normal people, varying from 20 to 65 years in age. Roaas and Anderson (1982) examined 108 normal people, aged 30 to 40 years, and studied the range of motion in the non-weightbearing joint. The results are listed in table 1.

The amplitudes of motion of left and right ankles were constantly similar and thus comparable (Roaas and Anderson - 1982). Moreover a tendency was found for the range of motion to decrease with increasing age (Sammarco et al. - 1973).

Table 1: Normal range of motion of the talocrural joint in weightbearing and non-weightbearing condition, as found in literature.

	weightbearing	non-weightbearing	
author	Sammarco et al. (1973)	Sammarco et al. (1973)	Roaas et al. (1982)
total range varying from to:	24°-75°	29°-63°	15°-95°
average range of plantarflexion:	23°	23°	40°
average range of dorsiflexion:	21°	23°	15°

The location of the axis of motion of the talocrural joint has been a matter of dispute for a long time. At first the talocrural joint was seen as a simple hinge joint in which the articular surfaces were described as part of a cylinder in which flexion movements take place around a fixed axis, running horizontally in a frontal plane.

In 1952 Barnett and Napier (quoted by Riede et al. - 1971, Schenk - 1978, Wirth et al. - 1978, Huiskes - 1979) described their findings and showed that the lateral sagittal profile of the talus resembles a part of a circle with its centre at the distal end of the fibula, whereas the medial sagittal profile shows an anterior curvature, being stronger than the posterior curvature. They concluded from this that the axis of motion of the talocrural joint differs

in plantar flexion and dorsiflexion, resulting in a lowering of the axis of motion in the medial side during plantar flexion and a rising on the medial side during dorsiflexion.
In 1976 Inman (quoted by Schenk - 1978, Wirth et al. - 1978, Huiskes - 1979, McCullough and Burge - 1980) showed that a single axis of motion for the talocrural joint exists, perpendicular to the lateral articular surface of the talus and running between the tips of both malleoli.
If the talus profile is measured perpendicular to this axis, then the differences in the curvature of the lateral and medial talar profile, as found by Barnett and Napier, are reduced to nil. The talus then can be described as part of a conus, with its base on the lateral side. The medial face is not perpendicular to the axis of rotation, but shows a slight deviation of 6° (fig. 4) which explains the elliptical curvature of the medial talar profile.

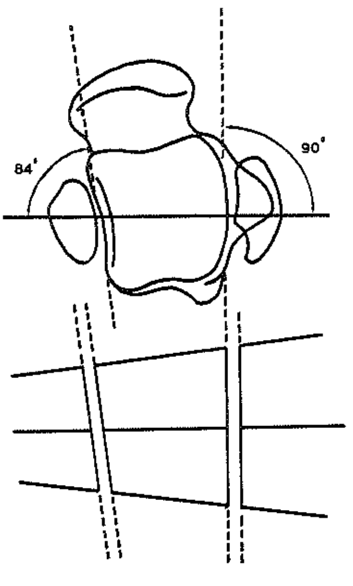


fig. 4
The talus is a section of a conus.
(After: Inman, 1976)

Regarding the rotatory movements made by the talus during dorsiflexion and plantar flexion different opinions are encountered in literature. According to Riede et al. (1971) and Wirth et al. (1978) the talus shows exorotation during plantar flexion and endorotation during dorsiflexion, resulting from the theory that the axis of motion of the talocrural joint is lowered medially during plantar flexion and raised medially during dorsiflexion (Barnett and Napier).
In contrast, Spier and Henkemeyer (1977), Rüter and Burri (1978) and McCullough and Burge (1980) concluded that the talus shows endorotation during plantar flexion and exorotation during dorsiflexion based on Inman's theory of the talus being a section of a conus.
The distal fibula, in order to preserve the close guidance of the talar movements in the ankle mortise, follows the rotatory movements as the talus during dorsiflexion and plantar flexion. Consequently, the same difference in opinion is found in literature concerning the rotatory movements made by the distal fibula. This contradiction is also noted by De Vogel (1970) in his

comprehensive study on functional anatomy.

The wedge-shaped talus is about 1½ mm wider anteriorly than posteriorly (Close - 1956, Grath - 1960, Den Herder - 1961, Golterman - 1965, De Vogel - 1970, Schenk - 1978) (fig. 1).
In enabling dorsiflexion whereby this wider anterior part occupies the ankle mortise, the distal fibula shows a range of motions in the frontal and sagittal plane and it moves longitudinally and rotates. The range of this motion averages 1-3 mm ventrodorsally, 1-2 mm mediolaterally, 0.5 mm craniocaudally and 2-3° in rotation (Bonnin - 1950, Weber - 1972, Spier and Henkemeyer - 1977, Henkemeyer - 1978). These movements occur in the inferior tibiofibular joint and are possible because of the orientation of the fibers in the inferior tibiofibular ligaments running in caudolateral direction (Golterman - 1975, Cedell - 1975).

1.3.2 The subtalar joints

The movements of the subtalar joints are closely related to the movements in the talocrural joint and the midtarsal joints, forming a functional entity. The total range of motion from full eversion to full inversion varies individually between 30-100° (Roaas and Anderson - 1982), the average inversion and eversion being both about 28°, but the position of the talus in the talocrural joint influences the degree of inversion and eversion of the foot occuring in the subtalar and midtarsal joints. Plantar flexion in the talocrural joint increases the range of inversion by approximately 10° (Makhani - 1962).
The axis of motion of the subtalar joints is a composition of several axes related to the different joint surfaces and was described first by Hicks in 1953 (quoted by Wright et al. - 1964). This axis passes from the anteromedial side of the talus, obliquely to the posterolateral side of the calcaneus and usually forms an angle of 10-15° with the sagittal plane and 45° with the horizontal plane (fig. 5).

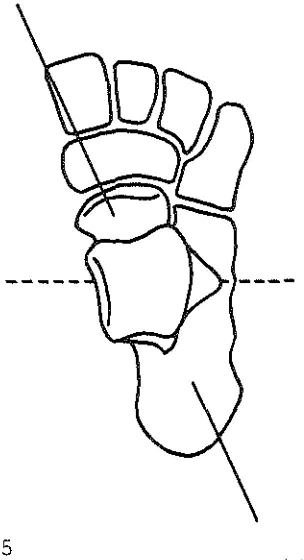


fig. 5
The axis of motion of the subtalar joints in relation to the axis of motion of the talocrural joint.

1.3.3 - Biomechanical aspects

The stability of the talocrural joint is provided by:

1. The congruency of the articular surfaces.
2. The muscles of the lower leg (dynamic support).
3. The ligamentous apparatus of the ankle (static support).

ad 1 - The congruency of the articular surfaces.

In neutral position of the talocrural joint the talus fits snuggly into the ankle mortise. Because of this congruency, the talocrural joint is relatively stable. In plantar flexion the posterior part of the talar trochlea, being less wide than the anterior part, occupies the ankle mortise, giving rise to certain rotational movements of the talus within the mortise, leaving the talocrural joint relatively unstable (Close - 1956, Den Herder - 1961, Percy et al. - 1969, Gerbert - 1975).

ad 2 - The muscles of the lower leg (dynamic support).

Insufficient muscular support from the muscles of the lower leg leads to functional instability ("subjective instability").

In case of capsuloligamentous rupture, afferent nerve fibers and mechanoreceptors, who control the instantaneous and qualitatively precise contractions of the muscles of the lower leg, are ruptured, leading to a disturbance of the ligamentomuscular proprioceptive reflex (Freeman - 1965, v.Enst - 1968).

ad 3 - The ligamentous apparatus of the ankle (static support).

Insufficient ligamentous support due to ankle ligament rupture leads to mechanical instability ("objective instability"). It is important to establish the specific value of the various ligaments in their contribution towards stability. Therefore several kinematic principles have to be brought into discussion.

a. The visco-elastic properties of a ligament.

A ligament with low elastic properties is stronger and provides more protection against pathological movements than a ligament with high elastic properties, which will in turn be tougher (Huiskens - 1979).

In contrast Sauer et al. (1978) reported that the highest tensile strength is found in ligaments with high elastic properties. From experimental investigations they concluded that the inferior tibiofibular ligaments show the highest tensile strength combined with the highest elastic properties, whereas the anterior talofibular ligament of all ankle ligaments has the lowest tensile strength and the lowest elastic properties.

b. The importance of the position of the ligaments in relation to physiological movements.

When a ligament inserts at the rotational axis of the joint, it will allow free

and undisturbed physiological motion. The axis of motion of the talocrural joint runs between both malleolar tips (see 1.3.1). All three lateral ankle ligaments have their insertion at the lateral malleolar tip, therefore allowing free and undisturbed physiological motion in the talocrural joints.
The calcaneofibular ligament also bridges the subtalar joints. Its attachment on the posterolateral aspect of the calcaneus is not exact in the axis of motion of the subtalar joints, but it reaches closely and will therefore not interfere seriously with physiological subtalar motion.

c. The importance of the position of the ligaments in relation to pathological movements, i.e. their importance in relation to stability.

When a ligament is orientated perpendicular to the plane in which the joint surface is orientated, it will give maximal protection against pathological movements, in other words, it will give maximal stability. When a ligament is orientated parallel to, i.e. in the same plane as the joint surface, it will give no stability to this joint.

When considering the position of the lateral ankle ligaments in relation to the movements in the talocrural joint and their subsequent possibilities to prevent pathological movement, i.e. to stabilize the ankle joint, the following can be determined.
In neutral position (90° dorsiflexion) (fig. 6A) the anterior talofibular ligament is relaxed and orientated almost horizontally, parallel to the long axis of the talus and perpendicular to the long axis of the tibia (Anderson et al. - 1952, Hupfauer - 1970, Röhlig - 1978, Rockenstein - 1978). In this position it will not withstand (pathological) supination in the talocrural joint.

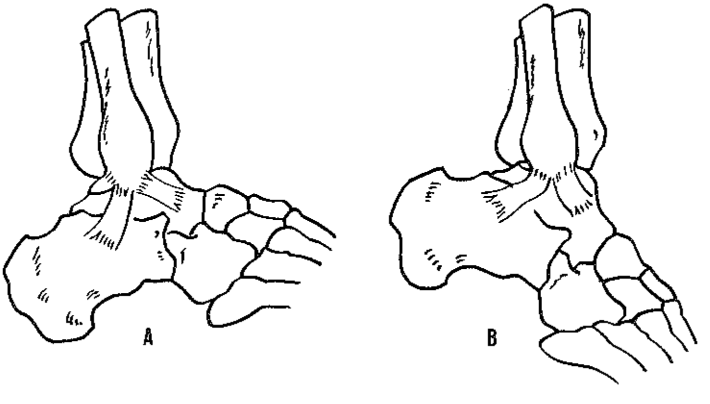


fig. 6
The position of the lateral ankle ligaments in neutral position (A) and in plantar flexion (B).

In this position of the foot, the calcaneofibular ligament runs posteriorly in an angle of 10-45° to the long axis of the fibula (Ruth - 1961) or even more horizontally (Kaye and Bohne - 1977, Müller - 1978), is slightly tensed and will only moderately resist pathological supination in the talocrural joint. Because of its position perpendicular to the subtalar joints it has an important function in stabilizing these joints. For the posterior talofibular ligament, completely relaxed and running medially in a horizontal plane, it is impossible to stabilize the talocrural joint.

In plantar flexion (fig. 6B) the anterior talofibular ligament becomes orientated almost vertically (Anderson et al. - 1962, Hupfauer - 1970, Röhlig - 1978, Rockenstein - 1978, Klein et al. - 1981), i.e. parallel to the long axis of the tibia, thus perpendicular to the plane in which the talocrural joint surface is orientated. In this position it will give maximal stability to the talocrural joint. On the contrary the calcaneofibular ligament now is orientated completely horizontally, stabilizing only the subtalar joints in relation to which it has not changed its direction. The posterior talofibular ligament again is horizontally or even superiorly orientated and does not support the talocrural joint.
Thus, in plantar flexion the anterior talofibular ligament is the only ligament stabilizing the talocrural joint on the lateral side.
The talocrural joint, because of anatomical considerations concerning the talus, is relatively stable in neutral position. As is discussed here, in this position the only moderate ligamentous support is derived from the calcaneofibular ligament.
In plantar flexion, the talocrural joint being relatively unstable, the only ligamentous support is provided by the anterior talofibular ligament. Therefore it is stated that the anterior talofibular ligament is the most important stabilizing ligament of the ankle (Güttner - 1941, Leonard - 1949, Anderson et al. - 1962, Broström - 1966, Cedell - 1975, Hackenbruch and Karpf - 1977, Johannsen - 1978, Grønmark et al. - 1980).
As early as in 1934 this was recognized by Dehne, when he stated: "Das Ligamentum talofibulare anterius ist also der Schlüssel zum oberen Sprunggelenk".

1.4 Pathological anatomy

1.4.1 Trauma mechanism

Lateral ligamentous injury is a much more common entity than ligamentous injury on the medial side. In literature several explanations are found for this clinical finding. Firstly, the oblique axis of the subtalar joint favours movement in the direction of inversion. Secondly, the strength of the lateral ligaments is considerable less compared to the medial side (Sauer et al. - 1978). Thirdly, in plantar flexion, the position in which most ankle sprains occur, the ankle joint is relatively unstable, as was mentioned before.

Inversion and eversion normally occur in the subtalar joints, but can be considered abnormal movements when occuring in the ankle joint. Internal and external rotation of the foot are essentially abnormal movements in both the talocrural and subtalar joints.

The most frequent mechanism by which lateral ankle ligament rupture is sustained, is the typical plantar flexion-inversion injury. In plantar flexion the anterior talofibular ligament is tightened, its tension being directly proportional to the degree of plantar flexion. In this position the calcaneofibular ligament, because of its almost horizontal position, does not protect the ankle against inversion stress.

Many authors have demonstrated that in these plantar flexion-inversion injuries the elements of lateral ligaments tear in a predictable sequence (Güttner - 1941, Dehne - 1943, Leonard - 1949, Coltart - 1951, Anderson et al. - 1952, Bosien et al. - 1955, Broström - 1964, Staples - 1965, Percy et al. - 1969, Dietschi and Zollinger - 1973, Grond - 1973, Tonino - 1973, Bouretz - 1975, Guise - 1976, Rechfeld - 1976, Hackenbruch and Noesberger - 1976, Kooyman and Ponsen - 1976, Seiler and Holzrichter - 1977, Wolf - 1978, Dias - 1979).

Whenever a plantar flexion-inversion movement goes beyond the point of its ligament containment, firstly rupture of the anterior talofibular ligament (ATaFL) occurs, together with the anterolateral joint capsule (single ligament rupture). With further forceful inversion, the calcaneofibular ligament (ATaFL+CFL) is also torn (double ligament rupture). Generally it is stated that only very rarely in extreme trauma, rupture of the posterior talofibular ligament (ATaFL+CFL+PTaFL) is seen (triple ligament rupture).

Accordingly, the anterior talofibular ligament is most commonly involved in lateral ligament rupture. Moreover, a complete rupture of this ligament may occur because of its relative thinness with a force which would only produce a minor sprain to a stronger ligament, such as the calcaneofibular ligament. Summarizing these facts, Bouretz (1975) described the anterior talofibular ligament as "le ligament de l'entorse".

When -following rupture of the anterior talofibular ligament- the ligamentous injury has failed to heal, renewed trauma can more easily lead to concomitant rupture of the calcaneofibular ligament and possibly to rupture of the posterior talofibular ligament (Pascoët et al. - 1972). This mechanism is known as "two-stage ruptures" (Heim and Famos - 1976).

1.4.2 - Extent of injury

Capsular tear without accompanying ligamentous damage is unlikely because of the capacious laxity of the joint capsule anteriorly and posteriorly. The ligamentous structures therefore form a more limiting factor in pathological movements and thus are more likely to rupture than the joint capsule itself.

Table 2: Literature findings concerning the incidence (%) of the extent of injury as found at operation.

Author	number of patients operated	isolated rupture ATaFL (%)	isolated rupture CFL (%)	rupture of ATaFL and CFL (%)	rupture of ATaFL, CFL and PTaFL (%)	criteria for surgical exploration
Broström (1964)	105	74	—	23	3	arthrography (+)
Judet (1975)	70	20	—	63	17	not montioned
Bouretz (1975)	104	13	3	58	26	not mentioned
Duquennoy et al. (1975)	98	13	—	60	27	talar tilt > 15°
Staples (1975)	27	11	—	81	8	talar tilt > 10° or arthrography (++)
Kooyman et al. (1976)	80	—	—	32.5	67.5	talar tilt > 6°
von Scheidt (1977)	180	—	—	90	10	talar tilt > 10°
Speeckaert (1978)	58	8	—	92	—	talar tilt > 10°
Emerson (1978)	17	18	—	76	6	talar tilt difference > 10°
Rockenstein (1978)	102	12	—	78	10	talar tilt difference > 2°
Lindholmer et al. (1978)	102	40	—	60	—	arthrography (+)
Seiler et al. (1978)	127	51	—	45	4	ADS > 3 mm
Prins (1978)	69	24	2	32	42	arthrography (++)
Grønmark et al. (1980)	95	56	—	44	—	talar tilt > ?°
Schweiberer et al. (1981)	127	46	—	50	4	ADS difference > 3 mm
v. Moppes et al. (1982)	50	38	—	62	—	arthrography (+)

ADS = anterior drawer sign
Arthrography (+) = assumed single or multiple ligament rupture
arthrography (++) = assumed multiple ligament rupture

Rupture of the anterior and posterior talofibular ligament is always associated with rupture of the joint capsule because these ligaments are incorporated in the joint capsule (fig. 7). The incidence of the extent of injury as observed at operation by different authors is listed in table 2.

It is evident that this incidence is dependent on the criteria used as indication for surgical exploration. The data given in table 2 are a reflection of these criteria, resulting in the fact that most authors observed far more double ligament injuries than single ligament ruptures.

Isolated rupture of the calcaneofibular ligament is a rare injury which can occur in a dorsiflexion-inversion injury (Speeckaert - 1978, Prins - 1978). Bonnin (1950) and Tonino (1973) stated that this could also occur with the ankle joint in neutral position. Prins (1978) mentioned one patient with this type of injury in a selected group of 69 operated patients. As shown in table 2 most authors did not encounter this injury.

Rupture of the posterior talofibular ligament is described with a remarkably varying frequency. This is explained by two reasons: firstly, this type of injury is not always recognized (Bouretz - 1975) and secondly, rupture of the posterior talofibular ligament is mostly a partial rupture from its talar insertion, which can easily be overlooked or not classified correctly (Broström - 1964).

Rupture of the anterior talofibular ligament and posterior talofibular ligament without demonstrable associated injury to the calcaneofibular ligament is described by Prins (1978). In these (rare) cases he found the calcaneofibular ligament to pass in a distinct posterior course, enabling a wider talar tilting which produces the above mentioned ligamentous injury.

1.4.3 Location of rupture

Rupture of a ligament can occur along its course in the ligamentous substance, at its periostal attachment or as an avulsion fracture. The latter is described as rare (Ruth - 1961). Broström (1964) found avulsion fractures (varying from tiny cortical fragments to fragments of 1x1 cm) in 7% of anterior talofibular ligament rupture and in 4% of calcaneofibular ligament rupture. According to literature the anterior talofibular ligament most frequently (60-70%) is ruptured halfway its course (Ruth - 1961, Broström - 1964), but Bouretz (1975) found 50% to be ruptured close to the lateral malleolus.

Partial rupture of the anterior talofibular ligament is extremely rare (Broström - 1964, Cedell - 1975, Lindstrand - 1976).

Rupture of the calcaneofibular ligament is described to be located mostly in its midportion (50-60%) (Ruth - 1961, Broström - 1964, Bouretz - 1975) and only in about 25% at its distal attachment on the calcaneus. Partial rupture of this ligament is frequently seen, varying from 6-60% of the total amount of calcaneofibular ruptures (Broström - 1964: 20%, Staples - 1975: 30%, Emerson - 1978: 57%, Rockenstein - 1978: 6%).

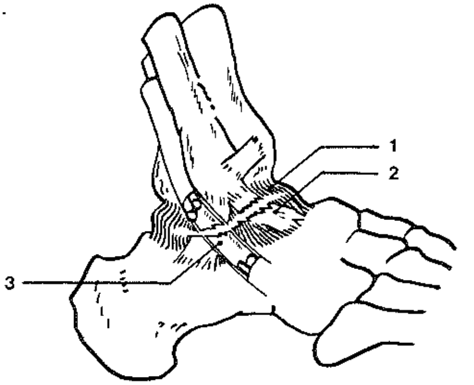


fig. 7
Rupture of the joint capsule (1) and of both the anterior talofibular (2) and calcalneofibular ligament, with concomitant rupture of the inner wall of the peroneal tendon sheath (3).

In case of complete rupture of the calcaneofibular ligament the inner wall of the peroneal tendon sheath is almost always torn (fig. 7) but can possibly be intact in case of partial rupture.

Injury to the posterior talofibular ligament mostly concerns partial rupture at the talar attachment, but without avulsion fracture. The short fibers of this ligament are the first to be torn when the talus subluxates out of the ankle mortise (Prins - 1978). This is shown in fig. 8.

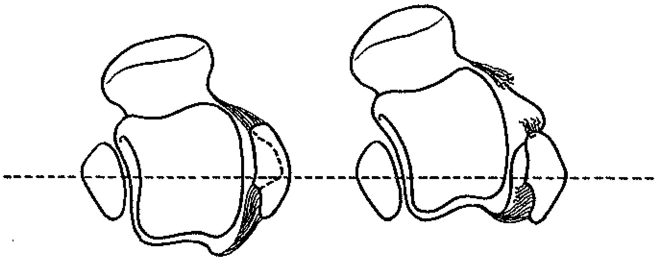


fig. 8
Normal situation (A): the posterior talofibular ligament is intact.
Lateral ankle ligament rupture (B): anterolateral subluxation of the talus; the short fibers of the posterior talofibular ligament are the first to be torn.

Injury to the lateral talocalcaneal ligament is only scarcely mentioned in literature, possibly because this ligament is not always distinctly developed.
Rupture of the anterior talofibular ligament can extend into this ligament which is then ruptured longitudinally (Ruth - 1961, Staples - 1975). Prins (1978) found this ligament to be ruptured in all of his patients with rupture of the anterior talofibular ligament and in 11% of his patients with combined rupture of both anterior talofibular and calcaneofibular ligaments.

Injury to the inferior tibiofibular ligaments can occur with accompanying fractures (Lauge-Hansen - 1949, Solonen - 1965, Monk - 1969, Weber - 1972, Rechfeld - 1976) or without (Outland - 1943, Lauge Hansen - 1949, Bonnin - 1950, Menelaus - 1961, Broström - 1964, Guise - 1976).
This can be limited to an isolated rupture of the anterior tibiofibular ligament (Outland - 1943, Menelaus - 1961) which is regarded as a rare injury (Cedell - 1975), associated with rupture of the deltoid ligament or fracture of the medial malleolus (Close - 1956, Staples - 1965), or extend into all inferior

tibiofibular ligaments, in which case fracture of the fibula is always present (Monk - 1969).
The mechanism by which this injury occurs is generally described as endo-rotation of the leg on the fixed foot. Lauge-Hansen (1949) pointed out that with the foot in supinated position (in which the deltoid ligament is relaxed) external rotation of the talus in the first place leads to rupture of the anterior tibiofibular ligament, while external rotation of the talus with the foot in pronation (the deltoid ligament being tight) firstly produces rupture of the deltoid ligament, followed by rupture of the anterior tibiofibular ligament.
Rupture of the anterior tibiofibular ligament is usually situated within the substance of the ligament (Broström - 1964). Avulsion fractures are rare (Bonnin - 1950) and almost exclusively limited to the anterior tubercle of the tibia. Interposition of the ligamentous fibers is rare, the ends being mostly well-approximated.

1.4.4 Damage to the crural fascia

Traumatic lesions of the crural fascia are scarcely mentioned in literature. Broström (1964) noted rupture of the crural fascia in about 30% of his patients with surgically confirmed lateral ligament ruptures, while Prins (1978) found the same in 68% of his operated patients.
Whether rupture of the crural fascia is in any way correlated to the presence or the extent of injury to the lateral ligamentous apparatus remains undiscussed, although it is suggested that damage to the crural fascia can occur previous to and thus irrespective of lateral ligamentous rupture (Hipp -1962).

1.4.5 Instability

Because the ankle ligaments are responsible for the static support of the talocrural and subtalar joints, ligament rupture leads to potential loss of stability, i.e. instability.
In literature four different manifestations of instability are found:

1. Talar tilt.

Talar tilt was first described by Faber in 1932. It is defined as the angle formed by the opposing articular surfaces of the tibia and the talus when these surfaces are separated laterally by a supination force applied on the hind foot (Faber - 1932, Dehne - 1934, Pennal - 1943, Rubin and Witten -1960, Cox and Hewes -1979) (fig. 9).

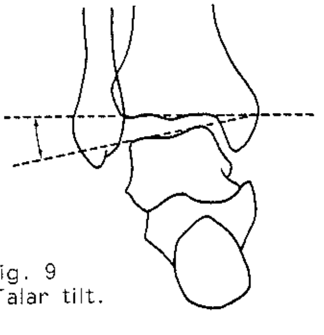


fig. 9
Talar tilt.

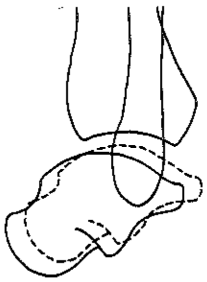


fig. 10
Anterior drawer sign.

2. Anterior drawer sign.

The anterior drawer sign (Schubladen symptom, tiroir astragalien antérieur) has been described first by Dehne in 1934. It is defined as an abnormal forward subluxation of the talus from the tibiofibular mortise when a forward axial force is applied on the heel (Dehne - 1934, Landeros et al. - 1968, Lindstrand - 1976) (fig. 10).

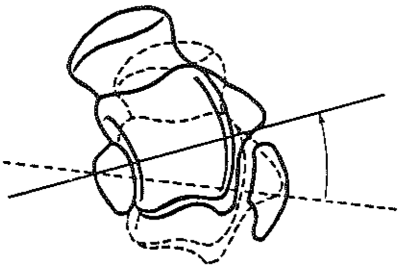


fig. 11
Anterolateral rotational instability.

3. Anterolateral rotational instability.

Anterolateral rotational instability, like the anterior drawer sign, was described first by Dehne (1934). It is defined as an anterolateral rotational movement of the talus in the horizontal plane (using the medial malleolus as a kind of axis) when an endorotational force is applied on the lateral margin of the foot (Dehne -1934, Anderson et al. - 1952, McCullough and Burge - 1980, Rasmussen and Tovborg-Jensen -1981, 1982) (fig. 11).

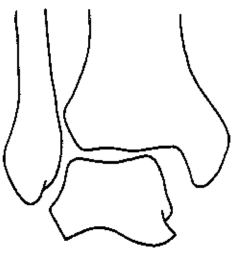


fig. 12
Lateral ankle instability.

4. Lateral ankle instability.

Lateral ankle instability was introduced by Kleiger (1954). It is defined as a lateral movement of the talus and the distal fibula when an abduction force is applied on the medial side of the heel (Kleiger - 1954, Staples -1960, 1972) (fig. 12).

Talar tilt, anterior drawer sign and anterolateral rotational instability are all demonstrations of instability due to lateral ligamentous injury.
"Lateral ankle instability" is a confusing name, chosen for a kind of instability that is demonstrable in case of rupture of the inferior tibiofibular ligaments, with or without fracture. When only the anterior inferior tibiofibular ligament is ruptured, this kind of instability does not occur. Since total rupture of the inferior tibiofibular ligaments without accompanying fracture is

very rare, this manifestation of ankle instability has no practical value in discussing ligamentous injuries.
To establish the importance of the various degrees of ligamentous injury in producing instability, a comprehensive amount of experimental cadaveric investigations has been carried out in the past by many different authors. Next, some important findings and conclusions from these investigations are mentioned, because they contribute in understanding the potential problem of instability.

Instability is fundamentally a pathological situation which can not be established in normal ankles with intact ligaments (Dehne - 1934, Güttner - 1941, Pennal - 1943).
After subsequent sectioning of one or more lateral ankle ligaments an increasing degree of talar tilt instability becomes demonstrable (Güttner - 1941, Pennal - 1943), depending on the position in which the joint is investigated. Talar tilt instability increases in plantar flexion as compared to neutral position of the joint (Leonard - 1949, Johnson and Markolf - 1983).
Anterior subluxation of the talus (i.e. anterior drawer sign) is closely correlated to the condition of the anterior talofibular ligament (Anderson et al. - 1952, Dietschi and Zollinger - 1973) and also increases in plantar flexion. Together with the anterior part of the deltoid ligament the anterior talofibular ligament stabilizes the talocrural joint like the reins of a horse (Padovani - 1975, Delpace and Castaing - 1975).
The degree of instability is also determined by the extent of injury to the anterolateral joint capsule (Makhani - 1962).
In case of rupture of the anterior talofibular ligament the posterior talofibular ligament stabilizes the ankle joint rather than the calcaneofibular ligament (Delpace and Castaing - 1975).

It is surprising that, although anterolateral rotational instability was already recognized by the early investigations of Dehne (1934), only few authors occasionally mentioned it afterwards (Leonard - 1949, Anderson et al. - 1952), the greater part of the experimental literature being occupied with talar tilt and anterior drawer sign investigations. It is not until the 1980's that anterolateral rotational instability was investigated seriously.
In intact ankles endorotational movements do not exceed some 2-10° (Parlasca - 1979, McCullough and Burge - 1980, Rasmussen and Tovborg-Jensen - 1982). After division of the anterior talofibular ligament endorotational rotatory instability increases with 7-18°, depending on the amount of experimental load bearing used.

The greatest increase in endorotational rotatory instability is found to occur already when the anterior talofibular ligament has been cut. Thus, the corresponding instability -anterolateral rotational instability- is also marked in injuries effecting only the anterior talofibular ligament (McCullough and Burge - 1980, Rasmussen and Tovborg-Jensen - 1981/1982, Johnson and Markolf - 1983).

CHAPTER 2 LIGAMENT HEALING

2.1. Introduction

In 1968 v.Enst wrote: "Knowledge of the process of ligamentous woundhealing is a basic necessity to find the best way of treatment. It is remarkable that in surgical literature so little attention is paid to the process of ligamentous healing and the time which is needed for tensile strength to re-occur."

Since then little has changed in surgical literature to attend to this lack of knowledge, although advocates of surgical treatment of ligamentous injury repeatedly have stated that on the basis of operative findings, sufficient ligamentous healing can only be obtained by anatomical and therefore surgical reconstruction of the ruptured ligaments, in order to prevent the formation of excessive amounts of scar tissue.

In this chapter the process of woundhealing in general is reviewed, as it is described in histological textbooks (Ham - 1965, Robbins - 1967, Dunphy and v.Winkle - 1969, Peacock and v.Winkle - 1970, Preston and Beal - 1969). Thereupon, the rather scarce literature on ligament healing and its correlation with tensile strength is discussed.

2.2 The process of woundhealing in general

Whenever cells are injured or destroyed, an immediate protective response called inflammation occurs in the surrounding tissues. The basic character of this immediate inflammatory response is almost the same, regardless of the nature of the injurious agent (Robbins - 1967).

However, depending on the site of trauma and the structures involved, there are various tissue responses. The basic inflammatory reaction to trauma is composed of complicated series of tissue adjustments involving the blood vessels, the fluid and cellular components of the blood and the surrounding connective tissue.

The quantity of the immediate inflammatory response is related to the severity of the injury (Peacock and v.Winkle - 1970).

The general process of wound healing can be divided into four phases (Preston and Beal - 1969) whereby sometimes the first and second phase are mentioned as one because they overlap.

1. The phase of traumatic inflammation (0-3 days).
2. The phase of destruction (1-6 days).
3. The phase of proliferation (3-14 days).
4. The phase of maturation (after 14 days).

2.2.1 The phase of traumatic inflammation (0-3 days)

Trauma leads to destruction of tissue, also including rupture of small vascular structures. This produces a transient vasoconstriction (5-10 min.) during which leucocytes seal off the ruptured venules and lymph vessels. The vasoconstriction is followed by a reactive vasodilatation in the surrounding tissue, with an increased blood flow through the arterioles, capillaries and venules and an increased permeability of capillaries and venules. This chain of events is initiated by the release of vaso-active substances such as histamine (from destroyed mast cells) and possibly serotonine.

The increasing permeability permits exudation of fluid, including all plasma proteins (albumin, globulin, fibrinogen) and migration of white cells through the vessel walls into the extracellular space and so into the injured focus.

The majority of cells seen during the first 24 hours are polymorph nuclear neutrophilic leucocytes. They can be recognized by their characteristic hydrolytic enzyme-containing granules, the glucogen deposits and the lack of rough endoplasmatic reticulum. These cells migrate through the wound and many of them appear to undergo lysis during the first 24-48 hours, releasing their hydrolytic enzymes from the granules.

2.2.2 The phase of destruction (1-6 days)

The amount of polymorph nuclear neurophilic leucocytes is maximal after 24 hours and decreases afterwards to be replaced by monocytes and histiocytes (macrophages). The release of proteolytic enzymes (amongst others collagenase) from the neutrophilic leucocytes is probably initiated by the lowered pH in the injured tissue, due to anoxia, glycolysis and consequent formation of lactic acid.

The primary role of the neutrophilic leucocytes consists of cell lysis and degranulation. Although they demonstrate little phagocytic activity, most of the phagocytosis appears to be the function of the monocytes, which predominate at a later time. The monocytes actively ingest neutrophilic granules, fibrin and cell debris.

With the exudation of fluid due to the increased permeability edema occurs, and so the wound tissue gradually shows a loose, reticulated appearance. Accompanying this fluid accumulation is the precipitation of fibrin as it escapes from the blood vessels. This produces a kind of "frame work" which provides a solid foundation for the growth of fibroblasts into the wound defect.

2.2.3 Phase of proliferation (3-14 days)

After the first 24 hours undifferentiated mesenchymal cells differentiate into fibroblasts and enter the wound defect. These fibroblasts can be clearly differentiated from the monocytes by their very different morphology. The monocytes have a relatively poorly developed and sparse rough endoplasmic reticulum, whereas the immature fibroblasts entering the wound contain a moderately developed rough endoplasmic reticulum.

As the defect becomes colonized by the newly formed reparative cells (proliferation of fibroblasts), the inflammatory exudate is resorbed. The white cells and fibrin are progressively digested by phagocytes. When the wound margins are in apposition the fibroblasts from each side may meet within the cloth in 2-3 days.

At the same time proliferation of endothelial cells of the injured blood capillaries occurs. Strands of endothelial cells follow the course of the fibroblasts along the fibrin meshwork and soon become canalized to establish blood flow from one wounded margin to the other. This newly formed, highly vascularized connective tissue is known as granulation tissue. The endothelial cells contain a plasminogen activator which is responsible for the fibrinolysis, the breakdown of the fibrin frame work.

Together with the increasing number of fibroblasts the formation of mucopolysaccharides starts and reaches a peak on the 5th or 6th day, after which it declines.

It has been suggested that less highly charged mucopolysaccharides, such as hyaluronic acid, stimulate the proliferation of fibroblasts in an early stage of the proliferation phase, while more highly charged mucopolysaccharides, like chondroitin sulphates, stimulate the differentation of fibroblasts and the production of collagen in a later stage. This explaines the so-called "lag-phase" of four days, in which no collagen is produced, and after which the collagen content of the wound increases rapidly. It also means that mucopolysaccharides, by means of a feed-back mechanism, influence the collagen synthesis.

Alternatively, it is said that "overpopulation" of proliferated fibroblasts leads to a saturation point after which collagen production starts.

The formation of collagen molecules by the fibroblasts commencing on about the 4th day after the injury results in a secretion of collagen molecules into the extracellular space. Here the formation of the first intramolecular cross-links occurs which will have little effect on tensile strength. This is rapidly followed by the formation of intermolecular cross-links which materially strengthens the wound because of a rapid increase in tensile strength.

At the end of this phase the tensile strength is sufficiently high in order to allow removal of the sutures although it is still only a small percentage of the final achievable tensile strength.

2.2.4 Phase of maturation (over 14 days)

This last phase in the process of wound healing is characterized by a continued production of collagen, resulting in an increasing number of collagen fibers and gradually increasing tensile strength, until ultimate tensile strength is reached. At the same time there is a gradual diminishing of blood vessels. This phase is said to last over a year.

2.3 Literature on ligament healing

In 1937 Miltner et al. described the pathologic changes following the experimental reproduction of mild sprain to the knee joint in rabbits. The characteristic changes consisted of an increase in amount and viscosity of the synovial fluid, subacute inflammation and haemorrhage into the synovial membrane, the loose subsynovial tissue and the loose periarticular tissue and early proliferation of fibroblasts and infiltration of lymphoid cells near the bony attachment of the injured capsule and ligaments and in the subsynovial tissue. In more severe sprains, in addition to the soft tissue changes just mentioned, degenerative changes of the articular cartilage were found.
Jack (1950) produced complete ruptures of the medial collateral ligament of the knee in cats after which the joints were explored immediately to determine the extent of injury. The ligaments were neither sutured nor immobilized. He observed that the ends of the ligaments were always recoiled but remained in contact when the tear was oblique and showed a wide gap when the tear was transverse. In 7 to 10 days the ligament shrank, became edematous and friable, making it impossible to suture accurately. When the ligament fragments remained in close approximation, the gap was filled with blood while proliferation of cells from the connective tissue covering the ligament on the superficial side, quickly converted the blood cloth into granulation tissue. New ligamentous cells from the torn ends migrated into granulation tissue until the gap was bridged by collagenous tissue. When there was no approximation of the ligament ends, the histological picture was quite different. The gap was filled with irregular scar tissue in which after three weeks the stumps terminated abruptly, showing an inert appearance with vacuolation in some cells, to the opinion of the authors suggesting ischaemic necrosis. The scar tissue had little tensile strength. So, it was concluded that accurate replacement could only be guaranteed by surgical intervention which should

be undertaken within the first week after injury. Later on, accurate repair would become impossible because of shrinkage and friability of the tissue.

Clayton and Weir (1959) compared the tensile strength and microscopic picture of divided knee ligaments in dogs, treated by simple immobilization or by suturing. Except for the manner of immobilization, for which they used a Steinmann pin, their method of investigation was also used in the experimental study described in chapter 7. A full description of this method will be given there. The authors concluded that ligaments which have been divided and immobilized heal with a gap of fibrous tissue while the ligament stumps were found to be inactive and rounded off.

Ligaments which have been sutured after dividing them, heal by union of the ligamentous fibers without a gap, resulting in a higher tensile strength in all specimens investigated.

Hutzschenreuter and Burri (1974) advocated "functional treatment" with early mobilization after suturing knee ligaments and demonstrated that after partial cutting of the medial collateral ligament of the rabbit knee, which they considered to be comparable to a sutured ligament, a parallel orientation of the fibroblasts was seen in the group treated by early mobilization, while in the group treated by immobilization a disturbed, disorientated histological pattern was found.

El Saman et al. (1978), from the same centre, confirmed these findings and demonstrated that longterm immobilization led to a considerable decrease in tensile strength, while early mobilization after partial injury to the medial collateral ligament of the rabbit knee resulted in a rapid restoration of tensile strength.

2.4 Tensile strength in ligament healing

Generally there is a correlation between tensile strength and collagen concentration. In addition, several other factors influence the tensile strength, like -at the molecular level- the covalent cross-linking of collagen and the cohesive forces between the collagen fibers.

Most methods of measuring tensile strength used in wound studies depend on the width of the strip of tissue used. However, ideally tensile strength should be measured per unit area of cross-section at the side of healing, expressed in kg/cm^2 or kg/mm^2. This would mean measuring of tissue thickness. In practice this is extremely difficult.

An alternative accurate method, pointed out by Gustavson (and quoted by Dunphy and v.Winkle - 1969), is measuring the mean breaking length (MBL).

$$MBL = \frac{B \times L}{1000 \times W}$$

where B = the breaking load

L = length (in wounds: the width of repair tissue)

W = weight of tissue in grams

The equation eliminates the necessity of measuring tissue thickness.

The basic pattern of changes in tensile strength conforms to the different phases of ligament healing.

During the lag-phase in which lysis and debridement take place, there is only little tensile strength depending on the presence of fibrin in the wound and the presence of sutures.

During the phase of proliferation there is rapid formation of collagen molecules by the fibroblasts. Extracellular formation of intramolecular and later intermolecular cross-links, produces a rapid increase in tensile strength.

During the phase of maturation there will be only a gradual increase in tensile strength due to the slow process of formation of further types of intramolecular cross-links, the change in orientation of the fibrils and the interaction with the mucopolysaccharides (ground substance).

Also gradual resorption of excessive collagen takes place, resulting in remodeling of the scar tissue.

On the basis of variable tissue responses in the process of healing, there will be differences in the normal pattern of increase in tensile strength in ligament healing, as compared to other tissues.

CHAPTER 3 CLINICAL DIAGNOSIS

3.1 Introduction

The correct treatment of ankle sprains is initiated by making the correct clinical diagnosis. There is much diversity of opinion regarding the diagnostic value of history and clinical findings. Many authors reported great use of history and physical examination (Carothers - 1942, Lettin - 1963, Cedell - 1975, Duquennoy and Lisélélé - 1975). Many others stated that history and physical examination were of limited diagnostic value (Güttner - 1941, Makhani - 1962, Broström - 1965, Pascoët - 1972, Delpace et al. - 1975, Rechfeld - 1976, Sanders - 1977, Tausch - 1978).

3.2 History

When taking the history of a patient who has sustained an ankle sprain, questions are posed regarding time, circumstances, mechanism of injury, primary treatment and previously sustained sprains. Most authors attach much value to this information (O'Donogue - 1958, Gerbert - 1975, Adler - 1976, Hackenbruch and Noesberger - 1976), others don't (Tausch - 1978).

Regarding the responsible trauma mechanism most patients state that the injury was caused by an inversion movement of the weight bearing foot, either in neutral position or in plantar flexion (Broström - 1965, Speeckaert - 1978). Prins (1978) found that only half of his patients were able to allege the injurious ankle movement, the remaining patients (48%) could not remember this detail, unlike v.Moppes and v.d.Hoogenband (1982) who observed that in their series only 10% could not remember the responsible movement.

Several authors reported that in case of severe ligamentous injury the patients mentioned having heard or felt a cracking sensation at the moment of injury. Duquennoy et al. (1975) and Dewijze and Tondeur (1979) reported this in about 50% of their patients, while Speeckaert (1978) found this in 18% of his patients. However, the diagnostic value of these data seems doubtful.

The possibility of weightbearing after the injury is investigated by several authors. Duquennoy et al. (1975) found in their series of 104 patients operated for ligamentous injury that 47% were unable to put weight on the foot, while 35% could do so only to a limited extent, whereas the remaining patients had only slight or no difficulty.

Prins (1978) reported in his series that 36% of his patients was unable to put weight on the foot, whereas 42% could do so only to a limited extent and 22% had more or less normal use of the foot. He found these percentages to be equally distributed in his different patient groups with various degrees of ankle sprain, so consequently he concluded that the degree of disfunction of the foot was not related to the severity of the ankle sprain.

When taking the history of the accident, many patients state that they sustained previous ankle sprains. Possibly this could entail a great risk for more severe ankle sprains, i.e. ligamentous ruptures (e.g. Pascoët et al. - 1972). Prins (1978) concluded from his series that a history of previous ankle sprains was no predisposition to more severe injuries.

Ankle ligament rupture is sustained mainly while practising sport. This is confirmed by the literature in which sport is mentioned as by far the most frequent cause, varying from 35 to 75% (Tonino - 1973, Reichen and Martí - 1974, Prins - 1978, Hansen et al. - 1979, Raaymakers - 1979, Danegger - 1979, Grønmark et al. - 1980, Brand et al. - 1981, v.Moppes and v.d.Hoogenband - 1982, Rogmans - 1982).

In absolute figures soccer causes most injuries, but as Raaymakers (1979) rightly remarked, this has to be regarded in proportion to the number of people who practise this popular kind of sport.

In relative figures indoor sports, like volleyball and basketball, show a much higher frequency in causing ankle ligament rupture.

A small but special group is formed by the classical ballet dancers. In 1973 Volkov et al. mentioned that at the Bolshoy Theatre ankle ligament injuries averaged 43.3% in women and 26.2% in men.

Other causes of ankle ligament rupture, although far less in frequency than sport, are also to be mentioned. According to literature labour causes about 10-30% of all ankle sprains. Especially construction workers, constantly working on uneven ground and truck drivers in the habit of jumping out of the cabin, easily sustain an ankle injury. Surprisingly, also normal walking without immediate cause during daily persuits causes a considerable number of ankle ligament ruptures.

When literature is reviewed concerning age, sex and side of injury, there is quite a conformity regarding age. Injury to the lateral ankle ligament is restricted mainly to the third decade, the average age being 24.5 years.

All publications show a clear predominance of male patients, varying from 60 to 90%. However, some patient material consisted at least partly of military conscripts (Broström - 1965).

Regarding the right-left ratio most authors find a predominance for the right ankle. Prins (1978) explained this phenomenon in assuming that the right ankle is more "at risk" because right-handed people are also inclined to use their right leg more readily and intensively. Predominance for the left ankle is rarely mentioned (Grønmark et al. - 1980).

3.3 Physical examination

The value of physical examination as a diagnostic aid in ankle sprain has long been a matter of dispute. In literature several authors reported that physical examination is of great importance to distinguish simple ankle sprains from severe ligamentous injuries, thereby avoiding large numbers of "unnecessary" radiological examinations (Carothers - 1942, Sherrod and Phillips - 1961, Lettin - 1963, Duquennoy et al. - 1975, Cedell - 1975, Hall -1976). Others stated that findings regarding swelling, pain and discoloration of the skin following ankle sprain were variable and unreliable in terms of ligamentous damage (Dehne - 1934, Güttner - 1941, Makhani - 1962, Broström - 1965, Pascoët et al. - 1972, Rechfeld - 1976, Stepanuk - 1977, Speeckaert - 1978, Tausch- 1978, Langer et al. - 1980, Schweiberer and Seiler - 1981).

Sanders (1977) reported that in a study of 300 patients with ankle sprains the clinical diagnosis based on physical examination, when correlated with arthrographic findings, was correct in only 27% and erroneous in 21%. In 28% the examiner was unable to make a tentative diagnosis, in the remaining 24% no clinical data were available.

Prins (1978) in a preliminary investigation correlated the clinical diagnosis with arthrographic findings in 79 patients. He reported that when the examiner considered ligament rupture to be definitely present, he was wrong in 21% (false positive clinical diagnosis), whereas in case he had excluded ligamentous injury on the basis of clinical findings, he was erroneous in 45% (false negative clinical diagnosis).

In order to determine the diagnostic value in patients with ankle sprains, the different symptoms as found in the physical examination will be discussed separately.

3.3.1 Swelling

Swelling following ankle sprain is a constant finding. It arises from intra-articular and extra-articular bleeding and as an inflammatory reaction to the trauma. The localization and extent of swelling is greatly influenced by the initial treatment (compression bandage, cooling) and the degree of activity during the period immediately following the injury. Of course it also depends on the time interval between injury and examination. Prins (1978) correlated the presence of swelling to the degree of ligamentous injury after the patient had worn a compression bandage for 24 hours. He reported that in case of minor ankle sprain without ligamentous injury, swelling was present in 54%, being limited to the anterior region of the lateral malleolus in 61%, and covering the complete lateral malleolus in the remaining 39%. In case of arthrographically proven ligamentous rupture, swelling was present in 91%, mostly (75%) covering the complete lateral malleolus.

V.Moppes and v.d.Hoogenband (1982) examined their patients after a 5-7 days period in which the patients were treated with a plaster splint, elevation and antiflogistics. In all 150 patients with ligamentous rupture they found swelling over and around the lateral malleolus but the extent was not mentioned.

Funder et al. (1982), who based their conclusions on arthrographic examination, concluded that swelling over the lateral malleolus -as a single finding- is a valuable diagnostic sign. They reported that swelling anterior to or over the lateral malleolus exceeding 4 cm is correlated with lateral ankle ligament rupture in about 70%.

3.3.2 Haemotoma

As early as 1932 Faber regarded the general idea that the severity of an ankle sprain could be judged by the extent of the haematoma to be erroneus. He emphasized that the extent of the haematoma was depending only on the degree of vascular damage, which presumably is not correlated to the ligamentous damage.

In discussing this symptom the findings of the initial physical examination immediately following injury have to be distinguished from the findings as they appear a few days later.

Shortly after the injury a circumscript rounded swelling (haematoma) can develop in front of the lateral malleolus. In literature this haematoma is referred to as "eggshell sign" or "pigeon's egg", in the French literature as "le signe de la coquille d'oeuf". According to Duquennoy et al. (1975) this phenomenon was described first by Roberte-Jaspar in 1956 and is caused by rupture of an arterial branch of the peroneal artery. Because of its fast appearance it is indeed likely that this haematoma is caused by arterial vascular damage.

Several authors state that this eggshell sign is characteristic for severe ligamentous damage (Duquennoy et al. - 1975, Cedell - 1975, Speeckaert - 1978, Dewijze and Tondeur - 1979).

This symptom is said to disappear within the first hours following trauma by diffusion into the surrounding tissues.
When physical examination is performed or repeated a few days after injury, it is frequently reported that an extravasation of blood has developed in the form of a purplish streak along the lateral margin of the heel (Güttner -1941, Ruth - 1961, Broström - 1965, Prins - 1978, v.Moppes and v.d.Hoogenband - 1982).
Broström (1965) reported this symptom in 47% of his patients with ligament rupture and in an even higher percentage when associated with an avulsion fracture.
Prins (1978) who found this symptom in 75% of his patients with ligament rupture and only in 33% of his patients without ligament rupture, presumed that this haematoma originated from the tarsal sinus and spread to the subcutaneous layer through a defect in the fascia cruris.

3.3.3 Pain

Pain is a predominant symptom in ankle sprain. Usually it is confined to the vicinity of the ruptured ligament. According to Ruth (1961) direct pain localized with a blunt object is a very accurate method to determine the site of a tear in a ligament. This opinion is confirmed by Grond (1973), Hackenbruch and Noesberger (1976) and Wolf (1978), but denied by Güttner (1941), Duqennoy et al. (1975) and Speeckaert (1978).
Since pain seems to correspond to the extent of swelling and haematoma, direct pain ("pressure pain") is observed best in the first hours following injury (Grond - 1973).
Funder et al. (1982) reported that tenderness of the calcaneofibular ligament is of more diagnostic value than tenderness over the anterior talofibular ligament, by observing that the former correlated in 72% and the latter in 58% with single or multiple ankle ligament rupture.
According to Prins (1978), who examined his patients after a delay of about 4 days, the area in which patients report pressure pain after this period, becomes too large to correlate with the particular ligament. He found pressure pain to be present more or less diffused in almost all of his patients with ruptured ligaments.

Durbin (1958), Landeros et al. (1968), Frost (1974) and Cedell (1975) emphasized the importance of "indirect pain" or "traction pain". They stated that the presence of indirect pain provoked by stressing the suspected ligament results from a partial rupture, whereas absence of indirect pain suggests complete rupture. However, Broström (1975) found indirect pain to be present

in all of his patients with ligament rupture.
Funder et al. (1982) found indirect pain on the anterior talofibular ligament in 55% correlating with ligament rupture and indirect pain of the calcaneofibular ligament in 66%.

3.3.4 Clinical instability tests

Based on the different types of instability, as described in chapter 1.4.5, clinical instability tests, especially the anterior drawer sign, are applied to reach more accurate clinical diagnoses.

The anterior drawer sign

The anterior drawer sign is associated with instability due to insufficiency of the anterior talofibular ligament (Anderson et al. - 1952, Gschwend -1958, Broström - 1965, Landeros et al. - 1968, Hupfauer - 1970, Cedell -1975, Delpace and Castaing - 1975, Lindstrand - 1976, 1977, Hackenbruch et al. - 1977, 1979) and can be performed in two ways:

1. With the patient lying supine and relaxed, the injured leg straight, the heel is grasped with one hand and the distal end of the lower leg is seized with the other. Anteroposterior instability then can be detected by pushing the distal tibia backwards and pulling the heel forwards.
2. Another method was described by Lindstrand (1976, 1977): the patient lies supine, with the hip and knee joint flexed, the heel resting against a support. The forefoot is held in pronate position with one hand, the other hand is placed over the distal part of the lower leg, which is then pushed backwards.

The anterior drawer sign is considered to be positive when there is a distinct pain reaction and a demonstrable displacement (Cedell - 1975, Lindstrand - 1977). The examiner can feel the talus slip forward out of the ankle mortise on the lateral side of the ankle. This can be observed also visually as a typical depression (sulcus) between talus and lateral malleolus and sometimes audibly as a characteristic crepitus or clicking sensation (Broström - 1965, Coutts and Woodward - 1965, Landeros et al. -1968). Hackenbruch et al. (1979) reported that forward subluxation was associated with internal rotation of the talus, indicating that the anterior drawer sign is partly based on anterolateral rotational instability.
Contrary opinions are expressed regarding the presence and degree of pain while performing this instability test. Several authors mentioned that this examination has to be carried out using the element of surprise because peroneal muscle spasm, resulting from pain, would render the examination

otherwise impossible (Cedell - 1975, Lindstrand - 1976, 1977, Prins - 1978). Gerbert (1975) used local anaesthesia, Ruth (1961) used a peroneal nerve block, while Broström (1975) reported that out of 239 patients with ligament rupture the anterior drawer sign could only be demonstrated in two unanaesthetized patients whereas this phenomenon was demonstrable in all cases during spinal anaesthesia.

In contrast Jungmichel (1978) reported that performing the anterior drawer sign is practically painless and can be carried out without anaesthesia. Hackenbruch et al. (1977, 1979) confirmed and explained this finding by demonstrating that the mean intra-articular pressure was reduced by enlarging the joint space in performing this examination.

Opposite opinions are also encountered regarding the position of the ankle while performing the anterior drawer sign. Although Anderson et al. (1952) reported on the basis of experimental investigations that increasing antero-posterior instability was associated with increasing plantar flexion and accordingly several authors described the anterior drawer sign to be elicited in a certain degree of plantar flexion (Prins - 1978, Hackenbruch et al. - 1979, v.Moppes and v.d.Hoogenband - 1982), others reported that the anterior drawer sign should be performed with the ankle at right angles (Lindstrand - 1976). Landeros et al. (1968) stated that even when marked instability existed in the right angle position, the anterior drawer sign was negative in 30° plantar flexion.

Regarding the diagnostic value of the clinical anterior drawer sign, it is generally stated that this examination is of great importance (Sherrod and Phillips - 1961, Coutts and Woodward - 1965, Staples - 1972, Cedell -1975, Hackenbruch and Karpf - 1977, Lindstrand - 1977, Danegger -1979). However, only a few authors based this opinion on well-documented series. Lindstrand (1977) compared his findings regarding the clinical anterior drawer sign in 110 non-anaesthetized patients with his operative findings. Out of 87 patients with rupture of the anterior talofibular ligament, the anterior drawer sign was positive in 71 cases (81%), in the remaining patients the anterior drawer sign became positive in another 10 cases using local anaesthesia. Of the 23 patients with ankle sprain without rupture, the anterior drawer sign was positive in 26%.

Prins (1978) also examined the clinical anterior drawer sign, without any form of anaesthesia and correlated his findings with the results of arthrography. He found a positive anterior drawer sign in 19% of patients without ligament rupture and a negative result in 43% of his patients with rupture of the anterior talofibular ligament for which this examination is said to be pathognomonic. In this patient group the findings were doubtful in 30% and positive in only 27%. In accordance with the findings of Broström (1965) a positive anterior drawer sign was found in all cases of ligament rupture when using general anaesthesia. V.Moppes and v.d. Hoogenband (1982) found the anterior drawer sign without anaesthesia to be present in 65% of 150 patients in which ligament rupture was diagnosed arthrographically. The findings were doubtful in 13% and negative in 9%. In the remaining 13% the examination was impossible because of defence reactions caused by pain. When compared to the operative findings in 50 cases they found no correlation with the extent of ligamentous injury.

In a group of 444 patients with recent inversion sprain Funder et al. (1982) were able to elicit a positive anterior drawer sign without anaesthesia in only 53 patients (12%) in which ligament rupture was present arthrographically in 71%.

Talar tilt

Talar tilt as a clinical test on instability is used less frequently when compared to the anterior drawer sign. Instability found by applying varus stress on the calcaneus is due to insufficiency of the calcaneofibular ligament (Dehne - 1934, Güttner - 1941, Pennal - 1943, Leonard - 1949, Ruth - 1961, Coutts and Woodward - 1965, Dietschi and Zollinger - 1973).

Talar tilt can be detected clinically as follows: The patient lies supine and relaxed, the injured leg straight. One hand is seized over the distal end of the lower leg, placing the index finger on the anterolateral margin of the joint surface. The other hand takes hold of the heel and inverts the ankle by applying varus stress on the lateral side of the calcaneus.

Talar tilt is regarded positive when the index finger feels the talus subluxating from the ankle mortise, resulting in a palpable and visual groove between the tip of the lateral malleolus and the lateral border of the talus.

Care must be taken not to apply varus stress on the forefoot, thereby twisting the metatarsal joints.

Most authors, who practise talar tilt clinically, use some sort of anaesthesia. Güttner (1941) and Staples (1965) used local anaesthesia, while Ruth (1961) and Coutts and Woodward (1965) prefer a peroneal nerve block.

The contradictory opinions regarding the position of the foot as discussed in relation to the anterior drawer sign are equally relevant to the talar tilt testing. Several authors perform this examination with the ankle joint in neutral position (Güttner - 1941), while others prefer plantar flexion (Leonard - 1949, Coutts and Woodward - 1965, Staples - 1965, Duquennoy et

al. - 1975, Prins - 1978, v.Moppes and v.d.Hoogenband - 1982).
Regarding the diagnostic value of clinical talar tilt Broström (1965) reported a remarkable finding. He stated that he was unable to demonstrate talar tilt clinically in 239 patients with operatively proven ligament ruptures even with the aid of anaesthesia. Prins (1978) and v.Moppes and v.d.Hoogenband (1982) investigated the value of clinical talar tilt in non-anaesthetized patients in relation to their arthrographic findings. Both authors reported that the examination was impossible in about 20% because of pain. In patients without ligamentous injury Prins (1978) found talar tilt to be absent in 90%. In patients with rupture of the anterior talofibular ligament 84% showed no talar tilt, whereas in patients with rupture of more than one ligament, the talar tilt phenomenon was negative still in 40%. In this patient group Prins also found the highest percentage of positive talar tilt (46%) and therefore concluded that in case of positive talar tilt a severe ligamentous injury should be suspected. V.Moppes and v.d.Hoogenband (1982) found no significant correlation between positive talar tilt and the extent of ligament rupture.
Similar findings were reported by Funder et al. (1982) who found a positive talar tilt in only 15% of patients with recent sprain. In 68% this positive test was correlated with ligament rupture.

CHAPTER 4 RADIOLOGICAL DIAGNOSIS

4.1 Introduction

In diagnosing lateral ankle ligament ruptures radiological examinations are indispensable to support the findings of clinical examination and their limited diagnostic value.

Except for standard radiography two other examinations, stress examinations and arthrography, are frequently used to demonstrate or exclude lateral ankle ligament rupture.

Tenography is a relatively new diagnostic procedure, less well-known and therefore less widely practised.

4.2 Standard radiographs

When an acute ankle sprain is present the clinician is always obliged to rule out the possibility of fracture. Although it has been stated (Hall -1976) that careful clinical examination will indicate the presence of a malleolar fracture in most cases, the examiner is often unable to differentiate with certainty between ligamentous ankle injury and malleolar fractures (Broström - 1965). Therefore standard radiographs are imperative.

Generally routine radiographs will be made in two directions, an anteroposterior view and a lateral view. The routine anteroposterior view is obtained with the foot in 15° endorotation, the lateral margin of the foot being at right angles to the film and the ankle joint in 90° dorsiflexion, because plantar flexion results in rotation of the talus and thus obscures the view. In this routine AP-view the central ray is in line with the inner surface of the medial malleolus resulting in a clear view of the medial joint space. However, following from the wedge-shaped configuration of the talus, this position gives an oblique projection of the fibula and the tibiofibular syndesmosis. The talus and distal fibula will overlap and consequently this view often fails to detect abnormalities of the lateral dome of the talus, such as flake fractures accompanying lateral ankle ligament injuries.

Bonnin (1950) introduced the "bimalleolar view", obtained by 30° endorotation of the foot, in which the central ray is at right angles with the bimalleolar axis. In this position the lateral articular face of the talus which is perpendicular to the bimalleolar axis (Inman - 1976) is in line with the central ray, resulting in a clear view of the lateral joint space. As was emphasized by Golterman (1965) this position results in a somewhat obscured view of the medial joint space. The optimal bimalleolar exposure (mortise view) in which the ankle mortise is projected as a symmetrical shadow therefore would be obtained by 20-30° endorotation of the medial margin of the foot (Monk - 1975, Müller et al. - 1977, Gerlach et al. -1978) preferably (theoretically) in postero-anterior direction in which the divergency of the X-rays corresponds with the wedge-shaped configuration of the talus (Golterman - 1965).

The routine lateral view is obtained in mediolateral direction, the central ray directed 1 cm below the tip of the medial malleolus, the foot again in 15° endorotation. In this position the fibula will be projected posteriorly over the tibia, the upper articular surface of the talus will be found to be congruous with the inferior articular surface of the tibia, although the slightly flattened posteromedial aspect of the talus may be visible.

In addition to these routine views some authors prefer special views, like the oblique view of the ankle with the foot rotated internally 45° in which also the posterior part of the subtalar joint is clearly visualized (Monk -1975, Gerbert - 1975), or the "axial view", recommended by Jacobson in 1963 (quoted by Gerbert - 1975), in which the malleolar tips, the lateral border of the calcaneus and the head and neck of the talus are visualized.

Except for malleolar fractures several other abnormalities can be observed on the standard radiographs. Recent avulsion fractures can be seen accompanying ligamentous injuries in 7-15% of the cases (Broström - 1965, Sanders - 1976, Dalinka - 1980).

Flake fractures of the lateral or medial talar dome are rare, varying from 2-10% (Bosien et al. - 1955, Berndt and Harty - 1959, Davidson et al. -1967, Hackenbruch and Karpf - 1977, Seiler and Holzrichter - 1977), but if present they are frequently missed, because of misjudgement or insufficient radiographs. In literature accurately comparable radiographs of both ankles are recommended to detect tibiofibular diastasis in case of injury to the distal tibiofibular ligaments (Berridge and Bonnin - 1944, Bonnin -1950, Gerbert - 1975, Gerlach et al. - 1978), although measuring the tibiofibular diastasis is far from accurate (Golterman - 1965) as a diagnostic method.

Burns (1942) emphasized the importance of lateral talar shift in the ankle mortise as a diagnostic aid in these injuries and showed that "Ashurst's sign", i.e. diminishing of the overlap between the anterior tibial tubercle and fibula is unreliable because of its variation with only slightly different rotational positions of the foot.

Different degrees of osteoarthrosis, following from previously sustained ankle injuries, can be seen on the standard radiographs. A useful classification of radiological findings in case of osteoarthrosis is described by Bargon (1978).

Another sign of previous ligamentous injury was reported by Guise (1976). Late recognition of a previously sustained rupture of the distal tibiofibular ligaments is possible when calcification occurs in the interosseus ligament.

4.3 Radiological stress examinations

In addition to standard radiographs diagnostic procedures are frequently supplemented by radiological stress investigations. These examinations are based on demonstrating the presence of instability as a result of ligamentous disfunction. Stress is applied basically in the same way as was described for the clinical testing (see chapter 3.3.4). The instability provoked then is radiologically recorded and measured.

4.3.1 Talar tilt (inversion stress examination)

Radiological demonstration of talar tilt is called inversion stress examination. According to Faber (1932) it was Von Bayer who was the first to visualize talar tilt radiologically.

On the radiograph the angle formed by the opposing articular surfaces of the tibia and the talus is measured and referred to as the "talar tilt angle" (Rubin and Witten - 1960).

Comparative examinations including the non-injured ankle have to be made to distinguish between traumatic and non-traumatic origins.

In reviewing the literature on inversion stress examination an amazing lack of consensus is found concerning examination and measurement technique, use of anaesthesia and interpretation of the findings.

Comparison of the results obtained by the different authors therefore is almost impossible.

V.Moppes et al. (1979) reported that three different measurement techniques are in use, but found no significant differences between them.

Those who practise inversion stress examination without anaesthesia generally claim that when performed gently and cautiously the examination causes minimal inconvenience (Tonino - 1973, Gross and McIntosh - 1973, Almquist -1974, Duquennoy et al. - 1975, Dewijze and Tondeur - 1975, Boomsma - 1979, Zinman and Reis - 1979)).

Usually however local infiltration (Grond - 1973, Gerbert - 1975, Tausch - 1978, Gerlach - 1978, Paul et al. - 1978, Glasgow et al. - 1980) or conduction anaesthesia is used (Ruth - 1961, Coutts and Woodward -1965, Marti - 1974, Reichen and Marti - 1974, Adler - 1976, Kooyman and Ponsen - 1976, Gerlach - 1978, Raaymakers - 1979, Fröhlich et al. -1980), although sometimes spinal anaesthesia (Broström - 1965, Olson - 1969, Landry - 1976, Speeckaert - 1978) and even general anaesthesia is employed (Berridge and Bonnin - 1944, Fordyce and Horn - 1972, Pascoët et al. - 1972, Toth et al. - 1974, Landry - 1976, Speeckaert - 1978, v.d.Hoogenband - 1981).

Inversion stress is either applied manually or by a device. Some authors fail to mention the technique used. Manual examination is performed by Staples (1972), Gross and Macintosh (1973), Almquist (1974), Duquennoy et al. (1975), Müller et al. (1977), Prins (1978), v.Moppes et al. (1979) and Glasgow et al. (1980). To obtain comparable results it is frequently stated that the examination should always be carried out by the same person, i.e. the surgeon or the radiologist (Ruth - 1961, Staples - 1965, Marti - 1974, Duquennoy et al. - 1975, Gerbert - 1975, Speeckaert - 1978, Tausch -1978, Paul and Lüning - 1978). The danger of radiation then must not be underestimated (Duquennoy et al. - 1975, Schmidt -1978), especially when protective gloves are omitted on behalf of a better grasp on the foot.

Zinman et al. (1979) reported the use of a longhanded wrench with which the patient himself without anaesthesia produced the stress manoeuvre ("self induced forced inversion").

To obtain a standardized technique with comparable position and equal stress, a device is used by Rubin and Witten (1960), Sedlin (1960), Clark et al. (1965), Laurin et al. (1968), Pascoët et al. (1972), Paul and Lüning (1978) and Schmidt (1978). Unfortunately only Rubin and Witten (5 kg) and Pascoët et al. (2-3 kg) reported the amount of stress applied.

Inversion stress on the talus is associated with external rotation of the lower leg, which reduces the angle of talar tilt when measured radiologically (Rubin and Witten - 1960, Prins - 1978).

However, Laurin et al. (1968) reported this is only to be correct when normal talar tilt is recorded in the non-injured ankle, whereas post-traumatic talar tilt is not associated with external rotation of the lower leg.

As was described for the clinical demonstration of talar tilt, there is no agreement on the correct position of the foot during radiological talar tilt examination. Plantar flexion is used by Ruth (1961), Gross and Macintosh (1973), Tonino (1973), Gerbert (1975), Seiler and Schweiberer (1977), Gerlach (1978), Prins (1978), Cox and Hewes (1979), Glasgow et al. (1980) and Frölich et al. (1980), while neutral position is preferred by Rubin and Witten (1960), Laurin et al. (1968) and Paul and Lüning (1978).

Sedlin (1960), Makhani (1962) and Boomsma (1979) examined their patients in both plantar flexion and neutral position, claiming that in the first position the anterior talofibular ligament is tested, while in the latter the calcaneofibular ligament is tested. Alquist (1974) reported no difference in results after testing in both positions.

4.3.2 Anterolateral rotational instability; radiological demonstration.

As shown recently by Rasmussen et al. (1981, 1982), anterolateral rotational instability is mainly associated with rupture of the anterior talofibular ligament, and is therefore demonstrated most easily in plantar flexion.

Makhani (1962) was the first to report radiological manifestations associated with anterolateral rotational instability. He noted incongruity of the talofibular joint space after sectioning the anterior talofibular ligament, followed by plantar flexion-inversion stress, and found this phenomenon to be absent when all ligaments were intact.

Weber and Hupfauer (1969), Hupfauer (1970) and Reichen and Marti (1974) reported the same radiological incongruity of the talofibular joint space while performing plantar flexion-inversion stress examinations in non-experimental clinical circumstances and found this also to be associated with rupture of the anterior talofibular ligament. However, it was emphasized that this finding depends on exact projections of the talofibular joint, corresponding with 25° internal rotation (Hupfauer - 1970) which in practise does not always succeed.

Cedell (1975) stated that this phenomenon could also be observed on standard radiographs in case of rupture of the anterior talofibular ligament, but emphasized that this sign would be false negative in case of pain and spasm.

4.3.3 Anterior drawer sign (sagittal stress examination)

Radiological demonstration of the anterior drawer sign was employed first by Dehne (1934), but it was not until the publications of Anderson et al. (1952) that this method became generally known.

When, in case of lateral ligamentous ankle lesion, stress is applied on the distal lower leg in posterior direction with the foot in fixed position, anterior dislocation of the talus is induced relative to the tibia. Radiologically this is observed as an incongruity (dorsal gap) between the inferior articular surface of the tibia and the superior articular surface of the talus in the coronal plane.

This method can be referred to as "sagittal stress examination" and is, when compared to inversion stress examination, considered more reliable in detecting rupture of the anterior talofibular ligament (Anderson et al. - 1952, Hupfauer - 1970, Delpace and Castaing - 1975, Cedell - 1975, v.Oberhammer - 1976, Hackenbruch and Noesberger - 1976, Adler - 1976, Gordon et al. - 1976, Dietschi and Zollinger - 1977, Geesink - 1977, Gerlach et al. - 1978, Paul and Lüning - 1978, Danegger - 1979, Glasgow et al. - 1980, Langer et al. - 1980).

In literature several measurement techniques are described.

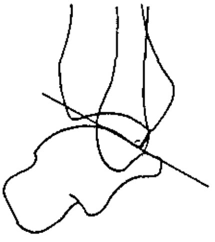


fig. 13

The technique used by the majority of authors was introduced by Landeros et al. in 1968. They measured the distance in mm between the posterior margin of the tibial surface and the nearest part of the dome of the talus (fig. 13) (Hackenbruch et al. - 1976, 1977, 1979, Müller et al. -1977, Noesberger et al. - 1977, Johannsen -1978, Speeckaert - 1978, v.Moppes et al. -1979, Glasgow et al. - 1980, Langer et al. - 1980).

fig. 14

Delpace and Castaing (1975) reported a somewhat different measurement technique. In this method the wideness of the dorsal gap is measured along a line between the posterior margin of the tibia and the middle of the talus. This method is also used by Noesberger (1976) and Danegger (1979). However, this technique is less accurate because the line cannot be positioned with sufficient precision since the middle of the talus is not precisely defined (Hackenbruch et al. - 1979) (fig. 14).

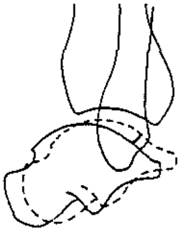


fig. 15

Adler (1976) measured the distance over which the dorsal articular surface of the talus is displaced, which necessitates two comparable exposures (fig. 15).

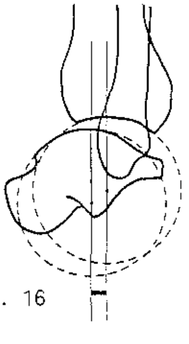
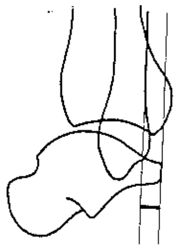


fig. 16

Lindstrand and Mortensson (1977), by considering the joint surfaces of tibia and talus to be a part of concentric circles, measured the perpendicular distance between lines drawn through the middle of the "tibial circle" and the "talar circle" (fig. 16).



V. Moppes et al. (1979) distinguished two components in the anterior drawer sign: the "tilting" component, measured as shown in fig. 13 and the "gliding" component, measured as the perpendicular distance between the posterior border of the posterior talar process and the line through the posterior border of the fibula (fig. 17).

fig. 17

Sagittal stress examination, like inversion stress examination, can be performed manually and mechanically. Manual force is applied by Landeros et al. (1968), Hupfauer (1970), Adler (1976B), Tausch (1978), Gerlach et al. (1978) and Prins (1978).

A device for sagittal stress examination was introduced in 1972 by Castaing and Delpace. They called it the "diagnentorse". Since then most authors report performing this examination with the aid of a similar device (Hackenbruch and Noesberger - 1976, Dietschi and Zollinger - 1977, Seiler and Holzrichter - 1977, Müller et al. - 1977, Paul and Lüning -1978, Raaymakers - 1979, Danegger - 1979, Dewijze and Tondeur - 1979, v.Moppes et al. - 1979, Glasgow et al. - 1980, Fröhlich et al. - 1980, Schweiberer and Seiler - 1981).

Although a standard device is used, the force applied differs frequently. The findings from literature are listed in table 3. Delpace and Castaing (1975) showed that the degree of dislocation in sagittal stress examination is related to the force used and advised to use a stress force not exceeding 4-5 kg.

Table 3: Literature findings concerning stressforce used in sagittal stress examination.

Author	stress force (kg)
Delpace and Castaing (1975)	4- 5
Gordon et al. (1976)	9
Dietschi and Zollinger (1977)	20-30
Seiler and Holzrichter (1977)	7.5
Lindstrand and Mortensson (1977)	4
Johannsen (1978)	5
Raaymakers (1979)	7.5
Danegger (1979)	10
Dewijze and Tondeur (1979)	5
v. Moppes et al. (1979)	5.5
Glasgow et al. (1980)	15
Fröhlich et al. (1980)	20
v. Moppes and v.d. Hoogenband (1982)	4.5

Noesberger (1976) and Hackenbruch et al. (1979) do not use a weight, but apply stress by strapping the lower leg to the device, thereby omitting standard stress forces.

Similar to inversion stress examination the results of sagittal stress examination should be compared to the opposite side to exclude ligament laxity from interfering with the results.

Sagittal stress examination does not require anaesthesia. This is an important difference with inversion stress examination, which is emphasized by almost every author.

The importance of maintaining stress during a short time to overcome muscle spasm is mentioned by several authors (Dietschi and Zollinger - 1977, Lindstrand and Mortensson - 1977, Danegger - 1979, v. Moppes et al. -1979).

Disagreement again exists on the position of the foot during examination. Plantar flexion is used by Delpace and Castaing (1975), Noesberger (1976), Gordon et al. (1976), Lindstrand and Mortensson (1977), Seiler and Holzrichter (1977), Prins (1978), Paul and Lüning (1978), Hackenbruch et al. (1979), Raaymakers (1979), Dewijze and Tondeur (1979), Fröhlich et al. (1980).

Neutral position is preferred by Landeros et al. (1968), Adler (1976B), Dietschi and Zollinger (1977), Tausch (1978), Gerlach et al. (1978) and v.Moppes and v.d.Hoogenband (1982).

4.3.4 Lateral ankle instability (exorotation stress examination)

To complete the literature findings on radiological stress examination, the radiological demonstration of lateral ankle instability is shortly discussed.

Lateral ankle instability is defined as abnormal lateral movement of the talus and distal fibula, with or without associated fracture of the distal fibula (Kleiger - 1954).

Absence of a fibula fracture in this injury is rare. This type of instability is generally caused by a pronation-exorotation injury (Lauge-Hansen - 1949, Solonen and Lauttamus - 1965) and is associated with tearing of the deltoid ligament and rupture of the distal tibiofibular ligaments. When concomitant rupture of the posterior tibiofibular ligament and interosseous ligament is present, then tibiofibular diastasis is possible, but lateral ankle instability may occur without diastasis.

Lateral ankle instability can be demonstrated radiologically by exorotation stress examination.

Kleiger (1954) has described a device to perform this examination in which the foot is fixed on the device and the patient is asked to turn towards the uninjured side, producing internal rotation of the leg, leaving the fixed foot in relative external rotation. In this position an AP-view is taken and demonstrates an increase of width of the interspace between talus and medial malleolus and, in case of diastasis, of the syndesmotic space.

4.3.5 Interpretation of the various radiological stress examinations

In any diagnostic examination the possibility to distinguish between normal and abnormal is imperative. However, concerning inversion stress examination there is much controversy regarding the correct interpretation.
Although majority opinion considers talar tilt angles exceeding 5° as pathological (Hughes - 1949, Bonnin - 1950, Ruth - 1961, Olson 1969, Fordyce and Horn - 1972, Staples - 1972, Pascoët et al. - 1972, Landry - 1976, Sanders - 1976, Seiler and Schweiberer - 1977, Müller et al. - 1977, Paul and Lüning - 1978, Tausch - 1978, Speeckaert - 1978, Cox and Hewes - 1979), a wide variation of physiological talar tilt is measured in large series of supposedly normal subjects.
Bonnin (1950), in performing manual examinations, found talar tilt angles varying between 5-25° in 4-5% of 200 normal subjects, aged 18-45 years. He called these ankles "hypermobile", provided the findings were bilateral.
Rubin and Witten (1960), in 152 subjects, found talar tilt in 56% varying between 3-23°, using a device without anaesthesia.
Laurin et al. (1968), under the same conditions, found talar tilt in 92 normal subjects, aged 6-60 years, averaging 7°, but varying from 0-27°.
Pascoët et al. (1972) using a device under general anaesthesia in 221 patients with ankle sprains found talar tilt on the contralateral ankle to be less than 6° in 91%; in only 3% talar tilt exceeded 10°.
Prins (1978) manually determined bilateral talar tilt in 100 normal subjects under general anaesthesia and reported in 80% talar tilt between 0-6°, in 17% between 6-11° and in 3% between 11-16°.
Cox and Hewes (1979) examined 404 ankles of U.S. naval personnel without history of ankle injuries and found no talar tilt in 90%, 1-5° in 8% and talar tilt exceeding 5° in the remaining 2%.

When both ankles of the same individual are compared, talar tilt difference is generally considered pathological when the difference exceeds 5-6° (Freeman - 1965, Tonino - 1973, v.Moppes et al. - 1979) although some authors regard a talar tilt difference of 3° or more as pathological (e.g. Clark et al. - 1965, Frölich et al. - 1980).
However, physiological talar tilt differences are also reported to show variety. Rubin and Witten (1960) found talar tilt differences to be less than 3° in 78%, but varying from 3-19° in the remaining 22% of 152 normal subjects.

Laurin et al. (1968) reported the average difference always to be less than 10° and not exceeding 15°.
Prins (1978) found the difference always to be less than 8°, the examination being performed under general anaesthesia in 100 subjects.
V.Moppes et al. (1979) reported physiological talar tilt differences in 100 cases not exceeding 5.5°.

Regarding the interpretation of the findings from sagittal stress examinations, more consensus is found in literature concerning normal and pathological displacement than was found with respect to inversion stress examination. Unilateral displacement up to 5-6 mm is regarded as normal (Landeros - 1968, Delpace and Castaing - 1975, Noesberger - 1976, Paul and Lüning - 1978, Danegger - 1979, Hackenbruch et al. - 1979, Glasgow et al. - 1980).
Anterior drawer sign differences between ipsi- and contralateral side are regarded normal up to 3 mm (Hackenbruch and Noesberger - 1976, Müller et al. - 1977, Lindstrand and Mortensson - 1977, Seiler and Holzrichter - 1977, Noesberger et al. - 1977, Paul and Lüning - 1978, Hackenbruch et al. - 1979, v.Moppes et al. - 1979, Glasgow et al. - 1980, Schweiberer and Seiler - 1981, v.Moppes and v.d.Hoogenband - 1982).
Unilateral anterior drawer sign exceeding 8 mm suggests rupture of the anterior talofibular ligament, while exceeding 10 mm indicates rupture of both anterior talofibular and calcaneofibular ligament, whereas exceeding 15 mm is associated with rupture of all three lateral ankle ligaments (Delpace and Castaing - 1975, Hackenbruch and Noesberger - 1976, Dewijze and Tondeur - 1979).
When a difference in anterior drawer sign is found between the ipsi- and contralateral side between 3-7 mm this suggests rupture of the anterior talofibular ligament. A difference between 5-16 mm indicates rupture of both anterior talofibular and calcaneofibular ligament (Seiler and Holzrichter - 1977, Hackenbruch et al. - 1979).

4.3.6 Reliability of the various radiological stress examinations

To estimate the diagnostic value of inversion stress examination Sanders (1976) examined 260 patients with recent ankle sprains and compared the results with the findings of ankle arthrography. Talar tilt was performed manually with the aid of intra-articular local anaesthesia as is routine in arthrographical examination. When in agreement with literature 6° of talar tilt was considered as the lower limit of abnormality, it was found that a talar tilt angle between 6-10° was associated in 61% with ligamentous injury and a talar tilt angle exceeding 10° was associated with ligamentous lesions in 96%. However, with a talar tilt angle of less than 6°, 30% nevertheless had ligament rupture, 11% even showed rupture of both anterior talofibular and calcaneofibular ligament.

When a talar tilt difference (between ipsi- and contralateral ankle) of 6° is taken as the lower limit of abnormality, it was shown that anything exceeding this 6° was associated with ligament rupture in 94%. However, with a talar tilt difference of less than 6°, still 39% nevertheless had ligamentous injury.

Prins (1978) also correlated the results of inversion stress examination with local intra-articular anaesthesia with the results of arthrographic examination. In 25 patients without ligament lesions he found the talar tilt angle to exceed 5° in 40%. Moreover, he reported the talar tilt angle to be unexpectedly small in patients with arthrographically assumed ruptures. In 53% of the patients with alledged rupture of the anterior talofibular ligament the talar tilt angle was less than 6°. When rupture of both anterior talofibular and calcaneofibular ligament was assumed, talar tilt angles were normal in 14%. Overall false negative talar tilt angles were found in 31% of the patients with arthrographically confirmed ligament rupture.

Another investigation in which inversion stress examination was compared to arthrography was performed by v.Moppes et al. (1979). In 185 patients with recent ankle sprains talar tilt differences were measured prior to arthrography. The use of anaesthesia was not mentioned. A talar tilt difference exceeding 5.5° was considered abnormal. When isolated rupture of the anterior talofibular ligament was assumed arthrographically inversion stress was positive in 32% and (false) negative in the remaining 68%. When rupture of both anterior talofibular and calcaneofibular ligament was assumed, inversion stress was positive in 60% and (false) negative in the remaining 40%. Rupture of all three ligaments was associated with positive inversion stress examination in all cases. No mention was made of how this latter diagnosis was made arthrographically. In 25 patients showing no signs of ligament rupture on arthrography, inversion stress examination was false positive in 12%.

The value of inversion stress examination can also be estimated when related to the findings at operation.

Broström (1965) reported abnormal talar tilt (exceeding 5°) under spinal anaesthesia varying from 5-16° in 19% of 158 patients with isolated rupture of the anterior talofibular ligament and varying from 5-23° in 30% of 47 patients with rupture of both anterior talofibular and calcaneofibular ligament.

Duquennoy et al. (1975) correlated their operative findings in 104 patients with preoperative talar tilt examination without anaesthesia. They found an

average talar tilt angle of 16° in case of rupture of the anterior talofibular ligament, 21° in case of rupture of both anterior talofibular and calcaneofibular ligament and 32° in case of rupture of all three ligaments. Unfortunately, only the average talar tilt angles were reported.
Raaymakers (1979) reported the results of inversion stress examination in 91 patients under conduction anaesthesia of the superficial peroneal nerve. He found no false positive results in his series when compared to the operative findings but was unable to correlate the talar tilt angles with the extent of ligamentous lesions.
V.Moppes and v.d.Hoogenband (1982) performed inversion stress examination under general anaesthesia in 35 out of 50 operated patients, using a talar tilt difference of 6° as the lower limit of abnormality. They found inversion stress examination to be correct in 92% of the cases but could not correlate talar tilt difference with the extent of ligamentous injury.

The validity of "the sign of incongruity" (anterolateral rotational instability) was investigated by Lindstrand et al. (1978). In 175 patients the condition of the anterior talofibular ligament was established either operatively or arthrographically, the contralateral ankle of 61 patients serving as a reference group. The talofibular joint was visualized in AP-views with different degrees of endorotation to obtain optimal demonstration of the joint space.
The findings concerning the appearance of the talofibular joint then were compared to the arthrographic and operative findings regarding the condition of the anterior talofibular ligament. It was found that congruity was associated with an intact ligament, but incongruity was only associated with ligament rupture in 41%, the remaining 59% being false negative results.
In the reference group false positive results were found in 16%. Provoking incongruity by applying inversion stress proved to be unsuccessful.
The authors concluded that incongruity suggests rupture of the anterior talofibular ligament, but that the practical value of this method is limited because of an unacceptably high percentage of false negative results caused by pain and spasm and false positive results caused by persistent instability following from previous ruptures.

Fröhlich et al. (1980), in addition to a comparative study on stress examination, measured the talofibular distance (fig. 18) to express the incongruity in the talofibular joint in 142 patients with recent ankle sprain in which the diagnosis was verified surgically. This procedure was possible in

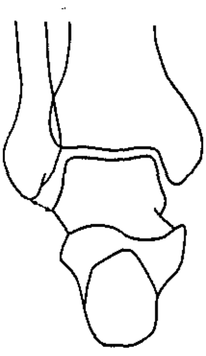


fig. 18
The talofibular distance.

only 116 patients. In the remaining patients the radiographs were non-comparable. From the operative findings it was concluded that a talofibular distance exceeding 6 mm is to be regarded as pathological, as is a difference of 2 mm or more between the ipsi- and contralateral side. The authors concluded that this method is of only limited importance because of its dependence on exact radiological projections.

The reliability of sagittal stress examination is generally regarded high as to detect rupture of the anterior talofibular ligament. However, Sanders (1976) compared his results of manual sagittal stress examination with the arthrographic results and reported in a series of 194 recent ankle sprains false negative results in 53% and false positive results in 1%.

Prins (1978) reported 6 cases (4%) of false positive anterior drawer sign in a group of 14 patients without arthrographic evidence of ligament rupture. Moreover, he found false negative results in 71% of a group of 69 patients, in which rupture of the anterior talofibular ligament was assumed arthrographically and in 62% of 92 patients in which rupture of more than one ligament was assumed arthrographically.

V.Moppes et al. (1979) also compared sagittal stress examination with arthrography and reported false negative findings in 45.5% and 33.4% respectively when rupture of one or more ligaments was assumed arthrographically. False positive results were found in 8% of 25 subjects.

Hackenbruch et al. (1979) only analysed the roentgenograms of patients in which ligament rupture was confirmed at operation and thus found no false negative results. However, no false positive findings were encountered either.

Gordon et al. (1976) stated that there is no correlation between the degree of displacement and the extent of ligamentous injury. However, this opinion is based on 11 operated patients only. Gerlach et al. (1978) reported that the displacement found in case of rupture of the anterior talofibular ligament does not increase with concomitant rupture of more than one lateral ligament.

Prins (1978) found the average anterior drawer sign to be the same in his different patient groups and thus found no correlation with the extent of injury.

Hackenbruch et al. (1979) verified the radiological diagnosis by surgical exploration in 94 patients and concluded that there is no statistical significant correlation between the findings in sagittal stress examination and the extent of ligamentous injury.

Inversion stress examination versus sagittal stress examination

In recent literature several authors reported comparative studies on inversion stress examination and sagittal stress examination in order to reveal whether one of these methods could be replaced by the other.

Johannsen (1978) studied 244 patients with recent ankle sprains. Inversion stress examination was performed manually, comparing both ankles. The distance in mm between the articular surface of the talus and the tibia was measured at the top of the lateral talar trochlea. A difference of 3 mm (i.e. about 6°) or more was considered pathological. Moreover, sagittal stress examination was performed using a weight of 5 kg. A difference in displacement of the talus of 2 mm or more was considered pathological. In all, 86 patients were submitted to operation. Ligament rupture was found in 83 patients. In one case all ligaments were found intact (ADS-difference 3 mm), while in two cases only capsular lesions were found.

In case of rupture of the anterior talofibular ligament (20 patients) inversion stress examination was correct in 35% and erroneous in the remaining 65%, while sagittal stress examination was correct in 65% and erroneous in 35%.

In case of double ligament rupture, inversion stress examination was correct in 81.5% and erroneous in 18.5%, the findings in sagittal stress examination being 77% and 23% respectively.

Overall, inversion stress examination was erroneous in 30% and sagittal stress examination was erroneous in 26%. However, if one was negative, the other was usually positive. In only 5% of the surgically verified cases both methods were negative at the same time. Consequently the authors concluded that inversion stress examination could not be replaced by sagittal stress examination, or vice versa, because the two methods were complementary.

Hackenbruch et al. (1979) compared the value of both radiological techniques in 94 patients in which the diagnosis was also verified surgically. Stress radiopgraphs of the contralateral side were used for comparison.

Sagittal stress examination was performed with the aid of a device but, as described previously, with the lower leg strapped (Noesberger - 1976), thereby not quantifying the amount of stress applied. An ADS-difference up to 2 mm was considered normal.

The method and interpretation for inversion stress examination unfortunately was not described but it is assumed from the figures that a talar tilt difference up to 4° was considered normal. In case of rupture of the anterior talofibular ligament, inversion stress examination was false negative in 34% of 38 cases studied, whereas sagittal stress examination was erroneous in none of the 48 cases studied.

In case of rupture of more than one ligament, inversion stress examination was erroneous in 15% of 39 patients, whereas sagittal stress examination was again erroneous in none. If an ADS-difference of 3 mm would have been regarded as the upper limit of normality, as is agreed generally in literature, sagittal stress examination would have been erroneous in 19% and 4% respectively.

The authors concluded that sagittal stress examination differentiated significantly more accurately than inversion stress examination between intact and ruptured ligaments, and consequently ceased performing the latter.

Langer et al. (1980) investigated 343 patients with recent ankle sprains and compared the results of sagittal stress examination with those of manually performed inversion stress examination. Sagittal stress examination was performed with a device described by Noesberger (1976). Unilateral talar displacement up to 5 mm and a bilateral difference up to 3 mm was considered normal.

Inversion stress examination was omitted when pain rendered the examination impossible and sagittal stress examination already had suggested ligamentous injury. A talar tilt difference exceeding 9° was considered pathological. Out of 343 patients, 202 patients showed no abnormalities using both stress examinations. In 58 patients, in which stress examination suggested ligament rupture, the diagnosis was verified surgically. In 33 patients with the same result from stress examination, operation was not performed. In 16 patients with normal findings in both stress examinations, surgery was performed based on the clinical aspects and revealed rupture of the anterior talofibular ligament in all cases. In the remaining 34 patients both stress examinations were negative but arthrography was performed and demonstrated rupture in 12 cases, which was confirmed at operation. In the 91 cases in which stress examination suggested ligament rupture in 63 patients (69%) this was solely based on sagittal stress examination. Both examinations were necessary in 24 cases (26%), whereas in 4 cases (5%) only inversion stress examination revealed the diagnosis. The authors concluded that sagittal stress examination is more reliable in diagnosing lateral ankle ligament lesions than inversion stress examination. However it has to be emphasized that a talar tilt difference of 9° is a very high reference as compared to majority opinion in literature.

Fröhlich et al. (1980) reported a comparative study on 142 patients with surgically verified ligament ruptures. Both inversion stress examination and sagittal stress examination were performed using a device which produced a stress force of 20 kg. All patients were anaesthetized using conduction anaesthesia of the superficial peroneal nerve. The opposite uninjured ankles were examined for comparison and a group of 156 supposedly normal subjects was used as a reference group. A talar tilt angle between 5 and 9° suggested rupture of the anterior talofibular ligament but in this range also 10% of the reference group was found. Therefore a talar tilt angle exceeding 10° was regarded as pathological. In sagittal stress examination a unilateral displacement exceeding 6 mm was regarded as pathological. Both references were obtained from frequency-analysis. The anterior drawer sign was less than 6 mm in 57% of isolated ruptures of the anterior talofibular ligament and in 44% of double ligament ruptures, whereas in the latter talar tilt was less than 10° in only 17%. No correlation was found between talar tilt angle and anterior drawer sign.

When differences with the contralateral side were measured, the anterior drawer sign showed a difference less than 3 mm in over 50% in both patient groups, whereas talar tilt differences exceeding 3° were found in 89% of all double ligament injuries.

The authors concluded that inversion stress examination gives more reliable information in diagnosing lateral ankle ligament lesion but that sagittal stress examination has to be performed additionally in case of doubt.

4.4 Arthrography

Arthrography of the ankle joint as a method of investigation in case of ankle sprain was introduced by Wolff (1940) and Hansson (1941) but its usefulness was not established until the comprehensive studies of Brostöm et al. (1965) on this subject were published.

In the Netherlands ankle arthrography was introduced by Den Herder (1961) and stimulated by Sanders (1972, 1976, 1977).

The findings in ankle arthrography are based on the intimate association of the ankle ligaments with the joint capsule and the surrounding tendon sheaths. Arthrography has to be performed within one week following injury because after this period the synovial membrane is sealed again and extra-articular contrast leakage can no longer be demonstrated (Broström et al. - 1965, Olson - 1969, Sanders - 1972, Fussell and Godley - 1973, Gerbert - 1975, Spiegel and Staples - 1975, Stepanuk - 1977).

Only a few contra-indications to this method of examination are mentioned in literature:

- advanced osteoarthrosis (Arner et al. - 1957)
- dermatogenic lesion near the ankle joint (Den Herder - 1961, v.Moppes and v.d.Hoogenband - 1982)
- hypersensitivity to iodine or local anaesthetics (e.g. Stepanuk -1977)

The theoretical complication of joint sepsis is not reported in the thousands of examinations described in the literature studied.

Broström et al. (1965) made mention of one patient with a distinct erythema around the puncture side which disappeared within 24 hours.

Rest and elevation are recommended for about 24 hours after ankle arthrography to avoid the occurrence of reactive synovitis which can occasionally follow arthrography (Spiegel and Staples - 1975, Tausch - 1979, Dalinka - 1980).

One patient suffering from this syndrome was described by v.Moppes and v.d.Hoogenband (1982). Complete recovery was achieved with rest and plaster immobilization only.

4.4.1 Technique

The patient is placed in a supine position on the fluoroscopic table. Strict aseptic conditions are imperative, but the prophylactic use of antibiotics is irrational.

The vast majority of ankle sprains involves the lateral ligaments. The area of choice for contrast injection is on the side opposite the injury. Therefore, the injection is usually made on the anteromedial side, preferably medial to the anterior tibial tendon, in order not to damage the dorsal artery of the foot. Other introductions are used occasionally, like puncture between the anterior tibial and extensor hallucis longus tendons (Callaghan et al. - 1970), lateral to the extensor hallucis longus tendon (Thys et al. - 1972) and the posteromedial approach (Berridge and Bonnin - 1944).

After disinfecting the skin with 1% iodine, the point of insertion of the needle is selected by using the line which connects the apices of the malleoli as anatomical guideline. The skin medial to the anterior tibial tendon is punctured and one ml 1% lidocaine is injected into the soft tissues.

Under fluoroscopic control the joint is entered and excessive joint fluid, often haemorrhagic, is aspirated so as not to dilute the contrast material. Next, 2 ml 1% lidocaine is injected, which can be done effortlessly when the needle is in the proper position. Then, contrast medium is injected, using for instance a mixture of 10 ml Conray 60 and 1 ml 1% lidocaine.

Some authors dilute the contrast medium with sterile water (Gordon - 1970). Resistance to the injection of the dye noticed by the examiner and a distinct pressure in the ankle joint, experienced by the patient, signals the amount of contrast material which is required.
When the joint capsule is intact, generally some 8 ml of contrast material can be injected, but in the presence of a large capsular tear, amounts exceeding 15 ml can be injected without resistance.
Excessive tension inside the joint causes pain and tends to create reflux of contrast medium along the needle tract. After the needle is removed the anterior aspect of the ankle is wiped free from contrast material so that no artifact will be visible. Then, the ankle is moved passively and actively in order to disperse the contrast medium throughout the ankle joint. Next, standard views in four positions are made: anteroposterior, medio-lateral, 20° endorotation and 20° exorotation of the foot.

Normally, the contrast material will remain in the joint in sufficient quantities for approximately 20 minutes. Therefore, the exposures must be taken within this limit, but preferably as soon as possible after injection.

The contrast injection into the joint cavity, resulting in distension of the joint capsule, causes some pain but lasts only a few minutes and is not severe. Para-articular contrast injection likewise causes some pain during a short period (Den Herder - 1961) but is not associated with complications (v.Moppes and v.d.Hoogenband - 1982).
Discomfort following arthrography consisting of painful pressure is seen sometimes in patients without ligament injury (Prins - 1978).
In case of absence of ligamentous injury the contrast medium injected will disappear slowly out of the ankle joint by diffusion. When the effect of the added lidocaine is dissolved, usually some 4-6 hours following arthrography a sensation of pressure pain can be experienced, lasting several hours but disappearing spontaneously within 12-24 hours.

4.4.2 Interpretation

The interpretation of abnormalities in ankle arthrography is not difficult if one is familiar with the normal findings and has a clear understanding of the anatomical alterations in consequence of ankle sprains.

Normal arthrograms

In the normal arthrogram the contrast material appears as a thin band between the tibia and the talus, extending down to the tips of the medial and

fig. 19
Normal arthrogram, AP-view. The apices of both malleolar tips are extra-articular. The syndesmotic recess is within normal limits.

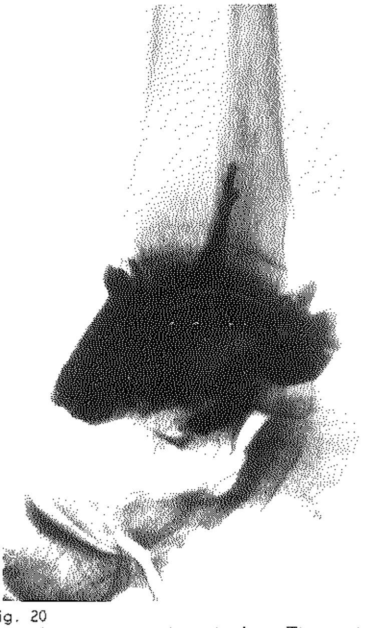


fig. 20
Normal arthrogram, lateral view. The posterior recessus is notched by tendinous structures.

fig. 21
Normal arthrogram, mortise view.

fig. 22
Normal arthrogram, mortise view, showing contrast-filling of the posterior part of the subtalar joint (arrows).

lateral malleoli of which the apices and external surfaces are extra-articular. The limitations of the ankle joint cavity are outlined by smooth definitions of the joint capsule (fig. 19).

On the lateral view two normal outpouchings (recesses) are seen anteriorly and posteriorly which tend to enlarge and become irregular with advancing age (Gerbert - 1975, Fulp - 1975, Dalinka - 1980). The posterior pouch is frequently notched by the tendon of the flexor hallucis longus and may show other tendinous indentations (Wolff - 1940, Berridge and Bonnin - 1944) (fig. 20).

On the AP-view and the mortise view a third recess is seen generally extending between the distal tibia and the fibula. This syndesmotic recess averages about 1 cm in height and 4.0 mm in width and normally extends upwards no more than 2.5 cm (Lindblom - 1952, Arner et al. - 1957, Broström et al. - 1965, Olson - 1969, Mehrez and El Geneidy - 1970, Dalinka - 1980) (fig. 21).

In addition, filling of the posterior subtalar joint is a normal variant which, according to literature, occurs in 5-20%. However, it seems to be less common in intact ankles than in cases of recent ligamentous injury, and therefore is regarded partly as having a traumatic origin (Broström et al - 1965, Gordon - 1970). Percy et al. (1969) and Callaghan et al. (1970) judged this finding as pathological, whereas according to Tausch and Maess (1978) it is associated with chronic instability (fig. 22).

Filling of both posterior and anterior part of the subtalar joint is much less frequent (3%). Dalinka (1980) reported that normally no communication exists between the anterior and posterior subtalar joint, which suggests that opacification of the complete subtalar joints is of traumatic origin.

Communication with the tendon sheaths on the medial aspect of the ankle, individually or combined, is a normal variation which has no diagnostic significance.

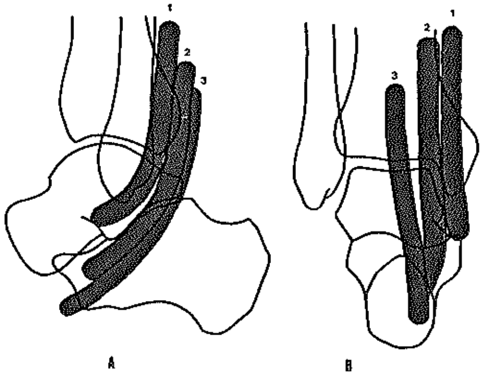


fig. 23
Projections of the tendon sheats on the medial aspect of the ankle; tendon sheath of the posterior tibial muscle (1), flexor digitorum longus muscle (2) and flexor hallucis longus muscle (3).

fig. 24
Normal arthrogram, lateral view, showing filling of tendon sheaths of the flexor digitorum longus and flexor hallucis longus muscle.

fig. 25
Normal arthrogram, AP-view. Contrast-filling in all three tendon sheaths on the medial aspect of the ankle.

fig. 26
Normal arthrogram, mortise view, visualizing the tendon sheaths of the extensor digitorum longus muscles.

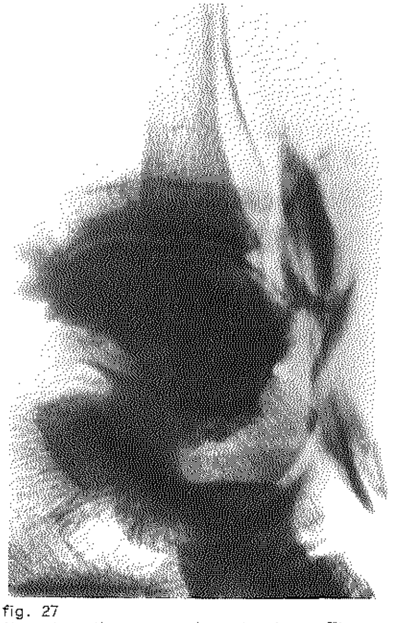


fig. 27
Normal arthrogram, lateral view. The same patient as fig. 26. Contrast leakage into the tendon sheath on the anterior aspect of the ankle.

In the lateral view the sheath of the posterior tibial muscle is projected superior to the sustentaculum tali whereas the sheath of the flexor hallucis longus muscle is seen inferior to the sustentaculum tali (Callaghan et al. - 1970), the sheath of the flexor digitorum longus muscle lying in between (fig. 23A and 24).
In the AP-view the tendon sheath of the posterior tibial muscle is projected over and distal to the medial malleolus, both other flexor tendon sheaths projected relatively more medially (fig. 23B and 25).
Opacification of the sheath of the flexor hallucis longus muscle is seen in 5-25%, of the flexor digitorum longus muscle in 4-9% and of the posterior tibial muscle in about 5%.

Normally there is no communication with the tendon sheaths of the peroneal muscles. However, Broström et al. (1965) indicated that in about 10% of the patients who sustained rupture of the lateral ankle ligaments including the calcaneofibular ligament, communication between the peroneal tendon sheaths and the ankle joint may persist. This was confirmed by Black et al. - 1978.
Visualization of the peroneal tendon sheaths without accompanying antero-lateral extra-articular contrast leakage therefore is associated either with previously sustained ligament injury, or with recent isolated rupture of the calcaneofibular ligament (fig. 32), which is a very rare injury. The findings from the history will normally supply the answer to this infrequent finding. Confusingly, several authors consider filling of the peroneal tendon sheath as a normal variant of ankle arthrography (Haage - 1967, Gordon - 1970, Mehrez and El Geneidy - 1970, Thys et al. - 1972, Pascoët - 1972, Fussell and Godley - 1973, Toth et al. - 1974).
Communications with tendon sheaths on the anterior aspect of the ankle are exceptional. According to the literature this occurs in 2-6% (Gordon - 1970, Sanders - 1972, Fussell and Godley - 1973) (fig. 26 and 27).

Pathological arthrograms

Except for the contrast distributions mentioned before, all other types of extra-articular contrast leakage are pathological.
The anterior talofibular ligament, most frequently ruptured in case of ankle sprain, is incorporated in the joint capsule. Rupture of this ligament therefore is inseparably associated with tearing of the anterolateral joint capsule, which can be of variable extent. Rupture of the joint capsule without ligament rupture is unlikely because of the capacious laxity of the joint capsule anteriorly and posteriorly.

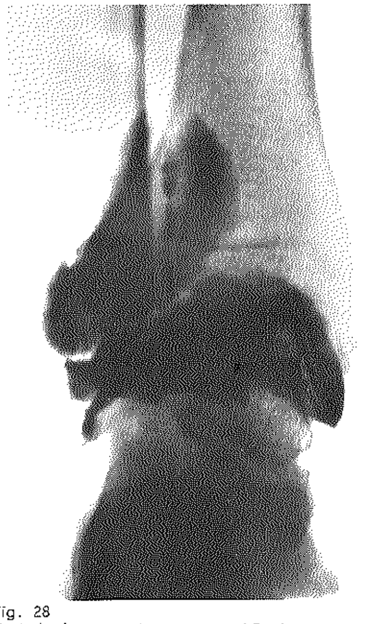


fig. 28
Pathological arthrogram, AP-view. Contrast leakage around the tip of the lateral malleolus, suggesting rupture of the anterior talofibular ligament.

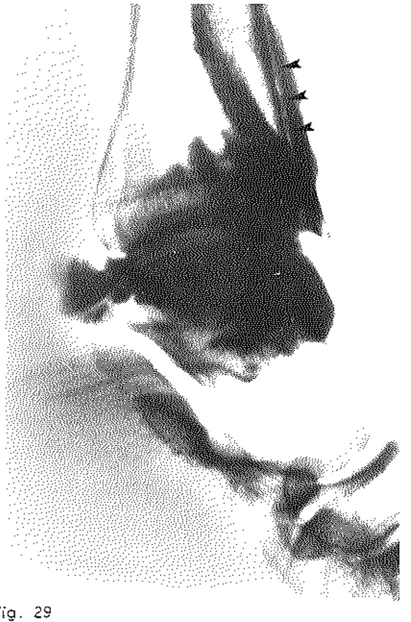


fig. 29
Pathological arthrogram, lateral view. Same patient as fig. 28. Note the (thin) contrast-free zone anterior to the tibia (arrows), indicating the integrity of the tibiofibular ligament.

fig. 30
Pathological arthrogram, mortise view. Contrast leakage around the tip of the lateral malleolus and into the peroneal tendon sheath (arrows), indicating rupture of both anterior talofibular and calcaneofibular ligament.

fig. 31
Pathological arthrogram, lateral view. Same patient as fig. 30. Contrast leakage into the peroneal tendon sheath, visualizing both peroneal tendons.

fig. 32
Pathological arthrogram, mortise view. Leakage of contrast into the peroneal tendon sheath without leakage around the lateral malleolar tip, suggesting recent isolated rupture of the calcaneofibular ligament (confirmed at operation).

fig. 33
Pathological arthrogram, mortise view. Contrast leakage through the tibiofibular syndesmosis, indicating rupture of the anterior tibiofibular ligament. Note the absence of the normal syndesmotic recess.

fig. 34
Pathological arthrogram, lateral view. Same patient as fig. 33. There is no contrast-free zone anterior to the tibia.

The interpretation of pathological arthrograms will now be described as it is generally reported in literature (Broström et al. - 1965, Olson - 1969, Sanders - 1972, Dalinka - 1980).
Rupture of the anterior talofibular ligament results in extra-articular contrast leakage around the tip of and anterolateral to the lateral malleolus, extending upwards along the fibula. More proximally the contrast medium may spread in medial direction, superimposing over the area of the syndesmosis and the interosseous space, especially in the endorotated view (mortise view), possibly giving rise to confusion as this may be interpreted as rupture of the anterior tibiofibular ligament. In these cases however usually a contrast free zone is present anterior to the tibia on the lateral view, indicating the integrity of the anterior tibiofibular ligament. This contrast-free zone may be absent due to insufficient lateral projections (fig. 28 and 29).

The calcaneofibular ligament is anatomically separated from the joint capsule but intimately associated with the inner wall of the peroneal tendon sheath. Rupture of this ligament therefore is virtually associated with rupture of the peroneal tendon sheath, although occasional exceptions occur, for instance when a partial rupture of this ligament is present.
When rupture of the anterior talofibular ligament is accompanied by rupture of the calcaneofibular ligament, arthrography thus demonstrates the findings as described in case of rupture of the anterior talofibular ligament together with contrast-filling of the peroneal tendon sheath (fig. 30 and 31).
Concomitant rupture of the posterior talofibular ligament is not associated with a pattern of contrast leakage, specifically different from that of rupture of both other lateral ligaments, and therefore can not be diagnosed arthrographically.

Rupture of the anterior tibiofibular ligament, which generally is not associated with damage to the lateral ankle ligaments because of contradictory trauma mechanism, results in contrast leakage which in de AP-view extends from the joint cavity through the tibiofibular syndesmosis upwards overlying the interosseous space. The normal syndesmotic recess is absent whereas no extra-articular contrast leakage is seen around the tip of the lateral malleolus (as is present in case of rupture of the anterior talofibular ligament) (fig. 33).
In the lateral view the extra-articular contrast is seen anterior to the tibiofibular syndesmosis extending upwards, the contrast-free zone being absent (fig. 34).

Rupture of the strong deltoid ligament is less common than rupture of the

lateral ligaments and usually is partial, involving only a portion of this broad fan-shaped ligament.
Arthrographically contrast leakage is seen distally and medially to the tip of the medial malleolus and, depending on the location of the tear, anteriorly or more posteriorly.

A different interpretation of the arthrographic findings is given by Percy et al. (1969).
In this classification, in which the criteria are based on the size and localisation of the contrast leakage, three types of leakage patterns are distinguished.
In type I a small flame-shaped contrast leakage is seen anteriorly, allegedly corresponding to rupture of the anterolateral joint capsule without ligamentous damage.
In type II contrast leakage is seen anterolaterally, but mainly anteriorly; this pattern is said to be seen in case of isolated rupture of the anterior talofibular ligament.
In type III, allegedly corresponding to rupture of both anterior talofibular and calcaneofibular ligaments, contrast leakage is seen mainly lateral to the lateral malleolus, extending upwards along the fibula.
In the Percy classification contrast filling of the peroneal tendon sheath has no diagnostic value.

Lindholmer et al. (1978), in a search for more sensitive criteria, introduced a new diagnostic method, based on the extent of extra-articular contrast distribution as seen in the lateral projection. It was postulated that lateral contrast posteriorly to the middle of the lateral malleolus suggests rupture of the calcaneofibular ligament.
Vuust (1980) described a new X-ray projection, "the oblique axial projection", in which the calcaneofibular ligament is demonstrated without the usual superimposition of bone or contrast medium. The value of this technique was confirmed experimentally by the author (Vuust - 1980) and clinically (Vuust and Niedermann - 1980) in verifying the radiological findings by means of operation in 19 cases.

Artifacts

Artifacts in ankle arthrography, showing extra-articular contrast distribution not associated with capsular or ligamentous tearing, are few. They are usually caused by reflux of contrast material along the needle tract or by accidental contrast injection into the soft tissues. Because the site of the injection is opposite the injury, artifacts can be easily recognized by their location. Spilling of contrast medium on the skin produces an artifact, which can be avoided by cleaning the skin with alcohol after removing the needle.

4.4.3 Reliability

In order to establish the incidence of ligament ruptures without extraarticular contrast leakage (false negative arthrography) it would be necessary to operate on patients with normal arthrograms. For ethical reasons this was not done in our series.

Lindholmer et al. (1978) operated on two patients, despite normal arthrography because of severe clinical symptoms suggesting ligament rupture. No ligament rupture was found.
No other mentions of false negative arthrograms were found in the literature studied, provided arthrography was performed correctly and within seven days following injury. From literature it is therefore accepted that the incidence of false negative arthrography is very low.

The reliability of pathological findings in ankle arthrography can only be assessed by verifying its results surgically in a fairly large number of unselected pathological arthrograms.
Broström et al. (1965) operated on 105 patients with recent ankle sprains. Extra-articular contrast leakage around the tip and anteriorly to the lateral malleolus was associated with rupture of the anterior talofibular ligament in all cases.
Lindholmer et al. (1978) operated on 105 patients using the criteria of Percy et al. (1969) regarding the anterior talofibular ligament and found this ligament to be ruptured in all but three cases (97%).
V. Moppes and v.d.Hoogenband (1982) reported the operative findings in 50 patients using the criteria of Broström et al. (1965). In 48 cases (96%) leakage below and lateral to the lateral malleolus was associated with rupture of the anterior talofibular ligament.
Therefore it can be concluded that the reliability of arthrography is as high as 96-100% in diagnosing rupture of the anterior talofibular ligament.
False positive arthrography according to literature occurs in 3-4%.
In using the criteria of Broström et al. (1965), concomitant rupture of the calcaneofibular ligament is diagnosed when contrast filling of the peroneal tendon sheath is seen. However, this opacification of the peroneal tendon sheath does not always occur.

"Partial false negative" results, a term suggested by Spiegel and Staples (1975) to indicate that visualization of the peroneal tendon sheath has not occured in the presence of a rupture of the calcaneofibular ligament, can have different reasons:

- the presence of a partial rupture of the calcaneofibular ligament whereby the inner wall of the tendon sheath does not necessarily rupture;
- the presence of blood clots and deposits of fibrin which prevent contrast medium from entering the ruptured peroneal tendon sheath (Broström et al. - 1965); here a correlation with the time interval between injury and subsequent arthrography is present;
- the presence of a large capsular tear resulting in rapid contrast leakage ("run off") anterolaterally, with failure to fill or enter other areas of injury (Spiegel and Staples - 1975).

It is suggested that a tourniquet (Ala-Ketola - 1977) and vigorous ankle movements after contrast injection can improve the reliability regarding the opacification of the peroneal tendon sheath.

"Partial false positive results", i.e. opacification of the peroneal tendon sheath in the absence of a calcaneofibular ligament rupture, suggests damage to the peroneal tendon sheath, not associated with this ligament.

However, insufficient surgical exploration, i.e. not opening the peroneal tendon sheath to inspect the calcaneofibular ligament, is likely to explain a part of these findings (Lindholmer et al. - 1978). Prins (1978) suggested another explanation by indicating that the tear in the lateral talocalcaneal ligament, which according to his findings frequently accompanies rupture of the lateral ligaments, usually is orientated longitudinally and may extend into the peroneal tendon sheath, resulting in opacification during arthrography.

4.5 Tenography

Tenography of the peroneal tendon sheath was introduced by Black and co-workers in 1978 and is said to have a higher degree of accuracy in evaluating the condition of the calcaneofibular ligament rupture, than obtained by arthrography (Eichelberger et al. - 1982).

The normal tenographic anatomy was recently described in detail by Mu Huo Teng et al. (1984).

4.5.1 Technique

Under aseptic conditions 5-15 ml contrast material is injected directly into the peroneal tendon sheath, approximately 4-5 cm proximally to the tip of the lateral malleolus. To prevent the dye from spreading proximally, a blood pressure cuff is placed around the distal lower leg and insufflated.

4.5.2 Interpretation

When the calcaneofibular ligament is intact it is assumed that the dye will be confined to the peroneal tendon sheath without leakage into the ankle joint (negative tenogram). In the presence of a rupture the dye will escape into the ankle joint (positive tenogram) and subsequently into the soft tissues through a capsular tear associated with assumed concomitant rupture of the anterior talofibular ligament.
Tenography sometimes is combined with inversion stress examination ("stress tenography") in which case talar tilt instability is used as an indicator for rupture of the anterior talofibular ligament and tenography is used to evaluate the calcaneofibular ligament (Evans and Frenyo - 1979).

4.5.3 Reliability

Black et al. (1978) reported that surgical exploration in 30 cases of positive tenograms has revealed complete rupture of the calcaneofibular ligament in 25 cases and partial rupture in the remaining 5 cases. In 2 cases of negative tenograms the calcaneofibular ligament was found to be intact at operation.
Sanders and v.Bouwhuysen (1983) correlated the results of tenography with ankle arthrography. Tenography proved to be negative in all cases in which ligament rupture was absent arthrographically.
Positive tenography was present in all cases in which arthrography suggested double ligament rupture and in 13% in which arthrography suggested isolated rupture of the anterior talofibular ligament.

CHAPTER 5 THERAPY

5.1 Introduction

Considerable controversy exists regarding the appropriate treatment of ligamentous ankle injuries. Despite the fact that these injuries are among the most common problems faced by casualty departments, general surgeons and orthopaedic surgeons, completely satisfactory guidelines for the treatment of these injuries are not available.

Simple sprains in which no ligamentous damage has occurred and consequently instability is absent, are usually treated by strapping or a short period of plaster cast immobilization.

When ligament rupture is diagnosed, bandage therapy, plaster cast immobilization during different periods and surgical repair followed by various periods of plaster cast immobilization, are recommended in literature. In this chapter the results of various comparative studies with regard to the treatment of lateral ankle ligament ruptures as found in literature will be discussed, followed by a review on the recommended indications for early surgical repair and the possible complications of this specific therapy.

5.2 Comparative studies

An overwhelming amount of papers have been published revealing the results of various treatments in case of ankle ligament ruptures.

Because of differences regarding constitution of patient groups, diagnostic methods applied, interpretations of the results obtained and because of various treatment programs, methods and periods applied for follow-up, comparison of the published results is hazardous.

Therefore, an enumeration of the results obtained by different authors with various treatments is of trifling importance.

Comparative studies however, performed by the same author using a defined method of examination, are more valuable to evaluate the results of various treatments. Therefore all comparative studies found in the literature survey were carefully reviewed and the main data and results listed.

Ruth (1961), using inversion stress examination to diagnose ligament rupture, compared 45 patients treated by primary surgical repair, followed by plaster cast immobilization with 190 patients treated by plaster cast immobilization only. Both groups were immobilized for a period of six weeks.

Clark et al. (1965) randomly selected 24 patients in a prospective study in which both patient groups consisted of 12 patients, treated in the same way as was performed by Ruth (1961).

Freeman (1965) diagnosed ligament rupture on the amount of talar tilt and subsequently treated 16 patients by suturing, followed by immobilization, 18 patients by plaster cast immobilization during six weeks and 12 patients by strapping and mobilization. Follow-up was performed by a postal questionnaire.

Broström (1966) reported the results of a prospective comparative study in 281 patients in which 96 patients were treated surgically, followed by immobilization in plaster for three weeks, 86 patients by casting only, during the same period and 107 patients by strapping, using an adhesive elastic bandage or ordinary elastic bandage. The presence of ligament rupture in all cases was established by ankle arthrography.

Staples (1972) published a series of 72 cases treated by plaster immobilization for 4-6 weeks. In 1975 he published a second paper representing a change in therapeutic approach. Because of disappointing results in the first group he applied surgical treatment in the second.

Niethard (1974) treated 51 patients with suturing of the ligaments followed by six weeks of plaster cast immobilization and 27 patients with plaster cast for eight weeks. The diagnosis was based on stress examination and partly on arthrography.

Duquennoy (1975) treated 104 patients with surgical repair and 34 patients with casting for four to five weeks. Unfortunately he did not mention the period after which follow-up was performed.

Grønmark et al. (1980) reported the results of a prospective study in which the patients were divided at random into three treatment groups. Diagnosis was based on talar tilt examinations. 32 patients were treated by primary suturing followed by six weeks of plaster, 33 patients by plaster immobilization only and 30 patients by strapping with non-elastic zincoxide strips.

Niedermann et al. (1981) published a report on the treatment of 209 cases in which diagnosis was based on ankle arthrography. At random, 107 patients were treated by casting during five weeks and 102 patients by surgical therapy, followed by five weeks of plaster immobilization.

V. Moppes and v.d.Hoogenband (1982) randomly divided 150 patients in which recent ankle ligament rupture was diagnosed arthrographically into three groups of 50 patients. The first group was treated by operative repair followed by plaster immobilization for 6 weeks. Non-operative treatment by means of a below-knee walking cast for 6 weeks was performed in the second group of 50 patients, whereas the remaining 50 patients were treated by a special bandage technique (Coumans-bandage), using adhesive elastic tape during a period of six weeks.

The data of these comparative studies, regarding the number of patients treated and followed up and the various periods of plaster cast immobilization and periods elapsed before follow-up was performed, are given in table 4. The results of these comparative studies are listed in table 5.

Table 4: Literature findings concerning comparative studies. Data on number of patients treated and followed up.

	number of patients treated		number of patients followed up		period of immobilization (wks)		average follow-up period (years)	
Author	operation	plaster	operation	plaster	operation	plaster	operation	plaster
Ruth (1961)	45	190	32	72	6	6	2.5	2
Clark et al. (1965)	12	12	12	12	6	6	?	?
Freeman (1965)	16	18	16	18	6	6	1	1
Broström (1966)	96	86	95	82	3	3	4.0	3.6
Staples (1972/1975)	27	72	20	51	4	4-6	1	9.4
Niethard (1974)	51	27	32	20	6	8	3.5	3.5
Duquennoy et al. (1975)	104	34	104	34	?	4-5	?	?
Grønmark et al. (1980)	32	33	32	33	6	6	1.5	1.5
Niedermann et al. (1981)	102	107	75	62	5	5	1	1
v. Moppes et al. (1982)	50	50	50	50	6	6	1	1

Table 5: Literature findings concerning comparative studies.
Data regarding residual symptoms, mechanical and functional instability.

	residual symptoms (%)		mechanical (objective) instability (%)		functional (subjective) instability (%)	
Author	operation	plaster	operation	plaster	operation	plaster
Ruth (1961)	9	58	0	34	0	9
Clark et al. (1965)	0	30	0	8	0	8
Freeman (1965)	75	47	0	11	37.5	39
Broström (1966)	3	20	5	30	3	21
Staples (1972/1975)	11	61	0	47	10	37
Niethard (1974)	41	55	19	50	19	30
Duquennoy et al. (1975)	16	51	16	45	12	33
Grønmark et al. (1980)	3	33				
Niedermann et al. (1981)			7	21	21	29
v. Moppes et al. (1982)			32	42	38	42

In the majority of cases less residual symptoms were found and better objective and subjective stability was obtained by operative treatment as compared to non-operative treatment by means of plaster cast immobilization (table 5).

Niedermann et al. (1981) and v.Moppes and v.d.Hoogenband (1982) reported no statistically significant difference between the results of operative and plaster cast treatment.
Residual symptoms seemed to be equally present in both groups, as given by these authors, but were classed in such a manner that listing them into table 5 was impossible.

Freeman (1965) was the only author who reported better results from conservative treatment. Consequently this paper is quoted very frequently by advocates of conservative treatment. However, the author himself assumed that the bad results regarding residual complaints of pain or swelling in the operative group (table 5) were probably due to insufficient surgical technique using "an incision which healed poorly and was perhaps unnecessarily extensive".
Moreover, the different treatment groups, although randomly selected, show initial average talar tilt differences, the average talar tilt being 11.4°, 16.2° and 18.4° in the different patient groups, respectively treated by strapping, plaster cast immobilization and surgical repair. This suggests an initial difference in the severity of the injury and thus makes the treatment groups non-comparable.
V. Moppes and v.d. Hoogenband (1982), as was mentioned, compared the results of operative repair and plaster immobilization with a third method of treatment, consisting of early mobilization by means of ankle taping. They reported that the short-term results were in favour of bandage therapy, whereas the long-term results were equally good in all three treatment groups.

5.3 Indications for surgical treatment

The aim of any treatment for lateral ankle ligament rupture should be to make the ankle asymptomatic and stable in vigorous occupations and strenuous athletic activities.
From the findings of the comparative studies discussed previously it is suggested that early surgical repair is the method of treatment most likely to produce these results.
However, it is generally felt that this does not mean that every patient with demonstrated ligament rupture should be operated on.
This implies a selection of patients for surgical treatment.
Various indications for surgical repair are found when reviewing literature. It is often said that treatment should be individualized and based on the pa-

tients present condition and future needs (Gordon et al. - 1976, Kingma - 1978).

However, in young patients it is quite difficult to define the future stability requirements with regards to athletic or professional activities.

When recent rupture of ankle ligaments is diagnosed in young patients this is generally regarded as a proper indication for surgical treatment (Broström - 1966, Cedell - 1975, Dequennoy - 1975, Emerson - 1978), especially when these individuals are engaged in athletic activities (Clark et al. - 1965, Staples - 1975, Gerbert - 1975, Gordon et al. - 1976, Hackenbruch and Karpf - 1977, Schmidt - 1978).

Broström (1966) reported that residual symptoms of ankle instability were more frequent in younger patients than in elderly. This is probably due to the fact that in younger patients the demands for stability are higher and also because older patients tend to avoid exertion which could evoke discomfort due to instability.

The need for surgical repair in patients whose professional activities necessitate a completely stable ankle (e.g. building labourers, military personnel, police forces etc.) is recognized by Broström (1966), Gordon et al. (1976) and Emerson (1978).

Also an avulsion fracture is considered an indication for surgery (Cedell - 1975, Brand et al. - 1981).

In case of lateral ankle sprain in children the seriousness of the injury sustained is not generally agreed. Jani and Baumgartner (1976) stated that in the growing period no ligamentous rupture occurs but instead an avulsion of the bony or cartilagenous insertion of the ligament is present, which, because of its usual intra-articular localization, renders normal healing impossible. Consequently operative revision is recommended in these cases. Recently this view was endorsed by Vahvanen et al. (1984).

Niedermann et al. (1981) believes that the corresponding trauma in children results in epiphysiolysis and accordingly recommends conservative treatment.

As was mentioned before (chapter 1.4.1) traumatic instability due to lateral ligament rupture can occur in different stages ("two-stage ruptures"), the first trauma resulting in rupture of the anterior talofibular ligament after which inadequate ligamentous healing and subsequent impairment of ligamentous support leads to more extensive ligamentous damage in case of renewed trauma. This mechanism is probably the explanation of the finding reported by Broström (1966) that the poorest results of non-surgical treatment were found in patients with repeated sprains.

Therefore, when pre-existent ligamentous damage is suggested in the case history or on the standard radiographs, recognizable as round calcifications or irregularities at the distal fibula, surgical treatment is said to be indicated (Broström - 1965, Cedell - 1975, Duquennoy - 1975).
Instability following from severe ankle sprain is generally considered the main reason which warrants surgical treatment. "Severe ligament lesion" or "major lesion" is taken to exist when both anterior talofibular and calcaneofibular ligaments are ruptured. Thus, double ligament rupture is generally accepted as an indication for surgical repair (Dziob - 1956, O'Donoghue - 1958, Sherrod and Phillips - 1961, Anderson et al. - 1962, Makhani - 1962, Bonnin - 1965, Coutts and Woodward - 1965, Speeckaert - 1978, Prins - 1978, Zinman et al. - 1979, Brand et al. - 1981).

To recapitulate, in literature surgical treatment is said to be indicated when double ligament lesion is present in one of the following groups:

- young and active individuals
- sportsmen
- subjects with vigorous occupations
- patients with repeated sprains

5.4 Complications of surgical treatment

The disadvantages of surgical treatment include the risk of infection, defective wound healing and surgical accidents such as damage to the superficial peroneal nerve or the sural nerve.
According to literature wound infection is seen in 1-4% in all cases being superficial infections (Reichen and Marti - 1974, Kooyman and Ponsen - 1976, Niedermann et al. - 1981). Deep wound infections (purulent arthritis) are not reported.
Superficial wound necrosis is sometimes seen at the wound edges (4-6%) but usually heals by secondary wound healing without special treatment (Ruth - 1961, Reichen and Marti - 1974, Staples - 1975, Seiler and Holzrichter - 1977, Speeckaert - 1978, Prins - 1978, Rogmans - 1982). Careful handling of the vulnerable tissue at surgery is of utmost importance to avoid this complication. In literature one patient is reported with more extensive superficial necrosis, which needed splitskin grafting (Broström - 1966).

The incidence of hypaesthesia of the dorsum of the foot and the fourth toe or of the lateral margin of the foot, resulting from accidental damage of the superficial peroneal nerve or the sural nerve respectively (ramus cutaneus dorsalis intermedius or lateralis) is reported in literature varying from 3-11% (Coutts and Woodward - 1965, Prins - 1978, Niedermann et al. - 1981). Hyperaesthesia of the scar, sometimes combined with paraesthesia radiating towards the fourth toe is described in 3-9% in literature. These latter symptoms tend to diminish in course of time.

CHAPTER 6 REFLECTIONS ON LITERATURE REVIEW

6.1 Introduction

When reviewing the comprehensive literature on lateral ankle ligament ruptures, various -sometimes contradictory- opinions and statements are encountered, regarding the value of anatomical structures in relation to function, the relevance of clinical symptoms, the reliability of different radiological diagnostic procedures and -last but not least- the choice of treatment.
Discussion on these subjects is not closed and probably will not be in the near future. However, every general surgeon, orthopaedic surgeon or physiotherapist, who is involved in the treatment of these ligamentous injuries, needs to have a guideline, based on solid theories, according to which these patients can be treated.
In this chapter the different opinions on the subjects of the previous chapters will be discussed and important conclusions and findings from literature will be emphasized in an attempt to obtain this guideline for diagnosis and treatment of lateral ankle ligament ruptures.

6.2 Anatomy

In chapter 1 the anatomy of the talocrural and subtalar joints as well as the functional anatomy of both joints was described in detail. Following, a description was given of the ankle ligaments and their anatomical and biomechanical aspects in relation to ankle stability. Thereupon the consequences of specific ligamentous lesions, resulting in different types of ankle instability were discussed as they were described in experimental investigations found in literature.

In contrast to the opinion of v.Moppes and v.d.Hoogenband (1982) it is generally concluded that the lateral ligamentous apparatus is composed of three distinct ligaments, each giving support to the talocrural and subtalar joints in a specific way, depending on the position of the ligament in relation to the joints. Although several authors emphasized the importance of the anterior talofibular ligament in relation to ankle stability (Anderson et al. - 1962, Broström - 1966, Cedell - 1975, Hackenbruch and Karpf - 1977, Röhlich - 1978, Johannsen - 1978, Raaymakers - 1979, Grønmark et al. - 1980) lateral ankle ligament rupture is generally considered not to be severe ligamentous damage unless at least concomitant rupture of the calcaneofibular ligament has been demonstrated (Clark et al. - 1965, Gordon et al. - 1976,

Speeckaert - 1978, Zinman et al. - 1979, Danegger - 1979, Brand et al. - 1981) thereby classifying isolated rupture of the anterior talofibular ligament as "minor injury" (Prins - 1978).
Following this point of view, the importance of the anterior talofibular ligament towards ankle stability in our opinion is considerably underestimated. This is illustrated by the following anatomical and biomechanical aspects concerning the anterior talofibular ligament.

Firstly, in plantar flexion, the position in which the ankle joint is relatively unstable, the only protection against inversion stress or endorotation stress is provided by the anterior talofibular ligament, both other lateral ankle ligaments being not in the proper position to contribute to ankle stability. This is even more important when one realizes that the muscular support on the anterolateral aspect of the ankle joint is provided by rather weak and inconstant muscles, giving only minimal protection against pathological inversion stress movements.

Secondly, the findings of several experimental investigations on cadaver specimen demonstrate that rupture of the anterior talofibular ligament results in distinct manifestations of instability of which talar tilt and anterior drawer sign initially were emphasized, while more recently rotatory instability is increasingly investigated.
This rotatory instability of the ankle joint seems comparable to the rotatory instability as described in the knee joint. Regarding this type of instability it has been demonstrated that the greatest increase in anterolateral rotational instability already occurs following isolated rupture of the anterior talofibular ligament (Rasmussen and Tovborg-Jensen - 1981, 1982). This phenomenon resembles the "pivot-shift-sign", as was described by Galway et al. (1972) with regard to ligamentous knee injuries.

Thirdly, in the "typical" plantar flexion inversion injury the lateral ankle ligaments rupture in an almost standardized sequence, the anterior talofibular ligament always being the first to tear. Therefore, rupture of this ligament is most frequently encountered. This is hastened by the fact that the anterior talofibular ligament of all ankle ligaments has the least tensile strength and the least elastic properties (Sauer et al. - 1978). Rupture of this ligament -when not properly healed- implies lack of the protective support of the anterior talofibular ligament, after which renewed trauma can more easily lead to more serious ligamentous damage.

Therefore, it has to be concluded that the anterior talofibular ligament is indeed "the key to the ankle joint" (Dehne - 1934)

- by being the most important stabilizing ligament of the lateral ligamentous apparatus
- and by being always the first ligament to tear in case of a typical plantar flexion inversion injury, leading to a marked anterolateral rotational instability of the ankle joint in case of rupture.

Consequently each ankle sprain, resulting in ligamentous damage is associated with loss of stability. Adequate diagnostic and therapeutic methods therefore have to be applied to prevent impairment of ligamentous support to proceed into residual instability with subsequent cartilaginous damage and osteoarthrosis.

6.3 Ligament healing

In summarizing the literature on wound healing it has become clear that the basic reaction of different tissues to trauma is essentially the same. The normal process of wound healing following trauma is a chain of events starting from the moment of impact and composed of a series of tissue reactions following a basic pattern which can be divided into the four phases mentioned.
The number of investigations concerning the healing of ligamentous structures seems rather limited, especially when compared with the comprehensive studies performed on tendon healing.
According to Jack (1950) the gap between two appositioned ligament ends is filled by granulation tissue deriving from the connective tissue which covers the ligament on the superficial side, after which this granulation tissue is changed into collagenous tissue by active migration of cells from the torn ligament ends.
When there is no approximation, the histological picture is said to be quite different (Jack - 1950, Clayton and Weir - 1959). Under these circumstances the gap between the ligament ends is filled with irregular fibrous (scar) tissue, whereas the ligament ends stay inactive and become rounded off.
However, in the investigations performed by Jack (1950) the ligaments were not immobilized at all during the process of healing, whereas Clayton and Weir (1959) obtained definite immobilization by using a Steinmann pen which renders resumption of function in course of time impossible, thereby most probably effecting the process of ligament healing and the increase in tensile strength.
Another finding from these investigations concerns the period of time within

which it is possible to improve ligament adaptation by means of suturing. As was also shown in investigations concerning tendon healing (Mason and Allen - 1941) the ligament ends become edematous and friable within the first week (phase of destruction), resulting in a gelatinous exudate, during which period the introduction of sutures is useless.

It is concluded from the literature survey on ligament healing that early adaptation of ruptured ligament ends is essential in achieving undisturbed ligament healing, while ligament ends which remain separate become inert and inactive and do not contribute to the process of ligament healing.

Because this conclusion is based on limited investigations which, regarding time of immobilization and resumption of function, do not resemble the clinical management of ligament rupture, it was judged useful to carry out an experimental investigation in ligament healing without the above mentioned restrictions regarding immobilization. This study and the results will be described in chapter 7.

6.4 Clinical diagnosis

In his comprehensive study on ankle injury Bonnin (1950) wrote: "Once associated fractures have been excluded, the seriousness of the sprain can be estimated on clinical grounds."

Following this point of view many authors in the past based their choice of treatment on different supposedly valuable clinical symptoms.

It seems clear from more recent literature findings reported in chapter 3 that clinical symptoms of swelling, pain and haematoma are inconclusive in diagnosing ligament ruptures. Even in those cases in which clinical examination suggests ligamentous damage it is often difficult or impossible to estimate the extent of injury.

Applying clinical instability tests does not contribute to the accuracy of clinical diagnosis, unless performed under general anaesthesia (Broström - 1965, Prins - 1978).

To verify these conclusions properly, it is necessary to compare the findings obtained by clinical examination with the results of surgical exploration. This was done within the prospective clinical study. The results are described in chapter 9.

6.5 Radiological diagnosis

Radiological examinations represent an important part of diagnostic procedures in case of ankle sprain. The importance of standard radiographs is scarcely questioned. Both inversion stress examination and sagittal stress examination

are frequently used to demonstrate or exclude pathological talar movement following ligamentous ankle injuries.
Anterolateral rotational instability can be demonstrated radiologically but, until now, has no practical value in diagnostic methods.
Lateral ankle instability (exorotation stress examination) was mentioned for the sake of completeness only, but has no role in diagnosing lateral ankle ligament lesions.

When reviewing the findings in literature regarding inversion stress examination and sagittal stress examination it has to be concluded that no agreement exists on examination technique, measurement technique and interpretation, especially with regard to inversion stress examination.
Some authors rely solely on inversion stress examination, others only on sagittal stress examination, but -as indicated in literature- one can not replace the other and vice versa; they are complementary examinations (Johannsen - 1978).
However, when compared to arthrography, both inversion stress examination and sagittal stress examination are insufficient in diagnosing the presence of ligamentous injuries because of inadmissably high percentages of false negative and false positive results (Sanders - 1976, Prins - 1978, v.Moppes et al. - 1979) unless performed under general anaesthesia (v.Moppes and v.d. Hoogenband - 1982).
Even then no correlation exists between the findings of stress examination and the extent of injury, i.e. the number of ligaments ruptured.

Arthrography of the ankle is used increasingly in the diagnosis of lateral ankle ligament ruptures. Although the use of an intra-articular puncture is repeatedly mentioned as a disadvantage of this diagnostic technique, the fear of complications has never been justified in large series of investigations. The interpretation of abnormalities in ankle arthrography is well defined (Broström et al. - 1965, Olson - 1969, Sanders - 1972, Dalinka - 1980) and usually does not yield difficulties.
However, the interpretation given by Percy et al. (1969) is based not only on the location of contrast leakage but also on the volume of extra-articular contrast. This volume, to our opinion, is not associated with the extent of ligamentous damage, but depends on the extent of capsular rupture and the volume of injected contrast medium.

The reliability of arthrography as to detect the presence of ligament rupture is very high and reaches the 100% (Broström et al. - 1965, Lindholmer et

al. - 1978, v.Moppes and v.d.Hoogenband - 1982) and thus by far exceeds the reliability of radiological stress examinations.
Less high percentages are obtained with arthrography when a distinction has to be made between isolated rupture of the anterior talofibular ligament and combined rupture of this ligament and the calcaneofibular ligament.
Determining the exact reliability of arthrography in this diagnostic problem is possible by verifying its results with surgical exploration. This was done within the prospective clinical study. Moreover the reliability of the Percy-classification and the Lindholmer-sign was investigated. The results are described in chapter 9 and discussed in chapter 10.

Whether tenography is capable of improving the results obtained with arthrography remains unanswered, because investigations on this subject are limited. Tenography was not applied within the prospective clinical study.

6.6 Therapy

Once the presence of an ankle ligament rupture is accurately diagnosed, an appropriate choice of therapy has to be made. This decision depends on several factors such as the personal circumstances of the patient, the preference of the patient or the therapist regarding a specific method of treatment, the possibilities within the hospital structure (burdening of the operation program) and last but not least economic reasons.
However, as the aim of any treatment of lateral ankle ligament rupture should be to obtain full recovery without residual complaints, the prime consideration should be a medical one: to offer the individual patient the method of treatment most likely to produce full recovery in the shortest possible period of time. All other considerations mentioned are, although important, secondary to this goal.

As was shown in chapter 5, when comparative studies are evaluated, majority opinion is in favour of surgical treatment. The favourable short term results reported by v.Moppes and v.d.Hoogenband (1982) by means of bandage therapy are at first sight promising, but were obtained by comparing them with surgical repair or plaster cast treatment, whereby in both groups immobilization for a period of six weeks was carried out.
The short term results in patients treated in this way are obviously not comparable to the results obtained by bandage therapy, as the latter is based on early mobilization.
Although in literature plaster immobilization of six weeks is generally accep-

ted, in our opinion, plaster immobilization as a solitary treatment or following surgical repair should not exceed a period of three weeks in order to avoid secondary disadvantages of prolonged immobilization such as joint stiffness and impairment of blood circulation.

In reviewing the indication for early surgical repair as recommended in literature it is frequently stated that only "total rupture" of the lateral ankle ligaments requires early surgical repair, whereas "partial rupture" is best treated conservatively.
In specified terms this means that in general double ligament ruptures (i.e. rupture of both anterior talofibular ligament and calcaneofibular ligament) or triple ligament ruptures (i.e. rupture of both anterior and posterior talofibular ligament as well as the calcaneofibular ligament) are regarded as an indication for operative treatment whereas single ligament rupture (i.e. isolated rupture of the anterior talofibular ligament) does not require surgery.
One of the studies in which this point of view is incorporated was published by Prins (1978). In his study of 298 patients he reported good results of early surgical repair in case of multiple ligament injury. The results of plaster immobilization in case of injuries with comparable extent were significantly worse. Equally worse however were the results obtained by non-operative treatment in case of single ligament rupture, although isolated rupture of the anterior talofibular ligament was considered to be "a minor injury", not requiring surgery.
These findings, in our opinion, suggest that isolated rupture of the anterior talofibular ligament, like more extensive ligamentous damage to the lateral ligamentous apparatus of the ankle, is probably better treated by early surgical repair rather than by plaster immobilization only.
Together with the conclusions regarding the importance of the anterior talofibular ligament in stabilizing the ankle joint (see paragraph 6.2), these findings have led to a prospective clinical study in which the results of early surgical repair of both isolated ruptures of the anterior talofibular ligament and more extensive damage (double and triple ligament ruptures) were investigated.
By treating large numbers of patients by surgical repair within a controlled study, the opportunity was also given to accurately determine the disadvantages of this method of treatment.
Within the prospective clinical study all complications of surgical therapy encountered were registrated and will be discussed. The study itself is described in chapter 8, the results are given in chapter 9.

PART II

CHAPTER 7 EXPERIMENTAL STUDY

7.1 Introduction

The general idea that early adaptation of ruptured ligament ends by means of sutures improves the process of healing, resulting in less scar tissue and better tensile strength, is frequently quoted by advocates of surgical repair of ankle ligament ruptures, but nevertheless is based only on limited investigations (see chapter 2.3, 2.4 and 6.3).

This experimental study was carried out to investigate the process of ligament healing under conditions resembling the clinical management of ligament ruptures regarding immobilization and subsequent resumption of function, in order to attempt to answer the following questions:

- What is the histological difference, if any, in the process of ligament healing between sutured and non-sutured ruptured ligaments?
- Does suturing of ruptured ligaments lead to a difference in tensile strength when compared to non-sutured ruptured ligaments?

The study was carried out at the Laboratory of Experimental Surgery, Erasmus University Rotterdam, in the period of October 1981 until February 1982.

7.2 Material and methods

7.2.1 Animals

The choice of experimental animals was based mainly on economic considerations. The experiments were carried out on the stifle joint of 48 healthy adolescent rabbits, aged about 3-4 months, their bodyweight varying from 2.1-3.5 kg (mean 2.7 kg). The weight of the laboratory animals was measured twice: once at the time of operation and once at the time of autopsy, so the increase in bodyweight during the period of observation could be followed. Additionally 10 healthy rabbits were used to form a control group.

7.2.2 Experimental groups

In order to investigate the possible differences between sutured and non-sutured ruptured ligaments regarding histological aspects and tensile strength two experimental groups were formed, each consisting of 24 rabbits. In the first group both the medial and the lateral collateral ligament of the right stifle joint were transected and subsequently sutured again (see paragraph 7.2.4). In the second group the ligaments were left unsutured after dividing. In both groups the left stifle joint was uninjured.

At intervals of 1, 2, 3, 4, 6 and 10 weeks postoperatively each time four rabbits with sutured ligaments and four rabbits with non-sutured ligaments were sacrificed by an overdose of Penthotal. So, at the end of each period there were four rabbits of both experimental groups available for further investigation.

7.2.3 Control group

In order to find out whether the results of tensile strength measurements in different individual rabbits would be mutually comparable, tensile strength was measured at the non-injured ligaments in a control group of 10 healthy rabbits, using the medial collateral ligament of both right and left stifle joints.

7.2.4 Surgical technique

All operations were performed under general anaesthesia and oral intubation, using atropine 0.125 mg intramuscularly and hypnorm 0.4-0.6 mg intravenously, followed by Ethrane N_2O and O_2.

The hair over the right hind leg was carefully shaved and the skin disinfected with chloorhexidine 0.5%.

All surgical procedures were performed under strict aseptic conditions, enclosing the operative field in sterile towels.

A medial skin incision was made over the patella, extending about 1 cm proximally and 2 cm distally from the patella. This incision allowed us, after the fascia on both sides was incised, to reach the medial as well as the lateral collateral ligament.

The joint line could always be easily identified by the palpating finger and because very regularly a venula was found passing the ligament transversely a few millimeters distally of the joint line.

The ligaments were transected horizontally at the joint line, with a scalpel.

The ligament ends on both the medial and lateral side then were sutured with three interrupted stitches of Vicryl® 6x0 or left unsutured, in accordance with the two experimental groups. The fascia was closed with interrupted stitches using chromic catgut 3x0 and the skin was closed with interrupted stitches of silk 3x0.

7.2.5 Postoperative treatment

Postoperatively the hind leg was immobilized in a well padded splint made of Baycast® (Johnson & Johnson Benelux BV), applied on the anterior side of the hind leg. The stifle joint was immobilized in 90° of flexion, in which

position both collateral ligaments proved to be relaxed. The Baycast-splint was fixed with elastic adhesive tape wrapped around the splint and the hind leg, carefully preventing the splint from being too tight. The ankle joint was not immobilized, enabling the animal to walk around without much discomfort.
All animals were kept in separate cages after the operations. No antibiotic therapy was given. All animals were checked daily and in some cases it was necessary to shorten the splint a little on the distal side to prevent the foot from getting edematous or developing pressure sores.
All animals were immobilized during a period of three weeks, except of course in those cases where autopsy was performed within this period. The rabbits were sedated with 1 ml hypnorm i.m. in order to remove the Baycast splint and the skin sutures.
After removal of the splint the animals were allowed to walk freely within the restriction of their cages.

7.2.6 Tensile strength measurements

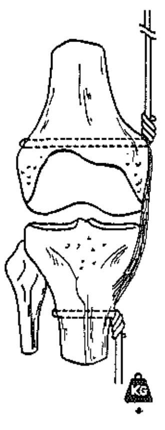


fig. 35
Tensile strength measurements.

At the time of autopsy the wound was carefully re-explored. The macroscopical appearance of the operational field was determined and next the lateral collateral ligament was removed for microscopical study. In view of the histological examination that was to follow, handling of the ligament itself was restricted to a minimum. After removal of the lateral collateral ligament all soft tissue structures connecting the femur and tibia, except the medial collateral ligament, were removed from the specimen. Then, the medial collateral ligament with the adjacent fragment of bone from femur and tibia was taken out. To determine the tensile strength on the medial collateral ligament the method described by Clayton and Weir (1959) was used.
A drill-hole was made horizontally through the femur and tibia, respectively just proximally and distally to the attachments of the medial collateral ligaments (fig. 35). Then the femur was fixed to a standard with the aid of iron-wire and the tibia was attached to a can with a maximum contents of 25 liters, its own weight being 0.5 kg.
By filling the can quickly with water, a pulling force was applied longitudinally on the medial collateral ligament. To fill the can with water at a constant rate a mechanical pump was used, its variable flow adjusted at 20 l/min.

The can was filled until the ligament ruptured after which the pump was switched off quickly. The can and its contents were weighed and its combined weight was used as the tensile strength of the ligament.
After measuring the tensile strength on the right medial collateral ligament, the same procedure was performed with the left (uninjured) medial collateral ligament of the same animal.

7.2.7 Histological technique

As mentioned in paragraph 7.2.6 the lateral collateral ligament of the right stifle joint was used for histological examination. The following technique was used. After fixation in a 4% solution of formaldehyde during several days, the transecting line, which by that time could still be easily recognized, was taken out as a central part, and after dehydration in a solution of aceton, embedded in spurr, an artificial resin of moderate hardness. With the aid of a Jung-microtome (type 1140) longitudinal sections were made, producing slices of four microns in thickness. Several methods of staining were used, mostly Haematoxilin and Eosin and Van Gieson's stain.

7.3 Results

7.3.1 Findings concerning the laboratory animals

After an immobilization period of three weeks the Baycast splint was removed and the hind leg of each rabbit carefully inspected. No serious damage or pressure sores caused by the splint were found.
One animal was able to free himself from the splint after one week. The results in this case were excluded and another animal was used instead.
No significant differences were found in increase in bodyweight between the two experimental groups. Although all animals received the same adequate diet throughout the experiment, there was one group of eight rabbits however, that showed a remarkable difference: their average increase in bodyweight was considerably less compared to the other rabbits. These eight rabbits were equally divided over both experimental groups and were all sacrificed after a period of six weeks. A suitable explanation for this finding could not be traced.
The data concerning the increase in bodyweight during the period of observation are listed in table 6 and set out in a diagram (fig. 36).

Table 6: Experimental study on rabbits. Average increase in bodyweight (kg) in the experimental groups during the period of observation.

period of observation	number of rabbits sacrificed	average increase in bodyweight (kg)
1 week:	8	0.20
2 weeks:	8	0.27
3 weeks:	8	0.31
4 weeks:	8	0.32
6 weeks:	8	0.12
10 weeks:	8	0.93

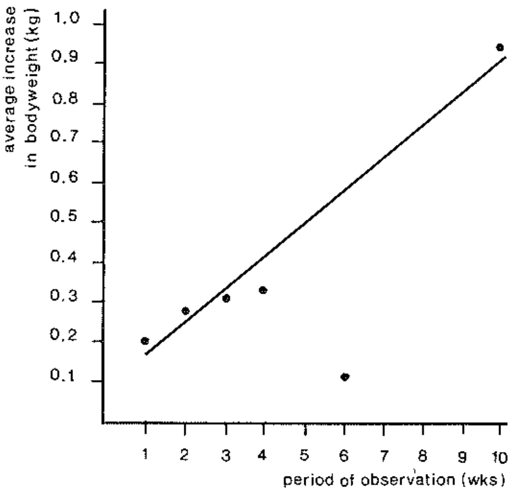


fig. 36
Average increase in bodyweight (kg) in the experimental groups during period of observation.

7.3.2 Results of tensile strength measurements in the control group

The results of tensile strength measurements in the control group in which the stifle joint of both sides of ten healthy rabbits was used, are listed in table 7.

Table 7: Experimental study on rabbits. Tensile strength of the non-injured medial collateral ligaments in 10 normal rabbits (control group).

body weight (kg)	tensile strength (kg)		
	right side	left side	R-L difference
3.1	21.6	23.4	− 1.8
3.3	11.0	12.4	− 1.4
2.9	9.3	9.4	− 0.1
2.5	9.8	10.5	− 0.7
2.4	9.1	9.4	− 0.3
3.4	14.4	12.0	+ 2.4
2.1	5.6	4.6	+ 1.0
2.2	6.6	6.8	− 0.2
3.0	15.6	15.8	− 0.2
2.8	8.4	8.1	+ 0.3

Wide variations in normal tensile strength were found between the individual rabbits of the control group. However, only small differences were found between the right and left side in each rabbit (table 7). In all cases rupture was located at the tibial periosteal insertion, obviously being the weakest spot.

It can be concluded from the results in the control group that comparison of the findings in tensile strength measurements between the individual animals

is without value because of considerable individual variations. However, comparison between the right and left side of the same animal is without difficulty because of the small differences found.
Therefore in the experimental groups, the left stifle joint, which was left uninjured at the time of operation, could be used as a reference, indicating the original tensile strength of the individual rabbit.
The tensile strength as found at the right side (transected ligament) thus could be expressed as a percentage of the tensile strength as found on the left side.

7.3.3 Results of tensile strength measurements in the experimental groups

The results of tensile strength measurements in the experimental groups are listed in table 8.

**Table 8: Experimental study on rabbits.
Results of tensile strength measurements in the experimental groups.**

	Sutured-group			Non-sutured group		
Autopsy after	sutured ligament (right side)	reference (left side)	R-L ratio (%)	non-sutured ligament (right side)	reference (left side)	R-L ratio (%)
1 week	1.7	11.5	14.8	2.0	9.1	21.9
	3.2	11.3	28.3	2.0	11.1	18.0
	2.9	8.5	34.1	2.3	6.7	34.3
	0.6	12.2	4.9	0.5	4.5	11.1
2 weeks	4.2	10.6	39.6	4.7	9.6	48.9
	3.3	10.8	30.5	2.6	9.3	27.9
	3.0	8.3	36.1	2.7	8.3	32.5
	3.8	10.7	35.5	1.6	7.8	20.5
3 weeks	7.7	9.4	81.9	2.6	7.1	36.6
	6.7	13.9	48.2	4.6	8.6	53.4
	7.5	25.1	29.8	4.6	15.4	29.8
	7.8	14.2	54.9	5.2	17.6	29.5
4 weeks	8.9	12.7	70.0	5.4	9.0	60.0
	6.0	13.6	44.1	3.4	10.6	32.0
	10.6	9.4	100	4.0	9.6	41.6
	11.5	12.0	95.8	4.7	10.6	44.3
6 weeks	12.2	23.0	53.0	10.1	18.4	54.8
	13.2	20.5	64.3	3.7	18.6	19.8
	10.6	22.1	47.9	5.4	21.8	24.7
	7.2	14.8	48.6	12.7	28.2	45.0
10 weeks	12.4	13.5	91.8	8.5	9.7	87.6
	10.6	12.9	82.1	10.8	12.4	87.0
	18.1	19.2	94.2	6.7	17.9	37.4
	8.9	10.1	88.1	8.1	15.1	53.6

As was found in the control group, rupture of the medial collateral ligament on the left (uninjured) side was predominantly located at the tibial periosteal insertion. In four cases however, a fracture through the drill-hole of the femur (twice) or the tibia (twice) arose.

7.3.4 Histological findings

From the preliminary histological studies it was established that the histological appearance of normal collateral ligaments of the rabbit stifle joint shows dense, relatively acellular and regular collagen tissue in which the fibers are arranged in parallel longitudinal bundles, while very sparsely capillary vessels can be seen. On the superficial side the ligament is covered with loose connective tissue containing some elastic fibers. The joint side of the ligament lies in relation to the synovial membrane. Elastic fibers are absent in the ligament itself.

In the experimental groups the following histological findings were obtained.
As early as in the first week after operation young connective tissue began to fill the space between the cut ends of the ligaments (fig. 37). It seemed to float into the gap as described also by Skoog and Persson (1954) in the process of tendon healing. Apparently this repair process did not arise from the ligament ends but from the connective tissue underlying the synovial membrane at the joint side of the ligament. It consisted mainly of fibroblasts but also lymphocytes, plasma cells, swollen endothelial cells and histiocytes were seen and at the synovial side, the proliferation of synovial fibroblasts. At the same time precipitation of fibrin was noted. In the sutured group also some foreign body giant cells were seen. The ligament ends in both the sutured and the non-sutured group stayed quite inert and did not participate in this process of regeneration, apart from a distinct inflammatory reaction consisting of lymphocytes and plasma cells (fig. 38, 39 and 40).
After one week in most cases the space between the two ligament ends was filled completely, the gap bridged with connective tissue.
After the second week the amount of fibroblasts was increased vigorously and the first immature collagen fibers were seen. The torn ends, completely embedded in this tissue were thereby continuous again.
After three weeks collagen fibers were increased in number and size, but the original pattern of parallel longitudinal arranged fibers was not yet restored.
After four weeks the collagen fibers were clearly arranged into bundles but the size of the fibers was not yet normal. Practically the same histological appearance was seen after six weeks.

fig. 37
Photomicrograph (x40) showing the repair process, arising from the subsynovial connective tissue. Connective tissue cells float into the gap between the ligament ends (H & E section).

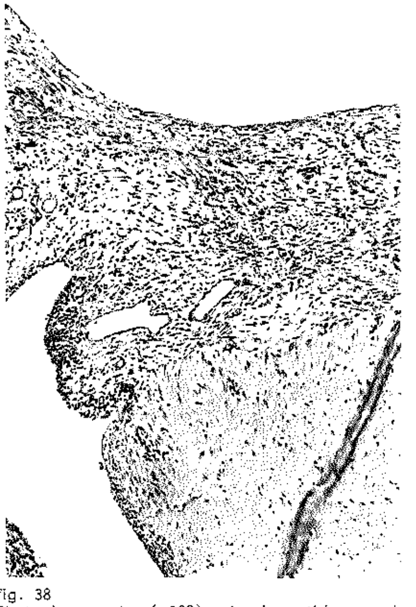


fig. 38
Photomicrograph (x100) showing this repair process in the first week. There is no active participation of the cells of the divided ligament, of which the stump stays inert (H & E section).

fig. 39
Photomicrograph (x125) showing the superficial side of the ligament. The loose connective tissue on this side does not participate in the repair process (H & E section).

fig. 40
Photomicrograph (x320) showing repair tissue: young fibroblasts, some lymphocytes and plasma cells and precipitation of fibrin (H & E section).

After ten weeks the collagen bundles had reached their normal size; the ligament appeared virtually normal and an almost fluent continuity was seen between the repair tissue and the original ligament fibers.
The process of ligament healing described above was seen both in the sutured group and in the non-sutured group. Histologically there was no difference between these two groups.

7.4 General discussion

In discussing the process of ligament healing it has to be emphasized that the findings obtained in the experimental investigations with rabbits are not necessarily comparable to the process of ligament healing as found in humans. Another point which has to be mentioned is the fact that in preliminary investigations it was established that it is impossible to rupture the ligaments of the stifle joints in rabbits by means of manual force and obtain a uniform reproducible and thus comparable lesion of the ligament. The same problem was faced by others in experimental studies, while using dogs (Clayton and Weir - 1959).
Although not quite comparable to the blunt separation obtained in the actual trauma situation, it was decided to transect the ligament sharply by means of a scalpel, in order to obtain comparable ligamentous lesions.
The method for studying the rate of wound healing by determining the tensile strength during the various phases of healing was introduced by Harvey in 1929 (Mason and Allen - 1941).
As was mentioned in chapter 2.4 an accurate measure to determine tensile strength is the mean breaking length (MBL).

$$MBL = \frac{B \times L}{1000 \times W}$$

where B = the breaking load
L = length (or in wounds:) width of the repair tissue
W = weight of tissue in grams

Since in this experimental situation the length (L) of the repair tissue and the weight (W) of the tissue are nearly constant because of invariable anatomical conditions, the breaking load obtained in the tensile strength measurements under the circumstances can be equalized to the tensile strength required.

In order to evaluate the findings of tensile strength measurements in both experimental groups as given in table 8, the average increase in tensile

Table 9: Experimental study on rabbits.
Average increase in tensile strength in the experimental groups, noted as a percentage of the original tensile strength as determined at the uninjured side.

	average increase in tensile strength	
Autopsy after	sutured group	non-sutured group
1 week:	20.5	21.3
2 weeks:	35.4	32.4
3 weeks:	53.7	37.3
4 weeks:	77.4	44.4
6 weeks:	53.5	36.0
10 weeks:	89.0	66.4

strength at the end of each period was determined and noted as a percentage of the original tensile strength. The percentages acquired are shown in table 9.

The results of tensile strength measurements, as listed in table 8 and 9, are visualized in a diagram in fig. 41.

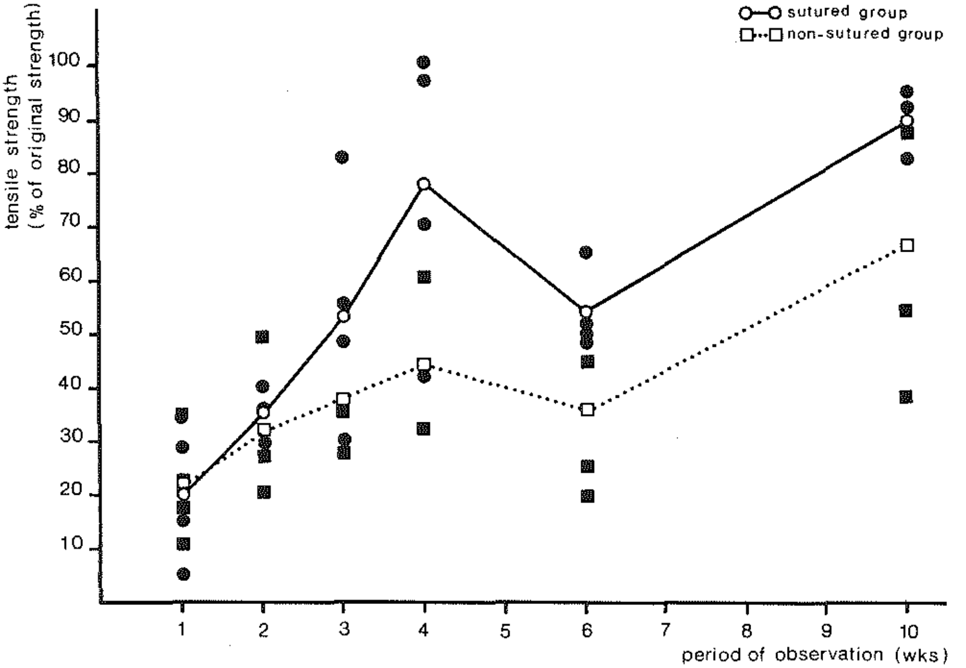


fig. 41
Average increase in tensile strength in the experimental groups.

In examining the results of the tensile strength measurements, the following findings were noted.

In the first two weeks no substantial difference was found concerning the average increase in tensile strength between both groups. In both groups tensile strength increased at approximately the same speed. As discussed

in chapter 2.4, this correlates with the phase of proliferation in which the collagen molecules are formed and the collagen fibers appear.
From the third week on the average increase of tensile strength is more rapid in the sutured group than in the non-sutured group.
After ten weeks the tensile strength obtained in the sutured group has reached high percentages (table 8), with an average of 89% (table 9). In this group all ligaments ruptured at the tibial periosteal attachment again, as was seen in the normal, uninjured ligaments, indicating that normal tensile strength had been regained.
In the non-sutured group two out of four ligaments reached good percentages of tensile strength after ten weeks, while both ligaments ruptured at the tibial periosteal attachment. Both other ligaments obviously failed to heal properly, reaching only 37.4% and 53.6% of their original tensile strength respectively (table 8), while rupture at the transecting line indicated that normal tensile strength had not yet been regained.

These findings suggest that in this experimental study adaptation of ruptured ligaments by means of sutures has created good conditions to regain full tensile strength in all cases, whereas in those cases where suturing was omitted, the average tensile strength after each period was less high as compared to the sutured group and proper ligament healing was obtained in only half of the cases within the time of follow-up.
The diagram (fig. 41) shows a remarkable "dip" in both the sutured group and the non-sutured group, both after a period of six weeks.
It seems unlikely that the changes in tensile strength during the process of ligament healing really show a temporary decrease. This finding possibly was caused by external factors.
As was described in paragraph 7.3.1 the group of eight rabbits sacrificed after a period of six weeks -due to unknown circumstances- showed considerably less increase in bodyweight during their observation period as compared to the other experimental animals (fig. 36).
Although throughout the observation period the eight rabbits did not show any sign of illness, it seems likely to suppose that the relatively small increase in bodyweight was related to a non-optimal nutricious state, which in turn could have influenced the results of tensile strength measurements. Histologically no differences were seen which could explain the temporary decrease in tensile strength in this subgroup.

Regarding the histological findings marked differences were found as compared to the findings in the literature. In contrast to the findings of others (Jack - 1950, Clayton and Weir - 1959) it was found that the process of ligament healing in both experimental groups was essentially the same and without direct relation to the ligament ends themselves.
Both in the sutured group and in the non-sutured group regeneration was found to rise mainly from the subsynovial connective tissue at the joint side of the ligament, whereas the ligament stumps themselves offered no noticeable contribution to the process of ligament healing, showing an inactive aspect.

7.5 Summary and conclusions

An experimental study on adolescent rabbits was performed to investigate the process of ligament healing under conditions resembling the clinical management of ligamentous ruptures in an attempt to answer the two questions posed at the introduction of this chapter.
Two experimental groups of 24 rabbits each were formed. In all cases the medial and lateral collateral ligaments of the right stifle joint were sharply transected. In one group these ligaments were subsequently sutured, in the other group the ligaments were left without suturing. Both groups were immobilized postoperatively in a Baycast splint for a period of three weeks, after which full resumption of function was allowed. At different intervals the rabbits were sacrificed. Tensile strength measurements were performed on the medial collateral ligaments of the right stifle joint, using the same ligament of the contralateral stifle joint as a reference. The experimental procedure is described. Histological investigations were carried out on the lateral collateral ligaments of the right stifle joint in both experimental groups. Histologically, the process of ligament healing was found to be the same in both experimental groups. Regeneration arises from the subsynovial connective tissue, at the joint side of the ligament, after which proliferation of fibroblasts restores the original aspect of parallel longitudinal bundles of collagen fibers within a period of ten weeks, without noticeable contribution of the ligament stumps.
Regarding the changes in tensile strength no significant differences were found between the sutured group and the non-sutured group within the first two weeks, tensile strength being only about 30-35% of its original level. However, from the third week on, a rapid increase in tensile strength was found in the sutured group, whereas the non-sutured group increased only gradually. After ten weeks, near normal tensile strength had been regained in all cases within the sutured group, whereas the unsutured ligaments had regained near normal strength in only half the cases.

In conclusion, it was found that within the experimental study suturing of ruptured ligaments has led to full restoration of tensile strength in all cases. Although histologically no differences could be found between the two groups, suturing of ruptured ligaments is the method of treatment most likely to produce adequate ligament healing.

PART III

CHAPTER 8 PROSPECTIVE CLINICAL STUDY

8.1 Introduction

Supported by the conclusions drawn from literature regarding the importance of the anterior talofibular ligament concerning ankle stability (chapter 6.2) and running parallel to the experimental study presented (chapter 7.5), a prospective clinical study was carried out in an attempt to evaluate the results of treatment of single and multiple lateral ankle ligament ruptures by means of early surgical repair.

During the period of October 1979 to August 1982 all patients with ankle sprains, seen at the casualty department of the St. Hippolytus Hospital Delft were examined by the assistant surgeon in charge, using a standard form to registrate all diagnostic data acquired from history, physical examination and radiological examinations (see Appendix).

8.2 History

The history-taking consisted of questions concerning the time and circumstances regarding the accident. Moreover, all patients were asked whether they had sustained a previous ankle sprain, and if so, on what side, how it was treated and whether or not residual complaints from this previous injury were still present. Also, all patients were asked whether or not, and in what way they were practising sport.

8.3 Physical examination

Physical examination of the injured ankle was performed twice. All patients were examined first when seen initially at the casualty department and next after an average delay of three days when the patients visited the outpatient department, prior to arthrographic examination.
Both times examination consisted of careful registration of the presence, degree and localisation of pressure pain, swelling, localized haematoma and discoloration of the lateral ankle region. Clinical instability tests were not routinely performed.

8.4 Standard radiographs

Standard radiographic examinations were performed in two directions on the day of the initial examination to exclude fractures. Avulsion fractures were not classified as fractures.

When standard radiographs had revealed no fracture, a cotton-wool bandage was applied and the patient was advised to rest and elevate the leg as much as possible. An appointment then was made for the second, the third or in exceptional cases the fourth day after injury to visit the outpatient department.

8.5 Arthrographic examination

In all cases where pressure pain, swelling or discoloration of the skin of the ankle region, or a combination of these symptoms was present at the second physical examination, arthrographic examination of the ankle joint was performed.

Only if none of these symptoms were present and the patient was free of complaints, arthrography was omitted. In all, 732 patients were submitted to arthrographic examination.

Arthrography was performed by one of the radiologists, using a mixture of 10 ml Conray 60 and 1 ml Lidocaine 2%. Initially also 0.5 ml Hyason (hyaluronidase) was added, but during the course of the study this was omitted by the radiologist without resulting in noticeable differences.

The technique and diagnostic criteria used in the clinical study were described in detail in chapter 4.4.

8.6 Treatment programs

8.6.1 No ligament rupture group (group O)

In 335 patients arthrography showed no sign of ligamentous injury. A cotton-wool bandage was applied in these cases. The patients were instructed to rest and elevate the injured extremity for 24 to 48 hours, in order to permit resorption of the contrast fluid from the ankle joint. Thereafter they were advised to resume normal activities wearing a non-adhesive elastic bandage during daily hours for a period of one or two weeks.

8.6.2 Ligament ruptures (i.a. group A)

In all 345 cases, in which arthrography revealed extra-articular contrast leakage suggesting single or multiple lateral ankle ligament rupture, surgical exploration was performed. Operation was generally carried out the same day as, or the day following arthrography.

The assumption of lateral ankle ligament rupture was confirmed at operation in 332 patients (group A).

In using the above mentioned criteria for surgical exploration in case of lateral ankle ligament ruptures the only selection made was based on age. Patients with ligament ruptures aged under 15 years were treated conservatively as were occasionally some elderly patients because of individual contra-indications.

When arthrography suggested rupture of the deltoid ligament (4 patients) or the anterior tibiofibular ligament (8 patients) surgical exploration was omitted. Instead these patients were treated with plaster immobilization; for this reason the follow-up results of these patients were excluded.

In 8 patients in which arthrography suggested lateral ankle ligament rupture, rupture of the anterior tibiofibular ligament was found at subsequent operation. In 3 other patients isolated rupture of the calcaneofibular ligament was found, while in 2 patients only a capsular tear without ligamentous damage (false positive arthrography) was encountered. The follow-up results of these 13 operated patients were excluded for statistical reasons.

8.6.3 Control group (group C)

Although the main intention of the clinical study was to investigate the ultimate results of surgical treatment of all degrees of lateral ankle ligament ruptures, it was felt there was a need for a control group, consisting of patients with single and multiple ankle ligament ruptures, treated non-operatively. Therefore, during the course of the study, on an aselect base, a control group (group C) was formed, composed of 40 patients.
Arthrographically this control group could be divided in two subgroups:

- 20 patients with assumed isolated rupture of the anterior talofibular ligament
- 20 patients with assumed rupture of both the anterior talofibular ligament and the calcaneofibular ligament

Following arthrography in these patients a cotton lined below-knee L- and U-shaped plaster splint was applied, after which the patients were instructed to rest and elevate the injured extremity for a period of one week. After this period the plaster splint was replaced by a below-knee walking cast and full weightbearing was allowed after 36 hours. After two weeks the walking cast was removed and further treatment and exercises were prescribed as in case of patients treated surgically (group A) (see chapter 8.8).

8.7 Surgical technique

All patients were operated on the same day or the day following arthrography. Operation was performed under general anaesthesia (87%), spinal (8%) or epidural anaesthesia (5%).

The patient was slightly turned towards the uneffected side by elevating the hip on the effected side using a sandbag. The uninjured leg beneath was straightened, the injured leg flexed at the hip and knee. The leg was exsanguinated using an air inflated tourniquet placed around the upper leg. After the skin of the foot, ankle and calf was disinfected with a 1% iodine solution, the toes and forefoot were enwrapped in a sterile surgical glove. Sterile drapes were applied around the calf. The skin of the operation field was covered with adhesive plastic sheet. The exact placement of the incision is imperative to permit examination of both anterior talofibular and calcaneofibular ligaments without forcible retraction of any tissue and to preserve the superficial peroneal nerve running about 1.5 cm medial to the anterior margin of the distal fibula. Because of considerable swelling sometimes the outlines of the lateral malleolus can only be located with great difficulty. It proved helpful to sketch the planned incision preoperatively with a marker pen (fig. 42).

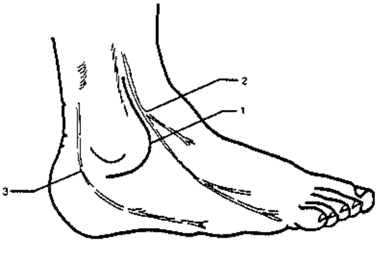


fig. 42
Incision for surgical repair of ruptured lateral ankle ligaments. Incision line (1), superficial peroneal nerve (2) and sural nerve (3).

A curved incision resembling an inverted interrogation mark was made on the anterodistal side of the lateral malleolus starting about 4 cm proximal to the tip of the lateral malleolus and close to the anterior border of the distal fibula. It extended downwards and somewhat anteriorly and then was curved posteriorly some 1.5 cm distal to the tip of the lateral malleolus so as to end at a point halfway between the lateral malleolus and the heel, anterior to the sural nerve. Next, the subcutaneous veins were ligated with catgut 000. Special notice was taken of the condition of the crural fascia. Location and extent of traumatic lesions to this fascia were registrated.
In case of total rupture of the crural fascia only minimal blunt dissection then

exposed the area of the lateral ligaments, which are hidden from view only by large bloodclots. If the fascia cruris was partly ruptured, a defect was found anteriorly to the lateral malleolus overlying the region of the anterior tibio-fibular ligament which at this point was inspected.
The crural fascia was then incised in the direction of the skin incision without undermining the wound edges, thereby uncovering the anterior talofibular ligament. Anterodistally to the lateral malleolus the fat pad was reached and divided.
At the posterior end of the incision the peroneal tendon sheath was found and opened transversally between the superior and inferior retinacula to explore the calcaneofibular ligament.
In case the tissues in the operative field were blood drenched the wound and joint cavity were thoroughly irrigated with normal saline solution. A clear view of the damage to the lateral ligaments then was obtained by inverting the foot while the peroneal tendons were retracted dorsolaterally. If the calcaneofibular ligament was ruptured at its calcanear attachment it was necessary to visualize its insertion by retracting the peroneal tendons antero-medially.
The posterior talofibular ligament could only be inspected by subluxating the lateral part of the talar trochlea anteriorly and at the same time rotating the talus internally. The possibility to dislocate the talus in this manner was sometimes very impressive. The posterior talofibular ligament then could be inspected in between the inner articular surface of the lateral malleolus and the lateral facet of the subluxated talus.
Rupture of the posterior talofibular ligament, if present, was usually partial and could not be reconstructed through this exposure. Therefore, if encountered, it was left untreated.
The talar trochlea was carefully inspected for osteochondreal fractures.

Repair was carried out using atraumatic Vicryl 000. Starting with the calcaneofibular ligament, the ruptured ends were carefully approximated by interrupted stitches. Working towards the anterior talofibular ligament the rupture through or parallel to the lateral talocalcaneal ligament was sutured, while the foot was held in slight plantar flexion. After suturing the anterolateral joint capsule the anterior talofibular ligament was reached and carefully approximated while the foot was held in 90° dorsiflexion and slight eversion. In this way no tension was placed on the newly sutured ligaments.
The peroneal tendon sheath was not closed in order to prevent sequelae resulting from scar tissue structures.
When boney ossicles or avulsion fractures were present, small fragments were

excised and larger fragments replaced, suturing the ligament through a drill-hole or to the periosteum.
Next, the fascia cruris was closed with interrupted stitches of Vicryl 000, preventing the skin sutures from being tensed. The skin was closed with atraumatic Ethilon 0000, using interrupted Allgöwer stitches.
A cotton-lined below knee L- and U-shaped plaster splint was applied with the foot in 90° dorsiflexion and slight eversion, taking care that no pressure was put upon the wound. The tourniquet then was released and the anaesthesia terminated.

8.8 Postoperative management

The patient was kept in bed for three days with the leg elevated during which time 5000 U calcium-heparine ("Calparine") was given subcutaneously twice a day to prevent thrombosis. On the fourth postoperative day the patient was mobilized within limits using elbow crutches.
One week postoperatively the plaster splint was removed and the wound inspected. Skin stitches were left in place and a below-knee walking cast was applied with which the patient was discharged the next day. Full weightbearing was allowed after drying of the cast 36 hours after application.
An attendance at the outpatient department was arranged at two weeks after discharge. By that time the cast and the skin stitches were removed and an elastic bandage or elastic tubular bandage was applied to wear during daily hours. The patient was allowed full weightbearing and instructed verbally and by a form to carry out an exercise program which aimed at achieving normal gait as quickly as possible, preferably in the first week following. Toe rising, heel rising and squatting exercises were prescribed in the second week following removal of the plaster cast, while running was allowed in the third week, provided the patient was able to walk without a limp.
In this period the patient was seen at the outpatient department once or twice to determine the improvements made.
Physiotherapy was not prescribed routinely. Only if improvement of ankle function failed to come, due to pain on weightbearing and normal walking was not achieved after three weeks, supporting physiotherapy, comprising of exercises and ultra short wave therapy was started.
Sport activity was allowed 4-6 weeks after removal of the cast, providing that hard running was possible surely and safely.

8.9 Administration of results

Evaluation of the results of treatment requires both the assessment by the patient and by the surgeon. Follow-up examinations were performed six months and one year following injury. Patients were convoked by means of written invitations. When there was no response, the convocations were repeated twice. Questionnaires by letter were not used, nor was follow-up performed by telephone.

Every month a special morning session was planned for follow-up examinations in which all patients were seen by the author personally. A standard questionnaire was used to register the results of the case history and the physical examination at follow-up, so as to compile the findings in as much the same way as possible (see Appendix).

Follow-up at six months and one year was considered a too short period to justify routine radiological examination to detect signs of osteoarthrosis. Therefore standard radiographs were repeated only in case of serious residual complaints, possibly associated with osseous abnormalities. Radiological stress examinations were not performed.

The follow-up study was closed at the end of October 1982.

8.9.1 Anamnestic information

Resumption of normal activities can generally be judged from resumption of work. All patients were asked how long they have been on sick leave, i.e. after what period they resumed their professional occupation. No distinction was made between heavy and light work. If their profession enabled the patient to work while still being immobilized in their walking cast, they were allowed to do so.

Resumption of sports activities is an important parameter in evaluating the ultimate results of treatment, especially when one realizes that ankle ligament ruptures are very frequently seen among sports injuries.

All patients were asked whether they practised sport prior to the ankle injury and whether they had resumed athletic activities afterwards.

If sport was resumed they were asked about the extent, about the possible limitations and about the period that elapsed before resumption of sport was possible. If not resumed, it was established as to how far this failure was related to the accident sustained.

As mentioned before, physiotherapy was not prescribed routinely in the treatment program, but only if the self-training program failed to result in improvement of ankle function and normal gait.

All patients were asked whether they had received physiotherapy during the course of recovery and if so during what period and in what frequency of treatment.

Detailed questions were posed regarding residual complaints. All patients were asked about pain at rest, during and following weightbearing, about persistent swelling following weightbearing and about recurrent sprain. Recurrent sprain after the initial treatment was recorded when a significant renewed inversion sprain was reported, which had resulted in at least 12-24 hours of pain and swelling of the re-injured ankle. If this recurrent sprain had led to long-term residual complaints, not present previously, or to deterioration of persistent complaints, this was also noted.

The presence of functional instability (i.e. subjective instability) as a residual symptom following ankle ligament rupture can be investigated by asking the patient whether "a tendency for the ankle to give way" (Freeman et al. - 1965), or "the feeling the ankle can not be trusted", is still present. When not accurately put, these questions about functional instability can be interpreted as "fear of renewed injury" which is probably present in many patients who sustained an ankle ligament rupture.

8.9.2 Physical examination

At physical examination the ankle was inspected for possible swelling, abnormalities of the scar and the possible presence of hypaesthesia, hyperaesthesia or paraesthesia. Ankle function was recorded by comparing the active and passive mobility of the talocrural and subtalar joints of both sides, in order to detect possible posttraumatic differences (Roaas and Anderson - 1982).
Clinical assessment of mechanical instability was achieved by using the anterior drawer sign which is judged reliable in detecting chronic instability (Broström - 1965, Cedell - 1975, Prins - 1978). If a positive anterior drawer sign was recorded on both sides, this was regarded as a non-posttraumatic condition.

8.9.3 Patient's assessment

All group A patients were asked about the inconvenience of hospitalization. Moreover every follow-up examination was completed with the recording of the patient's own assessment of the ultimate results of treatment of their injury, by asking all patients to classify their opinion into one of the following categories: good, satisfactory, moderate or poor.

8.9.4 Statistics

For comparison of the percentages reported in the findings of the clinical study, the X^2-test and Fisher's test were used.

CHAPTER 9 RESULTS

9.1 Introduction

The results obtained from the prospective clinical study can not be discussed without correlating the findings to the data concerning the individual patient. Therefore, firstly all patient-related data will be given. Next the different aspects of history and physical examination are listed, followed by the radiological findings. Thereafter the operative findings are given, as well as the complications seen in relation to surgical treatment.

The second part of this chapter deals with the results of follow-up examination after six months and one year following initial therapy.

To be able to correlate various findings with the extent of ligamentous injury as observed at operation, group A was divided into three subgroups (table 10).

When in the following tables both absolute figures and percentages are listed, the percentages will be given in brackets.

Table 10: Findings at operation in 345 cases of surgical exploration.

subgroup	lesion	n
A_1	rupture of the anterior talofibular ligament (ATaFL)	155
A_2	rupture of the anterior talofibular and calcaneofibular ligament (ATaFL + CFL)	147
A_3	rupture of the anterior talofibular, calcaneofibular and posterior talofibular ligament (ATaFL + CFL + PTaFL)	30
subtotal:		332
	isolated rupture of the calcaneofibular ligament (CFL)*	3
	capsular tear without ligamentous injury*	2
	rupture of the anterior tibiofibular ligament*	8
total:		345

* the results of these patients were excluded from follow-up evaluations for statistical reasons (see chapter 8.6.2.).

9.2 Patient-related data

9.2.1 Distribution of age, sex and side of injury

In group O (335 patients) the mean age was 26.2 years (men 25.8 years, women 26.6 years). In this group there were 182 men (54%) and 153 women (46%). As shown in table 11, the right ankle was involved in 175 cases (52%), the left ankle in 160 cases (48%). The distribution of age is shown in fig. 43. In group A (332 patients) the mean age was 24.5 years, 23.6 years in men and 26.6 years in women respectively. The distribution of age is shown in fig. 44.

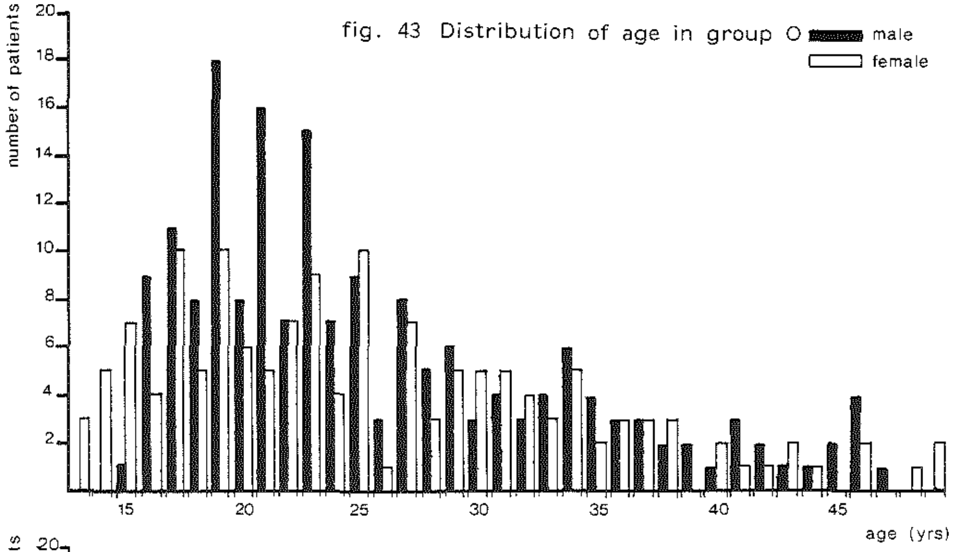


fig. 43 Distribution of age in group O
male
female
number of patients
age (yrs)

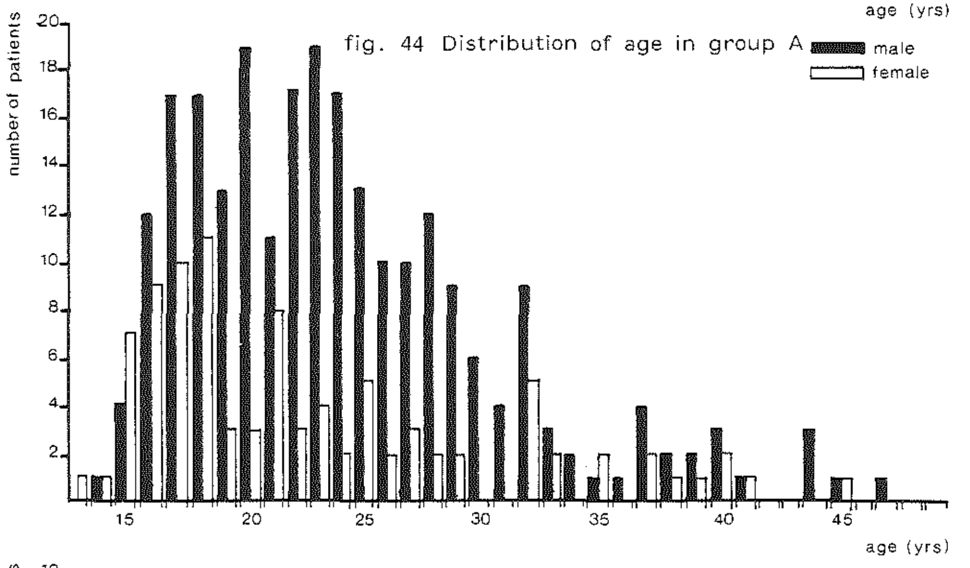


fig. 44 Distribution of age in group A
male
female
number of patients
age (yrs)

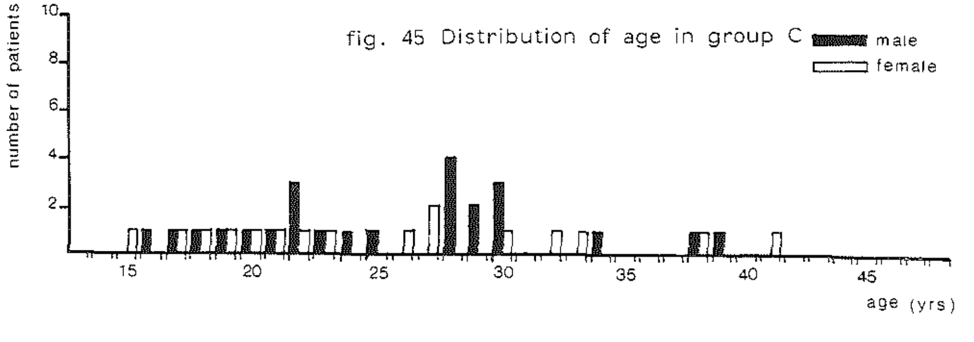


fig. 45 Distribution of age in group C
male
female
number of patients
age (yrs)

Group A consisted of 240 men (72%) and 92 women (28%). The right ankle was injured in 178 cases (54%), the left ankle in 154 cases (46%). (Table 11).

Table 11: Distribution of sex and side of injury.
Absolute figures.

Treatment group	O		A		C	
sex	♂	♀	♂	♀	♂	♀
right ankle	96	79	127	51	11	8
left ankle	86	74	113	41	14	7
subtotal	182	153	240	92	25	15
total:	335		332		40	

In group C (40 patients) the mean age was 24.9 years. The difference with group A is small. Both groups are therefore comparable with respect to mean age. As shown in table 11 there were 25 men (62.5%) and 15 women (37.5%). The right ankle was injured in 19 cases (48%), the left ankle in 21 cases (52%). The distribution of age is shown in fig. 45.

9.2.2 Sports activities

Rather high percentages of athletic activities prior to the present injury were reported in all treatment groups. In group A 87% practiced sport, in group O 71% and in group C 82.5%. Mostly sport was practiced with official sports clubs (group A 86.5%, group O 84%, group C 97%), in an average frequency of twice a week. The levels on which athletic activities were performed are shown in table 12.

Table 12: Various levels of athletic activities prior to the present injury in the different treatment groups.
Absolute figures and percentages.

Treatment group	O	A	C
occasional sport	2 (1)	2 (1)	
recreative sport	104 (43)	92 (32)	15 (45)
amateur competition	129 (54)	188 (65)	18 (55)
professional competition	3 (1)	2 (1)	
unknown	1 (1)	4 (1)	
subtotal	239 (100)	288 (100)	33 (100)
no sports activities	96	44	7
total	335	332	40

9.3 History

9.3.1 Causality

Sport is by far the most frequent cause of ankle sprain. The findings concerning causality in the clinical study are listed in table 13.

Table 13: Nature of accidents. Absolute figures and percentages.

Treatment group	O	A	C
sport	190 (57)	252 (76)	28 (70)
walking	64 (19)	41 (12)	8 (20)
traffic	18 (5)	9 (3)	1 (2.5)
home	17 (5)	2 (1)	
work	19 (6)	17 (5)	3 (7.5)
others	27 (8)	11 (3)	
total	335 (100)	332 (100)	40 (100)

The distribution of the different kinds of sports which caused ankle sprain are given in table 14, showing that, in absolute figures, soccer accounts for the highest accident score.

Table 14: Causal sports activities in 470 patients who subtained injury while practicing sport. Absolute figures and percentages.

soccer	193 (41)	tennis	19 (4)
volleyball	84 (18)	gymnastics	12 (2.5)
basketball	40 (8.5)	dancing	6 (1)
handball	38 (8)	hockey	4 (1)
jogging	34 (7)	fighting sports	4 (1)
badminton	28 (6)	others	8 (2)

9.3.2 Responsible trauma mechanism

Most patients were able to indicate the responsible trauma mechanism, mainly describing a plantar flexion-inversion injury as the injurious movement (table 15).

Table 15: Movement of the foot responsible for injury. Absolute figures and percentages.

Treatment group	O	A	C
inversion	305 (91)	309 (93)	35 (87.5)
eversion	2 (1)	4 (1)	1 (2.5)
exorotation	4 (1)		
unknown	24 (7)	19 (6)	4 (10)
total	335 (100)	332 (100)	40 (100)

9.3.3 Previous ankle sprains

Previous ankle sprains on the same side were recorded in 33% in group O patients, 29% in group A patients and 37% in group C patients.

In some 10% in each group patients were not certain about having sustained a previous ankle sprain on the same side, whereas in the remaining patients no previous ankle sprains were sustained on the same side as the recent injury.

As shown in table 16 the various relative figures are almost equal in the different treatment groups, indicating that there seems to be no correlation between the incidence of previously sustained sprains and the severity of the renewed trauma.

Table 16: Previous ankle sprains on the same side. Absolute figures and percentages.

Treatment group	O	A	C
previous and recent sprain on left side:	32 (29)	30 (31)	4 (27)
previous and recent sprain on right side:	43 (39)	34 (35)	6 (40)
previous sprain on both sides:	35 (32)	33 (34)	5 (33)
subtotal	110 (100)	97 (100)	15 (100)
no previous sprain	199	202	21
unknown	26	33	4
total	335	332	40

The distribution of the side of injury previously sustained differs only slightly in the different patient groups, showing a predominance for the right side, which is in accordance with literature findings (see chapter 3.2).

Table 17: Treatment of previous sprains on the same side. Absolute figures and percentages.

Treatment group	O	A	C
none	36 (33)	25 (26)	5 (33)
bandage	64 (58)	63 (65)	8 (54)
plaster cast	6 (5)	6 (6)	2 (13)
operative repair	4 (4)	3 (3)	
total	110 (100)	97 (100)	15 (100)

The treatment received in relation to previous sprains on the same side is listed in table 17, showing no significant differences in the various treatment groups (no therapy X^2=1.29 d.f.=2 $p>0.10$; bandage therapy X^2=1.37 d.f.=2 p>0.10). However, marked differences were found regarding the amount of residual complaints in relation to previous sprains sustained (table 18).

Table 18: Residual complaints following previous injury on the same side. Absolute figures and percentages.

Treatment group	O	A	C
residual complaints	23 (21)	43 (44)	6 (40)
no residual complaints	87 (79)	54 (56)	9 (60)
subtotal	110 (100)	97 (100)	15 (100)
no previous sprain	199	202	21
unknown	26	33	4
total	335	332	40

Patients with recent ligament rupture (group A and C) had far more residual complaints (44%) from their previous sprains than patients without recent ligament rupture (group O), who only had residual complaints in 21%.
This difference is highly significant (X^2=13.2 d.f=1 P<0.001), which indicates that patients with residual complaints from previous ankle sprains on the same side, apparently resulting from inadequate treatment, are significantly more prone to ligament rupture in case of renewed injury.
The residual complaints mentioned mainly consisted of the feeling having "a weak ankle", which is easily sprained again (fear of ankle giving way). Pain and discomfort during daily activities were mentioned to a less extent, as was swelling.

9.4 Physical examination

In a minority of cases, in which accident and primary examination had taken place elsewhere, the results of the first examination were not available.

9.4.1 Swelling

Swelling, as a result of oedema, is a predominant symptom following ankle sprains. The diagnostic value of swelling can be determined from table 19 and 20. When swelling is absent at the initial examination (table 19), this suggests absence of ligament rupture (PVneg=66), although still 34% of patients had indeed a ligament rupture without symptoms of swelling. When swelling is limited to the region anterolateral to the lateral malleolus, this symptom does not give substantial information about the presence or absence of ligament rupture (PVpos=46), whereas swelling extending over the region of the lateral malleolus is indicative for ligament rupture (PVpos=63). However extensive swelling was associated with absence of ligament rupture still in 37% of the patients.

Table 19: Extent of swelling at initial examination. Absolute figures and percentages.

Treatment group	O	A_1	A_2	A_3	C	total
no swelling	31 (66)	11 (24)	2 (4)		3 (6)	47 (100)
swelling anterolateral to lateral malleolus	192 (54)	78 (22)	55 (16)	13 (4)	15 (4)	353 (100)
swelling covering lateral malleolus	102 (37)	61 (22)	79 (29)	15 (5)	19 (7)	276 (100)
subtotal	325	150	136	28	37	676 (100)
not available	7	3	8	2	3	23
unknown	3	2	3			8
total	335	155	147	30	40	707

At second examination, usually the second or third day following trauma, there was no circumscript swelling left, but instead swelling diffused over the lateral ankle region and sometimes over the midfoot. Therefore, at second examination, swelling was classified only as "present" or "absent" (table 20).

Here the predictive diagnostic value of swelling was found to be somewhat higher, showing a PVneg of 71 in case of absence of swelling and a PVpos of 63 in case of presence of swelling.

Table 20: Swelling at second examination (2-4th day).
Absolute figures and percentages.

Treatment group	O	A_1	A_2	A_3	C	total
present	178 (37)	123 (25)	128 (26)	26 (5)	32 (7)	487 (100)
absent	154 (71)	31 (14)	19 (9)	4 (2)	8 (4)	216 (100)
subtotal	332	154	147	30	40	703 (100)
unkown	3	1				4
total	335	155	147	30	40	707

9.4.2 Haematoma

When haematoma is present following inversion sprain it can be seen shortly after injury as a circumscript rounded swelling anterolateral to the lateral malleolus (eggshell sign) or as a diffuse swelling with discoloration of the skin, extending over the region of the lateral malleolus.
The findings from the initial examination (table 21) show no significant differences between the different treatment groups regarding the presence or extent of a haematoma. Thus, the opinion found in literature that the eggshell sign is characteristic for severe ligamentous damage could not be confirmed in our series (PVpos=43).

Table 21: Haematoma at initial examination. Absolute figures and percentages.

Treatment group	O	A_1	A_2	A_3	C	total
no haematoma	179 (46)	97 (25)	79 (21)	15 (4)	15 (4)	385 (100)
eggshell sign	106 (57)	29 (16)	33 (18)	6 (3)	12 (6)	186 (100)
diffuse haematoma	40 (38)	24 (23)	23 (22)	7 (7)	10 (10)	104 (100)
subtotal	325	150	135	28	37	675 (100)
not available	7	3	8	2	3	23
unknown	3	2	4			9
total	335	155	147	30	40	707

The purplish streak along the lateral margin of the heel, which can be seen when examining the ankle several days after trauma, is caused by diffusion of haematoma into the surrounding tissues.

This discoloration of the lateral ankle region was registrated and classified as absent, minor or major streak haematoma or as diffuse haematoma.

From table 22 it can be concluded that only limited diagnostic value can be attached to the clinical symptom of skin discoloration, since no substantial correlation could be found between the presence or extent of discoloration of the lateral ankle region and the degree of injury.

Table 22: Haematoma at second examination (2-4th day). Absolute figures and percentages.

Treatment group	O	A_1	A_2	A_3	C	total
absent	92 (56)	34 (21)	24 (15)	9 (5)	5 (3)	164 (100)
minor streak	25 (51)	11 (23)	8 (16)	1 (2)	4 (8)	49 (100)
major streak	134 (42)	75 (24)	77 (24)	12 (4)	18 (6)	316 (100)
diffuse	81 (46)	35 (20)	38 (22)	8 (5)	13 (7)	175 (100)
subtotal	332	155	147	30	40	704 (100)
unknown	3					3
total	335	155	147	30	40	707

9.4.3 Pain

Pressure pain (direct pain) was localized using the palpating finger, recording the punctum maximum of pressure pain in relation to the course of the lateral ankle ligaments.

The value of pressure pain as a diagnostic aid in case of ankle sprain can be determined from table 23 and 24. When direct pain was absent, still 69% of patients proved to have a ligament rupture (PVneg=31).

In case of pressure pain over the anterior talofibular ligament this was associated with ligament rupture in 47% of patients, whereas the remaining 53% did not show ligament rupture.

In case of pressure pain over both the anterior talofibular and calcaneofibular ligament still 43% did not have a ligament rupture.

From table 23 it is therefore concluded that pressure pain as a symptom at initial examination has only a very limited predictive diagnostic value.

Table 23: Pressure pain at initial examination. Absolute figures and percentages.

Treatment group	O	A_1	A_2	A_3	C	total
absent	8 (31)	7 (27)	3 (12)	5 (19)	3 (12)	26 (100)
ATaFL	223 (53)	94 (22)	71 (17)	12 (3)	21 (5)	421 (100)
CFL	3 (21)	3 (21)	7 (50)	1 (7)		14 (100)
ATaFL + CFL	92 (43)	46 (21)	53 (25)	10 (5)	12 (6)	213 (100)
subtotal	326	150	134	28	36	674 (100)
not available	7	3	8	2	3	23
unknown	2	2	5		1	10
total	335	155	147	30	40	707

When recorded several days after trauma (table 24) absence of pressure pain is indicative for absence of ligament rupture (PVneg=63), although still 37% of patients had a ligament rupture.

As is shown in table 24, the presence of pressure pain does not give reliable information on the presence or extent of ligament rupture.

Table 24: Pressure pain at second examination (2-4th day). Absolute figures and percentages.

Treatment group	O	A_1	A_2	A_3	C	total
absent	22 (63)	6 (17)	4 (11)	2 (6)	1 (3)	35 (100)
ATaFL	243 (53)	108 (23)	71 (15)	10 (2)	30 (7)	462 (100)
CFL	7 (70)	1 (10)			2 (20)	10 (100)
ATaFL + CFL	57 (31)	36 (20)	65 (35)	18 (10)	7 (4)	183 (100)
subtotal	329	151	140	30	40	690 (100)
unknown	6	4	7			17
total	335	155	147	30	40	707

9.5 Standard radiography

Within the clinical study all 732 patients were submitted to standard radiographs of the injured ankle on the day of the initial physical examination.

All standard radiographs were reviewed by the author. In 632 patients (86%)

no abnormalities were found. In 34 patients (5%) standard radiographs were not available for evaluation because they were performed elsewhere or because of administrative mistakes.

9.5.1 Abnormal findings

Pathological tibiofibular diastasis, i.e. tibiofibular distance, measured at the level of the distal tibiofibular ligament, exceeding 5 mm was found in 2 patients, both with surgically confirmed rupture of the anterior tibiofibular ligament. The remaining patients with this type of ligamentous injury did not show pathological tibiofibular diastasis. Posttraumatic calcifications in the interosseous ligament, resulting from previous rupture of the distal tibiofibular ligaments (Guise - 1976), were seen in none of the patients.
Recent lateral avulsion fractures were diagnosed radiologically in 4 patients: 3 patients had an avulsion fracture of the fibular tip, 1 patient showed an avulsion fracture of the talar attachment of the anterior talofibular ligament.
In 18 patients old avulsion fractures were seen on the lateral side. All of these patients confirmed having sustained previous ankle sprains.

Recent medial avulsions were found in 3 patients, all malleolar avulsions. Old medial avulsion fractures were noted in 27 patients, some of which did not remember having sustained a previous ankle sprain. It is assumed therefore that at least partially these findings were erroneously classified as old avulsions, whereas they should have been classified as os subtibiale.

Osteochondral fractures of the talar dome (flake fractures) were seen in 2 male patients, one on the medial and one on the lateral trochlea, both associated with rupture of the anterior talofibular and calcaneofibular ligaments. This incidence of 0.2% is quite less than what is mentioned in literature (2-10%). Both osteochondral fractures were missed on the standard radiographs and only detected during follow-up, when supplementary radiographs were made because of persistent sequelae.
Manifestations of osteoarthrosis were found in 21 patients, their mean age being 32.6 years. In 11 patients the findings were classified as degree 0 (Bargon - 1978): sclerosis of the weightbearing subchondral bone without narrowing of the joint space. The other 10 patients were classified as degree 1: sclerosis, osteophyts and slight narrowing of the joint space. Other degrees of osteoarthrosis were not seen in our series.
In addition, in two cases, other abnormalities were found. One patient showed an avulsion fracture of the os cuboid, the other, who fell through a ceiling, showed a fracture of the talus with a concomitant avulsion fracture of the talar attachment of the anterior talofibular ligament.

9.6 Arthrographic examination

9.6.1 Arthrographic findings

To recapitulate, in all 732 patients with recent ankle sprains were submitted to ankle arthrography on the third or fourth day following injury. In 335 cases (group O) arthrography was normal, showing no signs of ligamentous injury. In 377 cases arthrography suggested lateral ankle ligament rupture, of which 40 patients were randomized to form a control group (group C). From the remaining 337 patients later on group A was formed.

In 16 patients arthrography suggested isolated rupture of the anterior tibio-fibular ligament and in 4 patients extra-articular contrast leakage was noted on the medial side suggesting rupture of the deltoid ligament.

Both in normal and pathological arthrograms opacification of tendon sheats on the medial or anterior aspects of the ankle and opacification of the subtalar joints was noted in numerous cases. The frequency of these findings is listed in table 25.

Table 25: Opacification of anterior and medial tendon sheaths and/or subtalar joints in 732 patients. Absolute figures and percentages.

extra-articular contrast leakage:	normal arthrography (n = 335)	pathological arthrography (n = 397)
extensor hallucis longus	—	1 (0.5)
extensor digitorum longus	3 (1)	31 (8)
anterior tibial	—	1 (0.5)
posterior tibial	4 (1)	3 (1)
flexor digitorum longus	17 (5)	12 (3)
flexor hallucis longus	66 (20)	48 (12)
posterior subtalar joint	50 (15)	84 (21)
posterior and anterior subtalar joints	5 (1.5)	3 (1)

No substantial difference was found between the normal and the pathological arthrograms with regard to filling of the surrounding medial or anterior tendon sheaths. Only communication with the posterior subtalar joint was seen somewhat more frequent in the pathological arthrograms.

9.6.2 Discomfort related to arthrography

When asked to classify the degree of pain suffered during arthrographic examination 10% of patients with normal arthrograms and 20% of patients with pathological arthrograms reported slight or moderate pain. Severe pain was experienced in only a few cases in both groups (table 26).

Table 26: Discomfort (%) in relation to arthrographic examination.

arthrography	normal	pathological
pain during arthrography:		
severe	4	7
slight/moderate	10	20
pain following arthrography:		
severe	19	—
slight/moderate	16	0.5

A marked difference was found regarding the incidence of pain following arthrography. In 35% of patients with normal arthrograms (no extra-articular contrast leakage) painful pressure was reported some 4-6 hours following arthrography, generally lasting a few hours. In contrast, patients with pathological arthrograms reported almost no complaints of pain following arthrography. This phenomenon is probably caused by contrast fluid which is still present in the ankle joint cavity in patients with normal arthrograms when the effect of the added lidocaine is dissolved.

9.6.3 Complications of arthrography

Within the clinical study there were no complications of bacterial arthritis, aseptic allergic reactions or reactive synovitis in relation to arthrographic examination of the ankle joint.

9.7 Operative findings

9.7.1 Extent of ligamentous injury

All patients in which arthrography revealed single or multiple lateral ankle ligament rupture were submitted to surgical exploration. Accordingly, 337 patients were operated upon. The findings at operation are listed in detail in table 27.

Additionally, 8 patients in which arthrography suggested rupture of the anterior tibiofibular ligament but was not sufficiently decisive, were operated to determine the exact nature of the underlying anatomical lesion. In all 8 patients rupture of the anterior tibiofibular ligament was revealed.

As shown in table 27, all but 5 patients (98.5%) had a rupture of the anterior talofibular ligament (ATaFL), with or without associated other ligamentous damage. Partial rupture of this ligament was a rare finding, which was noted in only 7 patients (2%). Isolated complete rupture of the anterior talofibular ligament was noted in 148 patients. Partial rupture of the calcaneofibular ligament (CFL) was seen in 32 patients (which is 18% of all calcaneofibular ruptures) and was always associated with complete rupture of the anterior talofibular ligament.

Table 27: Detailed operative findings in 337 patients with lateral ankle ligament ruptures. Absolute figures and percentages.

anatomical lesion	n	%
isolated partial rupture ATaFL	7	(2)
isolated complete rupture ATaFL	148	(44)
complete rupture ATaFL + partial rupture CFL	32	(9.5)
complete rupture ATaFL + complete rupture CFL	115	(34)
complete rupture ATaFL + complete rupture CFL + partial rupture PTaFL	27	(8)
complete rupture ATaFL + complete rupture CFL + complete rupture PTaFL	3	(1)
isolated complete rupture CFL	3	(1)
capsular tear without ligamentous lesion	2	(0.5)
total	337	(100)

In all, 180 patients had a rupture of the calcaneofibular ligament of which 3 patients showed an isolated rupture without the usually accompanying rupture of the anterior talofibular ligament.
The posterior talofibular ligament (PTaFL) was only ruptured in association with rupture of both other lateral ligaments. Partial rupture of this ligament was seen in 27 patients (90% of all posterior talofibular ruptures), complete rupture of the posterior talofibular ligament thus remaining a rare injury in our series.

Capsular tearing without lateral ligamentous damage, although considered to be an unlikely finding (chapter 1.4.2), was encountered in 2 patients. In both patients a capsular rupture was found just anteriorly to the anterior talofibular ligament, limited to the joint capsule itself, not extending into the ligament.

9.7.2 Location of rupture

In about 2/3 of all operated cases, but unfortunately not in all patients, the location of the ligamentous rupture along its course was registrated.

Rupture of the anterior talofibular ligament (ATaFL) was observed most frequently halfway its course (78%). In 7% it was associated with an avulsion fracture, mostly originating from the malleolar attachment, averaging about 4x4 mm. All avulsion fragments were reattached by means of a drill-hole and a suture.

fig. 46
Example of condition at operation. The anterior talofibular ligament is ruptured halfway its course (arrow). The calcaneofibular ligament (cf) is intact.

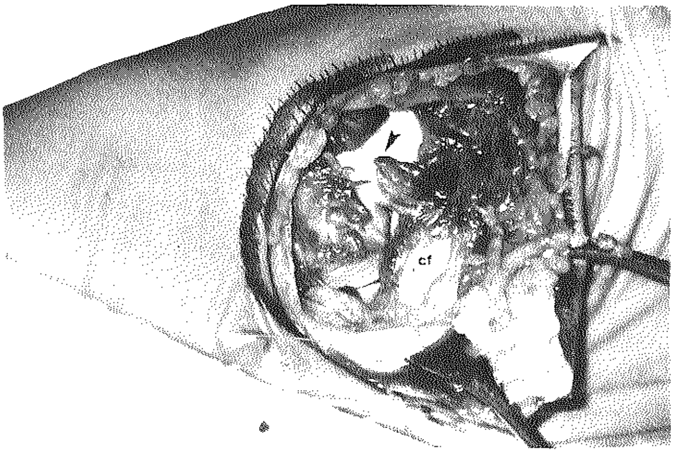
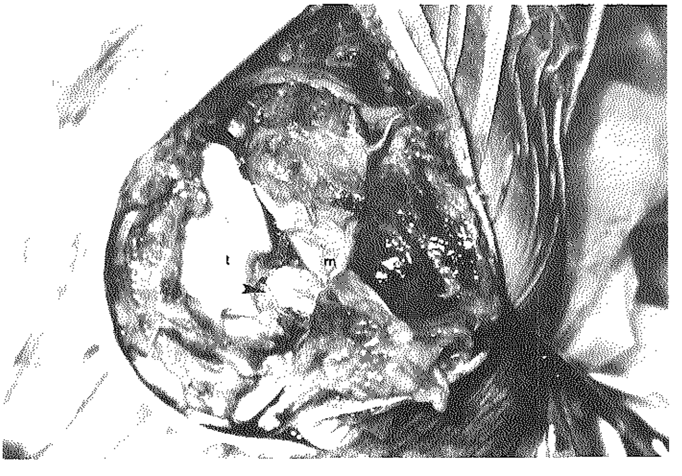


fig. 47
Example of condition at operation. The anterior talofibular ligament is ruptured halfway its course (arrow). The calcaneofibular ligament (cf) is ruptured at its distal attachment on the calcaneus and retracted from behind the peroneal tendon sheath.

fig. 48
Example of condition at operation. Same patient as fig. 47. The lateral part of the talar trochlea is subluxated. The posterior talofibular ligament, of which the short fibers are ruptured from their talar attachment (arrow), is seen in between the inner articular surface of the lateral malleolus (m) and the lateral facet of the subluxated talus (t) (see paragraph 1.4.3, fig. 8).



The calcaneofibular ligament (CFL) was found to be torn in its midportion in 42% and distally in 50%. In some cases the direction of the rupture was oblique or z-shaped, in which case some of the fibers had ruptured proximally, the remaining on the distal attachment.
Confusion with partial calcaneofibular rupture in these cases is possible (Vuust - 1980). In the group of 58 patients in which this ligament had ruptured close to its calcaneal attachment, the ligament was found to be retracted from behind the inner wall of the peroneal tendon sheath in 12 patients (21%), the ligament then lying intra-articular with the peroneal tendon sheath interposed. Avulsion fractures of the calcaneofibular ligament were observed in none of the patients.

Rupture of the posterior talofibular ligament (PTaFL), usually partial, in all these cases involved the talar attachment of the short fibers of this ligament. No avulsion fragments were observed in relation to this ligament.
In 28 patients (8%) signs were found of an old rupture of the anterior talofibular ligament. In these cases the fascia cruris was thickened by scar tissue and the ligament itself obscured by fibrous tissue in which its original ligamentous structure was hard or even impossible to recognize. In all cases this was associated with a recent rupture of the calcaneofibular ligament.
This finding in our opinion is an illustration of the so-called "two stage rupture", as described in chapter 1.4.1.

Table 28: Location of rupture in the various lateral ankle ligaments. Absolute figures and percentages.

ligament	ATaFL	CFL	PTaFL
avulsion of proximal attachment	10 (5)	—	—
rupture close to proximal attachment	13 (6)	9 (8)	—
rupture in mid-portion of ligament	166 (78)	48 (42)	—
rupture close to distal attachment	20 (9)	58 (50)	30 (100)
avulsion of distal attachment	4 (2)	—	—
subtotal	213 (100)	115 (100)	30 (100)
not registrated	119	65	—
not ruptured	5	157	307
total	337	337	337

A distinct anatomical variation concerning the anterior talofibular ligament was found in six cases. In these patients the superior part of this ligament was found to be ruptured, whereas the inferior part was intact and running posteriorly in between the lateral articular surface of the talus and the inner articular surface of the lateral malleolus, blending with the fibers of the posterior talofibular ligament, as shown in fig. 49.

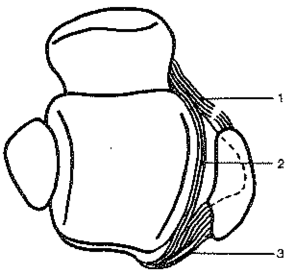


fig. 49
Rupture of the superior part (1) of the anterior talofibular ligament; the inferior part (2) is intact and in continuity with the posterior talofibular ligament (3).

No indications were found which could suggest that the inferior part had been attached to the inner articular surface of the lateral malleolus. The origin of this unusual finding is not known, and to our best knowledge has not been described previously. Possibly, this is a rudimental structure of the foetal lateral ligamentous apparatus.

9.7.3 Condition of the crural fascia

Rupture of the crural fascia in various extents was frequently seen accompanying rupture of the lateral ankle ligaments. In order to investigate the possible relationship between rupture of the crural fascia and the severity of the ligamentous damage, the condition of the crural fascia was registrated as observed at operation.

The following classification was used:

- intact fascia : no rupture of the fascia cruris
- partial rupture : a small defect of about 2-3 cm at the anterodistal margin of the lateral malleolus
- complete rupture : as above, extending into the fascia cruris, overlying the anterior talofibular ligament

The findings concerning the condition of the crural fascia related to the ligamentous damage present are listed in table 29.

Table 29: The condition of the crural fascia related to the ligamentous damage found in 332 patiënts. Absolute figures and percentages.

Treatment group	A_1	A_2	A_3	total
crural fascia:				
intact	54 (52)	36 (35)	13 (13)	103 (100)
partial rupture	47 (45)	51 (49)	6 (6)	104 (100)
complete rupture	47 (43)	52 (47)	11 (10)	110 (100)
not registrated	7 (47)	8 (53)	—	15 (100)
total	155	147	30	332

Rupture of the crural fascia was observed in 64% of all operated patients. As shown in table 29 no differences were found in the incidence of damage to the crural fascia between the various subgroups of ligamentous damage.
Therefore it is concluded that no correlation exists between the condition of the crural fascia and the severity of the ligamentous injury.

9.8 Complications of surgical repair

In our series fortunately there were no deep wound infections. Superficial wound necrosis at the wound edges was seen in 12 patients (3.5%), varying from some mm's to 3x1 cm. Secondary healing without special treatment occured in all cases but one, in which excision of necrosis under local anaesthesia was performed after which secondary healing and full recovery was achieved. One other patient developed a postoperative haematoma, resulting in wound dehiscention and superficial necrosis of the skin flap. Splitskingrafting resulted in full recovery without residual complaints.

Accidental damage to the superficial peroneal nerve was seen in 4 patients (1.2%). The resulting hypaesthesia of the lateral margin of the foot diminished gradually and was absent at follow-up after one year.
Damage to the sural nerve was seen in one patient (0.2%) only, but was still present, although diminished, after one year.
Hyperaesthesia of the scar, sometimes combined with paraesthesia radiating towards the fourth toe, was noted in 9% after six months and 4% after one year.
In two patients a moderate scar hypertrophy was observed.

9.9 Findings at follow-up at six months

9.9.1 Attendance

In group O (335 patients) in all 264 patients were convoked, of which 85% attended.
From group A (332 patients) 239 patients were convoked for follow-up examination after six months. The remaining 93 patients were not convoked because six months were not yet passed since the injury, at the time the follow-up was closed. The overall attendance in group A was 96%, showing no substantial differences within the subgroups (table 30).
In group C (40 patients) all patients were convoked. In this group evaluation was impossible in three cases. One patient could not be traced, one patient was in prison and unfortunately one young patient had a fatal accident in the mean time.

**Table 30: Attendance at follow-up after six months.
Absolute figures and percentages.**

Treatment group	O	A_1	A_2	A_3	C
convoked	264 (100)	112 (100)	111 (100)	16 (100)	40 (100)
attended	224 (85)	109 (97)	105 (95)	16 (100)	37 (93)
not attended	40 (15)	3 (3)	6 (5)		3 (7)
not convoked	71	43	36	14	
total	335	155	147	30	40

9.9.2 Anamnestic information

9.9.2.1 Residual complaints

Pain

At follow-up after six months in the patients treated surgically (group A) 7% complained about pain, distributed equally over the three subgroups (table 31). In group O patients 15% reported pain. In the control group (group C) conservative treatment had led to considerable complaints about residual pain. In this group pain was reported in 65%. The difference with the surgically treated patients is highly significant (Fisher's test, $p < 0.001$).
When asked to locate the pain most patients referred to the region anterior to the lateral malleolus, without being able to pinpoint the exact location.

**Table 31: Residual pain at follow-up after six months.
Absolute figures and percentages.**

Treatment group	O	A_1	A_2	A_3	C
Patients treated	335	155	147	30	40
Patients followed up	224	109	105	16	37
pain at rest	2 (1)				1 (3)
pain on weightbearing	28 (13)	5 (5)	6 (6)	1 (6)	23 (62)
pain following w. bearing	3 (1)	3 (2)	1 (1)		
subtotal	33 (15)	8 (7)	7 (7)	1 (6)	24 (65)
no pain	191 (85)	101 (93)	98 (93)	15 (94)	13 (35)

Swelling

When asked for swelling occuring during daytime activities, about 21-35% of patients reported this symptom, usually after several hours of standing or walking. There were no marked differences between the various treatment groups regarding this residual symptom (table 32).

Table 32: Residual swelling at follow-up after six months. Absolute figures and percentages.

Treatment group	O	A_1	A_2	A_3	C
Patients treated	335	155	147	30	40
Patients followed up	224	109	105	16	37
constant swelling	18 (8)	4 (4)	5 (5)	2 (12)	4 (11)
swelling following w. bearing	32 (14)	15 (14)	16 (15)	3 (19)	8 (22)
swelling following sport	8 (4)	5 (4)	1 (1)		1 (3)
subtotal	58 (26)	24 (22)	22 (21)	5 (31)	13 (35)
no swelling	166 (74)	85 (88)	83 (79)	11 (69)	24 (65)

The use of an elastic bandage of course could have influenced the results obtained, but when asked during what period the elastic bandage usually had been worn, over 80% reported they had omitted the elastic bandage after three weeks. No differences were found in the various treatment groups regarding this finding.

Functional instability

At follow up after six months 23% of group O complained of functional instability. The surgically treated patients (group A) reported this in 6-12%. Again, group C patients showed a significant difference to their disadvantage (Fisher's test, $p<0.001$). Plaster immobilization for a period of three weeks as solitary treatment had led to functional instability in 51% of these patients (table 33).

Table 33: Residual functional instability at follow-up after six months. Absolute figures and percentages.

Treatment group	O	A_1	A_2	A_3	C
Patients treated	335	155	147	30	40
Patients followed up	224	109	105	16	37
Functional instability:					
on even ground	2 (1)	2 (2)			
on uneven ground	28 (13)	8 (7)	5 (5)		9 (24)
on both	14 (6)	1 (1)		1 (6)	9 (24)
during sport	7 (3)	2 (2)	2 (2)		1 (3)
subtotal	51 (23)	13 (12)	7 (7)	1 (6)	19 (51)
no functional instability	173 (77)	96 (88)	98 (93)	15 (94)	18 (49)

Functional instability, if present, was usually reported in relation to walking on uneven ground; in control group C however a considerable percentage (24%) of functional instability on both even and uneven ground was recorded.

Recurrent sprain

Recurrent sprain within six months following initial therapy was recorded in 2-6% in group A and in 6% in group O. Group C patients reported recurrent sprain in 14%, which in contrast to both other treatment groups, resulted in residual complaints or in deterioration of the preexistent residual complaints in all cases (table 34).

The difference with group A patients is significant (Fisher's test, $p<0.001$). In several cases of recurrent sprain arthrographic examination was repeated. No renewed lateral ankle ligament ruptures were found in group A or O patients, but in group C arthrography suggested double ligament rupture in one patient, which was confirmed at subsequent operation.

Table 34: Recurrent sprain at follow-up after six months. Absolute figures and percentages.

Treatment group	O	A_1	A_2	A_3	C
Patients treated	335	155	147	30	40
Patients followed up	224	109	105	16	37
recurrent sprain without residual complaints	8 (4)	2 (2)	5 (5)	1 (6)	
recurrent sprain with residual complaints	6 (2)		1 (1)		5 (14)
subtotal	14 (6)	2 (2)	6 (6)	1 (6)	5 (14)
no recurrent sprain	210 (94)	107 (98)	99 (94)	15 (94)	32 (86)

9.9.2.2 Physiotherapy

As discussed in chapter 8.8, physiotherapy was not prescribed routinely but only in those cases in which improvement of ankle function and normal gait was not achieved within three weeks following the removal of the plaster cast. Physiotherapy was necessary in 5-14% of patients. No marked differences were recorded between the various treatment groups. The average duration was about 4 weeks in all groups, the frequency of treatment being two or three times a week (table 35).

Table 35: Necessity of physiotherapy. Absolute figures and percentages.

Treatment group	O	A_1	A_2	A_3	C
Patients treated	335	155	147	30	40
Patients followed up	224	109	105	16	37
Physiotherapy	30 (13)	5 (5)	15 (14)	2 (12)	2 (5)
average duration (weeks)	4.1	3.6	4.0	3.0	4.0

9.9.2.3. Resumption of work

Resumption of work, i.e. daily activities, is a parameter of general importance (calculation of expenses) and of importance to the individual patient, when various methods of treatment are discussed. Of all patients immobilized in plaster cast (group A and C) about 1/3 resumed their work while still immobilized in a walking cast. The results regarding the resumption of work in the various treatment groups are listed in table 36.

The average time to resume work was 4.5 weeks in group A_1, 4.6 weeks in group A_2 and 5.6 weeks in group A_3. A slight difference to the disadvantage of group A 3 was noticed.

The results in the control group C did not differ at all from the results obtained in group A. Therefore, it can be concluded that the limiting factor regarding resumption of work is not the operation itself.

In group O resumption of work was much quicker, as was expected. Three weeks after injury in this group 86% was back to work, which corroborates the arthrographic suggestion that only a minor sprain without ligament rupture had occurred.

Table 36: Resumption of work.
Absolute figures and cumulative relative percentages.

Treatment group	O	A_1	A_2	A_3	C
Patients treated	335	155	147	30	40
Patients followed up	224	109	105	16	37
time-interval between injury and resumption of work (weeks):					
1 week	87 (39)	5 (5)	5 (5)		3 (8)
2 weeks	66 (68)	31 (33)	34 (37)	5 (31)	7 (27)
3 weeks	39 (86)	13 (45)	6 (43)	1 (38)	4 (38)
4 weeks	12 (91)	10 (54)	13 (55)	1 (44)	6 (54)
5 weeks	5 (93)	15 (68)	6 (61)		2 (59)
6 weeks	7 (96)	15 (82)	17 (77)	3 (63)	4 (70)
7 weeks	1 (97)	3 (84)	5 (82)	1 (69)	4 (81)
8 weeks	3 (98)	12 (95)	12 (93)	2 (81)	4 (92)
9 weeks			2 (95)		
10 weeks	1 (99)	2 (97)	3 (98)	2 (94)	1 (95)
12 weeks		1 (98)	1 (99)	1 (100)	1 (97)
14 weeks	2 (100)				1 (100)
16 weeks		2 (100)	1 (100)		
average time-interval (wks)	2.3	4.5	4.6	5.6	4.9

In fig. 50 resumption of work is visualized in distribution curves. Quick recovery in group O and the somewhat slow recovery in group A_3 is shown clearly.

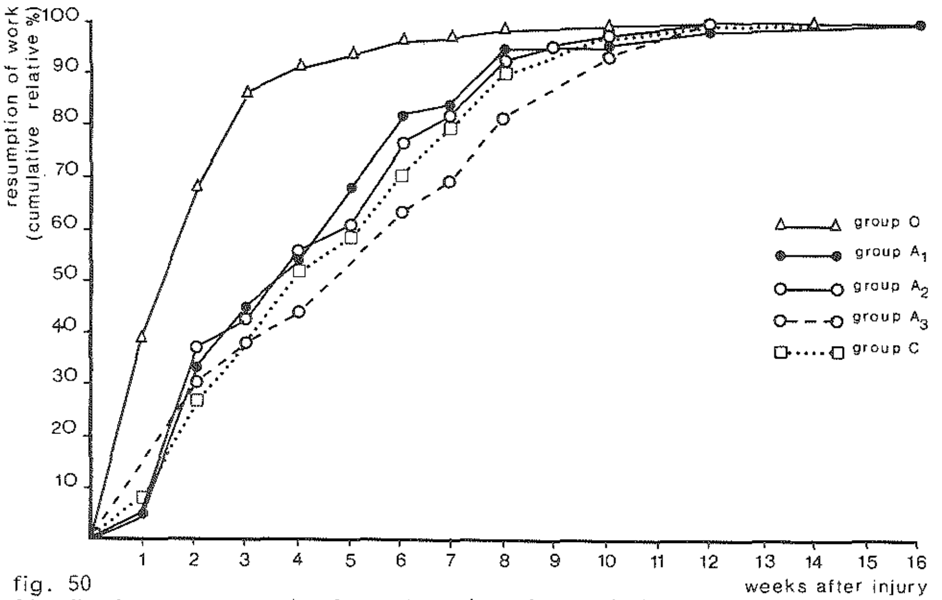


fig. 50
Distribution curves showing the time interval between injury and resumption of work in the various treatment groups.

9.9.2.4 Resumption of sports activities

Athletes are eager to resume their athletic activities in the shortest possible time, meanwhile making high demands upon complete recovery. Since an average number of about 80% of patients in all treatment groups practiced sport prior to their injury (paragraph 9.2.2) resumption of sports activities is an important parameter of the ultimate results of treatment regarding lateral ankle ligament rupture in our series.

The results are listed in table 37, 38 and 39. Of the patients treated by surgical repair 88-93% resumed their sports activities. Good results were also obtained in group O patients (88%). In the control group (group C) 69% resumed sport, which is a significant difference when compared to group A (Fisher's test, $p<0.01$)

A striking difference between group A and C was also found regarding the underlying reason of why athletic activities were not resumed. In group A 2% did not so because of reasons directly related to the injury sustained and the resulting sequelae; in group C patients this was 31%. The difference is highly significant (Fisher's test, $p<0.001$).

Regarding frequency and level of sports activities no marked differences were found between the various treatment groups, as compared to the situation prior to the accident (table 38).

Table 37: Resumption of sports activities. Absolute figures and percentages.

Treatment group	O	A_1	A_2	A_3	C
Patients treated	335	155	147	30	40
Patients followed up	224	109	105	16	37
sports activities prior to accident	165 (74)	93 (85)	90 (85)	15 (93)	32 (86)
sport not resumed:					
related to injury	7 (4)	2 (2)	2 (2)		10 (31)
not related to injury	13 (8)	9 (10)	7 (8)	1 (7)	
subtotal sport not resumed	20 (12)	11 (12)	9 (10)	1 (7)	10 (31)
sport resumed	145 (88)	82 (88)	81 (90)	14 (93)	22 (69)
total	165 (100)	93 (100)	90 (100)	15 (100)	32 (100)

Table 38: Resumption of sports activities. Results regarding frequency, level and use of bandages. Absolute figures and percentages.

Treatment group	O	A_1	A_2	A_3	C
Sport resumed	145	82	81	14	22
other sport		4	5	1	
same sport	145 (100)	78 (100)	76 (100)	13 (100)	22 (100)
Frequency:					
same	142 (98)	74 (95)	74 (97)	12 (92)	21 (96)
lower	2 (1)	1 (1)	2 (3)	1 (8)	1 (4)
higher	1 (1)	3 (4)			
Level:					
same	134 (92)	69 (88)	64 (84)	13 (100)	22 (100)
lower	3 (2)	2 (3)	6 (8)		
higher	8 (6)	7 (9)	6 (8)		
Supporting bandage:					
yes	53 (37)	26 (33)	32 (42)	5 (38)	13 (59)
no	92 (63)	52 (67)	44 (58)	8 (62)	9 (41)

A difference was found only regarding the preventive use of supporting bandages while practicing sport. In the control group (group C) about 60% reported using supportive bandages while only 37% did so in group A and O. This difference however is not significant (Fisher's test, p2= 0.07).
The average period of time required to resume sports activities was 8.2 weeks in group A patients, 5.2 weeks in group O patients and 9.0 weeks in group C patients. The difference between group A and C is not significant (table 39).

Table 39: Resumption of sports activities. Results regarding period of time required to resume sport. Absolute figures and cumulative relative percentages.

Treatment group	O	A_1	A_2	A_3	C
Sport resumed	145	82	81	14	22
time-interval between injury and resumption of sport (weeks):					
1 week	5 (3)				
2 weeks	21 (17)				
3 weeks	23 (33)				
4 weeks	26 (51)	6 (7)	5 (6)	1 (7)	
5 weeks	13 (60)	8 (17)	5 (12)		1 (4.5)
6 weeks	18 (73)	13 (33)	18 (34)	5 (43)	5 (27)
7 weeks	1 (74)	5 (39)	8 (44)		1 (31.5)
8 weeks	18 (86)	23 (67)	15 (63)	2 (57)	6 (58.5)
9 weeks	2 (87)	1 (68)	2 (65)		1 (63)
10 weeks	3 (89)	6 (75)	5 (71)		3 (77)
11 weeks					
12 weeks	8 (95)	12 (90)	8 (81)	1 (64)	1 (81.5)
13 weeks					
14 weeks		1 (91)	3 (85)	1 (71)	1 (86)
15 weeks					3 (100)
16 weeks	3 (97)	4 (96)	3 (89)	1 (78)	
> 16 weeks	1 (98)		4 (94)	1 (85)	
delayed resumption not related to accident	3 (2)	3 (4)	5 (6)	2 (5)	
average period (weeks)	5.2	8.2	8.0	8.3	9.0
median period (weeks)	4	8	8	8	8

9.9.3 Physical examination

At physical examination the ankle was inspected for swelling, disfunction of the talocrural or subtalar joints, or mechanical instability, always comparing the affected side with the unaffected side.

9.9.3.1 Swelling

When asked for reactive swelling after weightbearing patients reported this symptom in 21-35% in the various treatment groups (paragraph 9.9.2.1).At physical examination however objective findings regarding swelling at the region anterior to the lateral malleolus was observed only in a minority of cases, limited to patients in group O and C (table 40).

Table 40: Swelling; physical examination at follow-up after six months. Absolute figures and percentages.

Treatment group	O	A_1	A_2	A_3	C
Patients treated	335	155	147	30	40
Patients followed up	224	109	105	16	37
swelling present	1 (1)				4 (11)
swelling absent	223 (99)	109 (100)	105 (100)	16 (100)	33 (89)

9.9.3.2 Talocrural and subtalar mobility

At physical examination after six months hardly any difference was found comparing both sides regarding dorsiflexion and plantar flexion in the various treatment groups (table 41). However, inversion was slightly reduced (± 5°) in a noticeable percentage (6-18%) of patients in group A and C, apparently resulting from immobilization in plaster of Paris. In most cases patients appeared unaware of this reduced subtalar mobility, thus illustrating that this seems not a disabling limitation.

Table 41: Talocrural and subtalar mobility; physical examination at follow-up after six months. Absolute figures and percentages.

Treatment group	O	A_1	A_2	A_3	C
Patients treated	335	155	147	30	40
Patients followed up	224	109	105	16	37
dorsiflexion:					
not reduced	223 (99)	108 (99)	104 (99)	15 (94)	36 (97)
5° reduced		1 (1)	1 (1)	1 (6)	1 (3)
10° reduced	1 (1)				
plantar flexion:					
not reduced	220 (98)	106 (97)	104 (99)	16 (100)	37 (100)
5° reduced	4 (2)	3 (3)	1 (1)		
10° reduced					
inversion:					
not reduced	210 (93)	84 (77)	86 (82)	12 (75)	32 (86)
5° reduced	13 (6)	20 (18)	17 (16)	1 (6)	4 (11)
10° reduced	1 (1)	5 (5)	2 (2)	3 (19)	1 (3)

9.9.3.3 Mechanical instability

In patients with only minor sprains without ligament rupture (group O) unilateral positive anterior drawer sign (ADS, chapter 8.9.2) was recorded in 4%.

Table 42: Mechanical instability; physical examination at follow-up after six months. Absolute figures and percentages.

Treatment group	O	A_1	A_2	A_3	C
Patients treated	335	155	147	30	40
Patients followed up	224	109	105	16	37
positive ADS at the affected side	10 (4)	1 (1)	3 (3)	1 (6)	15 (41)
positive ADS at both sides	14 (6)	2 (2)	4 (4)	2 (12)	1 (3)

In group A_1 this was found in 1%, in group A_2 in 3% and in group A_3 in 6% (table 42). In the control group (group C) mechanical instability on the affected side was noted in 41%. The difference with surgically treated patients is highly significant (Fisher's test, $p2<0.001$).

9.9.4 Patient's assessment

Hospitalization is an unavoidable drawback of surgical therapy. However, from asking all group A patients about this inconvenience it became clear that this drawback is of only relative importance. Two patients (1%) had serious objections against hospitalization but nevertheless did not object against operative therapy. Twelve patients (5%) described hospitalization as a moderate inconvenience, whereas the remaining 94% had no objections against the necessary hospital stay in relation to surgical therapy.

When asked for their own opinion of the overall results (table 43), 85% of group O patients classified the results of treatment as "good" or "satisfactory", whereas 13% were less content and 2% claimed the results to be unsatisfactory. In group A 61% classified the results as "good", whereas 33% replied with "satisfactory".
Thus, 94% of the patients treated by early surgical repair were content with the overall results. In all, 6% in group A classified the results as "moderate" and only one patient (0.5%) as "poor".
In the control group (group C) patients were evidently less content with the overall results. "Good" results were recorded in 16%, "satisfactory" results in 46%, whereas the results were judged as "moderate" in 16% and "poor" in 22%. When compared with the findings in group A the difference with group C is highly significant (Fisher's test, $p2<0.001$).

Table 43: Patient's assessment of overall results at follow-up after six months. Absolute figures and percentages.

Treatment group	O	A_1	A_2	A_3	C
Patients treated	335	155	147	30	40
Patients followed up	224	109	105	16	37
overall results classified as:					
good	74 (33)	66 (60)	64 (61)	10 (62)	6 (16)
satisfactory	117 (52)	37 (34)	33 (31)	6 (38)	17 (46)
moderate	29 (13)	5 (5)	8 (8)		6 (16)
poor	4 (2)	1 (1)			8 (22)
	224 (100)	109 (100)	105 (100)	16 (100)	37 (100)

9.10 Findings at follow-up after twelve months

Long-term results were assessed in group A and O one year after initial treatment. From the control group (group C) four patients were operated subsequent to follow-up examination after six months: at their own request plastic reconstruction of the lateral ligamentous apparatus was performed by an orthopaedic surgeon because of persistent residual sequelae, consisting of instability and recurrent sprain.

As mentioned before (paragraph 9.9.2.1) one patient from group C was operated in the mean time by the author because of renewed sprain, resulting in a double ligament rupture and three other patients from group C were not available for follow-up examination because of various other reasons (paragraph 9.9.1).

Consequenty, group C became non-representative in obtaining relevant information regarding the results of conservative treatment of lateral ankle ligament ruptures and therefore follow-up examination after twelve months was omitted.

It is obvious, that serious criticism is justified with regard to this omission. However, because of circumstances beyond control we were -within the time limits of this study- unable to create a larger control group and moreover perform a one year follow-up.

This would have provided additional information regarding this treatment modality.

9.10.1 Attendance

Table 44: Attendance at follow-up after twelve months. Absolute figures and percentages.

Treatment group	O	A_1	A_2	A_3
convoked	202 (100)	97 (100)	92 (100)	7 (100)
attended	145 (72)	83 (86)	74 (80)	7 (100)
not attended	57 (28)	14 (14)	18 (20)	
not convoked	133	58	55	23
total	335	155	147	30

The attendance at follow-up after twelve months was 86%, 80% and 100% in groups A_1, A_2 and A_3 respectively, and 72% in group O (table 44). In the patients not convoked for follow-up examination, one year had not yet been passed since the injury.

9.10.2 Anamnestic information

9.10.2.1 Residual complaints

Pain

The low incidence of pain as found in group O and A at follow-up after six months was even diminished after one year. In groups A_1 and A_2 respectively 4% and 3% complained of pain during weightbearing while this complaint was absent in group A_3 and recorded in 7% in group O (table 45).

Table 45: Residual pain at follow-up after twelve months. Absolute figures and percentages.

Treatment group	O	A_1	A_2	A_3
Patients treated	335	155	147	30
Patients followed up	145	83	74	7
pain at rest	1 (1)			
pain on weightbearing	9 (6)	3 (4)	2 (3)	
pain following w.bearing				
subtotal	10 (7)	3 (4)	2 (3)	
no pain	135 (93)	80 (96)	72 (97)	7 (100)

Swelling

Reactive swelling of the lateral ankle region, still reported by 22% of patients in group A at follow-up after 6 months, had reduced to 9% at follow-up after twelve months. In group O 11% had residual swelling after one year (table 46).

Table 46: Residual swelling at follow-up after twelve months. Absolute figures and percentages.

Treatment group	O	A_1	A_2	A_3
Patients treated	335	155	147	30
Patients followed up	145	83	74	7
constant swelling	3 (2)	2 (3)	2 (3)	
swelling following w.bearing	10 (7)	5 (6)	3 (4)	
swelling following sport	3 (2)	1 (1)	1 (1)	
subtotal	16 (11)	8 (10)	6 (8)	
no swelling	129 (89)	75 (90)	68 (92)	7 (100)

Functional instability

In group O after twelve months 16% reported functional instability, mostly on uneven ground. In group A_1 6% and in group A_2 4% reported functional instability. This sequel was absent in group A_3, as was functional instability on even ground in all patients treated surgically (table 47).

Table 47: Residual functional instability at follow-up after twelve months. Absolute figures and percentages.

Treatment group	O	A_1	A_2	A_3
Patients treated	335	155	147	30
Patients followed up	145	83	74	7
functional instability:				
on even ground	2 (1)			
on uneven ground	12 (8)	1 (2)	2 (3)	
on both	6 (4)	2 (2)		
during sport	3 (3)	2 (2)	1 (1)	
subtotal	23 (16)	5 (6)	3 (4)	
no functional instability	122 (84)	78 (94)	71 (94)	7 (100)

Recurrent sprain

In group A_1 three patients sustained a new serious ankle sprain of which however only one had residual symptoms resulting from this renewed injury. In group A_2 recurrent sprain was recorded in only one patient, leaving no residual complaints. In group A_3 no recurrent sprains were reported. Therefore, the incidence of recurrent sprain in the patients treated by surgical repair was 2.5%; the incidence of recurrent sprain in group O patients was 6% (table 48).

Table 48: Recurrent sprain at follow-up after twelve months. Absolute figures and percentages.

Treatment group	O	A_1	A_2	A_3
Patients treated	335	155	147	30
Patients followed up	145	83	74	7
recurrent sprain without residual complaints	6 (4)	2 (3)	1 (1)	
recurrent sprain with residual complaints	3 (2)	1 (1)		
subtotal	9 (6)	3 (4)	1 (1)	
no recurrent sprain	136 (94)	80 (96)	73 (99)	7 (100)

9.10.3 Physical examination

9.10.3.1 Swelling

Swelling of the lateral ankle region was absent in all patients followed up after 12 months, both in group O and A.

9.10.3.2 Talocrural and subtalar mobility

Ankle function was virtually normal in all patients of both groups, whereas limitations in subtalar movement were diminished substantially, being present in only 4% in both group A and O patients (table 49).

Table 49: Talocrural and subtalar mobility; physical examination at follow-up after twelve months. Absolute figures and percentages.

Treatment group	O	A_1	A_2	A_3
Patients treated	335	155	147	30
Patients followed up	145	83	74	7
dorsiflexion:				
not reduced	145 (100)	82 (99)	74 (100)	7 (100)
5° reduced		1 (1)		
10° reduced				
plantarflexion:				
not reduced	143 (99)	83 (100)	74 (100)	7 (100)
5° reduced	2 (1)			
10° reduced				
inversion:				
not reduced	139 (96)	77 (94)	72 (97)	7 (100)
5° reduced	6 (4)	5 (6)	2 (3)	
10° reduced				

9.10.3.3 Mechanical instability

Unilateral mechanical instability on the affected side was present in only one patient in group A_2 (1%). In both other surgical groups mechanical instability was absent. In group O a positive unilateral anterior drawer sign (ADS) was found in 3% (table 50).

Table 50: Mechanical instability; physical examination at follow-up after twelve months. Absolute figures and percentages.

Treatment group	O	A_1	A_2	A_3
Patients treated	335	155	147	30
Patients followed up	145	83	74	7
positive ADS at the affected side	4 (3)		1 (1)	
positive ADS at both sides	6 (4)	1 (1)	3 (4)	1 (14)

9.10.4 Patient's assessment

To complete the follow-up examinations at twelve months after initial treatment all patients again were asked to classify their judgement on the ultimate long-term results (table 51).

In group O 86% had satisfactory or good results, 13% classified the results as moderate, while one patient reported poor results.
Patients treated by surgical repair reported satisfactory or good results in 96% in group A_1, 97% in group A_2 and 100% in A_3. Moderate results were reported by 5 patients (3%) whereas no poor results were recorded in this group.

Table 51: Patient's assessment of overall results at follow-up after twelve months. Absolute figures and percentages.

Treatment group	O	A_1	A_2	A_3
Patients treated	335	155	147	30
Patients followed up	145	83	74	7
overall results classified as:				
good	63 (43)	53 (63)	53 (71)	6 (86)
satisfactory	62 (43)	27 (33)	19 (26)	1 (14)
moderate	19 (13)	3 (4)	2 (3)	
poor	1 (1)			
total	145 (100)	83 (100)	74 (100)	7 (100)

CHAPTER 10 GENERAL DISCUSSION

10.1 Introduction

The main conclusions from the experimental study performed in rabbits to investigate the process of ligament healing under conditions resembling the clinical management of ligament ruptures are already discussed in chapter 7.4. Therefore they will be repeated only briefly.
Based on the findings in the prospective clinical study, the value of clinical symptoms and ankle arthrography in the diagnosis of ankle sprain is discussed and compared with the literature findings.
Thereupon the results of surgical treatment in the clinical study are judged on their own merits and compared with the results of other studies.

10.2 Ligament healing

Within the experimental study histological investigations showed that both in circumstances of sutured ligaments and non-sutured ligaments regeneration arose mainly from the fibroblasts of the subsynovial tissue at the joint side of the ligament.
The ligament ends themselves under both circumstances did not contribute noticeably to the process of ligament healing. The general idea that adequate ligament healing arises from active migration of cells from the torn ligament ends (Jack - 1950) and that inadequate adaptation leads to inactivity of the ruptured ligament ends (Clayton and Weir - 1979) could not be confirmed.
Regarding tensile strength measurements under experimental conditions, suturing of the ruptured collateral knee ligaments of young healthy rabbits had led to better results within the period of observation, when compared to non-sutured ligaments.

10.3 The value of history and clinical diagnosis

10.3.1 History

In taking the history of patients who sustained an inversion sprain of the ankle, useful information can be gained concerning the patient himself and concerning time and circumstances under which the accident took place, although it is not possible to correlate this information to the severity of the injury sustained.
However, some "high risk" groups can be distinghuised. Men are far more "rupture-prone" than women. In the treatment group with ligament ruptures (group A) the men-women ratio was 2.6:1, whereas in the group with minor injury (group O) this ratio was 1.1:1 (table 11).

A history of previous ankle sprain is not associated with the risk of a more severe ligamentous lesion in case of renewed sprain on the same side (Prins - 1978). Our findings (table 16) are in conformity with this statement. However, when this previous ankle sprain has resulted in residual complaints, more ligament ruptures were found to result from a recurrent sprain on the same side, as compared to patients who had no residual complaints of their previous injury (table 18). Therefore it can be concluded that patients with residual complaints from previously sustained ligamentous injuries, apparently resulting from inadequate treatment, are more "rupture prone" in case of renewed injury on the same side.

10.3.2 Swelling

Swelling anterior to or covering the lateral malleolus is a frequently noted symptom in case of ankle sprain. In literature it is said that swelling limited to the region anterior to the lateral malleolus suggests minor injury, without ligament rupture, while more pronounced swelling, exceeding approximately 4 cm and covering the lateral malleolus, is suspect for ligament rupture (Prins - 1978, Funder et al. - 1982).

Our findings regarding swelling of the lateral ankle region at physical examination shortly following trauma (table 19) show that limited swelling anterolateral to the lateral malleolus is equally found in both patients with and without ligament rupture and therefore has no substantial predictive diagnostic value. We agree with the findings of others that more extensive swelling is indicative for ligament rupture, since in our series a PVpos=63 was found regarding this symptom. However it should be clear that this symptom still is of relative diagnostic value.

When physical examination is repeated after several days, marked swelling was a constant finding in case of ligament rupture, although this symptom was noted also in 37% following minor injuries without ligament rupture (table 20).

Sanders (1976) reported a similar finding as he noted that the presence of swelling visible on the standard radiographs taken within five days after trauma, was associated with ligament rupture in 86%, whereas absence of swelling was associated with uncomplicated sprain (ligament rupture in only 22%).

In conclusion, the presence, location and extent of swelling can be indicative, but -as a single finding- in our opinion is not sufficiently conclusive in the diagnosis of ligament rupture or the severity of a ligamentous lesion.

10.3.3 Haematoma

As it was found in our series (table 21) that the "eggshell sign" was observed in 57% of all patients without ligament rupture, whereas it was associated with ligament rupture in only 43% of the cases in which there was no correlation with the extent of ligamentous injury, it is concluded that the "eggshell sign" allegedly pathognomonic of severe ligamentous damage, is of no use in de diagnosis of ankle ligament rupture.

Regarding the haematomatous discoloration of the skin on the lateral side of the heel, as this can be observed several days after sprain, we found no correlation between the presence or extent of this discoloration and the presence or extent of ligament rupture (table 22).
In our opinion this discoloration is correlated with the condition of the crural fascia. The crural fascia can be ruptured as a result of an inversion trauma. If so, the suprafascial venous network over the lateral malleolar region will be damaged, resulting in extra-articular bleeding, which in turn results in the discoloration of the lateral side of the heel. Moreover, a defect in the crural fascia enables intra-articular bleeding in case of ligamentous lesion to spread to the subcutaneous layer (Prins - 1978).
As shown in table 29 (chapter 9.7.3), we found no substantial correlation between the condition of the crural fascia and the extent of the ligamentous lesion. When however the findings concerning haematomatous discoloration are compared with the findings concerning the condition of the crural fascia (table 52) a clear correlation can be noted.

Table 52: Correlation between the condition of the crural fascia as observed at operation and haematomatous discoloration of the skin. Absolute figures and percentages.

haematomatous discoloration	absent	minor streak	major streak	diffuse	total
condition of the crural fascia:					
intact	51 (50)	7 (7)	16 (16)	29 (28)	103 (100)
partial rupture	12 (12)	12 (12)	45 (43)	35 (34)	104 (100)
complete rupture	4 (4)		93 (85)	13 (12)	110 (100)
unknown		1 (7)	10 (67)	4 (27)	15 (100)
total	67	20	164	81	332

Absence of haematomatous discoloration was clearly associated with an intact crural fascia, while a major streak-formed haematoma is associated with complete rupture of the crural fascia. Partial rupture of this fascia is manifested either as a major streak-formed haematoma or as a diffuse haematoma. In

other words: the kind of haematomatous discoloration of the skin on the lateral margin of the heel found several days after sprain, does not correlate with the severity of the ligamentous lesion, but with the condition of the crural fascia and the concomitant damage to the venous network of the lateral malleolar region.
Therefore this symptom has no value in the clinical diagnosis of lateral ankle ligament rupture.

10.3.4 Pain

Pressure pain, elicited with a blunt object in the vicinity of the ligaments is said to be an accurate diagnostic method to determine the presence of ligament rupture (Grond - 1973, Hackenbruch and Noesberger - 1976, Wolf - 1978). In contrast, Prins (1978) reported that the extent of pressure pain corresponds to the extent of haematoma, which irritates the periosteum and the tendon sheaths, resulting in more extended areas of tenderness.
In our series we found pressure pain elicited in the vicinity of the ligaments shortly after injury neither to be correlated with the presence or the absence of ligament rupture, nor with the extent of injury in case of rupture (table 23).
Although the incidence and extent of pressure pain was somewhat more accurate as a diagnostic aid when examined after several days (table 24), it has to be concluded from the findings in our series that pressure pain is inconclusive in determining the presence or extent of ligamentous injury following ankle sprain.

10.3.5 Summary and conclusions

From the findings in the clinical study it is concluded that neither history nor various clinical symptoms obtained from physical examination shortly after or a few days following injury have sufficient diagnostic value to distinguish between a minor injury without ligamentous lesion and a serious ankle sprain with ligament rupture.
As the diagnostic value of clinical instability tests without anaesthesia was already investigated by numerous authors and found to be of limited value because of considerable percentages of false negative results (Broström - 1965, Prins - 1978, v.Moppes and v.d.Hoogenband - 1982, Funder et al. - 1982) these diagnostic aids were not applied within the clinical study.

In conclusion, the results of history-taking and physical examination are indicative but not conclusive in the diagnosis of lateral ankle ligament rupture. Obviously, supplementary radiological examinations are necessary to acquire an accurate diagnosis.

10.4 The diagnostic value of ankle arthrography

10.4.1 Introduction

Because all patients in which ankle arthrography suggested lateral ankle ligament rupture were submitted to surgical exploration, it is possible to correlate the findings of arthrographic examination to the surgical findings in a large series of patients, thereby determining the exact diagnostic value of ankle arthrography in the diagnosis of lateral ankle ligament rupture. All pathological arthrograms were classified according to the different criteria as determined by respectively Broström (Broström et al. - 1965), Percy (Percy et al. - 1969) and Lindholmer (Lindholmer et al. - 1978).

10.4.2 The Broström classification

Since the anterior talofibular ligament (ATaFL) is the first ligament to tear in an inversion sprain, the presence of a rupture of this ligament has to be established in order to differentiate between the absence and presence of lateral ankle ligament rupture. The arthrographic results interpreted as indicated by Broström (1965) proved to be very reliable in diagnosing the presence of a rupture of the anterior talofibular ligament. When diagnosed arthrographically, rupture of this ligament was surgically confirmed in 99% of the patients (table 53).

Table 53: Correlation between arthrographic results and surgical findings in 337 patients. (Broström-classification). Absolute figures.

ligamentous damage as found at operation:	partial ATaFL	ATaFL	ATaFL + partial CFL	ATaFL + CFL	ATaFL + CFL+PTaFL	CFL	no ligament rupture	total
extra-articular contrast leakage:								
round the fibular tip (minimal leakage)	2	17						19
round the fibular tip and anterolateral to the lateral malleolus	5	117	25	60	16	1	2	226
as above, and in peroneal tendon sheath		14	7	55	14	1		91
in peroneal tendon sheath only						1		1
total:	7	148	32	115	30	3	2	337

In two patients however only an anterolateral capsular tear was found while all lateral ankle ligaments were found to be intact. In these two cases (0.6%) arthrography provided false positive results.
If the Broström classification was used in an attempt to differentiate between single ligament rupture (isolated rupture of the anterior talofibular ligament) and multiple ligament rupture, conformity between arthrographic results and surgical findings was evidently less good.

Table 54: Correlation between contrast leakage on the anterior and lateral aspect of the lateral malleolus (Broström classification) and surgically confirmed isolated rupture of the anterior talofibular ligament (ATaFL). Absolute figures.

ligamentous lesion observed at operation:	isolated rupture ATaFL	multiple ligament rupture	total
contrast leakage on the anterior and lateral aspect of the lateral malleolus	141	104	245
other contrast leakage patterns	14	78	92
	155	182	337

As shown in table 54 in a group of 245 patients in which arthrography suggested isolated rupture of the anterior talofibular ligament, the arthrographic diagnosis was correct in 141 patients (58%). In 104 patients (42%) however the arthrographic diagnosis was inaccurate, whereby surgical exploration revealed double ligament ruptures in 35% and triple ligament ruptures in 7%. Thus, in more than 40% the ligamentous damage proved to be more extensive than expected arthrographically.

Regarding the significance of leakage of contrast into the peroneal tendon sheath, according to the Broström criteria indicating rupture of the calcaneofibular ligament, it was found that in a group of 92 patients showing this characteristic leakage, 78 patients (85%) had partial or complete rupture of the calcaneofibular ligament (table 55). Yet in the remaining 245 patients in which opacification of the peroneal tendon sheath was absent, 102 patients (42%) proved to have ruptured the calcaneofibular ligament of which 25 patients showed a partial rupture of this ligament.
In 19 patients only a small inconspicious volume of extra-articular contrast leakage was seen distal to the lateral malleolus (table 53). Broström et al. (1965) associated this arthrographic finding with recent rupture of scar tissue surrounding the anterior talofibular ligament following previous ligament

rupture. In our series this surgical finding was present in 28 patients, but only one of these patients showed the above mentioned minimal leakage pattern. Therefore, in our series no correlation was found between minimal leakage and the presence of scar tissue. As shown in table 53, only 2 out of the 7 patients with partial rupture of the anterior talofibular ligament showed minimal contrast leakage. Thus, no correlation between these findings was present either.

Table 55: Correlation between contrast leakage into the peroneal tendon sheat (Broström classification) and surgically confirmed rupture of the calcaneofibular ligament (CFL). Absolute figures.

ligamentous lesion observed at operation:	rupture of the CFL	no rupture of the CFL	total
contrast leakage into the peroneal tendon sheath	78	14	92
no contrast leakage into the peroneal tendon sheath	102	143	245
	180	157	337

10.4.3 The Percy classification

As described in chapter 4.4.2 Percy et al. (1969) presented another classification to evaluate the arthrographic findings, based on the size and location of contrast leakage at the lateral malleolus. In this classification filling of the peroneal tendon sheath is not used as indicative for rupture of the calcaneofibular ligament.

In all, in four cases a Percy I lesion was noted, suggesting capsular tear without ligamentous damage. At subsequent operation however rupture of the anterior talofibular ligament was revealed in all 4 patients.

A Percy II lesion suggests isolated rupture of the anterior talofibular ligament. In 132 patients this type of contrast leakage was noted (table 56). In 67 patients (51%) operation revealed isolated rupture of the anterior talofibular ligament, in the remaining 65 patients (49%) showing multiple ligament ruptures.

A Percy III lesion suggests at least combined rupture of both anterior talofibular and calcaneofibular ligament (double ligament rupture). This type of contrast leakage was seen in 201 patients (table 57). At operation conformity with the arthrographic diagnosis was found in 117 patients (58%) of which 24 patients (12%) even had a triple ligament rupture. However in the remaining

136 patients, who did not show this type of contrast leakage multiple ligament rupture still was present in 46%.

Table 56: Correlation between Percy type II-contrast leakage and surgically confirmed isolated rupture of the anterior talofibular ligament (ATaFL). Absolute figures.

ligamentous lesion observed at operation:	isolated rupture ATaFL	multiple ligament rupture	total
Percy type II-contrast leakage	67	65	132
other than Percy type II-contrast leakage	88	117	205
	155	182	337

Table 57: Correlation between Percy type III-contrast leakage and surgically confirmed concomitant rupture of the calcaneofibular ligament (CFL). Absolute figures.

ligamentous lesion observed at operation:	concomitant rupture of the CFL	no concomitant rupture of the CFL	total
Percy type III-contrast leakage	117	84	201
other than Percy type III-contrast leakage	63	73	136
	180	157	337

10.4.4 The Lindholmer classification

Lateral contrast distribution posterior to the middle of the lateral malleolus in the lateral projection was introduced by Lindholmer et al. (1978) as a new criterion for calcaneofibular ligament rupture. This classification was also evaluated in our series. However, we agree with v.Moppes and v.d.Hoogenband (1982) that the extent of lateral contrast is not easy to estimate and is dependent upon what level it is defined.

The results of the evaluation of the Lindholmer criteria are given in table 58. As shown only in 37 patients, lateral contrast distribution posterior to the middle of the lateral malleolus was noted on the lateral projection of the arthrogram. In suggesting rupture of the calcaneofibular ligament, the arthrographic diagnosis was correct in 25 patients (68%). However, a large group of patients with surgically confirmed rupture of the calcaneofibular ligament did not show this Lindholmer criterion on their arthrograms.

Table 58: Correlation between Lindholmer-criterion and surgically confirmed rupture of the calcaneofibular ligament (CFL.) Absolute figures.

ligamentous lesion observed at operation:	concomitant rupture of the CFL	no concomitant rupture of the CFL	total
lateral contrast distribution posterior to the middle of the lateral malleolus	25	12	37
lateral contrast distribution not posterior to the middle of the lateral malleolus	155	145	300
	180	157	337

10.4.5 The diagnostic significance of the various classifications

To assess the diagnostic significance of the various classifications, enabling to compare them to one another, the following items have to be determined for each classification used (Rümke - 1983).

- The predictive value of a positive test (PVpos):
  i.e the percentage of patients with pathological arthrographic findings in relation to the presence of corresponding ligament rupture.
- The predictive value of a negative test (PVneg):
  i.e. the percentage of patients with normal arthrographic findings in relation to the absence of ligament rupture.
- Specifity:
  i.e. the percentage of patients without ligament rupture in relation to normal arthrography.
- Sensitivity:
  i.e. the percentage of patients with ligament rupture in relation to the corresponding pathological arthrographic findings.
- Prevalence:
  i.e. the percentage of patients in which the various types of ligament ruptures are present within the group of patients studied.

Regarding the predictive value (PVpos) of arthrography in differentiating between absence and presence of ligament rupture, high accuracy is found. In only two patients no ligament rupture was observed at operation, when suggested arthrographically (table 53). Therefore, the PVpos is as high as 99%.

Within the clinical study no patients with negative arthrographic findings were submitted to surgical exploration. Consequently, determination of the diagnostic reliability in case of a negative arthrographic finding (PVneg) is not possible from our series.

When isolated rupture of the anterior talofibular ligament (ATaFL) was to be diagnosed, the prevalence of which in our series was 46.9%, the Broström classification was correct in 141 out of 245 patients (table 54), the PVpos therefore being 58%. The sensitivity here is 91%. In using the Percy II criteria, the diagnosis was correct in 67 out of 132 patients (table 56), the PVpos therefore being 51%. Here the sensitivity is only 43%.

In determining the presence of a concomitant rupture of the calcaneofibular ligament (CFL), the prevalence of which in our series was 53%, opacification of the peroneal tendon sheath (Broström classification) provided the correct diagnosis in 78 out of 92 patients (table 55), the PVpos thus being 85%. The sensitivity of this diagnostic symptom however is rather low (43%). In using the Percy III criteria concomitant rupture of the calcaneofibular ligament was diagnosed correctly in 117 out of 201 patients (table 57), resulting in a PVpos of 58% and a sensitivity of 65%.
When the Lindholmer criteria were applied (table 58), concomitant rupture of the calcaneofibular ligament would have been diagnosed correctly in 25 out of 37 patients (PVpos 68%), but due to a very low sensitivity (14%) many double ligament ruptures would not have been diagnosed arthrographically.
The above-mentioned results regarding the arthrographic criteria for calcaneofibular ligament rupture are listed in table 59, enabling comparison of the various classifications and their diagnostic significance.

Table 59: Comparison of the diagnostic significance of the various arthrographic criteria in use to diagnose concomitant rupture of the calcaneofibular ligament as observed at operation in 337 patients (prevalence 53%).

	number of partial false positive results	number of partial false negative results	PVpos. (%)	PVneg. (%)	sensitivity (%)	specificity (%)
opacification of the peroneal tendon sheath (Broström)	14	102	85	58	43	91
contrast leakage lateral to the lateral malleolus (Percy III)	84	63	58	54	65	46
contrast leakage posterior to the middle of the lateral malleolus (Lindholmer)	12	155	68	48	14	92

If both single and multiple ligament rupture are regarded as an indication for surgical therapy, then ankle arthrography proved to be a very accurate diagnostic investigation of which the diagnostic reliability (PVpos 99%) by far exceeds the diagnostic reliability of radiological stress examinations.
If only multiple (double and triple) ligament rupture is considered as in need of surgical therapy and operating on single ligament ruptures is considered unnecessary, the arthrographic classification applied must have a high specifity along with a high PVpos, so that only a minimal number of patients with a partially false positive arthrographic result will be operated upon.
As shown in table 59, the Broström classification in our series proved to have the highest PVpos in combination with a high specifity.
Because of a low sensitivity however a considerable number of patients with double ligament ruptures will be missed by using the Broström classification.
In applying the Percy criteria a higher sensitivity will result in diagnosing more double ligament ruptures at the cost of a larger number of partial false positive results.
In our series the Lindholmer criteria turned out to have a very low sensitivity, the criteria thus being too exclusive to apply in practise.

10.4.6 Summary and conclusions

Regarding radiological stress examinations there is no consensus of opinion about examination technique and measurement technique, nor about the interpretation. Moreover these diagnostic examinations lead to high percentages of false positive and false negative results, unless performed under general anaesthesia. Even then no correlation exists between the results of stress examinations and the extent of ligamentous lesion.
Arthrography shortly following injury greatly improved the accuracy in diagnosing lateral ankle ligament rupture. Applied in large numbers of patients within the clinical study, the technique proved to be simple, safe and not time consuming. The interpretation of the findings -in our opinion- is not difficult. The inconvenience for the patient is low; however, patients who show a normal arthrogram in case of ankle sprain, should be warned that pain may possibly occur within a few hours following arthrography.

In our series the findings regarding physiological communications between the ankle joint and the subtalar joints or with the various tendon sheaths on the medial aspect of the ankle were in conformity with literature findings.
Contrast leakage into the peroneal tendon sheath is to be regarded as a pathological finding, associated with recent rupture of the calcaneofibular

ligament. The diagnostic significance of this phenomenon in differentiating between single and multiple ligament rupture and of two other arthrographic criteria serving this purpose, was investigated by comparing the arthrographic findings with the findings of surgical exploration in 337 patients, although this differentiation had no therapeutic consequences within our study.

Opacification of the peroneal tendon sheath proved to be associated with rupture of the calcaneofibular ligament in 85%. However a considerable number of patients (42%) showed rupture of the calcaneofibular ligament without contrast filling of the peroneal tendon sheath.

The Percy classification was found to have a higher sensitivity in diagnosing rupture of the calcaneofibular ligament, but consequently more partial false positive results were found, whereas partial false negative findings were obtained in equally high percentages (46%).

The Lindholmer classification in our series was found to be of rather limited diagnostic value.

It is because of this lack of reliability in differentiating between single and multiple ligament rupture that tenography was introduced. However, as yet there are only a few publications concerning this radiological examination, so knowledge about its diagnostic significance is still limited.

10.5 Evaluation of therapeutic results

10.5.1 Therapeutic results in the clinical study

Based on the assumption that no ligament rupture is present when ankle arthrography does not show pathological extra-articular contrast leakage, group O patients in our series were considered to have sustained only a minor ankle sprain without ligamentous lesion. From the results of treatment obtained in this group it seems to appear that the above-mentioned assumption had been correct. Treatment with only a cotton-wool bandage for a few days, followed by early resumption of normal activities wearing a non-adhesive elastic bandage, resulted in only minimal residual disabilities and resumption of work in three weeks by 86% of these patients.

Remarkably, a relatively high percentage of functional instability was recorded in this group after six months (23%) and twelve months (16%) indicating that functional instability apparently can also occur independently of capsular tearing and ligament rupture (cf. Freeman et al. - 1965).

It is concluded from the ultimate results obtained in group O that in case of ankle sprain with negative arthrographic examination, a minor sprain exists which can be treated sufficiently by a cotton-wool bandage for a few days, followed by early mobilization in an elastic bandage.

In evaluating the results obtained by surgical repair of ligament rupture (group A) in large series of patients, it appears that the disadvantages of surgical treatment are few. The inevitable hospital admission, according to the patients involved, is described as more or less inconvenient in only 6%. General sequelae due to anaesthesia were limited to a few cases of post puncture headache in case of spinal anaesthesia.
Complications in relation to surgical repair were limited to disturbance of primary healing of the wound edges in 3.5%, accidental nerve damage in 1.4% and paraesthesia in 4%.
The results at follow-up after six months and twelve months, obtained by surgical repair in single, double and triple ligament ruptures, show high percentages of patients who reached full recovery without any residual disabilities, following a reconvalescence period of 4.5 weeks and 4.6 weeks in group A_1 and A_2 respectively, and 5.6 weeks in group A_3. In group A patients, in which 87% was engaged in some sort of sports activity previous to their injury and in which 76% of these ligament ruptures were caused by sports accidents, only a few patients (2%) were unable to resume their athletic activities because of residual complaints after surgical repair.
These results meet with the strong wish of young athletic individuals to be able to continue their favourite activities without limitations and within the shortest possible time after treatment of their ligament rupture. The assessment of the ultimate results given by the patients themselves is a reflection of this demand for symptomless recovery. The ultimate results were classified as satisfactory or good in 94% and 97% respectively at follow-up after six months and twelve months.

In group C the diagnosis was based on arthrographic findings without verification by surgical exploration. However, based on the correlation between arthrographic findings and the extent of ligamentous lesion as found at operation in group A, it is a fair assumption that group C is quite comparable to group A with regard to this feature. Moreover, the constitution of group C regarding age, sex and athletic activities was at all points comparable to group A. Although the number of patients in group C was unintentionally small, the treatment results could be analysed statistically without difficulty. The conclusions drawn from comparison of the results of follow-up at six months with those of group A are therefore by all means valid.

When evaluating the results of the control group C in which single and multiple ligament ruptures were treated conservatively with plaster immobilization for three weeks, it appears that the period necessary for resumption of work was virtually the same as in group A patients, averaging 4.9 weeks.
At follow-up after six months residual complaints however were reported in fairly high percentages, consisting of pain in 65%, swelling in 35%, functional instability in 51% and recurrent sprain in 14%, all differing significantly from the results of surgical repair in group A. The same holds for mechanical instability as it was found in 41% at physical examination after six months. In group C 31% were unable to resume sports activities, in all cases as a direct consequence of residual complaints following from the injury sustained.
Patient's assessment of the ultimate results in this treatment group reflects the value of plaster cast immobilization during three weeks as a solitary treatment for lateral ankle ligament ruptures. Only 62% classified the ultimate results as satisfactory or good, whereas moderate results were reported in 16% and poor results in 22%.
Plaster immobilization for three weeks as a solitary treatment might be considered a too short period for sufficient ligament healing. However, prolonged immobilization for a period of six weeks or even longer, as advocated by Tonino (1973, 1979), does not lead to better results, as was shown by Prins (1978) and numerous other authors (see chapter 5.2, table 5).

10.5.2 Comparison with other studies

Early surgical treatment of both single and multiple ligament ruptures in our series resulted in high percentages of patients reaching symptomless recovery. Residual disabilities were reported in a minority of cases: at follow-up after one year pain was noted in 3%, swelling in 9%, functional instability in 5%, recurrent sprain 2.5% and mechanical instability 1%. These results are in conformity with the results of surgical treatment as reported in literature and differ favourably from the results of conservative treatment (see chapter 5.2, table 5).
In case of single ligament rupture however conservative treatment generally is considered adequate. As mentioned (chapter 6.6) a well-documented study in which this opinion is stressed was published by Prins (1978). If the results from our series in which single ligament ruptures were treated surgically are compared with those obtained by Prins, who treated single ligament rupture either by a below-knee plaster cast for three weeks or by an elastic bandage, then it is clear that the results of conservative treatment in case of single

ligament rupture can be improved substantially by employing surgical treatment followed by three weeks of plaster immobilization (table 60).

Regarding the period of plaster immobilization following surgical repair six weeks is generally considered a necessary period of time by most authors (chapter 5.2, table 4). From our study it is evident that this period can, without problem, be reduced to three weeks, thereby avoiding secondary disadvantages of prolonged immobilization such as joint stiffness, impairment of blood circulation, muscle atrophy and dystrophic changes of the articular cartilage resulting from a decrease in metabolism (Dustmann et al. - 1971).

Table 60: Comparison of results obtained at follow-up after six months following treatment of single ligament ruptures.

Author:	Prins 1978		Clinical study
Treatment:	elastic bandage	plaster immobilization (3 wks)	surgical repair (group A_1)
Number of patients treated	42	51	155
Number of patients followed up	41	49	109
resumption of work (wks)	3.9	5.6	4.5
resumption of sport (%)	41	56	88
pain on weightbearing (%)	32	29	7
swelling after weightbearing (%)	27	22	15
functional instability (%)	93	94	12
recurrent sprain (%)	10	12	2
positive ADS (%)	61	45	1

V.Moppes and v.d.Hoogenband (1982) applied a six-week period of plaster cast immobilization following surgical repair of lateral ankle ligament rupture and advised to abandon this treatment because of poor results as compared to bandage therapy combined with early mobilization, especially in relation to early resumption of normal and sporting activities. The advantages of bandage therapy however were limited to the immediate posttraumatic period, as their results after six months and twelve months showed no difference with the patients treated by surgical repair followed by six weeks of plaster immobilization.

Most likely the unfavourable short-term results following surgical repair were caused by the (unnecessarily) prolonged period of plaster immobilization and could simply have been reduced by shortening the period of plaster immobilization to three weeks.

In table 61 a comparison is made between bandage therapy (v.Moppes and v.d.Hoogenband - 1982) and surgical repair followed by a short period (three weeks) of plaster immobilization, as applied in our study.

Bandage therapy with early mobilization permitted early resumption of work. However, although this kind of therapy is allegedly favourable in relation to early functional recovery, the results regarding resumption of athletic activities are virtually the same as compared to early surgical repair followed by three weeks of plaster cast immobilization.
The results regarding residual disabilities at long-term follow-up are in favour of early surgical repair, especially concerning functional and mechanical stability as well as recurrent sprain.

Table 61: Comparison between the results of bandage therapy with early mobilization and early surgical repair followed by three weeks of plaster immobilization. Follow-up after one year.

Author:	v. Moppes and v.d. Hoogenband (1982)	Clinical study
Treatment:	bandage therapy with early mobilization	surgical repair followed by 3 weeks of plaster immobilization
Patients treated	50	332
Patients followed up	50	164
pain at rest (%)	6	0
pain following weightbearing (%)	10	3
swelling (%)	14	9
functional instability (%)	22	5
recurrent sprain (%)	14	2.5
mechanical instability (% ADS)	6	1
resumption of work (average period in weeks)	2.5	4.9
resumption of sports activities		
average (%) after 9 weeks	68	66
average (%) after 12 weeks	82	84

10.5.3 Summary and conclusions

When arthrography has excluded ligament rupture, treatment can be confined to a cotton-wool bandage for a few days, followed by early mobilization in an elastic bandage.
In 335 patients (group O) with minor sprains without ligament rupture this treatment has resulted in quick and symptomless recovery in 86% of cases. From the results of surgical treatment in 332 patients (group A) it is concluded that early surgical repair of both single and multiple ligament ruptures, followed by three weeks of plaster immobilization is the method of treatment most likely to result in complete and symptomless recovery (97% of cases). This is achieved by creating the best circumstances for adequate ligament healing, thus preserving the static support provided by the ligamentous apparatus.

When sufficient tensile strength is reached, immobilization subsequently is terminated after which restoration of motion accelerates the increase of tensile strength and the vigorous exercise program is to restore the dynamic support of the muscular system and normalizes the ligamento-muscular proprioceptive reflex.
Possibly the period of plaster immobilization following surgical repair can be reduced even more. However, tensile strength of sutured ligaments will drop considerably in the immediate postoperative period because of the gelatinous aspect of the tissues from which, when stress is applied in this stage, the sutures instead of breaking simply will pull out.
Therefore, in our opinion function and motion have to be highly restricted, at least in the first 7-10 days following early surgical repair.
Unfavourable results were obtained in group C in which 40 patients with single and multiple ligament ruptures were treated conservatively by plaster cast immobilization for a period of three weeks.

In case of non-operative therapy, such as plaster immobilization or bandage therapy, restoration of the ligamentous structures is not necessarily achieved, in case of failure leading to loss of static stability. Although an optimal muscular condition is capable of compensating this loss with excellent dynamic stability (Andrivet - 1975), the lack of static stability remains irreversibly present, leading to less predictable ultimate results.
To operate on all lateral ankle ligament ruptures is impossible and undesirable. However, on the other hand, a standardized non-operative treatment program, regardless of the severity of ligamentous injury, is an example of protocol-medicine, which is bound to result in considerable numbers of treatment failures.
Treatment of lateral ankle ligament ruptures therefore should be individualized, taking into account the patient's own preference towards therapy, his requirements towards symptomless recovery and full stability and his present condition. But if a demand for the best possible treatment is judged to exist, then early surgical treatment followed by three weeks of plaster immobilization in our opinion meets best with this demand, both in case of single and multiple lateral ankle ligament rupture. Plastic reconstruction of ruptured lateral ankle ligaments is to be seen as a last resort in order to re-establish already lost stability. It is not to be compared with adequate initial treatment.

SUMMARY

Lateral ankle ligament injury is a very common injury, mainly affecting young athletic individuals. The anatomical substitute of this syndrome can be:

- simple sprain without ligament rupture
- isolated rupture of the anterior talofibular ligament
- rupture of both anterior talofibular and calcaneofibular ligaments
- rupture of all three lateral ankle ligaments

The opinion that isolated rupture of the anterior talofibular ligament is a minor injury contradicts the high percentages of residual disabilities following non-operative treatment of single ligament ruptures.
This study was set up to evaluate the diagnostic significance of arthrography in diagnosing recent ankle ligament ruptures and to assess the value of early surgical repair of both single and multiple lateral ankle ligament ruptures.
Two suppositions were formulated at the onset of this study:

1. The value of the anterior talofibular ligament in stabilizing the ankle joint is generally underestimated.
2. Early surgical repair can improve the process of ligament healing by providing adequate coaptation of the ligament ends, thereby leading to early functional recovery.

Chapter 1 contains a detailed description of the anatomy and functional anatomy of the ankle joint and subtalar joints based on current anatomical literature. Furthermore, the consequences of specific ligamentous lesions in relation to ankle instability are discussed.

Chapter 2 describes the normal process of woundhealing and literature on ligament healing in relation to changes in tensile strength.

In chapter 3 the value of the case history and clinical examination is discussed as found in literature. Generally the history does not provide information which can be related to the severity of the trauma sustained. Clinical examination can provide supportive information but usually is not sufficiently conclusive in distinguishing between simple ankle sprain and ligament rupture.

In chapter 4 the technique and value of radiological examinations such as standard radiographs, inversion stress examination, sagittal stress exami-

nation, ankle arthrography and tenography are discussed. Regarding radiological stress examinations it is shown that no agreement exists on examination techniques, measurement techniques and interpretation of the findings, whereas no correlation exists between the degree of instability demonstrated and the severity of the ligamentous injury.
In contrast, arthrography is found to be a simple, standardized technique with a clear interpretation of the findings and a high reliabilty in diagnosing lateral ankle ligament ruptures.

Chapter 5 contains the literature findings regarding comparative studies with regard to the treatment of lateral ankle ligament ruptures. Majority opinion is found to be in favour of surgical treatment, especially when young athletic individuals with multiple ligament ruptures are involved. Thereupon, other indications for surgical treatment mentioned in literature are discussed, as well as the possible complications of this specific treatment.

In chapter 6 several conclusions from the literature review are brought together and discussed. Based on anatomical features, biomechanical principles and experimental findings, it is concluded that the anterior talofibular ligament is the most important ligament in stabilizing the ankle joint, leading to marked anterolateral rotational instability in case of rupture.
Regarding the process of ligament healing, it is concluded from literature that early adaptation of ruptured ligaments leads to undisturbed healing, whereas non-adapted ligament ends are said to become inert and inactive, resulting in impairment of ligament healing.

Chapter 7 contains the description and results of an experimental study on adolescent rabbits which was carried out in an attempt to conform the above mentioned assumptions found in literature, regarding the process of ligament healing.
Two questions were to be answered:

- What is the histological difference, if any, in the process of ligament healing between sutured and non-sutured ruptured ligaments?
- Does suturing of ruptured ligaments lead to a difference in tensile strength when compared to non-sutured ruptured ligaments?

From this experimental study it is concluded that regeneration of ruptured ligaments both sutured and non-sutured arises from the connective tissue zone, underlying the synovial membrane at the joint side of the ligament,

whereas the ligament ends themselves show no demonstrable contribution to the process of ligament healing in both conditions.
Regarding tensile strength measurements, under experimental conditions, suturing of transected collateral knee ligaments of young healthy rabbits has led to better results within the period of observation (10 weeks), when compared to non-sutured ruptured ligaments.

In chapter 8 a prospective clinical study is described, regarding 732 patients with recent lateral ankle ligament injuries, seen between October 1979 and August 1982 at the St. Hippolytus Hospital, Delft.
Based on arthrographic examination of the ankle joint, three treatment groups were formed:
- group O: 335 patients with simple ankle sprain without ligament rupture, treated by early mobilization in an elastic bandage
- group A: 332 patients with lateral ankle ligament rupture, treated by early surgical repair, followed by three weeks of plaster immobilization.
- group C: 40 patients with lateral ligament rupture, treated with plaster immobilization for a period of three weeks.

The data and results of the remaining 25 patients were excluded for various reasons. The different treatment programs in the various groups, including the surgical technique used, are discussed in detail, as is the postoperative management and the method whereby the results were administrated.

In chapter 9 the findings from the prospective clinical study are given regarding patient-related data, history, physical examination, radiological findings and findings at operation. Next, the results of follow-up examination are listed. Follow-up examination after six months was performed in 224 group O patients, in 230 group A patients and in 37 group C patients. At follow-up after one year 145 group O patients and 164 group A patients were examined. One year follow-up in group C patients was omitted.

In chapter 10 the findings of this study, compared with the different aspects as found in the literature review are discussed. Regarding history and physical examination, it is concluded that neither the history nor the various clinical symptoms are sufficiently conclusive in diagnosing lateral ankle ligament rupture, thereby stressing the need for accurate radiological examination.
Ankle arthrography has proved to be a simple and well-standardized technique with a very high diagnostic reliability (99%) in distinguishing between simple sprain and ligament rupture. As such, this examination technique was

found extremely useful in our study within which both single and multiple ligament ruptures were taken to be an indication for surgical repair.
When, for any reason, distinction between single and multiple ligament ruptures is requested, then the classification according to Broström seems the best available method.
From the treatment results in this study it is concluded that in case of ankle sprain without ligament rupture (group O) only a cotton-wool bandage for a short time is sufficient.
Both in patients with single and multiple ligament ruptures (group A) early surgical repair, followed by plaster immobilization for three weeks provides significantly better results than patients treated conservatively with plaster immobilization for the same period (group C).
Moreover, the results of early surgical repair of isolated rupture of the anterior talofibular ligament differ favourably from the results of conservative treatment of this type of ligamentous lesion, as reported in literature.
When our results of early surgical repair are compared to those of bandage therapy, the latter is in favour with respect to resumption of work. Resumption of sports activities is virtually the same in both treatment modalities whereas early surgical repair shows less residual disabilities at long term follow-up.

In conclusion: Early surgical repair of lateral ankle ligament ruptures followed by three weeks of plaster immobilization is the method of treatment most likely to produce complete and symptomless recovery.
This therapy seems to be indicated in the individual patient with high demands for complete recovery without residual disabilities, both in case of single and multiple ligament ruptures.

SAMENVATTING

Enkeldistorsie is een veel voorkomend letsel dat meestal jonge sporters treft. Het anatomisch substraat van dit syndroom kan bestaan uit:

- distorsie zonder ligamentaire ruptuur
- geisoleerde ruptuur van het ligamentum talofibulare anterius
- ruptuur van zowel het ligamentum talofibulare anterius als het ligamentum calcaneofibulare
- ruptuur van alle drie de laterale enkelbanden

De opvatting dat een geïsoleerde ruptuur van het ligamentum talofibulare anterius een weinig ernstig letsel zou zijn, is in tegenspraak met het hoge percentage restklachten dat wordt gevonden na conservatieve behandeling van enkelvoudig bandletsel.

De doelstelling van deze studie was het onderzoeken van de waarde van de arthrografie van het enkelgewricht als diagnosticum voor letsel van het laterale enkelbandapparaat en het vaststellen van de therapeutische waarde van primair chirurgische behandeling van zowel enkelvoudige als meervoudige laterale enkelbandrupturen.

Bij het begin van deze studie werden twee veronderstellingen geformuleerd:

1. De betekenis van het ligamentum talofibulare anterius met betrekking tot de stabiliteit van het enkelgewricht wordt over het algemeen onderschat.
2. Primair chirurgische behandeling kan het ligamentair genezingsproces bevorderen door adequate adaptatie van de ruptuuruiteinden, hetgeen bijdraagt tot een vroeg functioneel herstel.

Hoofdstuk 1 bevat een gedetailleerde beschrijving van de anatomie en de functionele anatomie betreffende het enkelgewricht en het subtalaire gewricht, gebaseerd op de gangbare literatuur. Bovendien worden de gevolgen van ligamentair letsel in relatie tot enkelinstabiliteit besproken.

Hoofdstuk 2 beschrijft het proces van wondgenezing in het algemeen en de literatuur betreffende het herstel van ligamentaire structuren in relatie tot de veranderingen in treksterkte.

In hoofdstuk 3 wordt de waarde van anamnese en physisch diagnostisch onderzoek besproken, zoals dit in de literatuur wordt vermeld. In het algemeen levert de anamnese geen informatie die verband houdt met de ernst van het ongevalsletsel. Physisch diagnostisch onderzoek levert aanvullende infor-

matie doch geeft gewoonlijk te weinig uitsluitsel om een onderscheid te kunnen maken tussen een eenvoudige verstuiking en een enkelbandruptuur.

In hoofdstuk 4 worden de techniek en betekenis van diverse radiodiagnostische onderzoeksmethoden besproken, zoals voor-achterwaartse en zijdelingse dwangstandopnames, enkelarthrografie en tenografie. Met betrekking tot dwangstandopnames blijkt er weinig overeenstemming te bestaan ten aanzien van onderzoekstechniek en interpretatie van de bevindingen, terwijl er bovendien geen verband blijkt te bestaan tussen de gevonden instabiliteit en de ernst van het ligamentaire letsel. Arthrografie daarentegen blijkt een eenvoudige, gestandardiseerde onderzoeksmethode met eenduidige interpretaties van de bevindingen en een grote betrouwbaarheid in het diagnostiseren van lateraal enkelbandletsel.

Hoofdstuk 5 bevat de literatuurgegevens aangaande vergelijkende onderzoekingen met betrekking tot de behandeling van laterale enkelbandrupturen. In het algemeen wordt de voorkeur gegeven aan operatieve behandeling, in het bijzonder wanneer het gaat om jonge sporters met meervoudig bandletsel. Vervolgens worden de overige indicaties voor operatieve behandeling en de mogelijke complicaties van deze behandelingsmethode besproken.

In hoofdstuk 6 worden de conclusies van de literatuurstudie gebundeld en besproken. Op grond van anatomische kenmerken, biomechanische principes en experimentele bevindingen wordt de conclusie getrokken dat het ligamentum talofibulare anterius de belangrijkste stabiliserende factor is voor het enkelgewricht. Ruptuur van dit ligament leidt tot evidente anterolaterale rotatie-instabiliteit.
Ten aanzien van het ligamentair genezingsproces wordt op grond van de literatuur geconcludeerd dat primair hechten van ligamentaire rupturen leidt tot ongestoord herstel, terwijl niet-geadapteerde ligamentuiteinden niet zouden bijdragen tot het genezingsproces, hetgeen leidt tot onvolledig herstel.

Hoofdstuk 7 omvat de beschrijving en de resultaten van een experimenteel onderzoek uitgevoerd op jong volwassen konijnen. In een poging om de voornoemde, uit de literatuur afkomstige veronderstelling ten aanzien van ligamentair herstel te bevestigen, werden de volgende vragen geformuleerd:

- Wat is het histologisch onderscheid, indien aanwezig, tussen het genezingsproces van gehechte en niet-gehechte ligamentaire rupturen?

- Is er verschil in treksterkte tussen gehechte en niet-gehechte ligamentaire rupturen?

Uit het histologisch onderzoek blijkt dat het herstel van zowel gehechte als niet-gehechte ligamentaire rupturen uitgaat van het bindweefselstroma dat gevonden wordt onder de synoviale membraan aan de gewrichtszijde van het ligament, waarbij de ligamentuiteinden zelf geen waarneembare bijdrage leveren aan het genezingsproces.

Uit de treksterkte metingen is gebleken dat, onder experimentele omstandigheden het hechten van doorsneden collaterale kniebanden van gezonde jonge konijnen -althans binnen de periode van observatie (10 weken)- tot betere resultaten heeft geleid in vergelijking met niet gehechte ligamentaire rupturen.

In hoofdstuk 8 wordt een prospectief klinisch onderzoek beschreven betreffende 732 patienten met een recente enkeldistorsie, behandeld in de periode oktober 1979 tot augustus 1982 in het St. Hippolytus Ziekenhuis te Delft.

Op grond van arthrografie van het enkelgewricht werden drie behandelingsgroepen gevormd:

- groep O: 335 patienten met een eenvoudige enkeldistorsie zonder ligamentaire ruptuur; zij werden behandeld met een vroegtijdige mobilisatie in een elastische zwachtel.
- groep A: 332 patienten met lateraal enkelbandletsel; zij werden behandeld middels primair operatief herstel, gevolgd door een gipsimmobilisatie gedurende drie weken.
- groep C: 40 patienten met lateraal enkelbandletsel; zij werden behandeld middels een gipsimmobilisatie gedurende drie weken.

De gegevens en de resultaten van de overige 25 patienten werden om diverse redenen buiten beschouwing gelaten.

De behandelingsschema's in de diverse groepen, waaronder de toegepaste operatietechniek, worden besproken, evenals de nabehandeling en de wijze waarop de resultaten van de behandeling werden verwerkt.

In hoofdstuk 9 worden de bevindingen van het prospectief klinisch onderzoek ten aanzien van samenstelling van patientenmateriaal, anamnese, physisch diagnostisch onderzoek, röntgendiagnostische bevindingen en operatiebevindingen vermeld.

Vervolgens worden de behandelingsresultaten vermeld, zoals verkregen bij na-onderzoek.

Na-onderzoek na zes maanden werd verricht bij 224 patienten uit groep O, 230 patienten uit groep A en 37 patienten uit groep C. Na een jaar werden 145 patienten uit groep O en 164 patienten uit groep A onderzocht. Na-onderzoek na een jaar bij patienten uit groep C werd niet verricht.

In hoofdstuk 10 worden de resultaten van deze studie besproken en vergeleken met de verschillende aspecten, zoals die in de literatuur worden vermeld. Ten aanzien van anamnese en physisch diagnostisch onderzoek kan worden geconcludeerd dat geen van beide afdoende uitsluitsel geven bij het diagnostiseren van lateraal enkelbandletsel, waarmee de noodzaak van een nauwkeurige röntgendiagnostische onderzoeksmethode wordt onderstreept.
Arthrografie van het enkelgewricht blijkt een eenvoudige en bruikbare methode met een zeer hoge betrouwbaarheid (99%) wanneer het gaat om onderscheid te maken tussen een eenvoudige enkeldistorsie en een enkelbandruptuur. Als zodanig was deze onderzoeksmethode bij uitstek bruikbaar bij ons onderzoek, omdat hierbij zowel enkelvoudige als meervoudige enkelbandrupturen geacht werden een operatie-indicatie te vormen.
Wanneer om welke reden dan ook de behoefte bestaat om onderscheid te maken tussen enkel- en meervoudig enkelbandletsel, dan lijkt de interpretatie volgens Broström de meest bruikbare methode.
Op grond van de behandelingsresultaten uit dit onderzoek wordt geconcludeerd dat, in geval van een eenvoudige enkeldistorsie zonder ligamentaire ruptuur (group O) behandeling middels een drukverband gedurende een korte tijd voldoende is.
Bij patienten met zowel enkelvoudig als meervoudig bandletsel (groep A) leidt primair chirurgische behandeling, gevolgd door een gipsimmobilisatie gedurende drie weken tot significant betere resultaten dan bij patienten die alleen met gipsimmobilisatie gedurende dezelfde periode werden behandeld (groep C).
Bovendien steken de resultaten van primair operatieve behandeling van van geïsoleerd letsel van het ligamentum talofibulare anterius gunstig af bij de resultaten van de conservatieve behandeling van dit letsel, zoals vermeld in de literatuur.
Wanneer wij onze resultaten van primair chirurgische behandeling vergelijken met die van bandagetherapie, dan leidt de laatstgenoemde tot snellere werkhervatting. Beide behandelingsmethoden maken het hervatten van sport na een nagenoeg gelijke periode mogelijk. Bij na-onderzoek na een jaar werden evenwel na primair operatieve behandeling minder restklachten gevonden.

Samenvattend: Primair operatieve behandeling van laterale enkelbandrupturen, gevolgd door een gipsimmobilisatie gedurende een periode van drie weken is de behandelingsmethode die de beste waarborgen lijkt te bieden voor een volledig en symptoomloos herstel.

Deze behandelingswijze lijkt derhalve de voorkeur te verdienen bij de individuele patient die hoge eisen stelt aangaande volledig herstel zonder restklachten, zowel in het geval van enkelvoudig als van meervoudig enkelbandletsel.

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APPENDIX

VRAGENLIJST PROSPECTIEF ONDERZOEK ENKELBANDLETSEL

Personalia patiënt		
naam+voorletters	:	
geboortedatum	:	
geslacht	:	m/v
Ongevalsanamnese		
datum trauma	:	
ongevalsmechanisme	:	inversie/eversie
welke zijde	:	links/rechts
oorzaak	:	sport/lopen/hardlopen/verkeer/ huishouden/.............
bij sport: welke?	:	
Onderzoek enkel		
datum onderzoek	:	
zwelling	:	ja/nee
zo ja,	:	vóór lat.malleolus/hele gebied lat.malleolus
haematoom	:	ja/nee
zo ja,	:	vóór lat.malleolus/hele gebied lat.malleolus
drukpijn	:	ja/nee
zo ja,	:	vóór lat.malleolus/hele gebied lat.malleolus
Aanvullende anamnese		
enkeldistorsie		
in het verleden	:	ja/nee
zo ja,		
- welke zijde	:	links/rechts/beiderzijds
- behandeling	:	geen/zwachtel/gips/operatie
- restklachten	:	ja/nee
Sportanamnese		
sportbeoefening	:	ja/nee
zo ja,		
- welke sport(en)	:	
- in clubverband	:	ja/nee
- hoeveel maal/week	:	
- wedstrijden	:	ja/nee
belang van sport	:	onbelangrijk/gezellige ontspanning/amateur-wedstrijdsport/beroeps-wedstrijdsport
Poliklinische revisie		
datum	:	
zwelling	:	ja/nee
drukpijn LTA	:	ja/nee
drukpijn LCF	:	ja/nee
haematoom	:	ja/nee
zo ja,	:	bandhaematoom/diffuus
arthrogram	:	ja/nee
uitslag	:	

NA-ONDERZOEK ENKELBANDRUPTUREN - HALFJAARSCONTROLE

arthrogram
negatief/positief: ruptuur LTA/LTA+LCF/LCF

pijnklachten tijdens onderzoek: veel/matig/geen
pijnklachten na onderzoek : veel/matig/geen

therapie operatief : fascie/LTA/LCF/LTP
conservatief : elastische zwachtel .... weken
gips .... weken

opname zeer bezwaarlijk/bezwaarlijk/niet bezwaarlijk

narcose algemeen/spinaal/epiduraal

hervatten dagelijks werk c.q. beroep na .... weken

elastische zwachtel na gipsafname na .... weken

fysiotherapie nee/ja, gedurende .... weken

hernieuwd zwikken nee
ja, onbehandeld/behandeld met ..
restklachten/geen restklachten

pijnklachten nee
ja, in rust
bij lopen/rennen/traplopen/springen

zwelling nee
ja, constant/alleen bij belasten/alleen bij sport

angst om te zwikken nee
ja, op vlakke/oneffen ondergrond

sporthervatting
- sporten voor ongeval : ja/nee
- sporten oorzaak ongeval : ja/nee
- sporthervatting :
nee, vanwege ongeval/niet vanwege ongeval
ja, na .... weken
soort : dezelfde/andere sport omdat ...
frequentie : onveranderd/minder vaak/vaker
niveau : onveranderd/lager/hoger
zwachtel : ja/nee

fysisch diagnostisch onderzoek
litteken : geen afwijkingen/hypaesthesie/paraesthesie
functie : dorsoflexie :
plantair flexie :
subtalair :
zwelling : ja/nee
schuiflade : rechts/links

oordeel patiënt(e) : ontevreden/matig tevreden/
tevreden/zeer tevreden

opmerkingen/bijzonderheden

complicaties

NA-ONDERZOEK ENKELBANDRUPTUREN - JAARCONTROLE

Alle vragen hebben betrekking op de periode van zes maanden tot een jaar na de primaire behandeling.

<u>hernieuwd zwikken</u>
nee
ja, onbehandeld/behandeld met .....
restklachten/geen restklachten

<u>pijnklachten</u>
nee
ja, in rust
bij: lopen/rennen/traplopen/springen/
sport/startpijn/weersveranderingen

<u>zwelling</u>
nee
ja, constant/bij veel belasten/bij sport

<u>angst om te zwikken</u>
nee
ja, op vlakke/oneffen ondergrond/bij sport

<u>sport</u>

- sporthervatting	nee, wel/niet vanwege ongeval
	ja, na .... weken/maanden
- soort	dezelfde/andere sport omdat ..
- frequentie	onveranderd/minder vaak/vaker
- niveau	onveranderd/lager/hoger
- dragen zwachtel	ja/nee

<u>fysisch diagnostisch onderzoek</u>

- litteken	......	
- sensibiliteit	geen afw./hypaesth./paraesth.	
- functie	dorsoflexie :	......
	plantair flexie :	......
	subtalair :	......
- zwelling	ja/nee	
- schuiflade	rechts/links	

<u>oordeel patiënt(e)</u>
ontevreden/matig tevreden/tevreden/zeer tevreden

<u>opmerkingen/bijzonderheden</u> ....

<u>complicaties</u> ....

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