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From the Department of Orthopaedic Surgery
University Hospital, S-750 14 Uppsala, Sweden
(Head: Professor Sven Olerud)

Operative Treatment of Ankle Fractures

By
ULF LINDSJÖ

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OPERATIVE TREATMENT OF ANKLE FRACTURES

by Ulf Lindsjö, Department of Orthopaedic Surgery, University Hospital, S-750 14 Uppsala, Sweden

ABSTRACT. In an unselected prospectively planned series of 611 ankle fractures 25 % were of the AO (Weber) type A, 56 % type B and 13 % type C; 4 % were impact fractures. The fractures were also classified according to Lauge Hansen's system, which was considered more complicated and not suitable for planning of operative treatment. Lauge Hansen's theory of the mechanism of the supination-eversion (SE) injury is questioned - outward rotation does not seem to be obligatory for the typical SE injury. 345 fractures were operated on, and 327 (95 %) of them were followed up 1-6 years after operation. The range of motion was measured as loaded dorsal extension (normal value 33^{o}) and loaded plantar flexion (normal value 45^{o}). The clinical results were "excellent" to "good" for 81 % of the dislocation fractures, 38 % of the impact fractures and for two of the six combined shaft/ankle fractures. In 14 % of the dislocation fractures and 50 % of the impact fractures posttraumatic arthritis developed. There was a significantly higher degree of arthritis among the patients with a posterior articular surface bearing fragment. There was also a strong correlation between the degree of arthritis and poor clinical results. The clinical and radiographic results from use of the AO (ASIF) method were better than those of conservative treatment or other operative methods. According to an AID analysis the most important factors for the final outcome were: 1) type of fracture, 2) accuracy of operative reduction and 3) the patient's sex.

Key words: Ankle, classification, follow-up study, functional anatomy, fractures, osteo-arthritis, operative treatment.

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To Agneta,
Eva and
Fredrika

FOREWORD

Sprains and fractures about the talocrural joint are very common injuries. The contributions by Lauge Hansen, Danis and Weber, among others, have led to a greater understanding of the nature of ankle fractures, both as regards their mechanism of occurrence and concerning possible associated injuries.

In the work described in this book, in which the fractures have been grouped both by the Lauge Hansen and by the AO (ASIF) system, Dr. Lindsjö has shed light on the advantages of the simpler AO classification, which was originally introduced by Danis.

Among the many interesting results in this investigation, I would like to draw particular attention to the cases with a posterior articular surface bearing fragment. The presence of such a fragment, even if it is radiographically well reduced, implies a substantially increased risk of arthritis and thus a poorer prognosis. This fracture component therefore deserves special consideration.

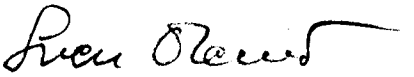
Since the 1940s surgical treatment of ankle fractures has become more and more widely accepted, while at the same time the operative methods and techniques have been continuously improved.

Dr. Lindsjö has demonstrated that a more careful operation technique with correct application of simple mechanical rules in order to achieve optimal fragment fixation by interfragmentary compression, together with functional after-care (joint exercises and weight-bearing in a walking plaster), has hitherto led to the best results.

To accomplish the best outcome in the treatment of ankle fractures, much effort is required on the part of the orthopaedic surgeon. Thus he must gain good knowledge and understanding of the biomechanics of the ankle joint and the effects of fractures around this joint, he must understand the implication of surgical effects on both soft tissues and bone tissue, and he must be able to master different fixation techniques.

From the present very extensive analysis of the results in a series of ankle fractures it is clear that adequate education in the principles for fracture treatment and training in the operation technique is essential to guarantee the best possible treatment for our patients.

Uppsala, January 1981



Sven Olerud

Professor of Orthopaedic Surgery,
Uppsala University.
Head of the Department of Orthopaedic
Surgery, University Hospital, Uppsala.

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"Early effective surgery
is the secret of success
in many serious injuries
to the ankle".
(Bonnin 1948)

Chapter I

INTRODUCTION

With the availability of roentgenology, aseptic operation techniques and general and regional anaesthesia at the end of the 19th century, successful treatment of fractures and joint injuries by operative methods became possible (von Volkmann 1875, Lane 1893, 1905, Lambotte 1913). Comprehensive historical reviews of ankle fractures and their treatment, from Hippocrates onwards, have been presented by Ashhurst & Bromer (1922), Lauge Hansen (1942), Bonnin (1950) and Weber (1972), among others.

During the first six decades of the 20th century the most common method of treatment of ankle fractures was closed reduction and external fixation with a plaster cast (Böhler 1957). Using Lauge Hansen's (1942) "genetic" method of reduction, Baek Kristensen (1949,1953) succeeded in improving the results of conservative treatment. It was generally considered, and recommended in standard textbooks, that surgical intervention should only be resorted to in exceptional cases and only after failure of a conservative approach (Palmer 1941, Watson-Jones 1944, Bonnin 1950, Kaye & Conwell 1956, Braunstein & Wade 1959, Kleiger 1961, Reimann 1963, Böhler 1965, Henne & Müller 1968).

The applicability of earler operative methods was limited by the stabilizing capacity of the internal fixation devices. In order to avoid infection, as small areas as possible were exposed. The internal fixation therefore often consisted of apposition of the fragments and fixation without a high demand on stability. The chief interest was focused on the medial malleolus and the deltoid ligament and on large posterior tibial margin fragments (Muller 1945, Bonnin 1950, Fackert 1954, Perkins 1958, Penrose 1966). By open reduction and fixation of these fractures it was hoped to achieve medial support in order to facilitate more exact closed reduction of the other fracture components. To maintain the reduced position and to give sufficient fixation, a plaster cast was also required. Such limited operative measures gave unsatisfactory results (Svend Hansen et al. 1978).

Danis (1932, 1949, 1979) emphasized that the internal fixation should be so complete and rigid that the injured joint can be exercised

postoperatively. In this way swelling, joint stiffness and soft tissue atrophy, which commonly occur after conservative treatment of fractures, colud be avoided. He recommended a more radical operative technique, with repair also of the fibular injury and stabilization of the fibular fracture. Palmer (1941,1944) underlined the importance of minor deformities for the development of post-traumatic osteo-arthritis. The same author (1950), Rudberg (1953), Proctor (1954) and others advocated precise open reduction and internal fixation in cases of syndesmotic rupture and fracture of the fibula. Vasli (1957) recommended that several fracture fragments be fixed in order to get the greatest posssible stability and thereby permit early postoperative joint exercises.

Many authors have reported improved results with operative treatment of ankle fractures as compared with conservative methods (e.g., Buck-Gramcko 1955, Vasli 1957, Braunstein & Wade 1959, Klossner 1962, Henke 1964, Wilson & Skilbred 1966, Cedell 1967, Solonen & Lauttamus 1968, Colton 1971). As internal fixation appliances these authors used vitallium screws, cerklage wires, pins, staples, and Rush pins.

Since 1957 the further development of methods and material for internal fixation within the frame of AO, "Schweizerischen Arbeitsgemeinschaft für Osteosynthesfragen" ("ASIF", Swiss Association for Internal Fixation) has increased the possibilities of maintaining an exactly reduced position and of achieving stable internal fixation even of fractures close to joints. The AO principles for the treatment of ankle fractures were based on Danis's recommendations and on biomechanical studies of the importance of the lateral malleolus and the syndesmosis for the stability of the ankle (Willenegger 1961, Müller, Allgöwer & Willenegger 1963, 1965, Weber 1972, Heim & Pfeiffer 1972, Müller et al. 1977). Immediate operation without any preceding attempts at conservative treatment were advocated. Weber (1972) and Forudastan (1970) reported improved results from this operative approach. A good outcome from application of the AO principles and methods has also been claimed by a number of other authors (Maurer & Lechner 1965, Leitz 1966, Tscherne 1967, Rüedi, Matter & Allgöwer 1968, Mintzel et al. 1968, Rüedi & Allgöwer 1969, Willenegger 1971, Müller, Plass & Willenegger 1971, Luhnau 1972, Rüedi 1973, Renné & Meinhardt 1974, Weyand et al.1974, Müller 1975, Henkemeyer et al. 1976, Nonneman & Brautigam 1977, Pankarter 1977, Wolf & Klammer 1977, Müller, Bachmann & Willenegger 1978 and Hughes et al. 1979, Mitchell et al. 1979).

The AO (ASIF) principles for surgical treatment of ankle fractures are still comparatively seldom mentioned, on the other hand, in the

British and American Literature. In many relatively recent textbooks there are no references to the works of the AO (ASIF) group. Closed methods of treatment or older operation techniques are often advocated (e.g. Penrose 1966, McDade 1975, Wilson 1975, Apley 1977, Yablon 1979, Segal 1979, Crawford Adams 1980, Heppenstall 1980).

At the University Hospital in Uppsala, operative treatment of ankle fractures according to the AO (ASIF) principles was introduced by Olerud, Johansson and Thorén in 1965 (Johansson & Olerud 1967).

The experiences from the first years were encouraging and for that reason Olerud and Hallin started a prospectively planned series in February 1972 (Hallin 1974). The collection of the patient material went on for 40 months until June 1975. During this time a total of 611 fractures were treated; 345 of them were operated on. The follow-up examinations of the operated cases were made during the years 1974 to 1978.

The aim of this work is to report the experiences of the operative treatment and the clinical and radiographic results achieved by use of the AO (ASIF) method and principles in daily routine clinical practice. The results are compared with those of earlier operative methods.

As opinions still differ concerning the classification of ankle fractures, I have tested both the system of Lauge Hansen and Weber's system, and their relevance and practicability in clinical routine.

The primary material includes every ankle fracture treated at the Department of Orthopaedic surgery during the period in question, thus information on the epidemiology of ankle fractures in a mixed urban and rural population can be gained from the study.

STATISTICS

Statistical analyses were performed in collaboration with Associate Professor Adam Taube, Department of Statistics, Uppsala University.

In the results of statistical computations, "highly significant" means that $p < 0.001$, "significant" $p < 0.01$ and "almost significant" $p < 0.05$.

DEFINITIONS

Dislocation fracture: Ankle fracture caused by indirect violence, e.g. forced supination, pronation or rotation of the foot.

Displaced fracture: Ankle fracture which is not perfectly reduced.

Impact fracture: Ankle fracture caused by direct violence on or compression of the ankle joint ("Pilon tibial").

Combined fracture: Fracture of tibial shaft combined with ankle fracture.

ABBREVIATIONS

AO = Schweizerischen Arbeitsgemeinschaft für Osteosynthesefragen, (Swiss Association for Internal Fixation, often abbreviated as "ASIF" in British and American literature.)
SA = Supination - Adduction (Fracture mechanism according to Lauge Hansen (1942)).
SE = Supination - Eversion " " " " "
PA = Pronation - Abduction " " " " "
PE = Pronation - Eversion " " " " "
PTB = Patellar Tendon Bearing

Chapter II

THE NORMAL ANATOMY AND FUNCTION OF THE ANKLE - A brief review

In the ankle joint three skeletal structures articulate with one another - the distal part of the tibia with the medial malleolus, the lateral malleolus and the trochlea of the talus. The joint is often called the ankle mortise.

Malleoli and ligaments

The fibula ends distally in the lateral malleolus, which is joined to the tibia, the talus and the calcaneus by six ligaments. The anterior and posterior tibiofibular ligaments and the interosseous ligament constitute the syndesmosis of the ankle, and join the distal end of the fibula to the tibia in the fibular notch.

The anterior fibulotalar ligament is phylogenetically the youngest ligament in the ankle joint (Inman 1976). It arises from the anterior distal aspect of the lateral malleolus and is inserted into the talus immediately antero-lateral to the base of the trochlea. It has its greatest effect of lateral stabilization at maximal plantar flexion, when it is extended in the longitudinal axis of the leg (Inman 1976, Kaye 1977). With the ankle in the neutral position this ligament counteracts the anterior "drawer" effect (Andersson & Lecocq 1952, Broström 1966, Olerud 1967, Lindstrand 1976, Adler 1976).

The fibulocalcaneal ligament arises from the posterior aspect of the tip of the fibula and when the ankle is in the neutral position it runs obliquely postero-inferiorly, to insert into the calcaneus. At maximal dorsal extension (see "Movements of the talocrural joint", below) it stabilizes the joints laterally. The strong posterior fibulotalar ligament joins the posterior margin of the tip of the fibula to the posterior portion of the talus. It is considerably thicker than the anterior fibulotalar ligament and is said to limit the talar movements at dorsal extension in the ankle (Lauge Hansen 1942). Leonard (1949) found that after cutting this ligament there was increased dorsal extension in the ankle but no other instability.

The medial malleolus is a blunt projection at the inner distal end of the tibia. It has two blunt tips - colliculi - divided by a groove.

On the posterior surface of the malleolus there is a shallow groove through which pass the tendons of the posterior tibial and flexor digitorum longus muscles.

The thickest part of the anterior superficial portion of the deltoid ligament arises from the anterior colliculus of the medial malleolus and inserts into the sustentaculum tali. The posterior, deep portion consists mainly of the strong posterior tibiotalar ligament arising from the posterior colliculus and inserting into and anterior to the medial tubercle of the talus. This is the strongest single ligament of the ankle joint and constitutes the medial attachment of the talus. It limits lateral displacement of the talus to about two millimetres (Lauge Hansen 1942, Close 1956, Grath 1960, Pankovich & Shivaram 1979).

The mobility of the fibula

The fibula moves in the distal tibiofibular joint antero-posteriorly, medio-laterally and with some rotation around its longitudinal axis (Fick 1911, Lauge Hansen 1942, Bonnin 1950, Barnett & Napier 1952, Baltensperger 1970, Henkemeyer 1975, Inman 1976, Weinert et al. 1976).

There is also some mobility in the longitudinal axis of the fibula. During active movements in the ankle joint the muscles attached to the fibula bring about elastic movements of the fibula in both the horizontal and vertical direction (Hendelberg 1946). Scranton et al. (1976) reported that on contraction of the peroneal muscles, the flexor hallucis longus muscle and the posterior tibial muscle, the fibula is drawn downwards by an average of 2.4 mm, which they considered to have a stabilizing effect in that the syndesmotic ligaments are stretched and the ankle mortise becomes more rigid.

The fit of the talus into the ankle mortise

Viewed from above, the talar trochlea looks like a trapezium, transversely broader anteriorly than posteriorly. The acuteness of its wedge shape varies between different individuals. The difference between its anterior and posterior transverse measurements has been reported to be between nought and 6 mm (Barnett & Napier 1952, Inman 1976). This concept of the shape of the talus previously led to the assumption that the ankle mortise was widened on dorsal extension and that there was some "play" between the talus and the mortise on plantar flexion (e.g. Fick 1911, Bonnin 1950, Reimann 1963, Burmeister 1963). Ashhurst (1922) reported widening of the ankle mortise of 2-3 mm during

the entire range of ankle joint motion. Lauge Hansen (1942) failed to note such an increase in the intermalleolar distance. Close (1956) found that the distance between the malleoli varied only 1-2 mm throughout the entire range of movement. This is less than the difference between reported transverse measurements of the anterior and posterior portions of the talar trochlea. Close also pointed out that the articular surfaces of the malleoli are in good contact with the lateral surfaces of the trochlea during the entire movement of the talus in the ankle mortise. Grath (1960), using a method of direct measurement of the intermalleolar distance in living persons, noted that the greatest total increase in mortise width on movement from maximum plantar flexion to maximum dorsal extension was 1.6 mm and the least was zero.

Inman (1976) described the talar trochlea as being shaped almost as a part of a frustum of a cone. He demonstrated this experimentally by making saw cuts in the trochlea, by means of a saw-blade fixed into the ankle mortise in the frontal plane, through the entire range of movement in the talocrural joint. The saw cuts converged medially at a mean angle of 24 $\pm$ 6^{o}. The anterior and posterior transverse widths of the talar trochlea along these saw cuts differed by a maximum of 2 mm, even in the case of trochleas with a pronounced wedge shape. This finding is more compatible with the small fibular movements measured experimentally by different authors, and explains why the talus is able to move in the mortise with a combined rolling and gliding motion without play or locking (Figure II:1).

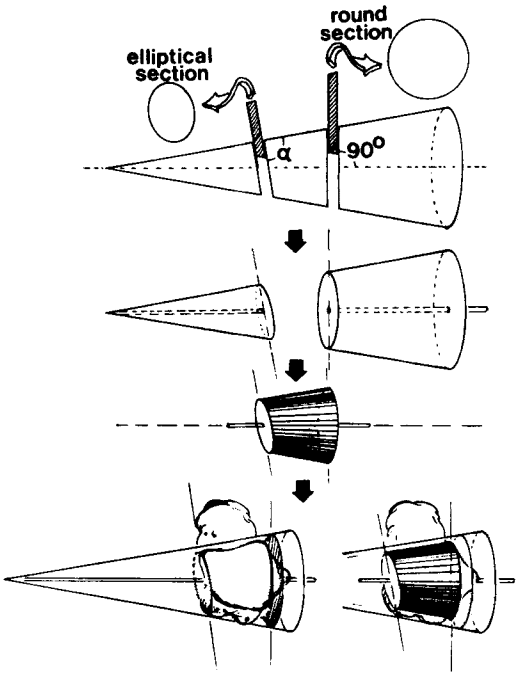
Computed tomography of transverse sections in the malleolar plane has shown that there is no "play" between the talus and the malleoli throughout the entire range of talar movement (Lindsjö et al. 1979).

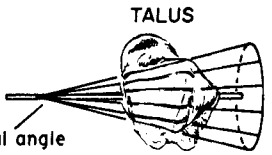
Lauge Hansen (1942) found malleolar separation of two to three millimetres during weight bearing in amputation specimens. He explained this separation as being caused by the vertical wedge shape of the trochlea. Grath (1960) found no such widening either by radiographic or by direct measurements on living persons.

Axis of movement of the talocrural joint

The talocrural joint is not, as it has often been previously assumed, a simple hinge joint. Its axis of movement is not horizontal and neither is it constant or the same in all individuals.

Barnett & Napier (1952) described the axis of movement as varying, inclining infero-laterally on dorsal extension and infero-medially on plantar flexion. Inman (1976) found that no fixed single axis which permits full mobility of the trochlea in the





Pictorial representation of present concept of construction of trochlea of talus. A frustum is cut from a cone. The section cut at 90° to the axis of the cone is circular when projected onto a transverse plane of the cone (see Barnett and Napier, 1952); this corresponds to the fibular (lateral) facet. The section cut obliquely is elliptical; this corresponds to the tibial (medial) facet. Note that the fibular facet, being farther from the apex of the cone, possesses greater dimensions. With minor modifications, a section of the frustum is converted into the trochlea of the talus. The anteroposterior curve of the fibular facet is an ellipse because of the oblique orientation of the conical surface of the trochlea when viewed from above.

Figure II:1 CONICAL SHAPE OF THE TROCHLEA

(After V.T. Inman: "The Joints of the Ankle", Williams & Wilkins Co., Baltimore 1976. Reproduced with permission from the author and the publishers.)

ankle mortise with maintenance of full articular surface contact during the entire range of movement could be demonstrated experimentally.

From the practical viewpoint, Inman considered that movements in the upper talocrural joint may be said to take place around an axis passing immediately below and slightly behind the anterior colliculus of the medial malleolus and the distal tip of the lateral malleolus. Inman reported that the angle between the empirically found axis of the talocrural joint and the tibial midline was 82.7 ± 3.7^{o}, with a range of variation of 74 to 94^{o} (Figure II:2).

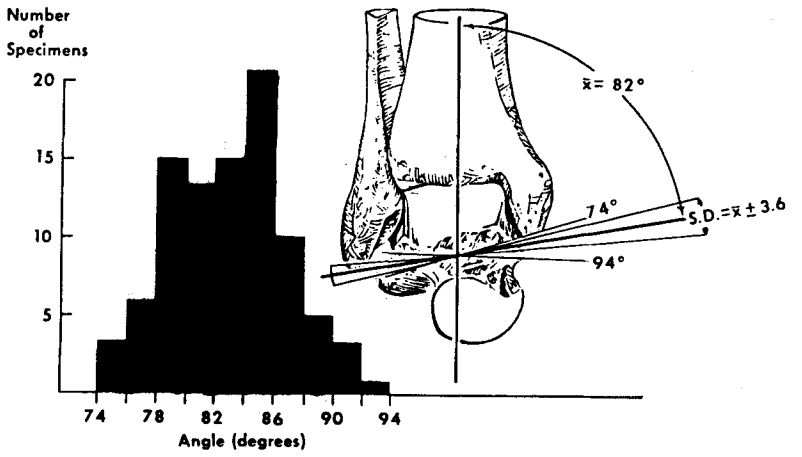


Figure II:2 OBLIQUITY OF ANKLE AXIS

Variations in angle between midline of tibia and empirical axis of ankle. The histogram reveals a considerable spread of individual values. (After V.T. Inman: "The Joints of the Ankle", Williams & Wilkins Co., Baltimore 1976. Reproduced with permission from the author and the publishers.)

Movements of the talocrural joint

The use of the terms "extension" and "flexion" as applied to the ankle joint varies. When the dorsum of the foot approaches the tibia, this is often called "dorsiflexion". In "Joint Motion - Method of Measuring and Recording" published by the American Academy of Orthopaedic Surgeons (Heck et al 1965), the movement in the talocrural joint whereby the dorsum of the foot is brought upwards is denoted "extension". To avoid misunderstanding, the term "dorsal extension" will be used in the following presentation. The normal value for this dorsal extension is given in "Joint Motion" as varying between 15 and 20 degrees.

During walking on flat ground, about 10^{o} of the capacity for dorsal extension is utilized during the stance phase and toe-off. In addition, dorsal extension is needed when walking on stairs, when squatting, and in certain sports activities. A full range of movement of the talocrural joint in the opposite direction - plantar flexion -

is needed for walking on one's toes, jumping, etc. During normal gait approximately 20^{0} plantar flexion is utilized (Murray et al. 1964, Wright et al. 1964, Stauffer, Chao & Brewster 1977, Morris 1977).

Measurement of the range of movement

In clinical practice many different methods are used for measuring the range of movement at the talocrural joint.

At follow-up examination of surgically treated ankle fractures, I have measured the range of movement in 317 uninjured ankle joints. The measurements were made as the angle between the lateral margin of the foot and the longitudinal axis of the tibia, with the patient supine with the knee straight, sitting with the knee flexed, and standing with the knee flexed and bearing weight on the ankle (Table II:1).

Table II:1 RANGE OF MOVEMENT AT THE TALOCRURAL JOINT

Mean values, in degrees, with standard deviations in parentheses. (n = 317)

	Dorsal extension			Plantar flexion		
	Men	Women	Total	Men	Women	Total
Supine with knee straight	10.9 (5.6)	8.7 (5.6)	9.8 (5.7)	35.7 (6.6)	39.4 (6.0)	37.6 (6.6)
Sitting with knee flexed	14.4 (6.3)	13.5 (5.8)	14.0 (6.0)	40.3 (7.1)	43.3 (6.2)	41.8 (6.8)
Standing with weight-bearing	33.6 (6.5)	31.4 (7.1)	32.5 (6.9)	43.0 (7.3)	46.4 (7.5)	44.7 (7.6)

There was a clear difference between the range of movements as measured in the different positions. The greatest range was obtained in measurements during weight-bearing (for examination technique, see Chapter VII), and the range of movement observed in this way was greater than that generally reported in the literature (cf. Heck et al. 1965).

Subtalar mobility

Pronation (a combination of outward rotation of the front part of the foot and abduction of the foot), supination (a combination of inward rotation of the front part of the foot and adduction of the foot) and pure abduction and adduction of the middle part of the foot take place

in the subtalar joints. The mean value for combined pro- and supination for 317 uninjured ankles was 33.1° (men 32.3°, women 33.9°). For method of measurement, see Chapter VII.

Loading on the talocrural joint

Under different loading conditions and with different ranges of movement, different parts of the talar trochlea are in contact with the distal articular surface of the tibia. At slight weight-bearing the talar trochlea is in direct contact with the inner aspects of the malleoli and the marginal zones of the tibial dome. At full loading with the whole body weight, the greater part of the upper surface of the talar trochlea (about 2/3) is in contact with the distal articular surface of the tibia (Greenwald et al. 1976). Riede, Heitz & Ruedi (1971) demonstrated that as a rule younger persons have a more concave upper articular surface on the talar trochlea, which is thus flattened out during the course of the years, and pointed out that pronounced concavity probably implies an increased risk of arthritis. (See also Chapter III.)

In studies of amputation preparations under conditions of static loading, Lambert (1971) found that one-sixth of the load on the lower leg during standing is taken up by the fibula via the distal fibulotalar joint. Very little of the load is taken up via the interosseous membrane.

According to investigations referred to by Weber (1972), the load on the talocrural joint under static conditions corresponds to twice the body weight during standing on the heels, is equal to the body weight during standing on the entire sole of the foot, and is three times the body weight during standing on the toes. This was calculated from the torsional momenta caused by the pressure against the ground, the levers in the foot, and the muscular forces. During walking there are additional deceleration and acceleration forces parallel to the ground, and shearing forces at right angles to the direction of walking. At heel-strike, the resultant of these forces exerts its action on the lateral malleolus and the posterior margin of the tibia. In the stance phase practically only vertical forces come into play, with an even distribution of the load in the joint. At toe-off the resultant of the forces acts mainly on the anterior tibial margin and also on the medial malleolus. During heel-strike and the first half of the stance phase, the stress on the lateral aspect of the joint, according to Weber (1972), amounts to about one-fifth of the total load on the joint.

During all phases of walking a valgus-inducing torsional momentum also exerts an action around the sagittal longitudinal axis of the foot. This torque is counteracted by the tendency to varus rotation during normal talocrural movements, by supinating muscle forces and by the lateral support supplied by the lateral malleolus and the syndesmotic ligaments (Baltensperger 1970).

The syndesmotic ligaments and the lateral malleolus are thus of great importance in maintaining congruity during normal weight-bearing.

SUMMARY

This chapter gives a brief description of the normal functional anatomy of the talocrural joint.

I. The syndesmotic ligaments and the deltoid ligament counteract the tendency towards valgus rotation and lateral displacement of the talus in the ankle mortise.

II. The anterior fibulotalar ligament counteracts anterior instability and, together with the fibulocalcaneal ligament, instability of supination and adduction. The posterior fibulotalar ligament restricts talar movements on forced dorsal extension.

III. The fibula moves in the distal tibiofibular joint antero-posteriorly, medio-laterally and with some rotation along its longitudinal axis. Movements of the fibula are initiated by the interaction of forces in the ankle joint and the muscle activity in the lower leg, and are limited by the syndesmotic ligaments and interosseous membrane.

IV. The talar trochlea is shaped almost as a frustum of a cone. This shape permits movements within the entire range of motion of the ankle joint with good contact between the articular surfaces and with very little demand for widening of the ankle mortise on dorsal extension.

V. The talocrural joint is not a simple hinge joint. Its axis of movement is oblique and varies between different phases of motion and between different individuals. From the practical viewpoint it may be assumed that there is one single axis of movement passing immediately below and slightly behind the anterior colliculus of the medial malleolus and below the distal tip of the lateral malleolus. The talus moves in the ankle mortise with a combined rolling and gliding motion.

VI. On examination of 317 uninjured ankle joints, I found that during weight-bearing the mean range of dorsal extension was 33^{o}, plantar flexion 45^{o} and total pro- and supination 33^{o}.

VII. During normal gait about 10^{o} of the capacity for dorsal extension and 20^{o} plantar flexion in the talocrural joint are utilized.

VIII. About 1/5 of the total load on the ankle joint during walking is taken up by the lateral malleolo-syndesmosis complex, especially during heel-strike and in the first part of the stance phase. During all phases of walking there is also a valgus-inducing torsional momentum which is counteracted by the normal movements of the talus, by the supinating muscles and by the lateral support of the malleolo-syndesmosis complex.

Chapter III

POSTTRAUMATIC ANATOMY

Classification systems

During the last two centuries several classification systems for ankle fractures have been proposed, most of them merely descriptive with a classification into uni-, bi- and trimalleolar fractures. The first functional classification of fractures of the ankle was made by Ashhurst & Bromer (1922). They divided the fractures according to the mode of occurrence, into outward rotation, abduction and adduction fractures and fractures that occurred by compression in the longitudinal axis of the lower leg. The two systems most often used today are the Lauge Hansen (1942) system and Weber's system (1972) modified after Danis (1949).

The Lauge Hansen system

Lauge Hansen (1942) proposed a detailed "genetic" classification with the aim of obtaining a basis for an improved closed reduction technique. In cadaver experiments he produced a number of different types of fractures by provocation of the ankle in different directions, each type with a characteristic radiographic appearance.

The fractures were classified into supination-adduction (SA), supination-eversion (SE), pronation-abduction (PA), and pronation-eversion (PE) fractures, each with a number of subgroups. The first part of the fracture's double name refers to the position of the foot at the accident, and the second part to the direction of the dislocating force momentum causing the fracture. A supination-eversion fracture thus means that a supinated foot has been exposed to outward-rotation violence at the moment of injury.

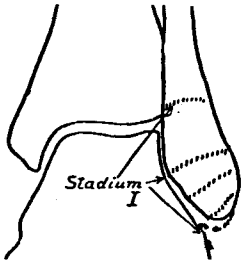
A brief review of the Lauge Hansen system is given below. Table III:1.

The Lauge Hansen classification has met with some criticism (Jergesen 1959, Cedell 1967, Olerud 1968, Hierton 1969, Weber 1972, McDade 1975), but is nevertheless often used. In later publications Lauge Hansen has stated that at certain stages instead of a fracture there may be a pure ligament injury - a so called "ligamentous fracture" (Lauge Hansen 1949), which makes the system more comprehensive. In spite of

Table III:1 LAUGE HANSEN'S CLASSIFICATION OF ANKLE FRACTURES

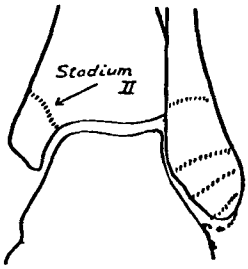
(After Lauge Hansen: Ankelbrud I, Munksgaard, Copenhagen 1942. Reproduced with permission from the publishers.)

Supination-Adduction (SA) fractures



Stage I:

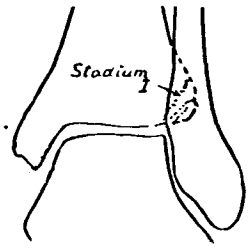
Avulsion fracture through the lateral malleolus below the level of the talo-crural joint or a lateral ligament lesion.



Stage II:

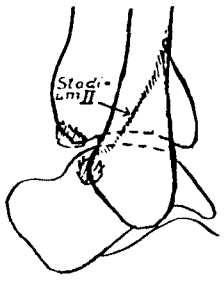
Added: Vertical fracture through the medial malleolus.

Supination-Eversion (SE) fractures:



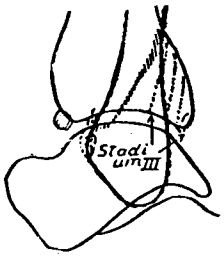
Stage I:

Fracture through the anterior tibial tubercle or a small fragment avulsed from the anterior margin of the lateral malleolus implying a rupture of one of the attachments of the anterior tibio-fibular ligament, or a rupture through the ligament proper.

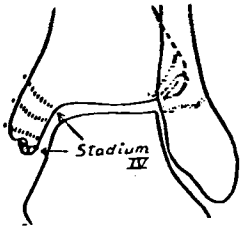


Stage II:

Added: Oblique distal fibular fracture running from the level of the talo-crural joint anteriorly in a postero-superior direction. Best visible on radiographs in the lateral view.

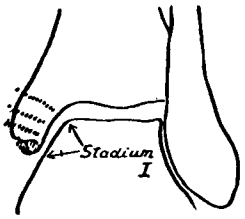


Stage III:
Added: Fracture through the posterior margin of the tibia.

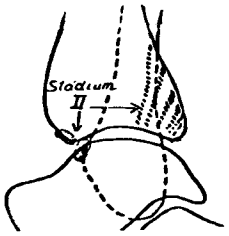


Stage IV:
Added: Transverse fracture (avulsion fracture) through the tip of the medial malleolus.

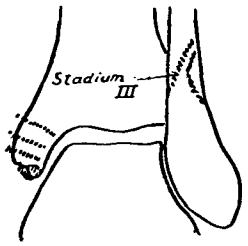
Pronation-Abduction (PA) fractures



Stage I:
Short avulsion fracture through the tip of the medial malleolus.

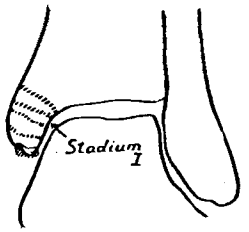


Stage II:
Added: Avulsion(s) at the attachments of the anterior tibiofibular ligament, possibly also fracture through the posterior margin of the tibia. Risk for compression of the lateral part of the distal joint surface of the tibia.

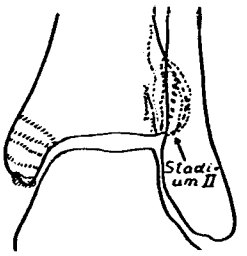


Stage III:
Added: Short oblique fracture through the lateral malleolus immediately above the level of the talocrural joint, sometimes with a small lateral wedge-shaped fragment.

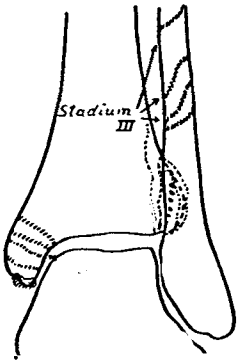
Pronation-Eversion (PE) fractures:



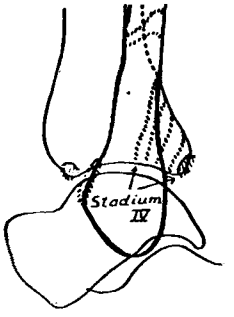
Stage I:
Avulsion fracture through the medial malleolus.



Stage II:
Added: Avulsions at attachments of the anterior tibiofibular ligament, or fracture through the anterior tibial tubercle, or rupture of the ligament proper.



Stage III:
Added: High fibular fracture caused by torsion.



Stage IV:
Added: Fracture through the posterior margin of the tibia.

this there have been a number of cases in most reports that have not been classifiable by the Lauge Hansen system.

Palmer (1962), under the influence of Lauge Hansen's work (1942), modified the system of Ashhurst & Bromer (1922) and divided the fractures of the ankle into: 1) pronation, 2) supination, 3) outward rotation and 4) central compression fractures.

The AO (ASIF) system

Danis (1949) proposed a pathological-anatomical system of classification that was more suited for operative treatment. This classification has since been taken up in a modified form by the AO (ASIF) group (Weber 1972).

According to this system, dislocation fractures are divided into three classes, A, B and C, depending upon the height of the fibular fracture in relation to the syndesmosis and to the talocrural joint (Weber 1972, Müller, Allgöwer, Schneider & Willenegger 1977). Figure III:1.

Fractures of type A comprise fractures of the lateral malleolus below the level of the talocrural joint. In these cases the syndesmosis and the deltoid ligament are most probably uninjured. Instead of an avulsion fracture in the lateral malleolus there may be a rupture of the anterior fibulotalar ligament and the fibulocalcaneal ligament. If a fracture of the medial malleolus occurs, it is often a high vertical or almost vertical fracture. There may be a medial posterior tibial fragment. According to Weber (1972) the main causative mechanism is supination violence.

Fractures of type B comprise fractures of the lateral malleolus at the syndesmotic level. According to Weber (1972) they involve a 50 % risk of injury to the syndesmosis. On the medial aspect dislocation is accompanied by injury to the deltoid ligament or a malleolar fracture. There may be a lateral posterior tibial fragment. Weber states that these fractures are usually caused by forced outward rotation of the talus.

Fractures of type C are fibular fractures above the syndesmotic level, invariably involving a risk of damage to the syndesmosis. On the medial aspect there is an avulsion fracture through the malleolus or injury to the deltoid ligament. A lateral posterior fragment may be present. According to Weber the causative mechanism is outward rotation violence with a component of impact violence.

The two classification systems only partly overlap, and the two

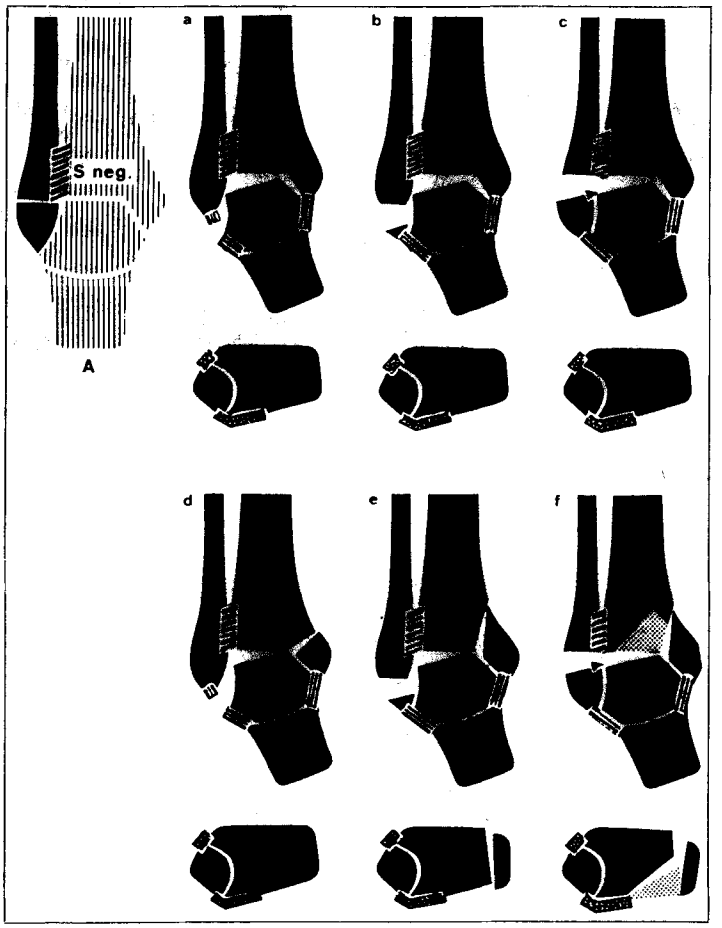


Figure III:1 a VARIANTS OF TYPE A FRACTURES

(After Weber:Die Verletzungen des oberen Sprunggelenkes. Verlag Hans Huber, Bern 1972. Reproduced with the permission of the author and the publishers.)

A. Type A fracture ("S neg" means the syndesmosis is not damaged.)

a.Rupture of lateral ligaments. b.Avulsion fracture of the distal end of the fibula. c.Transverse fracture at the level of the joint space. d.Additional transverse fracture of the medial malleolus. e.Additional vertical fracture of the medial malleolus. f.Additional fracture of the posterior margin of the tibia, oriented medio-dorsally. Transverse sections: Syndesmotic ligaments invariably intact.

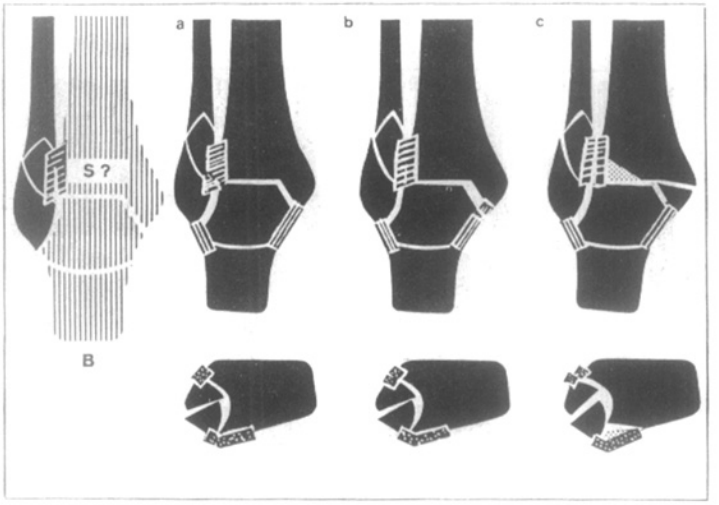


Figure III:1 b VARIANTS OF TYPE B FRACTURES

B. Type B fracture ("S ? " means the syndesmosis is damaged in about 50 per cent of the cases.)

a.Isolated oblique fibular fracture. b.Additional rupture of the deltoid ligament. c.Additional fracture of the medial malleolus. Transverse sections: The syndesmotic ligaments are either intact or injured.

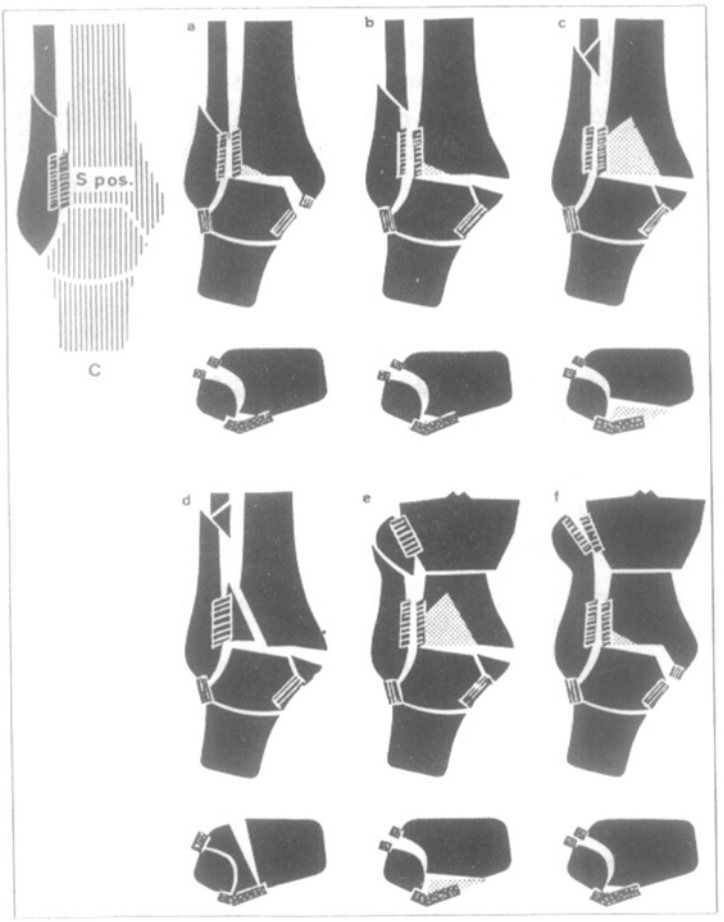


Figure III:1 c VARIANTS OF TYPE C FRACTURES

C. Type·C fracture ("S pos." means the syndesmosis is always damaged.)

In all cases the fibular fractures are more or less at a high level.In exceptional cases there is no fibular fracture at all.
a.Additional rupture of the deltoid ligament. b.Additional fracture of the medial malleolus c.Additional fracture of the posterior margin of the tibia, oriented latero-dorsally. d.Sagittal fracture of the tibial tubercles en bloc. e.Subcapital fracture of the Maisonneuve type. f.Apparently isolated widening of the ankle mortise without a fibular fracture.

Transverse sections: The syndesmotic ligaments are invariably damaged.

authors' aetiological theories also differ. The pronation-abduction and pronation-eversion injuries of grade I (PA I and PE I) both imply an almost horizontal fracture through the medial malleolus as the only radiographic sign. Such fractures are classified as type A injuries by Weber, with forced supination of the foot as the proposed injury mechanism.

Impact fractures

If the foot is exposed to direct violence, for example from a fall from a height, or in a traffic accident or if it is crushed, impact or compression fractures with a different appearance and functional pathology than dislocation fractures occur. Weber (1972) also divides these fractures into three classes:

A. Crush fracture at the distal end of the tibia with a fibular fracture. The talar trochlea is intact.

B. Variable mortise injuries with simultaneous fracture of the talar trochlea.

C. Crush fracture at the distal end of the tibia without a fibular fracture. Talar trochlea intact, syndesmosis always injured.

This classification is of most interest in planning of an operation. Weber (1972) also divided impact fractures according to their appearance in the tibial plateau, into "central, "ventral" and "dorsal".

Combined fractures

Fractures at the distal end of the tibia may be combined with an ankle injury. Distal spiral fractures of the tibia may be extended to the joint and be accompanied by a fracture of the medial malleolus and a risk of injury to the syndesmosis. If the distal ends of both the tibia and fibula are fractured, there is less risk of a syndesmotic injury.

Widening of the Ankle Mortise

Pathological widening of the ankle mortise implies altered loading conditions and a great risk of incongruence arthritis. Riede, Schenk & Willenegger (1971) demonstrated experimentally that even minor displacements of the lateral malleolus and the talar trochlea imply a substantial reduction of the area of contact between the talus and tibia; lateral displacement of the talar trochlea by two millimetres means a reduction of the tibiotalar contact area on weight bearing of almost 60 %. Displacement of the lateral malleolus antero-posteriorly or inwardly, or a rotation deformity, also reduces the contact area to varying degrees. In similar studies Ramsey & Hamilton (1976) found a reduction of the tibiotalar contact area by 42 %, 14 %, 9 % and 3 % on lateral displacement by one, two, four and six millimetres.

The role of the syndesmosis

Cutting of the syndesmotic ligaments increases the risks of pathological outward rotation of the talus and backward displacement of the lateral malleolus (Close 1956). If the deltoid ligament is uninjured the talus can be laterally displaced only two millimetres even though the lateral support of the lateral malleolus and the syndesmosis is missing (Lauge Hansen 1942, Close 1956, Grath 1960, Pankovich & Shivaram 1979). The most important role in prevention of minor, but important, displacements is accordingly played by the lateral malleolo-syndesmosis complex.

Baltensperger (1970) showed on specimens that during movements at the talocrural joint the talus rotated not only around its vertical axis but also around its sagittal axis (varus-valgus). A normal tendency to varus rotation on dorsal extension neutralizes the valgus torsional momentum which acts on the talus at heel-strike during walking. Rupture of the syndesmosis results in some reduction of this compensation mechanism, and if the deltoid ligament is ruptured at the same time the mechanism is quite impossible. The talus will then give way to the valgus-inducing torsional momentum when loaded.

Shortening of the fibula

Palmer (1946), Willenegger (1961), Weber (1972) and Mitchell et al. (1979) warned against shortening of the distal fibular fragment, the lateral malleolus. When the fibula is shortened it will not reach the bottom of the fibular notch on the tibia, resulting in lateral displacement of the lateral malleolus and widening of the ankle mortise.

Outward rotation also occurs; Henkemeyer (1975) made studies on anatomical specimens with standardized shortening osteotomies of three millimeteres in the fibula. When a transverse screw was inserted for fixation of the syndesmosis, the fibula was forced, after shortening, into an outward rotation deformity of 4.65 $\pm$ 0.13 degrees.

A shortened fibula also changes the axis of motion in the talocrural joint, which may give rise to later osteoarthritis induced by incongruence.

Injuries to Cartilage and Articular Surfaces

The direction of the trauma and its energy content decide the extent of injury to articular surfaces and cartilage. In abduction and outward rotation injuries there is some risk of compression of the articular surface of the talus and/or of the distal articular surface of the tibia and of damage to the cartilage at the anterior lateral corner. In fractures of types B and C there is a risk of medial talar cartilaginous injury (Johansson & Olerud 1967).

In adduction injuries with a vertical fracture through the medial malleolus, the medial portion of the horizontal articular surface of the tibia may be fractured and compressed in the proximal direction close to the medial angle of the joint and the fracture line (Palmer 1962, Heim & Pfeiffer 1972). This compressed articular surface area may be difficult to see radiographically.

Fracture through the posterior margin of the tibia

A medial posterior fragment occurs mainly in type A fractures. Small or large lateral fragments are found mostly in fractures of types B and C.

In fluoroscopy studies, Hendelberg (1943,1946) found that the size of the posterior fragment cannot with certainty be decided from the conventional radiographic projections; the fracture line is not always perpendicular to the plane of projection of the standard radiograph.

A lateral posterior fracture fragment often includes the tibial insertion of the posterior tibiofibular ligament, the strongest ligament of the syndesmosis system. Fracture through the lateral part of the posterior margin of the tibia thus means with the greatest

probability that the ligament insertion is avulsed, implying a rupyure of the syndesmosis and a risk of widening of the ankle mortise. The presence of a posterior fracture fragment also indicates significant damage to the joint cartilage, with discontinuity of the distal joint surface of the tibia and perhaps also detachment of small cartilaginous fragments, which will increase the risk of posttraumatic arthritis. Many authors have found that the occurrence of a posterior tibial fracture fragment can be used as a prognostic criterion (Felsenreich 1931, Graff 1954, Willenegger 1961, Klossner 1962, Henke 1964, Cedell 1967, Tauber et al. 1971, McDaniel & Wilson 1977, Nonnemann & Bräutigam 1977, Niethard & Plaue 1977, Plaue 1978).

Ligamentous Injuries

Damage to the anterior fibulotalar ligament causes antero-posterior instability - the so-called "anterior drawer" effect (Anderson & Lecocq 1952, Broström 1966, Olerud 1967, Lindstrand 1976, Adler 1976). If, in addition, the fibulocalcaneal ligament is ruptured, pronounced supination instability will be the result.

In the presence of a high fibular fracture superior to the joint space, the anterior tibiofibular ligament or one of its attachments and also the interosseous ligament and the whole or parts of the interosseous membrane are invariably ruptured. Rupture of the very strong posterior tibiofibular ligament proper is less common. More usual are fractures through the tibial attachment of this ligament in the posterior tibial tubercle (Maisonneuve 1840, Weber 1972).

Lateral displacements of the talus by more than two millimetres imply syndesmotic insufficiency and also a fracture through the medial malleolus or incompetence of the deep posterior portion of the deltoid ligament (Grath 1960, Pankovich & Shivaram 1979). A fracture through the anterior colliculus of the medial malleolus does not preclude a rupture of the deep posterior portion of the deltoid ligament (Pankovich & Shivaram 1979).

Diagnosis of ligamentous injuries

A prerequisite for a proper diagnosis of injuries to the ligaments is that the examiner has good knowledge of the normal and posttraumatic anatomy of the ankle, both clinical and radiographic. Inspection, with regard to dislocation, swelling and bruises and careful palpation with recording of any local, direct or indirect tenderness and a clinical examination of the stability of the ankle provide, at least in a re-

cent injury, a good basis for a clinical evaluation of what ligaments are damaged.

When a fracture is suspected the manual examination should be complemented with radiography. A systematic examination of the appearance of the skeletal injuries on the radiograph will yield more useful information on suspected damage to ligaments (Lauge Hansen 1942, Danis 1949, Weber 1972, Kaye 1977). The diagnostic procedure will be more precise with the use of radiographs taken under provocation of the ankle in supination-adduction, pronation-abduction or as drawer-test images (ex. Olerud 1967, Weber 1972, Adler 1976, Lindstrand 1976, Larsen 1976). In recent injuries these manoeuvres cannot be performed without anaesthesia.

SUMMARY

In this chapter the posttraumatic anatomy and pathological function of the talocrural joint are reviewed.

I. The two systems most commonly used today for classification of dislocation fractures of the ankle, the Lauge Hansen and Weber (AO) systems, are presented. Weber's classification of impact (pilon tibial) fractures is described.

II. Even minor displacements of the talus in the ankle mortise give rise to considerable changes in loading conditions and a risk of incongruence arthritis.

III. The lateral malleolo-syndesmosis complex plays a decisive role in preventing even minor deformities in the talocrural joint. Syndesmotic incompetence implies a risk of lateral displacement and valgus rotation of the talus. Shortening of the fibula results in a rotation deformity of the lateral malleolus and dysarticulation due to widening of the ankle mortise.

IV. Injuries to articular surface cartilage on the talus or distal end of the tibia can lead to permanent damage to joints and may predispose to arthritis. Impressions of the medial part of the distal articular surface of the tibia sometimes occur in adduction injuries.

V. Fractures through the posterior margin of the tibia imply considerable cartilaginous damage. A lateral posterior fragment generally implies that the attachment of the posterior syndesmotic ligament has been avulsed, with a risk of widening of the ankle mortise.

VI. Rupture of the anterior fibulotalar ligament causes an "anterior drawer" effect and when combined with rupture of the fibulocalcaneal ligament will result in instability of supination and adduction.

VII. Rupture of the anterior tibiofibular ligament or a fracture through one of its attachments occurs in fibular fractures above the articular surface level. Rupture of the posterior syndesmotic ligament proper is less common; more often its area of attachment - the posterior tibial tubercle - is fractured.

VIII. When the talus is laterally displaced more than 2 mm, the deep posterior portion of the deltoid ligament is damaged. Such damage can occur simultaneously with a fracture through the anterior colliculus of the medial malleolus.

IX. Ligamentous injuries of the ankle joint should be diagnosed in the first place by careful palpation and clinical stability tests, and by radiographic examination of the fracture lines. Further diagnostic information can be obtained by radiographs taken during provocation.

Chapter IV

PRIMARY MATERIAL

From the beginning of February 1972 to the end of June 1975, 608 patients between 15 and 85 years of age with 611 ankle fractures received primary treatment at the Department of Orthopaedic Surgery of the University Hospital in Uppsala. (The three patients with bilateral fractures are not treated separately in the statistical analysis). Thus, in the following the word 'case' will refer to a fracture and not to a patient. The patient material was unselected.

Area served

The primary area served for emergency fracture surgery by the Department of Orthopaedic Surgery comprises the greater part of the County of Uppsala. In the years 1972-1975 the mean number of inhabitants of this area of ages 15 years and older was 146,261. During ten months of the year the population of the city of Uppsala is increased by students at the university and other adult education centres, and in the years in question the mean additional number per year was 17,782. Of these, 71.5 % were registered for census purposes elsewhere, and it was therefore calculated that the population of the area served should be increased by 0.715 x 17,782 x 10/12 = 10,595. The total mean number of inhabitants of ages 15 years and older served by the Department of Orthopaedic Surgery was thus about 157,000.

Incidence rate

Of the 611 fractures, 15 had occurred outside the catchment area. The patients with the other 596 ankle fractures were treated during a period of 40 months. This corresponds to an average of 179 new cases per year. Thus, of those inhabitants who were 15 years of age or older, 1.14 per thousand sustained ankle fractures during the first years of the 1970's.

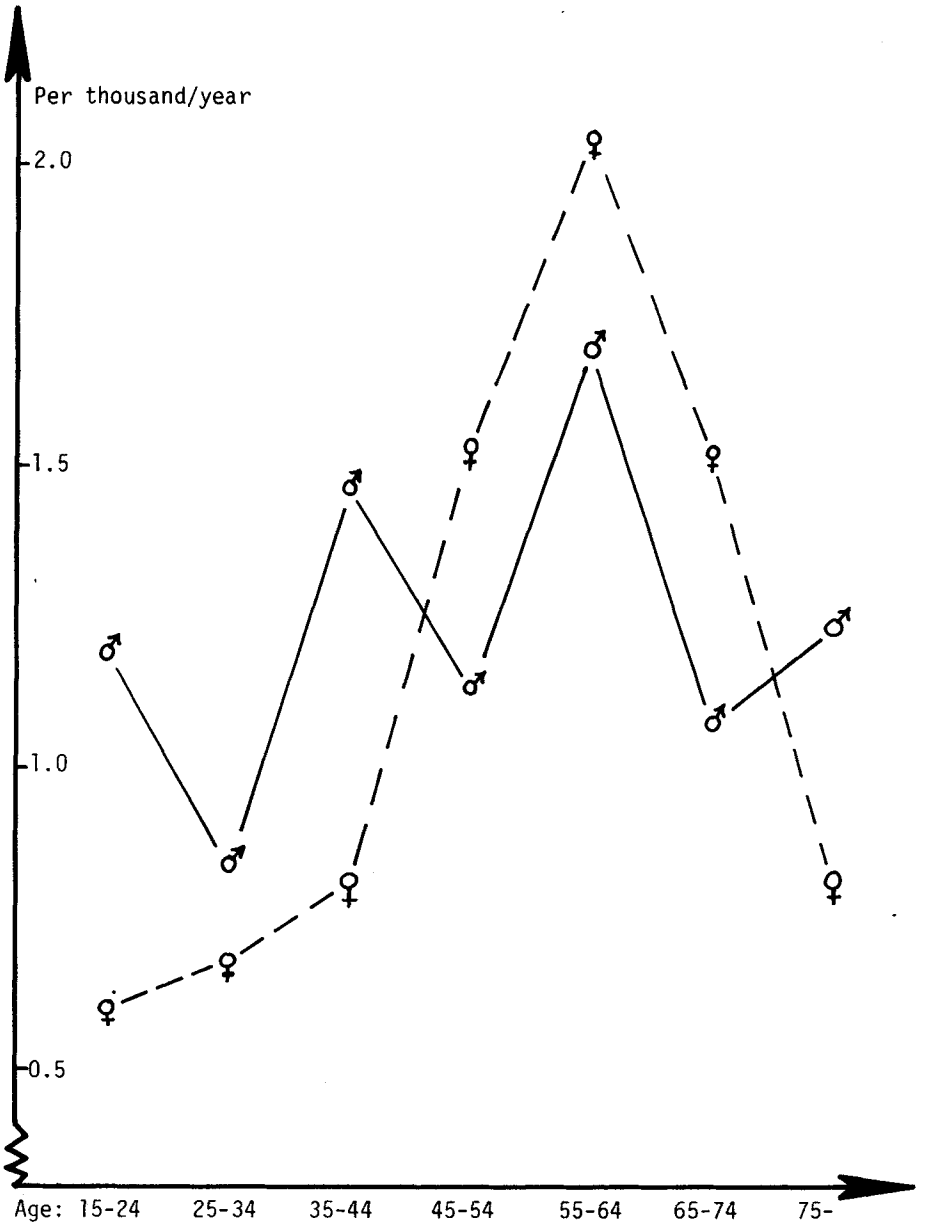


Figure IV:1 INCIDENCE RATE
Ankle fractures (n=611)
Men ♂———♂ Women ♀---------♀

Who sustained fractures?

Of the ankle fractures, 322 occurred in males and 289 in females. The sex difference in the whole patient material with respect to the number of fractures was not greater than that explainable by chance. When the different age groups were examined separately, the incidence of fractures at the ages below 45 years was found to be markedly lower among the women than among the men. The difference was highly significant.

For the men the incidence rate showed no obvious age dependence, whereas for the women the pattern clearly deviated from that of the background population. Among the younger women the incidence rate was markedly low. At ages between 45 and 74 years, on the other hand, this rate was higher among the women; the difference from the men was almost statistically significant. Figure IV:1.

In many clinical reports the ratio of men to women in the material is given (Lauge Hansen 1942, Hendelberg 1943, Magnusson 1944, Baek Kristensen 1953). This information is not of great value if the background population is not known. The incidence rates give a truer idea of whether or not sex differences in the occurrence of ankle fractures are present (Colton 1974, Miettinen et al. 1975, Taube 1980).

Accident situation

Most of the accidents occurred during unspecified leisure activities (47 per cent), during sports and physical exercise (22 per cent) and in traffic (18 per cent). Details of this distribution are given in Table IV:1.

Over half of the fractures sustained during sports and physical exercise occurred during football (am: soccer) (men) and physical exercise (women) (Lindsjö 1980, Lindsjö & Amici 1980).

Of the patients injured in traffic accidents, 50 per cent were pedestrians, 24 per cent were cyclists, 11 per cent were riding a moped or motor-cycle and 15 per cent were victims of car accidents.

Most of the patients who sustained their fractures in accidents at work (13 per cent) were male labourers with heavy work. Table IV:2. The frequency of accidents at work was significantly higher among male patients with heavy physical work than among female patients with corresponding types of occupations. Male patients with light non-sedentary work also had a higher frequency of fractures than women with similar occupations and this difference was almost significant.

Table IV:1 ACCIDENT SITUATION

Ankle fractures (n=604)

	Age, years						
	15-44		45-74		75-		Total
	Men (n=186) %	Women (n=101) %	Men (n=118) %	Women (n=166) %	Men (n=17) %	Women (n=16) %	(n=604) %
Accidents at work	20	4	22	5			13
Traffic accidents	14	24	25	16	29	13	18
Sports & exercise	34	30	11	14	6	6	22
Unspecified leisure activities	32	42	42	65	65	81	47
Total	100	100	100	100	100	100	100

Table IV:2 ACCIDENTS AT WORK

Ankle fractures (n=552)

Occupation	Men:		Women:	
	Fractures at work	Other fractures	Fractures at work	Other fractures
Heavy work	47	61	4	30
Light, mobile	14	72	7	115
Light, sedentary	1	34	2	38
Retired	2	58	0	67
Total	64	225	13	250

Among the patients under the age of 45 a much greater proportion of men than women sustained their ankle lesions at work or during sports or leisure activities (Table IV:3).

Table IV:3 ACCIDENT SITUATION

Patients under 45 years of age (n=287)

	Men	Women
Accident at work	38	4
Traffic accident	25	24
Sports and other physical activities	63	30
Of which: Soccer	(27)	(4)
Exercise/ training	(8)	(5)
Others	(28)	(21)
Other accidents	60	43
Total	186	101

Causes of fractures

Most of the fractures (63 %) were caused by stumbling or a fall on the same level. This is also the most common cause of ankle fractures reported by other authors (e.g. Burwell & Charnley 1965, Cedell 1967, Weber 1972). Twenty-eight per cent occurred in falls from a height or by crushing or a blow. Nine per cent were caused by a fall from steps, Table IV:4.

Table IV:4 CAUSE OF INJURY

Ankle fractures (n=608), Weber's (AO) classification

	AO:A (n=151) %	AO:B (n=340) %	AO:C (n=81) %	Impact fractures (n=22) %	Miscellaneous (n=14) %	Total (n=608) %
Stumbling or fall on the same plane	60	69	58	4	43	63
Fall from steps	8	11	8	9	0	9
Fall from a height	13	12	12	55	21	14
Direct violence	19	8	22	32	36	14
Total	100	100	100	100	100	100

Social situation

Marked mental disturbances or drug addiction was suspected in 43 patients (7 %). Alcoholism was established in 29 patients (5 %). The group of drug addicts and alcoholics in the material was probably somewhat greater than was apparent from the medical records. The observed frequency of twelve per cent is in good agreement with the figure given by Karlström (1976). In a series of 129 patients with tibial fractures from the same catchment area he found that 15 per cent were alcoholics, mentally disturbed or had a criminal record.

Eighty-seven patients were covered by accident insurance in addition to the general national health insurance at the time of the accident.

Types of Fractures

Classification according to the AO (ASIF) system

One-fourth of the ankle fractures were of type A. The largest group consisted of type B fractures (56 %). Thirteen per cent of the fractures were of type C. Impact fractures (caused by direct violence) and combined fractures comprised 4.7 per cent. Figure IV:2 and Table IV:5.

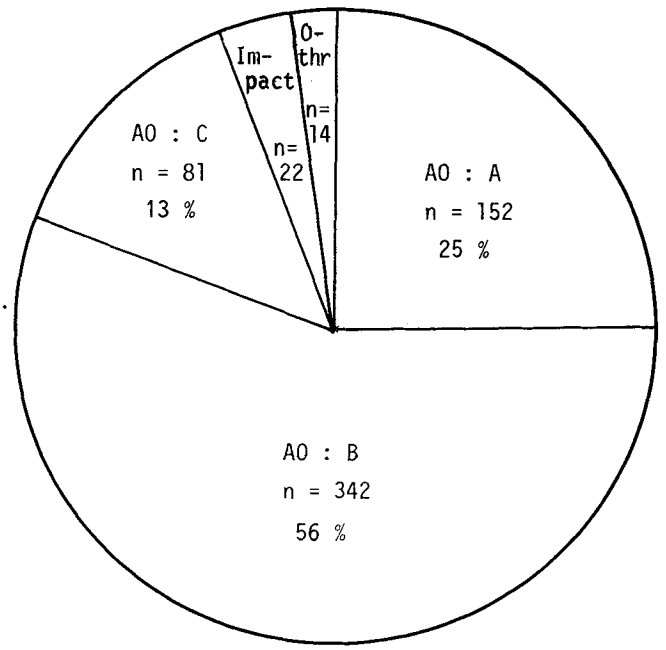


Figure IV:2 ANKLE FRACTURES
Classification by the AO (ASIF) system (n=611).

Table IV:5 CLASSIFICATION OF THE 611 ANKLE FRACTURES

	Men Number	%	Women Number	%	Total Number	%
AO:A	82	25	70	24	152	25
AO:B	169	52	173	60	342	56
AO:C	50	16	31	11	81	13
Impact fractures	13	4	9	3	22	4
Combined fractures	4	1	3	1	7	1
Isolated posterior tibial fragment	3	1	3	1	6	1
Epiphysio-lysis	1		0		1	
Total	322	100	289	100	611	100

The distribution of the 22 impact fractures according to Weber's (1972) classification was as shown in Table IV:6.

Table IV:6 IMPACT FRACTURES
(Fractures caused by direct violence)
Weber's classification (n=22).

	Men	Women
Type A (with fibular fracture)	7	7
Type B (with talar fracture)	1	1
Type C (without fibular fracture)	5	1

Combined fractures

A combination of a distal tibial fracture and a malleolar fracture was found in seven cases - four spiral fractures of the distal end of the tibia and fibula with continuation to the ankle joint and two transverse fractures of the tibial shaft combined with a fracture of the medial malleolus. It is possible that more combined fractures may

have occurred in addition to those included in this material which instead were registered as fractures of the tibial shaft alone.

Classification according to Lauge Hansen

In order to allow comparisons with other reports and also to be able to compare the practical applicability of different modes of classification, the primary material was also divided according to the "genetic" system of Lauge Hansen (1942).

Supination-eversion (SE) fractures were most common (43%), followed by the supination-adduction (SA) type (21 %), pronation-abduction (PA) (17 %) and pronation-eversion (PE) (13 %). Forty-three fractures (7 %), including 22 impact fractures (3.6 %), did not fit into the Lauge Hansen classification. Figure IV:3. Table IV:7.

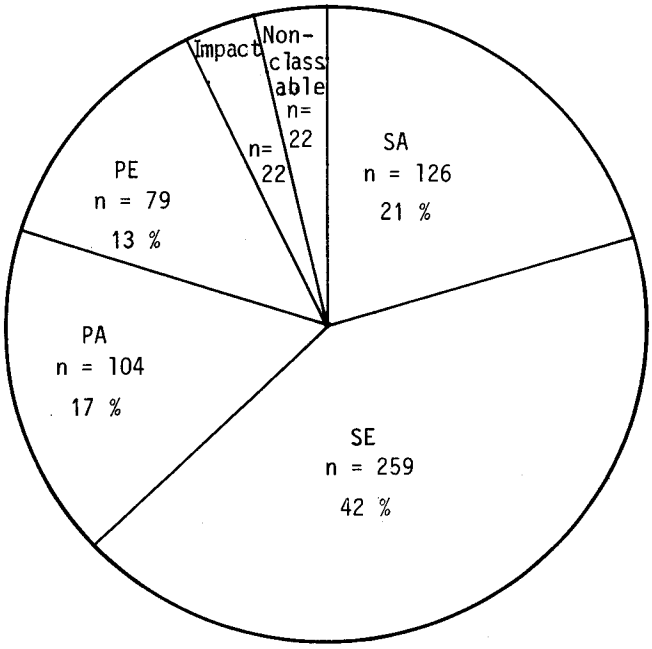


Figure IV:3 ANKLE FRACTURES
Lauge Hansen's classification (n=611)

Table IV:7 CLASSIFICATION OF THE 611 ANKLE FRACTURES
Lauge Hansen system

	Men		Women		Total	
	Number	%	Number	%	Number	%
SA I	43	13.4	52	18.0	95	15.5
SA II	21	6.5	10	3.5	31	5.1
SE I	0	0.0	2	0.7	2	0.3
SE II	66	20.5	58	20.1	124	20.3
SE III	18	5.6	18	6.2	36	5.9
SE IV	47	14.6	50	17.6	97	15.9
PA I	16	5.0	6	2.1	22	3.6
PA II	3	0.9	2	0.7	5	0.8
PA III	32	9.9	45	15.6	77	12.6
PE I	0	0.0	1	0.3	1	0.2
PE II	6	1.9	2	0.7	8	1.3
PE III	23	7.1	4	1.4	27	4.4
PE IV	24	7.4	19	6.6	43	7.0
Impact fractures	13	4.0	9	3.1	22	3.6
Non-classifiable	10	3.1	11	3.8	21	3.4
Total	322	100	289	100	611	100

Specific lesions

Fracture through the posterior tibial margin

A distinction was made between "small", i.e., non-articular surface bearing, and "large", i.e., articular surface bearing posterior fragments. By articular surface bearing it is meant that in the lateral or oblique radiographic view the fragment includes a part of the distal horizontal articular surface of the tibia.

A radiographically demonstrable posterior fragment was found in 40 % of the dislocation fractures. Most common was a lateral posterior fragment, which was seen mainly in fractures of types B and C.

A posterior fragment as the only skeletal injury occurred in six patients (1 %). Table IV:8.

Table IV:8 POSTERIOR TIBIAL MARGIN FRACTURES
Relative frequencies in different fracture types

	Small lateral	Large lateral	Small medial	Large medial	Total
	%	%	%	%	%
Weber's (AO) classification					
AO:A (n=152)	0	0	0.7	1.3	2
AO:B (n=342)	25	13	7	1	46
AO:C (n=81)	28	25	0	9	62
Total (A+B+C) (n=575)	19	11	0.7	2.3	33
Lauge Hansen's classification					
SA II (n=31)	0	0	3	10	13
SA III (n=36)	64	25	3	3	98
SE IV (n=97)	50	24	1	3	78
PA III (n=77)	21	21	1.3	1.3	45
PE IV (n=43)	51	42	0	7	100

Anterior tibial tubercle

The anterior tibial tubercle (ATT), which comprises the tibial attachment for the anterior tibiofibular ligament, was totally or partially fractured in one type A fracture, 41 per cent of type B, 49 per cent of type C and 41 per cent of the impact fractures. An isolated ATT fracture occurred in four cases. Using the Lauge Hansen classification, ATT fractures were found mainly in SE, PA and PE fractures with a high stage number.

Injuries to the talus

Talar injuries could be diagnosed to some extent, partly on inspection of radiographs taken immediately after the accident, and partly on inspection of the joint at operation in surgically treated patients. At operation, as a rule only the anterior part of the talocrural joint

could be inspected, and the occurrence of minor talar fractures was therefore probably greater than is reported.

Some form of talar injury was found in 16 per cent (54/345) of the operatively treated fractures. Ruptured cartilage on the talus was noted in 37 cases (3 type A, 24 type B, 8 type C and 2 impact fractures). Only in 29 operation reports was the location of the cartilage defect on the talus noted. In 24 of these cases the anterior lateral corner of the talus was fractured. Minor compression fractures at the upper articular surface of the talus were seen radiographically in seven cases (one type A fracture, two type B, two type C and two impact fractures). Two impact fractures combined with a talar fracture (Weber's type C) were included in the material - one with a transverse fracture through the body of the talus and one with a fracture through the talar trochlea. Thirty-five of the 54 talar fractures (64 %) were combined with a fracture through the posterior tibial margin.

Injuries to the syndesmosis

The diagnosis of injury to the syndesmosis was based on observations during surgery. In 345 operatively treated fractures 213 cases (62 %) with a partial or total rupture of the syndesmosis were found. In 60 % of the type B injuries and all type C injuries the syndesmosis was damaged.Of the impact fractures, six (27 %) were accompanied by a syndesmotic injury, which was sutured; in five of these six cases a suprasyndesmotic screw was also used.

Other ligamentous injuries

Preliminary preoperative diagnosis of ligamentous injuries was based on clinical examination and radiography in standard projections. Provocation films (see Chapter III) were used to a very little extent at the acute stage. When an injury to the ligaments was suspected the anterior fibulotalar and deltoid ligaments were explored during operation. Exploration of the fibulocalcaneal ligament was undertaken only on rare occasions and therefore no frequency figures for this ligament can be given. The anterior fibulotalar ligament was injured in 32 out of 144 explored cases, or nine per cent of all surgically treated fractures. Table IV:9.

The corresponding figures for the deltoid ligament were 53 out of 102 and 15 per cent. Table IV:10.

Table IV:9 INJURIES TO THE ANTERIOR FIBULOTALAR LIGAMENT DIAGNOSED DURING OPERATION (n=144)

Type of fracture	The ligament explored but intact	The ligament sutured
AO:A (n=26)	7	7
AO:B (n=229)	79	16
AO:C (n=66)	21	8
Impact fractures	4	1
Combined fractures	1	0
Total	112	32

Table IV:10 INJURIES TO THE DELTOID LIGAMENT DIAGNOSED DURING OPERATION (n=102)

Type of fracture	The ligament explored but intact	The ligament ruptured All	Total rupture	Anterior part	Posterior part	Non-specified
AO:A (n=26)	9	0	0	0	0	0
AO:B (n=229)	31	33	10	15	1	7
AO:C (n=66)	9	19	7	2	1	9
Impact fractures (n=18)	0	1	0	0	0	0
Total	49	53	17	17	2	9

Comparison with other series

Lateral ligamentous lesions are reported in approximately the same frequency by Weber (1972) and Pankarter (1977). An injury to the anterior fibulotalar ligament is also perhaps the easiest to diagnose of all ligamentous injuries around the ankle. The frequencies of injury to the deltoid ligament differ more, probably because of different indications for exploration of this ligament. The frequencies of syndesmotic injuries were about the same in all three series. Table IV:11.

Table IV:11 LIGAMENTOUS INJURIES
Relative frequencies in three different series

Weber (1972)	"Lateral ligament lesion"	Injuries to the deltoid ligament	Injuries to the syndesmosis
AO:A (n=29)	31 %		
AO:B (n=55)		42 %	53 %
AO:C (n=76)		54 %	100 %

Pankarter (1977)	"Ligament injuries"	Injuries to the syndesmosis
AO:A (n=20)	40 %	
AO:B (n=90)	15 %	57 %
AO:C (n=30)	23 %	100 %

Lindsjö (1980)	Injuries to the anterior fibulotalar ligament	Injuries to the deltoid ligament	Injuries to the syndesmosis
AO:A (n=26)	27 %		
AO:B (n=229)	7 %	14 %	61 %
AO:C (n=66)	12 %	29 %	100 %

Open fractures

Six of the fractures were open. Five of these were treated with internal fixation (one type B, two type C and two impact fractures).

Growing skeleton

In four patients the epiphyseal lines were not yet closed; one was an impact fracture and three were dislocation fractures - two type B and one type C.

Treatment

Operative treatment was chosen for 345 fractures (57 %). For details of procedure, see chapter V. The proportions of different types of fractures treated operatively varied. Table IV:12.

Table IV:12 TYPE OF TREATMENT IN THE 611 ANKLE FRACTURES

	Operative treatment	Non-operative treatment
AO:A	26	126
AO:B	229	113
AO:C	66	15
Impact fractures	18	4
Combined fractures	6	1
Other fractures	0	7
Total	345	266

Non-operative treatment was used in 266 cases (43 %). The main reasons for not operating on these patients were absence of displacement, acceptance of minor displacements by the orthopaedic surgeon, or the presence of only a small undisplaced fracture fragment (207 fractures). Other reasons for the choice of this form of treatment were: complicating injuries or disease or personality problems (20 cases), an elderly patient (16 cases), or alcoholism (3 cases).

Twelve patients refused operation, two were referred immediately to their local hospital and six came to our hospital such a long time after the accident that the fracture had already healed in an acceptable position. Table IV:13.

Table IV:13 REASONS FOR CONSERVATIVE TREATMENT

Ankle fractures (n=266). Weber's (AO) classification.

	AO:A	AO:B	AO:C	Impact fractures	Epi-physio-lysis		Combined shaft ankle fracture	Total
No deformity	69	34	5	0	1	5	0	114
Minor, accepted deformity	50	40	1	1	0	1	0	93
Pat. refused operation	3	8	1	0	0	0	0	12
Arrived late, fracture healed in acceptable position	0	4	2	0	0	0	0	6
Patient's age	1	12	3	0	0	0	0	16
Alcoholism	0	3	0	0	0	0	0	3
Complicating injuries or disease or personality problems	3	11	2	3	0	0	1	20
Referred to local hospital	0	1	1	0	0	0	0	2
Total	126	113	15	4	1	6	1	266

SUMMARY

This chapter describes the primary material and gives data concerning the epidemiology of ankle fractures and the types of fractures, ligament lesions and treatment chosen.

I. The primary material of 608 patients of ages 15 years and older, with 611 ankle fractures, was unselected and collected during a period of 40 months from an area with an average number of inhabitants of these ages of about 157,000.

Thus during the period in question 1.14 per thousand of the population per year sustained ankle fractures.

II. Among the men no special age pattern was observed with respect to the fracture frequency. Among the women the fracture frequency varied considerably between different age groups. The risk was lowest for women below 45 years of age and highest at about the age of 60. Consequently, most of the younger patients were men and most of the older patients women. The sex difference in frequency is highly significant for the younger patients and almost significant for patients above 45 years of age.

III. The fractures most commonly occurred during unspecified leisure acticities at home or elsewhere (47 %). Twenty-one per cent occurred during sports or physical exercise, 19 per cent in traffic and 13 per cent as accidents at work. The frequency of ankle fractures sustained at work was highly significantly greater among male than among female patients.

IV. Stumbling or a fall on the same level were the most common causes of ankle fractures, followed by a fall from a height, direct violence and a fall from steps.

V. Pronounced mental disturbance, drug addiction or alcoholism was established in 12 per cent of the patients, a figure which corresponds to a previously reported frequency among patients with tibial shaft fractures from the same area.

VI. Most of the fractures were of type B (56 %), and most of these were women. Type A fractures occurred in 25 per cent and among these there was no significant sex difference. Of the patients with type C fractures (13 %), the majority were men, but the difference in frequency

between the sexes was not statistically significant. Neither was there any significant difference in frequency between the sexes among the 22 patients (3.6 %) with impact fractures.

The material also included seven combined tibiofibular and ankle fractures (1.2 %) and six isolated fractures through the posterior tibial margin (1 %). As this primary material was completely unselected, the frequency figures obtained can be assumed to correspond to the predicted frequency in a mixed urban and rural population such as that of the area served by the University Hospital in Uppsala.

VII. Using the classification of Lauge Hansen, the most common fracture was the supination-eversion (SE) type (42 %), followed by supination-adduction (SA) (21 %), pronation-abduction (PA) (17 %) and pronation-eversion (PE) (13 %) fractures. In addition to the 22 impact fractures, a further 22 fractures (3.6 %) did not fit into the Lauge Hansen classification system.

VIII. A posterior tibial margin fragment occurred in 40 per cent of the dislocation fractures, most commonly among those of types B and C.

IX. Talar injuries were observed in 16 per cent, but the true frequency was probably higher.

X. Injuries to the syndesmosis were observed in 60 per cent of the type B fractures and in all type C fractures.

XI. Injuries to the anterior fibulotalar ligament were observed in nine per cent of the surgically treated fractures - 27 per cent of type A, seven per cent of type B and 12 per cent of type C. The deltoid ligament was damaged in 15 per cent of all cases operated on, 14 per cent of the type B fractures and 29 per cent of type C.

XII. 345 fractures (57 %) were operated on (see Chapter V). The most common reasons for conservative treatment of the rest of the fractures (266) were: no or minimal deformity, complicating injuries or diseases or personality problems, the age of the patient, alcoholism or the patient's refusal of operation.

OPERATIVELY TREATED FRACTURES

Three hundred and forty-three patients with 345 ankle fractures were treated with open reduction and internal fixation. Figures V:1 and V:2 and Table V:1.

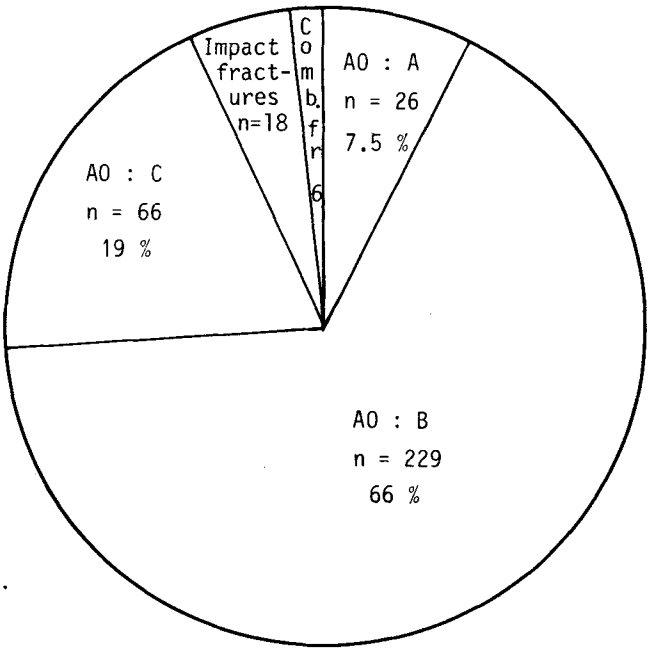


Figure V:1 OPERATIVELY TREATED ANKLE FRACTURES
Classification by the AO (ASIF) system (n=345).

Indications for operation

Palmer (1941, 1950, 1962) and Proctor (1954), among others, emphasized the importance of operating on unstable ankle fractures and of repairing and fixing the syndesmosis. In the opinion of Danis (1949) and Vasli (1957), as many fracture components should be fixed as will

provide stability of the joint, so as to permit early postoperative exercises. Weber (1972) considered that every injury at the talocrural joint involving one or more ligamentous or bony lesions is an absolute indication for operative treatment. According to Olerud (1968), all ankle fractures with incongruity of joint surfaces should be regarded as cases for surgery. Both Weber and Olerud held the opinion that only in the presence of general contraindications should it be decided not to operate.

In the individual fractures in the present series a decision to operate was made after an analysis of the injury based on the case history, clinical examination of the foot, radiography and general examination. If from the combined findings operation was indicated, this was planned as the primary measure.

Operation in different types of fractures

Of the 126 non-operatively treated type A fractures, 121 (96 %) showed no or just a minimal displacement and 84 (67 %) were fractures through the lateral malleolus without any other skeletal injury.

Of the 26 operatively treated type A fractures (17 % of all fractures of type A) only five (19 %) were isolated fractures of the lateral malleolus. Of the remaining 21, ten were fractures of the medial malleolus without any other bony lesion and 11 were fractures through both malleoli.

Of the 111 non-operatively treated type B fractures, 68 (61 %) were fractures of the lateral malleolus alone. In 73 fractures there was no or only a few millimetres' displacement. Of the 229 operatively treated type B fractures, 71 (30 %) consisted of fractures through the lateral malleolus alone, and only 24 (10 %) of these were not accompanied by ligamentous injuries.

Of the 66 type C fractures, 51 (77 %) were operated on. Only in six of the 15 treated conservatively was absence of displacement the reason for this treatment. In the remaining nine cases there were various reasons for not operating on the fractures (Table IV:13).

The majority of impact fractures were operated on. In the few conservatively treated cases this treatment was chosen because of other injuries or disease.

Impact fractures are caused by high-energy violence and as a rule are comminuted. It is impossible to restore the joint surface anatomy by closed reduction in these cases. Open reduction with a possibility of bone grafting provides a greater opportunity of regaining a

Table V:1 OPERATIVELY TREATED ANKLE FRACTURES
Weber's (AO) classification.

Age, years	15 - 24		25 - 34		35 - 44		45 - 54		55 - 64		65 - 74		75 - 85		Total		All
Sex	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	
Type of fracture																	
Dislocation fractures																	
Type A	5	5	1	1	4	1	2	0	2	2	1	1	0	1	15	11	26
Type B	22	13	32	20	21	12	17	27	20	25	6	11	0	3	118	111	229
Type C	7	4	10	7	7	4	2	2	9	9	1	2	2	0	38	28	66
Impact fractures	2	1	2	0	2	1	1	2	1	4	1	1			9	9	18
Combined fractures	2	0	1	1	0	1	0	1							3	3	6
Total	38	23	46	29	34	19	22	32	32	40	9	15	2	4	183	162	345

functioning talocrural joint (Maurer & Lechner 1965, Weber 1965,1972, Rüedi & Allgöwer 1969, Rüedi 1973, Heim & Näser 1976, Spiegel 1979).

In the combined shaft and ankle fractures the fracture of the tibial shaft often receives the greatest attention. The indications for operation in different types of tibial fractures have been thoroughly described by Karlström (1976). Of the seven combined shaft and ankle fractures in the present material, the ankle fracture was operated on in six cases.

Timing of operation

According to Weber (1972), ankle fractures should be operated on as soon as possible after the accident unless the patient's general condition or any local soft tissue changes indicate that it should be postponed. This view is shared by many other authors (e.g. McLaughlin & Ryder 1949, Willenegger 1961, Olerud 1968, Plaue & Hinz 1970, Müller, Allgöwer, Schneider & Willenegger 1977). This is also the main principle that was applied in the treatment of the present material.

One hundred and twenty-six fractures (37 %) were operated on within the first eight hours after the accident. Forty fractures (12 %) were operated on 9 - 48 hours after the accident and 29 fractures (8 %) were operated on within three to four days. One hundred and fifty fractures (44 %) were operated on five days after the accident or later.

A delay of over eight hours was due in most cases (111, 54 %) to soft tissue swelling and skin complications and in 21 cases (10 %) to technical and personnel problems - mainly overburden of the operating theatre.

Preoperative treatment

Displaced, unstable ankle fractures were, as a rule, provisionally reduced immediately on admission of the patient to the emergency department, before radiography. These fractures were operated on as soon as possible if there was no contraindication.

Because of soft tissue swelling and skin damage, 15 fractures of type B, four of type C and two impact fractures were treated primarily with provisional reduction and temporary longitudinal calcaneotibial transfixation with a pair of Steinman pins (Sokolowski 1958, Duke 1963, Childress 1965, Olerud 1968 b, Mattsson 1968, Husebø & Solhaug 1976).

During the waiting period, the injured limb was elevated and the ankle was bandaged with a crepe bandage, sometimes a plaster cast was

also applied. At the beginning of the investigation period antiphlogistic therapy was regularly given, with oxyphenbutazone (Tanderil ^{R}) and furosemide (Lasix ^{R}). Later these drugs were only used in selected cases with severe swelling of soft tissues.

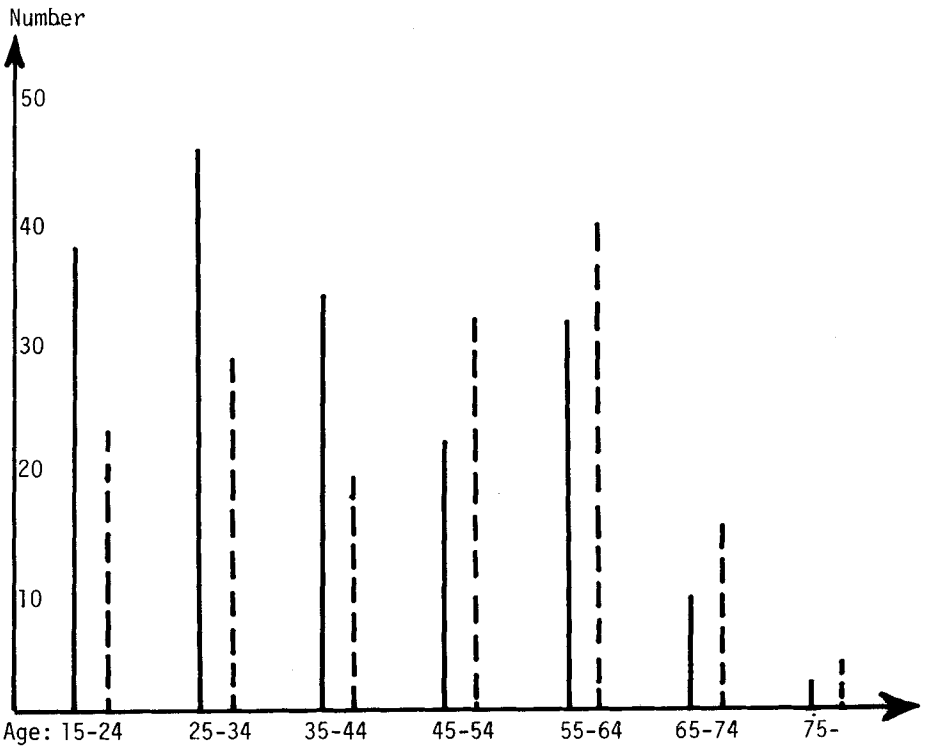


Figure V:2 OPERATIVELY TREATED ANKLE FRACTURES (n=345)
Whole lines = men. Dashed lines = women.

Operation technique

The aim of the operations was to achieve accurate reduction and the greatest possible stability with use of the smallest possible amount of internal fixation material.

The operations were performed in a bloodless field, under general or epidural anaesthesia. An original AO fracture instrumentarium was used in all cases (Müller, Allgöwer & Willenegger 1963, 1965, Müller et al. 1977, Weber 1972, Heim & Pfeiffer 1972).

Malleolar fractures were fixed with screws, "Zuggurtung" (figure of eight tension band wiring), plates and screws, or cerclage. For fractures at the end of the distal fibula screws or a semitubular plate were used. The posterior fragments were generally fixed with a screw from the front after primary fixation and a radiographic check of the accuracy of the reduction.

The syndesmosis was explored in 311 cases, and in 211 of these it was found to be partially or totally ruptured. Sixty syndesmotic lesions (28 %) were treated by suturing alone.

After reduction and fixation of the bony lesions and suturing of ruptured ligaments, the stability of the syndesmosis was tested with a single hook around the distal end of the fibula. If the play was more than 2 mm, the fibula was fixed preliminarily with AO pins in its correct position in the fibular notch, whereafter a fibulotibial screw was inserted above the tibiofibular joint to secure the syndesmosis (suprasyndesmotic screw). Such a screw was used in 40 % of type B fractures and in 80 % of type C. Two suprasyndesmotic screws were used in one case, a type C fracture. Exploration of seven impact fractures revealed no damage to the syndesmosis; three such fractures were not explored in this respect. In six cases the syndesmosis was repaired, and in five of these a suprasyndesmotic screw was used for additional fixation. Ninety-five per cent of the screws (143/151) were threaded in the fibula, and 79 % of them (119/151) passed through both cortical layers of the tibia.

The operations were regarded as routine procedures. They were performed by a total of 31 surgeons, 11 of whom operated on only a few cases (less than four). The majority of the operations were thus carried out by a total of 20 surgeons.

Postoperative treatment

As a rule the operation area was drained with suction drainage (Redon) for 24 hours. After skin closure and bandaging, a split below-knee plaster or a padded U-splint was applied. This primary plaster was left on for about two days, and the patient was then allowed to exercise the ankle without weight-bearing. When some dorsal extension were possible, the ankle was immobilized in a below-knee walking plaster. After a few days of walking training with full weight bearing, the patient was discharged. Follow-up clinical and radiographic examinations were then performed at intervals in the hospital's outpatient department until the end of the patient's

sick-leave period.

The median duration of immobilization in plaster for all patients was six weeks and for impact fractures somewhat longer - eight weeks. Ten patients were given a PTB splint instead of plaster. These were three patients with bilateral fractures and seven patients in whom a long period without weight-bearing was prescribed because of the nature of the injury. (See also Chapter VI.)

The median length of time after operation before removal of supra-syndesmotic screws was nine weeks. As a rule full weight-bearing without external immobilization was then allowed. Residual internal fixation material was removed from 199 ankles 48 weeks, on the average, postoperatively (range of variation 9-97 weeks). All types of internal fixation material were removed in approximately the same relative frequency. In general, patients below 50 years of age were recommended to have the internal fixation material removed, and older patients only if they had local symptoms attributable to such material.

Duration of hospital stay

A preoperative stay in the hospital longer than 24 hours occurred in 189 cases; the median duration was four days and the range of variation 1-28 days. In 342 cases in-patient care was also required postoperatively. This median duration was seven days, with a range of variation of 1 - 182 days. Table V:2

Thus totally, over a period of 40 months 345 surgically treated ankle fractures accounted for 4,232 bed-days in connection with the operation. This corresponds to an average of 3.5 hospital beds for this type of emergency fracture surgery.

Sixty patients received in-patient care after the primary stay in hospital, usually for removal of internal fixation appliancies. Table V:3. The total duration of secondary stay in hospital was 516 days. If this stay is also included, the need for hospital beds for ankle fractures will increase from the above-mentioned figure of 3.5 to 4.0. The populatione of ages 15 years and older served by the hospital was about 160,000. The total need for hospital beds for surgery of ankle fractures can then be estimated to be at least 2.5 beds per 100,000 inhabitants.

Table V:2 POSTOPERATIVE HOSPITAL CARE. DAYS.
Relation to different types of ankle fractures (n=342)

Type of fracture	Number of patients	Shortest duration	1st quartile	Median	3rd quartile	Longest duration
AO:A	25	2	6	7	9	32
AO:B	228	1	6	7	10	84
AO:C	66	3	6	9	12	53
Impact fractures	17	4	9	15	20	182
Combined fractures	6	6	9	10	11	14
Total	342	1	6	7	11	182

Table V:3 SECONDARY HOSPITAL CARE. DAYS.
Relation to different types of ankle fractures (n=60)

Type of fracture	Number of patients	Shortest duration	1st quartile	Median	3rd quartile	Longest duration
AO:A	3	1	1	4	91	91
AO:B	29	1	3	4	6	73
AO:C	18	2	3	4	5	20
Impact fractures	6	4	5	8	11	17
Combined fractures	4	2	3	5	9	9
Total	60	1	3	4	8	91

SUMMARY

In this chapter the operative treatment of 343 patients with 345 ankle fractures is described.

I. The operations were performed according to the AO (ASIF) principles, and the AO instrumentarium was used in all cases.

II. Thirty-seven per cent of the fractures were operated on within eight hours after the injury. The main reason for delay beyond this time in other cases was soft tissue swelling or skin damage.

III. Displaced fractures were temporarily reduced as soon as possible after admission of the patient and 21 of these were temporarily fixed by means of longitudinal calcaneotibial transfixation with a pair of Steinman pins.

IV. A suprasyndesmotic screw was used in 72 per cent of all cases with syndesmotic lesions (40 % of type B and 80 % of type C fractures). In most cases the screw was threaded in the fibula and 79 per cent of the screws passed through both cortical layers in the tibia.

V. The median duration of postoperative plaster immobilization was six weeks in the case of dislocation fractures and eight weeks for impact fractures. Ten patients received a PTB splint instead of plaster.

VI. The suprasyndesmotic screw was removed nine weeks (median value) after operation, whereafter full weight-bearing without external immobilization was generally allowed.

VII. The 345 surgically treated ankle fractures together required 4,232 bed-days in connection with the operation, corresponding to an average of 3.5 hospital beds for this type of emergency fracture surgery. If the secondary in-patient care is included, this figure rises to 4.0 which corresponds to 2.5 hospital beds per 100,000 inhabitants.

EARLY RESULTS

Reduction and fixation

In 310 cases (90 %) the reduction was reported by the surgeon to be "exact". Of the remaining 35 fractures two were of type A, 17 of type B, six of type C, and 10 were impact fractures. Of the 345 internal fixations, 296 (86 %) were judged to be sufficiently rigid for early joint exercises. This meant that active ankle exercises, without weight-bearing, were permitted on the second to the fifth day postoperatively. The other 47 internal fixations were considered by the surgeon to be not stable enough for early exercises. These were three type A fractures, 24 type B and nine type C, all of which had a high grade according to the Lauge Hansen classification. Eleven of the 17 impact fractures completed this group.

Comparison with other materials

Although there is now wide agreement concerning the importance of exact anatomical reduction, only a few authors have reported on the extent to which this has been achieved.

In Willenegger's series (1961) of 113 fractures, 35 (31 %) were not accurately reduced. The total series was treated during the earliest stage of development of the AO technique and included, for example, fibular fractures fixed with a Rush pin. Cedell (1967), who did not use the AO method, reported "anatomical" reduction in 68.2 % of his material of 406 SE fractures of grades II, III and IV. Brodie & Denham (1974) achieved "accurate reduction" in 86 %; the AO method was not used. Weber (1972) reported nine cases of postoperative displacement among 160 fractures (6 %). Pankarter (1977) stated that "technical faults" occurred in 13.5 % of a series of 140 patients.

The discrepancies in the reported proportions of successful reduction results may partly be due to differences in the evaluation of "anatomical" reduction (cf. Chapter IX), but they may also reflect the increased demands placed on the surgeon and the improvements in the operation technique during the last two decades.

Wound healing

The operation wound healed primarily in 90 % (306/340). There were eight cases of deep infection, corresponding to an infection frequency of 2.3 % in the whole material. Among the 327 closed, uncomplicated dislocation fractures there was no septic arthritis and the frequency of infection was 1.8 %. Necrosis of the wound margin without secondary infection occurred in 10 cases (2.9 %) (Table VI:1).

Table VI:1 WOUND COMPLICATIONS
Surgically treated ankle fractures (n = 340).

Type of fracture	Slight rubor and swelling	Wound margin necrosis	Purulent wound infection	Deep joint infection and septic arthritis
AO:A	1	1		
AO:B	11	7	4	
AO:C	3	1	2	
Impact fractures		1		2
Total	15	10	6	2

One of the infected patients, an alcoholic with a type B fracture,also sustained a pressure sore from the plaster, with skin necrosis over the head of the fibula, two weeks after the operation.

Comparison with other series

Results concerning wound healing in some series in which the AO method was not used are given in Table VI:2. In several series operated on by the AO method the frequency of infection tended to be lower than in series operated on by earlier techniques. Table VI:3.

Secondary operations

Twenty-one fractures underwent reoperation. Secondary operation because of infection was performed in five cases. In nine fractures a further operation was necessitated by a technical fault at the primary internal fixation. Arthrodesis was undertaken at an early stage in two impact fractures. In one case a bone graft was applied to the distal end of the tibia two months after the injury. In another case an amputation neuroma in the superficial peroneal nerve was suspected and the operation scar was explored, but no definite neuroma was found.

Table VI:2 WOUND HEALING DISTURBANCES. OTHER METHODS

	Wound infections			Osteo-myelitis or sepsis	Wound margin necro-sis
	Superficial	Deep	Superficial + deep		
Vasli (1957)			2.2 %	0.5 %	19.5 %
Burwell & Charnley (1965) n =135	6 %	0.7 %	6.7 %	0.7 %	
Cedell (1967) n=417			2.6 %		2.2 %
Solonen & Lauttamus (1968) n=350			0.9 %		
Brodie & Denham (1974) n=298			2.7 %		

Table VI:3 WOUND HEALING DISTURBANCES. AO METHODS

	Wound infections			Wound margin necro-sis
	Superficial	Deep	Superficial + deep	
Boettcher, Moschinski & Kovacicek (1970) n=72			0 %	18 %
Weber (1972) n=160			0.6 %	
Müller (1975) n=198		0.5 %	0.5 %	4 %
Fasol (1976) n=55			9 %	
Pankarter (1977) n=140		0.7 %	0.7 %	2.9 %
Decker (1977) n=164			3.1 %	
Lindsjö (1980) (dislocation fractures) n=305			1.8 %	2.9 %

Table VI:4 SECONDARY OPERATIONS ON ANKLE FRACTURES (n=21).

Sex	Age, years	Type of fracture	Secondary operation
I. Infected cases			
m	32	AO:A	Necrotic wound margin and infection. Revision and flush drainage 9 days postoperatively.
f	32	AO:B	Infection. Evacuation of abscess and removal of internal fixation material 4 months postoperatively.
m	44	AO:B	Infection. Removal of internal fixation material 10 weeks postoperatively.
f	58	Impact	Deep infection with arthritis. Protracted postoperative course with several revisions and further operations.
m	68	Impact	Infected . Secondary operation with external fixation (Hoffman) + arthrodesis + flush drainage 3 months postoperatively. Below-knee amputation 2 months later.
II. Technical faults			
m	52	AO:A	A small staple, used for ligament fixation on the talus, was removed 6 weeks postoperatively because of its position.
m	72	AO:A	Attempts at re-reduction 2 and 3 weeks postoperatively.
f	41	AO:B	Suprasyndesmotic screw wrongly placed. Secondary operation the same day.
f	61	AO:B	Primary internal fixation unsatisfactory. Secondary operation 4 weeks postoperatively.
f	48	AO:B	Malleolar screw in the fibula too long; removed 7 weeks postoperatively.
f	38	AO:B	Suprasyndesmotic screw re-positioned 8 days postoperatively.
m	31	AO:B	Screw in the lateral malleolus too long; removed 3 months postoperatively because of local symptoms from the peroneal tendons.
m	61	AO:B	Pseudarthrosis in the medial malleolus and unreduced posterior fragment. Secondary operation 8 months postoperatively.
f	47	AO:C	1) Posterior fragment re-reduced 8 days postoperatively. 2) Plate fixation and bone grafting of fibular pseudarthrosis 18 months postoperatively.

Table VI:4 cont.

Sex	Age, years	Type of fracture	Secondary operation
III. Early arthrodesis			
m	48	AO:B	Primarily open fracture with bone defect. First fixation with a Hoffman appliance. Arthrodesis 6 weeks postoperatively.
m	23	Impact	Ugly comminuted fracture. Arthrodesis of the talocrural joint 3 weeks postoperatively.
IV. Others			
f	28	AO:B	Exploration of operation scar because of suspected neuroma.
f	77	AO:B	Got out of bed and fell on day of operation. Re-fracture. Internal fixation again performed on the same day.
m	29	AO:C	Bone graft to distal end of tibia 2 months postoperatively.
f	56	Impact	Loosening of internal fixation appliance, which was removed 27 weeks postoperatively.

Bone healing

Most of the fractures were healed after 12 weeks. In cases where no signs of fracture healing in the form of external callus or disappearance of the fracture line were observed after 12 weeks, the bone healing was noted as delayed. Such delayed bone healing occurred in 16 cases (4.6 %), namely, in two type A fractures, nine type B, four type C and one impact fracture. In two cases (0.6 %) pseudarthrosis developed - in the medial malleolus in one type B fracture and in the fibula in one type C. The first case must be regarded as a technical fault - the fracture in the medial malleolus was not operated on according to the AO principles but fixed only with two pins. The fixation of the fibular fracture was also incomplete - a cerclage wire was used instead of a plate and screws. The non-unions were diagnosed after

six and 14 months, respectively. Both patients underwent secondary internal fixation, and in the case of the fibular pseudarthrosis this was combined with bone grafting. Table VI:4.

Clinical healing

As an expression of the clinical healing of the fractures, the length of time from the operation until the patient was allowed full weight-bearing without external support, is used. In male patients the median period for dislocation fractures was 10 weeks and for impact fractures 11 weeks. In female patients the median periods for dislocation fractures varied between 8 and 10 weeks, and for impact fractures the median value was 16 weeks. Table VI:5.

Table VI:5 CLINICAL HEALING
Time, weeks, from operation till full weight-bearing without external support. Operated ankle fractures (n=335).

Type of fracture	Sex	Shortest duration	1st quartile	Median	3rd quartile	Longest duration
AO:A	M (n=14)	6	7	10	12	18
	F (n=11)	5	7	8	10	12
AO:B	M (n=115)	4	8	10	12	24
	F (n=109)	5	9	10	12	24
AO:C	M (n=38)	5	9	10	12	29
	F (n=27)	4	10	10	15	21
Impact fractures	M (n=7)	7	9	11	17	27
	F (n=8)	11	13	16	22	27
Combined fractures	M (n=3)	10	10	16	24	24
	F (n=3)	19	19	28	30	30

Primary sick-leave periods

Information concerning the length of time on the sick-list was available for 320 patients. The median period for type A fractures was 13 weeks (3 months), for type B 16 weeks (3.7 months), for type C 18 weeks (4.2 months), for impact fractures 28 weeks (6.5 months) and for combined fractures 25 weeks (5.8 months). Table VI:6 The total of primary sick-leave periods was 6,656 weeks.

Table VI:6 PRIMARY SICK-LEAVE PERIODS (WEEKS).
Surgically treated ankle fractures (n=320).

	Shortest duration	1st quartile	Median	3rd quartile	Longest duration
AO:A	6	12	13	20	110
AO:B	1	12	16	22	140
AO:C	4	13	18	22	155
Impact fractures	11	15	28	39	46
Combined fractures	20	24	25	39	41

Comparison with other materials

Information on the length of sick-leave necessitated by ankle fractures is very sparse in the literature.

Solonen & Lauttamus (1968) found shorter sick-leave periods for conservatively treated cases (4.3 months) than for surgically treated ones (4.5 months). In the material of Brodie & Denham (1974) 27 of the patients were retired, and among the other 271 the sick-leave period was about 3.5 months. In these two series the AO principles were not applied in the operative treatment. Cedell (1967) reported sick-leave periods for 355 SE fractures in a Swedish series. His mean values do not differ from those of the present material, but for fractures with a higher grade number in the Lauge Hansen classification the sick-leave periods are somewhat longer in Cedell's series. Table VI:7.

Table VI:7 SICK-LEAVE PERIODS FOR SUPINATION-EVERSION FRACTURES
Weeks. Comparison between Cedell (1967) and Lindsjö (1980).

	SE I	SE II	SE III	SE IV
Cedell (1967)	10.1 ± 4.2 (n=9)	13.5 ± 4.0 (n=119)	14.1 ± 5.4 (n=21)	20.2 ± 4.2 (n=198)
Cedell (1967), including extreme values		14.0 (n=122)	19.0 (n=24)	20.5 (n=200)
Lindsjö (1980), including extreme values	- (n=2)	14,6 ± 15.6 (n=66)	16.2 ± 12.8 (n=23)	19.4 ± 25.8 (n=67)

Weber (1972) reported that the average sick-leave period for type A fractures was 6-8 weeks, for type B about 12 weeks and for type C about 14 weeks - somewhat shorter than in the present series.

Differences in sick-leave periods between different materials should be interpreted with great caution. The social conditions and health insurance situation of the patients and the general attitude of the community towards absence from work probably play a more decisive role than the methods of fracture surgery employed.

Secondary sick leave

The duration of further sick leave, often connected with removal of the internal fixation material, is reported for 164 patients in Table VI:8.

Table VI:8 THE DURATION OF SECONDARY SICK-LEAVE. (WEEKS). Followed up, surgically treated ankles (n=164).

	No. of patients on sick-list	Shortest duration	1st quar-tile	Median	3rd quar-tile	Longest duration
AO:A	13	1	1	2	3	5
AO:B	106	1	1	2	3	400
AO:C	33	1	1	2	3	40
Impact fractures	7	2	3	5	9	12
Combined fractures	5	2	2	4	5	8
Total	164	1	1	2	3	4

The total secondary sick-leave period was 1,006 weeks. A few further patients may have undergone removal of the internal fixation material after the end of the investigation, and the above values are probably therefore slightly too low.

The combined primary and secondary sick-leave period was 7722 weeks, which divided among 343 patients amounts to 22.5 weeks per accident.

SUMMARY

In this chapter the primary results of operative treatment of the ankle fractures are reported and technical faults and early complications are described.

I. In the opinion of the surgeons the reduction was exact in 90 per cent of the surgically treated fractures, and 86 per cent of the internal fixations were considered sufficiently rigid for early joint exercise.

II. The operation wound healed primarily in 90 per cent of the cases. The frequency of infection in the whole material was 2.3 per cent and among the dislocation fractures 1.8 per cent. There were two cases of septic arthritis among the impact fractures and none among the dislocation fractures. Necrosis of the wound margin without secondary infection occurred in 2.9 per cent.

III. Twenty fractures underwent secondary operation because of technical faults, postoperative infection or bone healing disturbances. In two cases secondary arthrodesis was performed at an early stage.

IV. Most of the fractures healed within 12 weeks. Delayed bone healing (over 12 weeks) occurred in 4.6 per cent. Pseudarthrosis due to incorrectly performed internal fixation occurred in two cases (0.6 %).

V. The median length of time until the fractures were clinically healed (when full weight-bearing without external support was allowed) was in male patients ten weeks for dislocation fractures and 11 weeks for impact fractures. In female patients the corresponding periods were 8 - 10 weeks and 16 weeks, respectively.

VI. The mean duration of sick leave was 22.5 weeks per accident. The median sick-leave periods varied between 13 weeks for type A fractures and 28 weeks for impact fractures. No difference was found in this respect between the present material and a previously reported Swedish series (Cedell 1967).

THE FOLLOW-UP MATERIAL

Prospective study

The investigation was planned and performed as a prospective study of 345 ankle fractures treated operatively between February 1972 and June 1975. Of these, 327 fractures (95 %) were followed up. As two patients had bilateral fractures, fracture was used as the unit in the statistical calculation. The division of the fractures into different AO types is shown in Fig. VII:1 and Table VII:1. The table also gives the age and sex distribution.

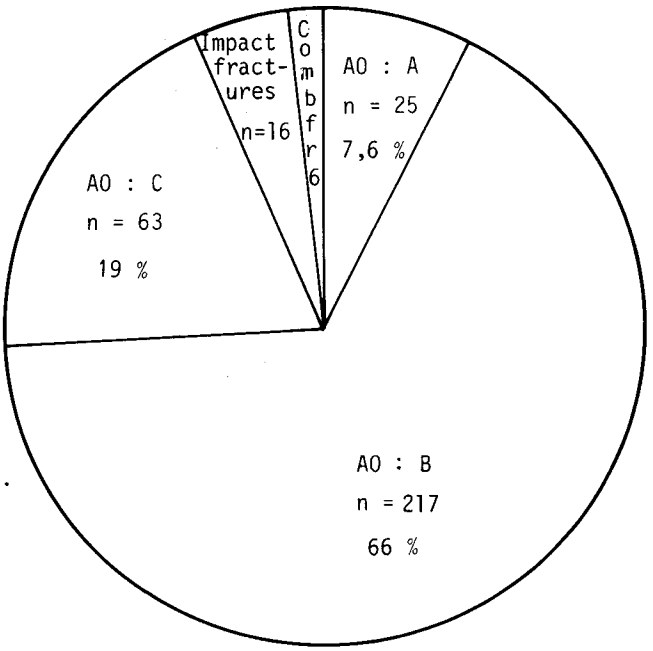


Figure VII:1. CLASSIFICATION OF THE 327 OPERATIVELY TREATED FOLLOWED-UP ANKLE FRACTURES (AO system).

Dropout

Seventeen patients could not be followed up. Ten had died before the follow-up, three were abroad and two refused further examinations.

Table VII:1 FOLLOWED-UP ANKLE FRACTURES

Weber's (AO) classification. Relation to age and sex.

Type of fracture	Age, yrs	15-24		25-34		35-44		45-54		55-64		65-74		75-85		Total		All
	Sex	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	
AO:A		5	4	1	1	4	1	2	0	2	2	1	1	0	1	15	10	25
AO:B		21	13	31	20	19	12	16	27	17	24	5	9	0	3	109	108	217
AO:C		6	4	10	7	7	4	2	2	9	8	0	2	2	0	36	27	63
Impact fractures		2	1	2	0	2	1	1	2	0	4	0	1	0	0	7	9	16
Combined fractures		2	0	1	1	0	1	0	1	0	0	0	0	0	0	3	3	6
Total		36	22	45	29	32	19	21	32	28	38	6	13	2	4	170	157	327

Table VII:2 PATIENTS WHO WERE NOT FOLLOWED UP (n=17)

Sex	Age at accident yrs	Fracture type	Early results Reduction	Rigid fixation	Wound healing	Bone healing within 12 weeks	Reason for no follow up
F	18	A	Exact	Yes	Primary	Yes	Refused
F	61	B	Exact	Yes	Primary	?	New injury same ankle operated on in another hospital
F	66	B	Exact	Yes	Primary	Yes	Refused (no residual symptoms)
F	58	C	Exact	Yes	?	?	Abroad
M	58	B	Exact	Yes	Primary	Yes	Dead
M	68	B	Exact	Yes	Skin necrosis	Yes	Dead
M	23	B	Exact	Yes	Primary	?	Abroad
M	44	B	Exact	Yes	?	?	Abroad
M	26	B	Exact	Yes	Primary	Yes	Dead
M	62	B	Exact	Yes	?	?	Dead
M	62	B	Not exact	No	Primary	Yes	Dead
M	46	B	Exact	Yes	Primary	Yes	Dead
M	72	C	Exact	Yes	Primary	Yes	Dead
M	38	C	Exact	Yes	Primary	Yes	Dead
M	19	C	Exact	Yes	Primary	Yes	Dead
M	64	Impact	Not exact	No	Primary	Yes	Dead
M	68	Impact	Not exact	Yes	Infection	No	Amputation (see Table VI:4)

One patient had sustained a further fracture in the same ankle in the interval and had been operated on at another hospital. One patient had undergone a below-knee amputation. The primary results for these patients are reported in Table VII:2.

Observation periods

One hundred and sixty-two fractures were followed up on two occasions and two fractures on three occasions. In these cases the first follow-up took place about six months after the fracture and the subsequent examinations were performed to lengthen the observation periods. In the analysis of the results the latest follow-up was used as a basis.

One female patient, who was followed up 24 weeks after the operation, had died before the second follow-up and was thus excluded from the follow-up series. (Her fracture was type B; at the time of follow-up there was some medial incongruency but no arthritis and the clinical result was excellent.)

No patient was followed for less than one year. Only two more patients were followed for a shorter period than 1.5 years. The mean observation period was 3.7 years (SD = 1.2 years) and the median 3.5 years. The longest was about six years. Figure VII:2.

Method

When the injured patients arrived at the hospital the ordinary medical record was complemented with a so called computer record for recording of the nature of the injury, case history, the type of fracture, the state of the fracture area and operation data. This record followed the patient through the period of treatment. In the computer record there was also space for noting the findings at follow-up.

At follow-up examination, the patients, on the basis of a previously sent questionnaire, were interviewed concerning any persistent symptoms from the surgically treated ankle. Information concerning the following was noted: Pain on walking on different kinds of ground, the need for walking aids, any reduction of the capacity to work or carry out other occupations, any reduction of sports, exercise or leisure activities, limp, the ability to manage stairs, subjective stiffness in the fractured ankle, subjective stiffness of toes, and subjectively experienced swelling (all day or only in the afternoon and evening). The patients were also questioned about their health

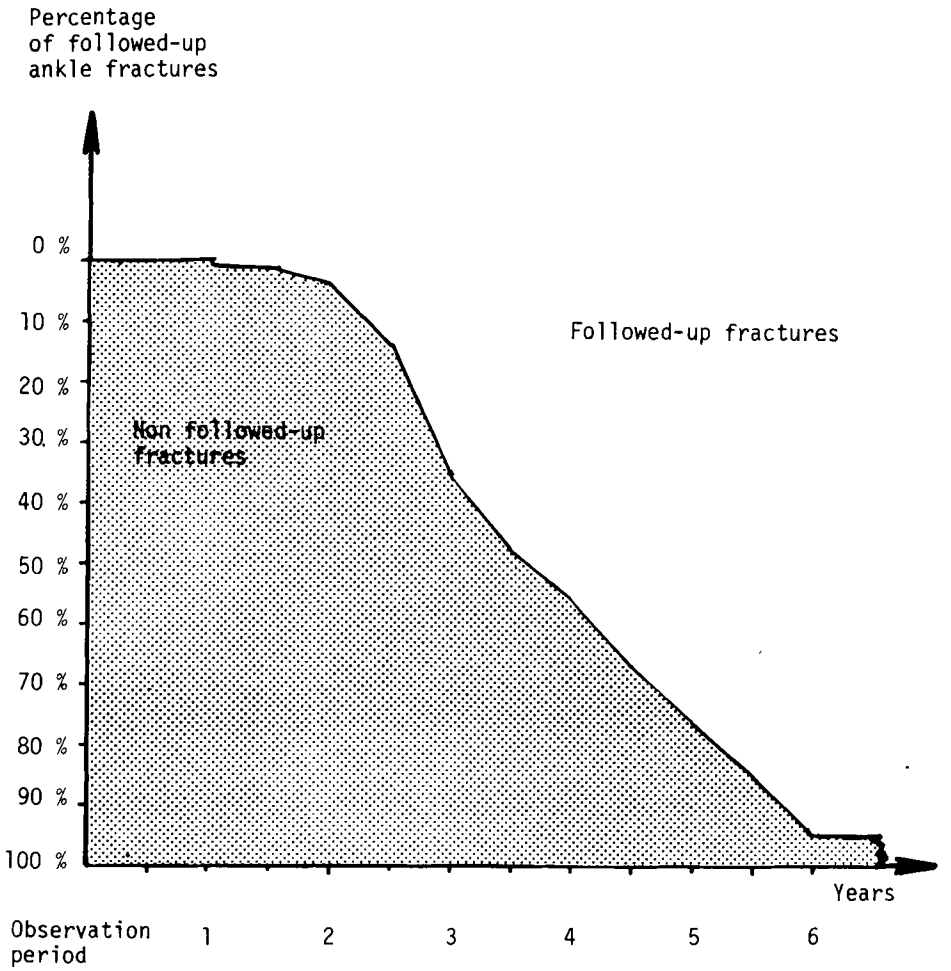


Figure VII:2 FOLLOWED-UP OPERATIVELY TREATED ANKLE FRACTURES
Cumulative frequency of latest follow-up examination.

insurance situation at the time of the injury and also concerning any symptoms from the ankle before the fracture, due to disease or previous injury.

At the clinical examination the ability to walk was studied in the examination room and in corridors. Visible swelling, local tenderness and its location, and any symptoms from the operation scar were noted. The calf and ankle circumferences were measured on the injured and uninjured side. Any restriction of toe movement and occurrence of so called "short foot" as a sign of contracture of the muscles in the deep posterior compartment were also noted. The stability of the ankle joint was assessed and the presence or absence of the drawer phenomenon ascertained by manual examination. Examination for increased or decreased pes planus was performed with the patient standing both with the legs straight and with the knees bent on a podometer. The patient did twenty heel-raising movements while standing first on one leg and then on the other, so that the condition and function of the calf muscles could be roughly appraised. The knee and hip joints were examined in order to exclude disorders or limited movements in these joints as the cause of any symptoms.

The mobility of the talocrural joint was recorded as "loaded dorsal extension" and "loaded plantar flexion" (Lindsjö 1979). These were measured with the patient standing with one foot on the floor and the examined foot on a stool about 30 cm high. The patient then leaned forward with the greater part of the body weight on the examined foot. Dorsal extension, with the sole of the foot flat on the stool, was measured with a protractor. Figure VII:3. For measuring plantar flexion the patient was asked to lift the heel so that with the examined foot she stood on her toes on the stool, still with the knee flexed and with the greater part of the body weight resting on the examined foot.

The mobility of the talocrural joint in the injured and uninjured foot was also examined with the patient both sitting and recumbent. Any equinus deformity was noted. The mobility of subtalar joints, and passive pronation and supination in both feet, were assessed manually with the patient recumbent.

At follow-up radiographs of both ankles were taken in standard projections, namely frontal, frontal with 20 ^{o} inward rotation, lateral and lateral with outward rotation (see Chapter VIII). Two patients refused radiographic examination.

Special conditions, e.g., multiple injuries, or a new injury or disease occurring after the accident, were noted. The duration of

sick-leave was recorded. In cases where information on the length of the sick-leave period was not available from the medical record or from the patient, this was obtained from the social insurance office concerned.

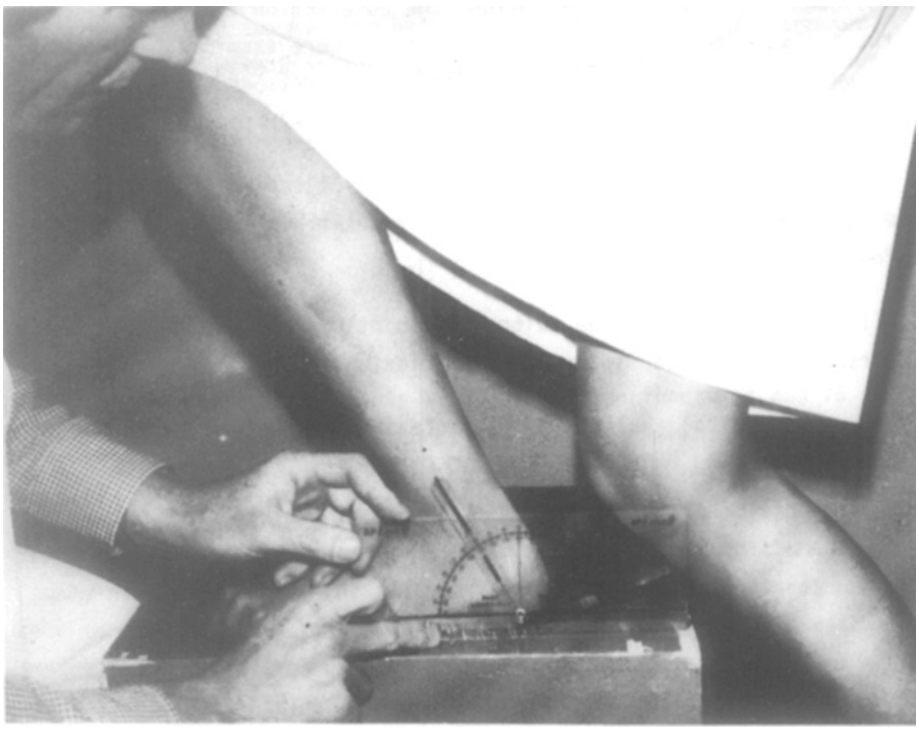


Figure VII:3 MEASUREMENT OF LOADED DORSAL EXTENSION

The majority of the follow-up examinations were performed at the out-patient clinic of the Department of Orthopaedic Surgery of the University Hospital, Uppsala. About 10 patients were examined by me at other hospitals and three patients were examined in their homes. Other orthopaedic surgeons participated in 30 of the first follow-up examinations. Of these patients all except one, who died in the interval, were later examined by the author. Thus all followed-up patients except one were examined by me on at least one occasion.

Data from the patient's medical record, the computer record, the record of the radiographic examination, and the social insurance office were entered on a punch form and processed in a computer at the Uppsala Computer Centre.

SUMMARY

In this chapter the follow-up material, the general scheme of the examinations and the examination techniques are described.

I Of the 345 surgically treated ankle fractures, 327 (95 %) were followed up. With a few exceptions the observation times were between two and six years. All patients except one were examined by the author. Seventeen patients were not followed up. The reasons for this and the primary results of treatment in these cases are reported.

II. At follow-up subjective symptoms and objective findings at examination were noted and both ankles were examined radiographically in four standard projections.

III. The mobility of the talocrural joint was recorded as loaded dorsal extension and loaded plantar flexion.

IV. Statistical analysis of the material was performed with the aid of a computer.

Chapter VIII

CLINICAL RESULTS

Three hundred and twenty-five patients with 327 operatively treated ankle fractures were examined one to six years after the injury (see previous chapter).

In patients who had a follow-up examination on two occasions, both the subjective and objective results were better after the longer observation period. All results reported below are therefore from the latest follow-up.

Functional ability

Ninety per cent of the patients with dislocation fractures and 75 per cent of those with impact fractures had the same work or occupation at follow up as before the injury. Sports and other physical activities were unchanged in 82 per cent of the patients with dislocation fractures and in only 44 per cent of those with impact fractures. Eighty-nine per cent of the patients with dislocation fractures were able to walk normally, while only 56 per cent of the patients with impact fractures walked without any limp. Eighty-five per cent of the patients with dislocation fractures managed stairs easily, while only 50 per cent of the impact fracture patients had this ability. There was no significant difference in working capacity, sports capacity, walking capacity or ability to manage stairs between male and female patients. Table VIII:1.

Ten of the patients with dislocation fractures (3 %) needed some kind of aid, for example a walking stick, orthopaedic shoes or an elastic stocking; the corresponding figure for the impact fracture patients was 25 per cent. Of the six patients with combined fractures none had changed to lighter work, four had reduced their sports activities, two walked with a slight limp and had some difficulties in managing stairs.

Subjective symptoms

Seventy-eight per cent of the patients with dislocation fractures were completely free from pain during walking on different types of

Table VIII:1 FUNCTIONAL ABILITY AT TIME OF FOLLOW-UP
Operatively treated ankle fractures.

		Dislocation fractures M (n=160)	F (n=145)	Impact fractures M (n=7)	F (n=9)
Working or occupational capacity	Maintained	93 %	88 %	5/7	5/9
	Reduced	4 %	8 %	2/7	2/9
	None	3 %	4 %		
Sports and exercises capacity	Maintained	86 %	78 %	3/7	2/9
	Reduced	11 %	18 %	4/7	2/9
	None	3 %	4 %		3/9
Gait	Maintained	89 %	88 %	6/7	3/9
	Slight limp	9 %	11 %	1/7	5/9
	Heavy, disabling limp	2 %	1 %		1/9
Ability to manage stairs	Maintained	88 %	80 %	5/7	3/9
	Reduced	11 %	20 %	2/7	6/9
	None	1 %			

Table VIII:2 PAIN DURING WALKING AT TIME OF FOLLOW-UP
Operatively treated ankle fractures

	Dislocation fractures M (n=160)	F (n=145)	Impact fractures M (n=7)	F (n=9)
No pain	81 %	75 %	4/7	3/9
Pain while walking on rough ground	14 %	11 %	0	3/9
Pain while walking on flat ground out of doors	3 %	6 %	2/7	1/9
Pain while walking indoors	2 %	8 %	1/7	2/9

ground. There was no statistically significant difference between male and female patients with respect to pain during walking. Table VIII:2.

Four of the dislocation fracture patients and one patient with an impact fracture complained of aching during climatic changes. Four of the patients with dislocation fractures also complained of aching of the injured ankle when resting.

Sixty-four per cent of the dislocation fracture patients did not complain of any swelling or sensation of swelling in the injured ankle. Among those who complained of swelling sensations in the injured ankle there was a highly significantly greater proportion of women than men. Table VIII:3.

Table VIII:3 SUBJECTIVE SWELLING AT FOLLOW-UP
Operatively treated dislocation ankle fractures

	M (n=153)	F (n=142)
No swelling	76 %	50 %
Swelling only during afternoons	19 %	42 %
Constant swelling	5 %	8 %

There was also an almost significant difference between the frequencies of male and female patients with dislocation fractures who complained of a sensation of stiffness in the injured ankle. Table VIII:4.

Table VIII:4 SUBJECTIVE STIFFNESS AT FOLLOW-UP
Operatively treated dislocation ankle fractures

	M (n=153)	F (n=142)
Subjective stiffness in the ankle	22 %	34 %
Subjective stiffness in the toes	3 %	6 %

Of the patients with impact fractures 10/14 complained of sensations of swelling in the injured ankle and 11/14 of stiffness in the ankle. For the patients with combined fractures the corresponding figures were 3/6 and 3/6, respectively.

Objective findings

Swelling

On measurement with a tape measure there was no difference in calf or ankle circumference between the injured and uninjured leg in 77 per cent of the dislocation fractures. The corresponding figure for impact fractures was 50 per cent.

An increased calf circumference was observed in six of the dislocation fractures (2 %) and in one of the impact fractures. An increased ankle circumference was found in 61 (20 %) of the dislocation fractures and in five (31 %) of the impact fractures. Table VIII:5.

Post-thrombotic status

At follow-up a distinct post-thrombotic condition that was referable to the ankle injury was noted in two patients, both men. One of them was 55 years old at the time of the accident (type B fracture). He was given a PTB splint postoperatively and two weeks after the operation the whole of the lower leg became heavily swollen. He was subsequently mobilized without the PTB splint. At the follow-up examination he still had some swelling and had reduced his sports and other physical activities.

The other patient, with a type C injury, was aged 31 at the time of accident. After his discharge from hospital, general swelling of the lower leg developed without any other subjective symptoms. At follow-up the ankle circumference was increased by 1 cm but the patient had no discomfort and stated that his ability to work and carry out sports and other physical activities was unrestricted.

Atrophy

A decrease in calf circumference was noted in association with 20 per cent of the dislocation fractures and 44 per cent of the impact fractures. The majority of the patients with slight atrophy of the calf muscles had no subjective symptoms from this condition and neither did they have any functional impairment.

A decreased ankle circumference on the injured side was observed in only two cases. Table VIII:5.

Instability

The majority of the ankle joints (98 %) displayed no signs of instability.

Table VIII:5 CHANGES IN CALF AND ANKLE CIRCUMFERENCE
Operatively treated, followed-up ankle fractures

		Calf circumference Increased by (cm)			Reduced by (cm)					Ankle circumference Increased by (cm)			Reduced by (cm)
		1	2	3	1	2	3	4	5	1	2	3	1
AO:A	M (n=15)	0	0	0	3	0	0	0	1	0	0	0	1
	F (n=10)	0	0	0	1	0	1	0	0	2	0	0	0
AO:B	M (n=109)	0	0	1	8	4	2	1	0	12	1	0	0
	F (n=108)	1	0	0	19	8	0	0	0	18	6	0	1
AO:C	M (n=36)	1	1	1	5	1	0	0	0	9	1	0	0
	F (n=27)	1	0	0	6	3	0	0	0	9	3	0	0
Impact fractures	M (n=7)	0	0	0	3	2	0	0	0	1	0	1	0
	F (n=9)	1	0	0	0	2	0	0	0	1	2	0	0
Combined fractures	M (n=3)	0	0	0	1	0	0	0	0	0	0	0	0
	F (n=3)	0	0	0	1	0	0	0	0	0	0	0	0
Total		4	1	2	47	20	3	1	1	52	13	1	2

In three cases (one type A fracture and two type B) moderate mediolateral instability - "play" in the ankle mortise - was noted. In one of these patients a drawer test was also positive, a finding which was made in four patients (one type A fracture, two type B and one type C).

Restriction of movement

In assessment of the range of ankle movement, the uninjured ankle served as a control. Differences in mobility were grouped in classes of 10^{o} each.

Talocrural joint

Loaded dorsal extension was unrestricted in 59 per cent of the patients with dislocation fractures and was restricted by up to 10^{o} in 31 per cent. There was a highly significant difference between male and female patients in the frequency and amount of restriction of loaded dorsal extension. Table VIII:6.

Table VIII:6 RESTRICTION OF LOADED DORSAL EXTENSION
Operatively treated, followed-up dislocation ankle fractures

	M (n=151)	F (n=142)
No restriction	68 %	53 %
$0^{o} \leqq 10^{o}$	29 %	40 %
$10^{o} \leqq 20^{o}$	2 %	11 %
$20^{o} \leqq 30^{o}$	1 %	2 %

Among the patients with impact fractures, loaded dorsal extension was restricted by up to 10^{o} in 38 per cent, up to 20^{o} in 23 per cent and between 20 and 30^{o} in 15 per cent. Of the six patients with combined fractures it was restricted by up to 10^{o} in two patients, while the other four patients were normal in this respect.

A normal capacity for loaded plantar flexion was exhibited by 81 per cent of the patients injured by dislocation; 17 per cent showed restriction by up to 10^{o} and 2 per cent between 10 and 20^{o}. There was no significant differerence in the frequency of restricted movement between the male and female patients. Table VIII:7.

Table VIII:7 RESTRICTION OF LOADED PLANTAR FLEXION

Operatively treated, followed-up dislocation ankle fractures.

	M (n=150)	F (n=142)
No restriction	85 %	78 %
$0^0 \leqq 10^0$	14 %	20 %
$10^0 \leqq 20^0$	1 %	2 %

In the patients with impact fractures loaded plantar flexion was restricted up to 10^0 in 30 per cent, between 10 and 20^0 in 15 per cent and between 20 and 30^0 in 8 per cent. None of the patients with combined fractures had any restriction of the capacity for loaded plantar flexion.

Equinus deformity

Equinus deformity directly referable tc the ankle injury was seen in five patients. Equinus of up to 10^0 was noted for two type B fractures, one type C and one impact fracture. One patient with a type B fracture had an equinus deformity of 20 degrees.

Subtalar joint

The capacity for pronation and supination in the injured foot was normal in 81 per cent of the dislocation fractures. There was a significant difference between the number of male and female patients with restricted pro- and supination. Table VIII:8.

Table VIII:8 RESTRICTION OF PRONATION AND SUPINATION

Operatively treated, followed-up ankle fractures

	M (n=153)	F (n=144)
No restriction	87 %	75 %
0^0 - 10^0	10 %	17 %
10^0 - 20^0	3 %	8 %

Of the patients with impact fractures 27 per cent had a restriction of up to 10^0, 9 per cent between 10 and 20^0, and 27 per cent between 20 and 30^0. One of the patients with a combined fracture had a restriction of up to 10^0.

The foot

The toe movements were restricted in nine cases: four type B, two type C, two impact fractures and one combined fracture.

So called "short foot", i.e. excavation and shortening as a result of damage to calf muscles (Karlström, Lönnerholm & Olerud 1975), occurred in one case, an impact fracture in a patient with multiple injuries. Three patients, one with a type B fracture and two with impact fractures exhibited pes plano-valgus of some degree; so also did another patient with a type C fracture, but only during knee bending.

Comparison between subjective symptoms and objective findings

Of 128 patients who felt their ankle was swollen, only 66 (52 %) showed objective signs of swelling about the ankle joint.

The reverse was found with respect to post-traumatic stiffness. Thus, only 96 patients stated that the ankle felt stiff, whereas restricted dorsal extension was found in 135 patients. Only 36 (33 %) of the 108 patients with reduction of dorsal extension by up to 10^{o} reported a sensation of stiffness of the ankle joint. Two-thirds of the patients with reduction of dorsal extension by 10 to 20^{o} and all of those with 30^{o} reduction felt that the ankle was stiffer than the uninjured one.

In 33 of the patients who stated that the ankle felt stiff there was no measurable limitation of movement.

Thus with regard to swelling and stiffness the patients' subjective symptoms were poorly correlated to the objective findings at the follow-up examination. A slight restriction of dorsal extension by up to 10^{o} compared with the uninjured ankle joint was associated with subjective symptoms in only one-third of the cases.

Tenderness on palpation

All the 24 patients who reported tenderness on palpation over the malleoli had healed fractures, and among the 19 patients who reported tenderness over ligamentous structures a clinically unstable ankle was found in only four. Of the seven patients with some degree of clinical instability only four had tenderness over ligaments. Thus tenderness on palpation over bony and ligamentous structures was poorly related to persistent lesions of bones and ligaments.

In 70 per cent of the 21 patients who complained of tenderness over the site of the internal fixation appliances, such appliances were

still present in the ankle. There was no preponderance of any particular type of internal fixation appliance among these patients.

Tenderness over the operation scar or joint space was noted in five cases, hyperaesthesia at the scar in nine and reduced sensitivity distal to the scar in seven. Three scars were ugly and disfiguring.

The tenderness on palpation in previously injured ankles probably derives mainly from the skin and subcutaneous structures.

Evaluation from combined subjective symptoms and examination findings

The patients were classified into six groups in which the subjective symptoms and objective findings at follow-up were combined, and implying a score of 0 to 5, as follows:

0 No subjective symptoms or objective signs of post-traumatic pathological conditions. On clinical examination, no difference between the injured and uninjured ankles. Full ability to work and carry out leisure activities. "Restitutio ad integrum".

1 No subjective symptoms or complaints. On examination, compared with the uninjured ankle, there is a difference of no clinical importance. A maximum difference of 10^{0} in the range of movement of the talocrural joint. Full ability to work and carry out leisure activities.

2 Slight, intermittent symptoms but these do not affect the ability to work or to carry out sports and other physical activities.

3 Fully able to work, but sports and other physical activities are limited compared with the pre-injury period.

4 Constant subjective symptoms. Reduced ability to work.

5 Disabled, receiving a pension on account of the injury.

In the following the clinical results of the treatment in groups "0" and "1" are designated "excellent", in group "2" "good", in group "3" "acceptable" and in groups "4" and "5" combined, "poor".

In assigning patients to groups "2" to "5" the functional history was decisive. These groups include a small number of patients in whom the objective findings at follow-up corresponded to group "0" or "1", but who had subjective symptoms or a reduced functional ability which led to placement in group "2", "3" "4" or "5".

With the above classification, the clinical results were as shown in Table VIII:8.

Table VIII:8. CLINICAL RESULTS
Operatively treated, followed-up ankle fractures (n=327)

	Fracture type: AO:A	AO:B	AO:C	Impact fractures	Combined shaft & ankle fractures	All types
	%	%	%	%		%
Excellent	44	59	55	19	1/6	57
Good	20	24	29	19	1/6	25
Acceptable	20	7	6	19	3/6	8
Poor	16	9	10	43	1/6	10

Compare also Tables VIII:9 and VIII:10 and Figures VIII:1 and VIII:2.

Table VIII:10 CLINICAL RESULTS
Impact fractures (n=16)

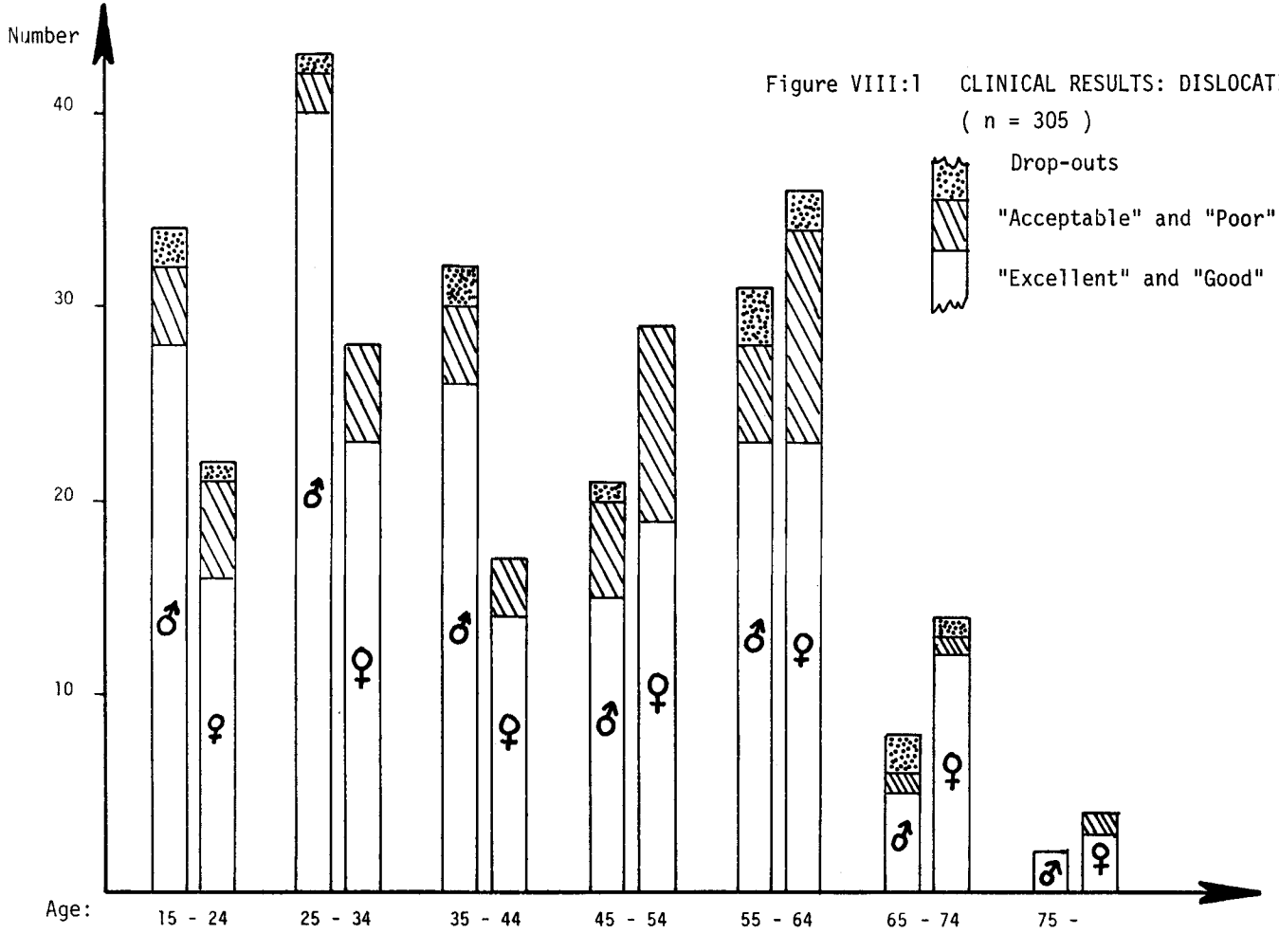
		M	F	M + F	%
Excellent	"0"	0	0	0	0
	"1"	2	1	3	19
Good	"2"	1	2	3	19
Acceptable	"3"	2	1	3	19
Poor	"4"	2	4	6	37
	"5"	0	1	1	6
Total		7	9	16	100

TABLE VIII:9 CLINICAL RESULTS

Dislocation fractures (n=305). Weber's (AO) classification

		AO:A (n=25) Number		%	AO:B (n=217) Number		%	AO:C (n=63) Number		%	Total (305) Number			%
		M	F		M	F		M	F		M	F	all	
Excellent	"0"	4	3	28	45	27	33	8	3	17	57	33	90	30
	"1"	2	2	16	29	26	26	16	8	38	47	36	83	27
Good	"2"	3	2	20	22	30	24	10	8	29	35	40	75	25
Acceptable	"3"	2	3	20	4	13	8	1	3	6	6	19	25	8
Poor	"4"	3	0	12	8	8	7	0	3	5	11	11	22	7
	"5"	1	0	4	1	4	2	1	2	5	3	6	9	3
Total		15	10	100	109	108	100	36	27	100	160	145	305	100

Figure VIII:1 CLINICAL RESULTS: DISLOCATION FRACTURES
(n = 305)



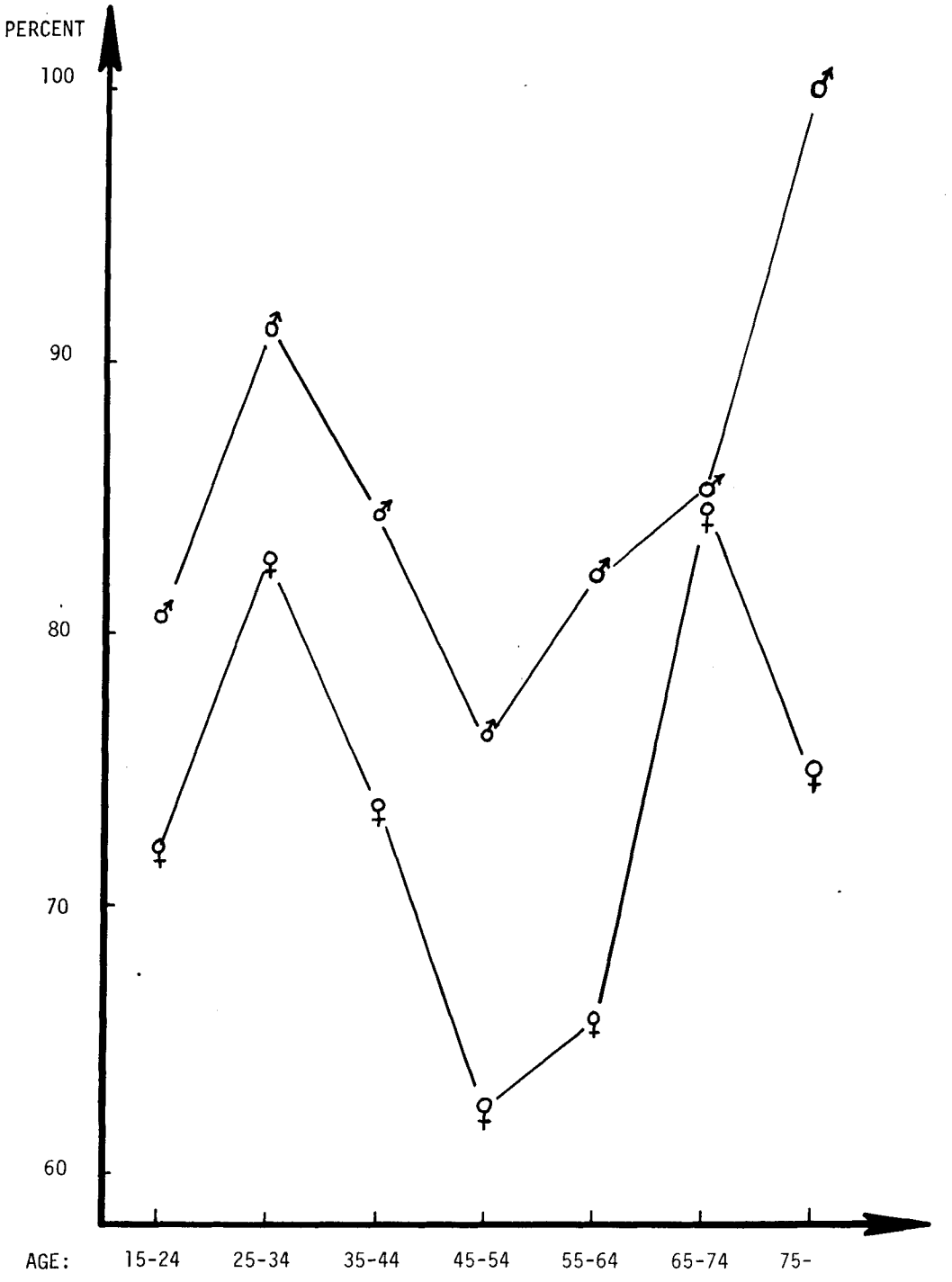


Figure VIII:2 PERCENTAGE OF "EXCELLENT" AND "GOOD" CLINICAL RESULTS

Male: ♂——♂ Female: ♀——♀

Factors that may influence the treatment results

In statistical calculations in this section of the study the material was divided into two result groups, namely "excellent to good", comprising 256 fractures, and "acceptable to poor", with 71 fractures.

The latter group included all patients with functional impairment of their ability to work or to carry out sports or other physical activities.

Sex and age

Of the male patients, 84 per cent attained "excellent to good" clinical results, and of the female patients only 72 per cent. This difference is significant. The results were poorer for women of all ages, except for the age group 65-74 years, where the proportion of "excellent to good" results was almost the same as in the men.

The poorest results were noted for women of ages 45-64 years. Among the men, the poorest results were found in the age group 45-54 years and in the group over 75 years old (Figure VIII:2).

Type of fracture

The best clinical results were attained by patients with fractures of types B and C, 83 and 84 per cent of whom, respectively, were classified as "excellent to good". The corresponding figure for type A fractures was lower, 64 per cent,and this difference is highly significant. Patients with impact fractures had considerably poorer results. Of these, only 38 per cent were designated "excellent to good". Table VIII:11.

The number of combined fractures in the material was too small to permit any conclusions to be drawn in this respect. Moreover, it is highly likely that in these cases the tibial shaft fracture would be the decisive factor for the final result - they are reported for the sake of completion.

Fracture type and sex

In the follow-up material no significant sex difference was found in the distribution of the different types of fractures. The clinical results, on the other hand, differed in men and women with the same type of fracture. Table VIII:11.

Concerning type A fractures, the male patients showed poorer

results than the female (56 and 70 %, respectively, in the "excellent to good" class). This difference is not significant. The results in women with fractures of types B and C were, on the contrary, almost significantly and significantly poorer, respectively, than those for men with these types of fractures.

Table VIII:11 CLINICAL RESULTS

Percentage of "excellent to good" results in different types of operatively treated ankle fractures (n=327)

Type of fracture	Men	Women	Both sexes
AO:A	56 %	70 %	62 %
AO:B	89 %	77 %	83 %
AO:C	94 %	70 %	84 %
Impact fractures	43 %	33 %	38 %
Combined fractures	(1/6)	(2/6)	(3/6)
All types	84 %	72 %	78 %

Posterior fragment

Among the patients with small non-articular surface bearing posterior fragments, the proportion of "excellent to good" results was just as high (81 %) as among those without a posterior fragment.

The results in the patients with large articular surface bearing posterior fragments were almost significantly poorer, and only 70 per cent of this group were in the "excellent to good" class.

An almost significant difference was also found between the result groups with respect to the occurrence of a posterior fragment that had not been accurately reduced. Of the 123 cases with a posterior fragment in the group with "excellent to good" results, only 16 (13 %) were not accurately reduced, whereas the corresponding figures in the "acceptable to poor" group were 14 out of 51 (27 %).

Talar injuries

Injuries to the talus occurred more commonly among the "excellent to good" cases (14 %) than among the "acceptable to poor" (8.5 %), suggesting the possibility that a number of talar injuries may have been overlooked among the cases with "acceptable to poor" results.

Ligamentous injuries

The deltoid and anterior fibulotalar ligaments were sutured to similar extents in the two result groups "excellent to good" and "acceptable to poor". Injuries to these ligaments do not appear to have been a discriminating factor of importance in this material.

Reduction results

The clinical results were highly significantly poorer in the dislocation fracture cases that had not been accurately reduced according to postoperative radiographic evaluation. Only 70 % of these cases were classified as "excellent to good", while the corresponding figure for the accurately reduced cases was 87 %. Table VIII:12.

Table VIII:12 DISTRIBUTION OF THE CLINICAL RESULTS ACCORDING TO THE ACCURACY OF THE FRACTURE REDUCTION.
Dislocation fractures, AO classification (n=305)

Clinical result		Completely reduced		Incompletely reduced	
		No.	%	No.	%
Excellent	"0"	78	36	12	14
"	"1"	57	26	26	30
Good	"2"	53	25	22	25
Acceptable	"3"	15	7	11	12
Poor	"4"	11	5	11	12
"	"5"	3	1	6	7
Total		217	100	88	100

Persistent postoperative radiographically demonstrable displacement occurred in 46 per cent of the "acceptable to poor" cases but in only 23 per cent of those that were "excellent to good". This difference is highly significant.

Other factors

The social situation of the patients did not appear to have impact on the result of the fracture treatment with respect to the variables recorded in this investigation. The type of work or occupation and the frequency of alcoholism, drug abuse or psychological disturbances were similarly distributed among patients with different clinical results.

Neither was there any difference in the frequency of different accident situations. There was some accumulation of "acceptable to poor" cases among patients who had fallen from a height, in keeping with the higher energy component of the trauma.

There was no significant difference with respect to the duration of postoperative exercises between patients with an "excellent to good" clinical result and those classified as "acceptable to poor".

Better clinical results were noted for the patients who were operated on after some delay, probably connected to different indications for emergency surgery (cf page 107).

AID analysis

With the aim of determining which factors had the greatest influence on the clinical result, the material was subjected to an AID analysis (Automatic Interaction Detective Programme) (Sonqvist et al. 1973, Andersen, Smedby, Eklund 1971). The factor which discriminated best between a good and poor result was the type of fracture, with the better results for fractures of types B and C, while type A, impact and combined fractures showed poorer results.

The second most decisive factor was the accuracy of the reduction and the third was the sex of the patients. Figure VIII:3.
The AID analysis was performed despite the fact that the total number of patients in the material was comparatively small (Sonqvist et al. 1973, Wold 1979). The result appears adequate and seems to be well in accordance with the findings at analysis of the individual variables. The result of this AID analysis should nonehteless be interpreted with caution - it should be regarded rather as a guide to where

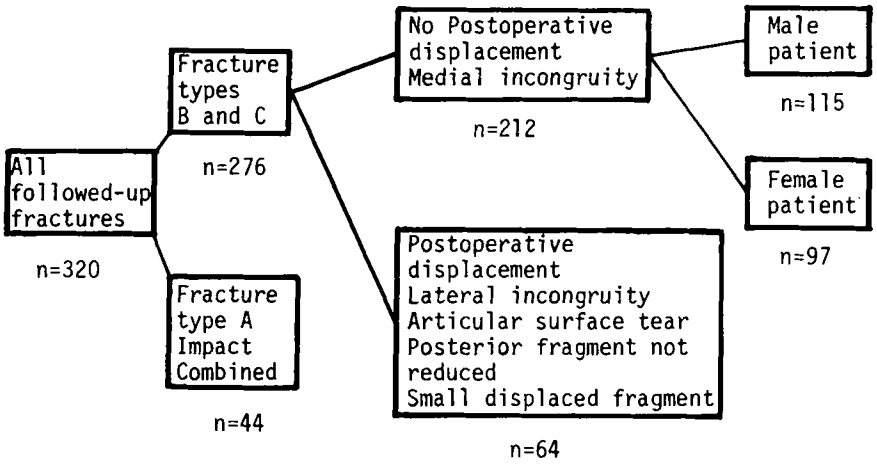


Figure VIII:3 FACTORS WHICH INFLUENCED THE CLINICAL RESULTS ACCORDING TO AID ANALYSIS.

correlation and structure in the material are to be sought.

The following non-ranked predictors were included in the test: The patient's sex and age. Any psychological disturbance, alcoholism or drug abuse. Cause of fracture. Soft tissue swelling on admission. Type of fracture. Fracture through lateral malleolus. Fracture through medial malleolus. Presence of posterior fragment. Syndesmotic injury. Injury to deltoid ligament. Timing of operation. Surgeons' evaluation of accuracy of reduction. Postoperative displacement according to radiographs. Posterior fragment reduced/not reduced. Posterior fragment fixed/not fixed. Arthritis at follow-up examination.

SUMMARY

This chapter describes the clinical results observed at follow-up examination of 327 of 345 operatively treated ankle fractures.

I. In patients who were followed up on two occasions, the clinical result was better after the longer observation period.

II. Among the patients with dislocation fractures, there was no change in the ability to work in 90 per cent, to carry out sports and other physical activities in 82 per cent, to walk in 89 per cent and to manage stairs in 85 per cent. The corresponding figures for the patients with impact fractures were: 75 per cent (working capacity), 44 per cent (sports), 56 per cent (gait), and 50 per cent (stairs).

III. Seventy-eight of the patients with dislocation fractures were completely free from pain during walking, 64 per cent were free from a sensation of swelling and 72 per cent had no sensation of stiffness of the ankle joint. The corresponding figures for the impact fracture patients were: 56 per cent (no pain), 29 per cent (no swelling) and 21 per cent (no stiffness).

IV. The capacity for dorsal extension was unimpaired in 59 per cent of the patients with dislocation fractures and restricted by up to 10^{o} in 31 per cent. A normal capacity for plantar flexion was shown by 81 per cent of the patients injured by dislocation, and 17 per cent were restricted by up to 10^{o}. Eighty-one per cent showed normal pro- and supination. Only 24 per cent of the patients with impact fractures had normal dorsal extension, and another 38 per cent were restricted by up to 10^{o}; 47 per cent had a normal capacity for plantar flexion and in 37 per cent pro- and supination were normal.

V. Concerning swelling and stiffness, the patient's subjective symptoms were poorly related to the objective findings. Only 67 per cent of the patients who felt that the ankle was swollen showed objective signs of ankle swelling. Limitation of dorsal extension of up to 10^{o} was associated with symptoms in only one-third of the patients.

VI. Persistent tenderness on palpation over the ligaments showed a poor correlation to ankle instability as a sign of a residual ligamentous lesion.

VII. Residual instability was present in 2 per cent, symtomatic thrombosis in 0.6 per cent, some degree of plano-valgus deformity in 1.3 per cent, and equinus deformity in 1.5 per cent.

VIII. When the subjective symptoms and objective findings were combined, the following clinical results were obtained:

	Excellent	Good	Acceptable	Poor
Dislocation fractures (n=305)	57 %	24 %	9 %	10 %
Impact fractures (n=16)	19 %	19 %	19 %	43 %
Combined shaft and ankle fractures (n=6)	1/6	1/6	3/6	1/6

IX. The male patients showed a significantly better result than the female ones in all age groups below 65 years. Of all patients, the smallest proportion of "excellent to good" results was found among middle-aged women 45 to 64 years old.

X. Concering the types of fractures in all patients, the results were best among men with dislocation fractures of types B and C, and poorest among patients with impact fractures.

XI. The clinical results were highly significantly poorer in patients with inaccurately reduced fractures than in those in whom the fractures were accurately reduced.

XII. AID analysis, undertaken to determine which factors might have influenced the clinical result, revealed that the most decisive factor in this respect was the type of fracture, followed by the accuracy of the reduction and the sex of the patient.

Chapter IX

RADIOGRAPHIC RESULTS

Method

The injured ankle was examined radiographically at the time of the accident, immediately after the operation and at the follow-up examination. At follow-up, radiographs of the uninjured ankle were also taken for comparison. At all these examinations four standard projections were used, namely frontal, lateral, and frontal with eversion and inversion. The films were scrutinized and the results compiled in collaboration with Associate Professor Bo Sahlstedt of the Department of Diagnostic Radiology at the University Hospital in Uppsala.

The preoperative films taken at the time of accident were examined with respect to:

1. The appearance of the skeletal injury (lateral malleolus and fibula, anterior tibial tubercle, medial malleolus and distal articular surface of the tibia). If a fracture through the posterior tibial margin was present, the size and position of the fragment and the degree of involvement of the articular surface were noted.
2. Degree of displacement.
3. Radiographically detectable talar fractures.
4. Signs of arthritis.
5. Type of fracture according to Weber's (AO) and Lauge Hansen's classifications.

The postoperative films taken during and after the operation were examined with respect to:

1. The internal fixation appliances - their type and position.
2. Postoperative displacement: Small displaced fragments. Incongruity between the articular surfaces. Articular surface defects. Irregularity of the surface level, e.g., after displacement of a posterior articular surface bearing fragment.

At follow-up a record was made of:

1. Any internal fixation appliance still in situ: its type and position.
2. Residual displacement or articular incongruity (cf. above).
3. Soft tissue calcifications.
4. Any arthritis: its degree and location.

Any post-traumatic changes that could not be found on radiographs taken at the time of the accident or on those of the uninjured ankle at the follow-up examination were considered to be related to the ankle fracture.

Results

Displacements

No displacement was detected at postoperative radiography in 249 of the 345 surgically treated ankles (72 %). At follow-up 234/324 cases (72 %) displayed a correct radiographic anatomy.

There were no major postoperative displacements in this series of fractures. The observed displacements comprised no more than a few millimetres compared with the anatomy of the uninjured ankle. In 27 cases such minor displacements observed on postoperative radiographs were not visible at the follow-up examination. Some of the discrepant results may be due to the use of different projections at the different examinations, but it is also possible that some adaptation of the joint and reconstruction of articular surfaces and spongy bone may have taken place in the malleoli and distal end of the tibia.

Clinical and radiographic evaluation of displacements

The surgeons had judged 310 of the 345 fractures (90 %) to be accurately reduced. On inspection of the postoperative radiographs we found minor displacements in 67 of these 310 cases, and among the 35 fractures which the surgeons had considered to be not accurately reduced, we found six cases without any radiographic displacement. Thus in 21 per cent of the cases the surgeons' clinical evaluation of the reduction did not correspond with the postoperative findings at radiography.

Soft tissue calcification

Different degrees of soft tissue calcification and ossification at the suprasyndesmotic area between the fibula and the tibia were observed in 43 cases (13 %). In ten cases a synostosis had developed. Soft tissue calcification close to bony structures near the joint was interpreted as a residue after capsular and ligamentous damage. Such ligament calcifications attributable to the actual injury were found in 83 dislocation fractures (27 %), five impact fractures (31 %), and one of the six combined fractures.

Osteo-arthritis

Observed signs of osteo-arthritis were formation of osteophytes at the joint edges, subchondral sclerosis and narrowing of the joint space. The definition of radiographic signs of arthritis varies. Some authors (e.g., Klossner 1962) state that spurring on the joint margins constitutes the mildest degree of arthritis. Bargon & Henkemeyer (1977) consider that subchondral sclerosis is of no prognostic importance and that when it occurs as the only change it does not justify a diagnosis of arthritis.

The most common and most generally accepted criterion of arthritis is reduction of the joint space (Magnusson 1944, Cedell 1967, Matzen & Fleissner 1969, Elmendorff et al. 1971, Bargon & Henkemeyer 1977). This criterion was used in the present investigation for rough grading of the degree of arthritis, as follows:

1. Slight diminution of the joint space compared with the uninjured ankle.
2. Narrowing of the joint space to half or less compared with the uninjured ankle.
3. The joint space almost eliminated, and seen only as a very thin line on the radiograph.

The width of the joint space was evaluated on radiographs taken without weight-bearing on the ankle. It was considered that a reduction of the joint space visible on such films would imply a distinct change in the anatomy of the articular surface due to defects and a decreased cartilage height combined with cicatricial alteration and shrinkage of ligaments and the joint capsule.

Arthritic lesions that were considered to be related to the fracture were found in 14 per cent of the dislocation fractures. The frequency of arthritis was 4 per cent in type A fractures, 12 per cent in type B and 33 per cent in type C. The difference in the frequency of arthritis between different types of dislocation fractures is highly significant. Among the impact fractures the frequency was 50 per cent. No arthritis was observed in the combined fractures.

The arthritic changes were mostly general (about 70 %). In 20 per cent they were located at the lateral part of the joint and in 10 per cent at the medial aspect.

Post-traumatic osteo-arthritis was more common among the middle-aged patients than among the yonger ones. The highest frequency was found in the ages 55 - 64 years. Most of the patients with arthritis were women, 65 per cent of the patients with dislocation fractures, and 63 per sent of the patients with impact fractures. This sex difference of frequency was most obvious among middle-aged patients with dislocation fractures - among the male patients over the age of 35 years the frequency of arthritis was 10 per cent and for the females 26 per cent. This frequency difference is statistically significant. Figure IX:1.

Posterior tibial margin fracture and arthritis

The occurrence of an articular surface bearing posterior fragment markedly influenced the frequency of arthritis. In 34 per cent of the dislocation fracture cases with such a lesion arthritis developed, while the frequency of arthritis among the cases with small posterior fragments not including the articular surface was 17 per cent and for the cases without any posterior fragment 4 per cent. These frequency differences are highly significant. Among the patients with a not perfectly reduced posterior fragment the frequency of arthritis was 44 per cent, and among those with an exact postoperative position of the fragment 30 per cent.This frequency difference is not significant.

Thus, the mere existence of an articular surface bearing posterior tibial fragment seem to be of great importance for the development of post-traumatic osteo-arthritis.

Time of development of arthritis

One hundred and sixty-one patients underwent a follow-up examination on two occasions, after mean periods of 1.5 ($\pm$1.6) and 4.1 ($\pm$2.4) years, respectively, from the time of operation. At the first examination the frequency of arthritis was 20.5 per cent and at the second

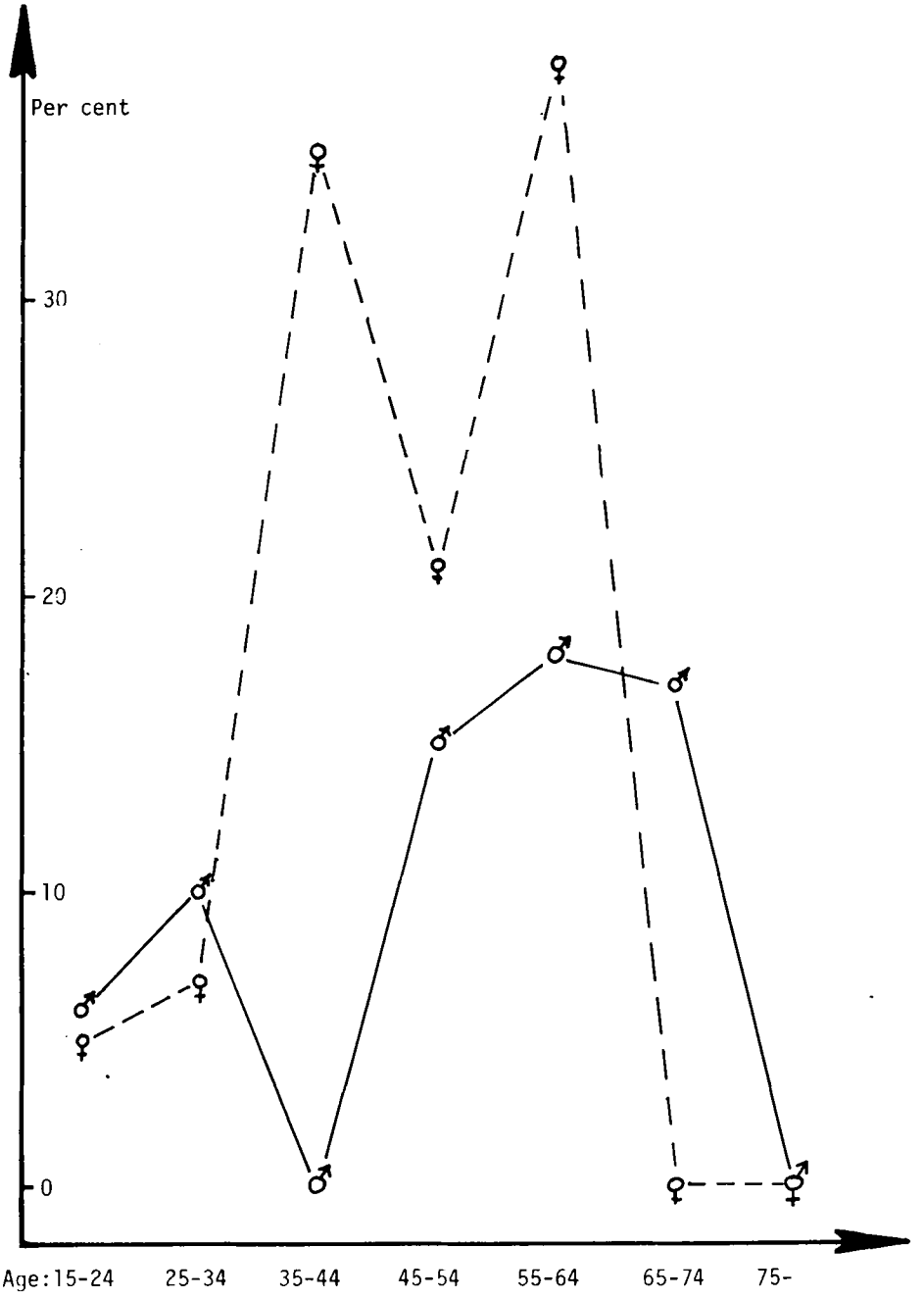


Figure IX:1 POST-TRAUMATIC OSTEO-ARTHRITIS. DISLOCATION FRACTURES.

Whole lines = men (n=160), dashed lines = women (n=143).

25.5 per cent. The frequency difference is not significant.

The majority of the post-traumatic arthritic changes thus developed during the first 1 - 1.5 years after the injury, a finding compatible with reports by other authors (Willenegger 1961, Rüedi & Allgöwer 1969, Bargon & Henkemeyer 1977).

The observations also illustrate that it is mainly patients with symptoms who come for follow-up examination at the first call. The frequency of arthritis among the patients who were examined twice was higher than that in the whole material. When all patients had been collected and examined the frequency decreased considerably.

Epiphyseal injuries

Of the four patients whose epiphyseal lines were not closed at the time of the accident, three showed a satisfactory end result radiographically. In the fourth, a female patient, the epiphyseal line closed prematurely, resulting in a slightly oblique (valgus) position of the distal articular surface of the tibia.

Relation between radiographic findings and clinical results

Displacement

Eighty-seven per cent of the patients with accurately reduced fractures had "excellent to good" results of the treatment. The corresponding figure for those with postoperative displacement was 70 per cent. Radiographically demonstrable postoperative displacement was highly significantly more common among the "acceptable to poor" cases. The primary result of reduction was thus of decisive importance for the clinical end result (cf. Chapter VIII).

Bone healing

Delayed bone healing beyond 12 weeks occurred to similar extents among cases with an "excellent to good" clinical result (5 %) and among those designated "acceptable to poor" (7 %). The few instances of bone healing disturbances in this material were not decisive for the clinical results. There were two non-unions, see Chapter VI.

Ligament calcifications

The proportion of "excellent to good" clinical results among the patients without post-traumatic skeletal changes was 80 per cent, and

among those with ligament calcifications as the only radiographic finding 87 per cent. The patients with ligament calcifications alone thus attained a better result than those without post-traumatic skeletal changes, suggesting that the ligament calcifications did not give rise to symptoms.

A better result was also noted for the patients with calcification at the site of the suprasyndesmotic screw (85 % "excellent to good"). The presence of non-bridging callus in this area thus does not seem to be of importance for the clinical end result. Furthermore, patients with synostosis also had a better result. These patients were so few that no definite conclusions can be drawn from this difference in clinical results.

Arthritis

A relation was found between the degree of arthritis and a poor clinical result, as is evident from the percentages of "excellent to good" results in cases with different degrees of arthritis. Table IX:1.

Table IX:1 FREQUENCY OF EXCELLENT TO GOOD CLINICAL RESULTS

No arthritis	82 %
Slight narrowing of joint space	76 %
Joint space reduced to at least half	42 %
Joint space virtually eliminated	0 %

The difference in frequencies is highly significant.

Among the patients with local arthritis in the medial or lateral joint space, the proportion of "excellent to good" clinical results was 65 per cent.

SUMMARY

In this chapter the radiographic results of the fracture treatment are reported, based on a scrutiny of films taken at the time of injury, at the time of operation and at follow-up. Criteria for radiographic diagnosis are described.

I. Just under one-third of minor displacements seen postoperatively could be found at follow-up. This may suggest that the ankle joint has some capacity to adapt itself to small displacements by reconstruction of articular surfaces and spongy bone at the distal end of the tibia and in the malleoli in the cases where the differences could not be explained by different projections.

II. In 21 per cent of the cases the surgeon's evaluation of the accuracy of reduction did not correspond with the postoperative radiographic findings.

III. Soft tissue calcifications at the site of the suprasyndesmotic screw were found in 13 per cent, and ligament calcifications in 27 per cent. The clinical results were not affected by these changes.

IV. Post-traumatic arthritis occurred in 14 per cent of the dislocation fractures and 50 per cent of the impact fractures. Among the dislocation fractures the frequency in type A fractures was four per cent, in type B 12 per cent and in type C 33 per cent.

V. Arthritis was significantly more common among women than men in the ages over 35 years.

VI. The arthritic changes were general in 70 per cent, located at the lateral aspect of the joint in 20 per cent and at the medial aspect in ten per cent.

VII. Among the patients who underwent follow-up on two occasions, no significant difference of arthritis was found between the earlier and the later examination, indicating that arthritis following ankle fractures develops at an early stage.

VIII. Post-traumatic arthritis was highly significantly more common among cases with surface bearing posterior fragments (34 %) than in cases with small posterior fragments (17 %) and cases without posterior fragments (4 %).

IX. The clinical results were highly significantly poorer in patients with postoperative displacement.

X. There was a clear relation between the degree of arthritis and the clinical result. An "excellent to good" result was noted in 82 per cent of the patients without arthritis, in 76 per cent of those with a alight narrowing of the joint space, in 46 per cent of those in whom the joint space was reduced to half and in no patient whose joint space was completely eliminated. These frequency differences are highly significant.

Chapter X

DISCUSSION

Anatomical and functional considerations

During normal walking a large proportion of the load on the ankle is taken up by the lateral malleolus and the syndesmosis (Wright, Desai & Henderson 1964, Weber 1972, Stauffer, Chao & Brewster 1977). Even minor displacements of the lateral malleolus and the talar trochlea imply considerably reduced contact between the talar trochlea and the distal articular surface of the tibia, with a consequent risk of incongruity arthritis (Müller, Allgöwer & Willenegger 1963, Riede, Schenk & Willenegger 1971, Ramsey & Hamilton 1976). The lateral malleolus and the syndesmosis thus play an important part in the maintenance of the congruence and stability at the talocrural joint (Danis 1932, 1949, 1979, Lauge Hansen 1942, Close 1956, Grath 1960, Willenegger 1961, Müller, Allgöwer & Willenegger 1963, 1965, Johansson & Olerud 1967, Baltensperger 1970, Lambert 1971, Weber 1972, Henkemeyer 1975, Inman 1976, Yablon et al. 1977), and these components of the joint should therefore be given great attention in the treatment of ankle injuries.

The medial malleolus does not have a corresponding supportive function (Weber 1972), but plays a significant role as a strong medial anchor for the talus via the deep posterior portion of the deltoid ligament. The deltoid ligament, when uninjured, permits up to two millimetres of lateral displacement of the talus if the lateral support is impaired (Lauge Hansen 1942, Close 1956, Grath 1960, Pankovich & Shivaram 1979).

The lateral support of the talus provided by the lateral malleolus and the syndesmotic ligaments therefore can be said to be responsible for the precision of the ankle joint function, while the role of the medial malleolus and the deltoid ligament is more one of coarse strength.

The concept of the talar trochlea as being shaped as part of a frustum of a cone (Inman 1976) implies talar movement with very little demand for widening of the ankle mortise in dorsal extension, as has been verified in laboratory studies and on human subjects (Close 1956, Inman 1976, Lindsjö et al. 1979).

Frequencies of ligamentous injuries

On the basis of the frequency figures given in Chapter IV and information from other series (Tables IV:9, IV:10, IV:11) the following frequencies may be expected: Damage to lateral ligaments in about 30 % of type A fractures; damage to the deltoid ligament in 20 - 30 % of type B fractures and in 20 - 50 % of type C fractures; incompetence of the syndesmosis may be suspected in about 60 % of type B fractures and in all fractures of type C.

Classification of ankle fractures

The Lauge Hansen system

Lauge Hansen's (1942) "genetic" classification has gained widespread acceptance. This system was intended as a guide for closed reduction manoeuvres in non-operative fracture treatment.

The basic material of the present investigation was classified by the Lauge Hansen system. A comparison with five other series showed a highly significant difference in the frequency of different types of fractures. Table X:1. An explanation is probably to be found in differences in the selection criteria used in collection of the materials and personal interpretations of the classification principles.

Lauge Hansen's system demands very careful evaluation of the radiographs. Even so it is impossible to decide on the basis of the radiographic findings alone whether a transverse fracture in the medial malleolus is of the PA I or PE I type. For this, it is also necessary to know how the fracture occurred.

In several series there have been a number of fractures that have not fitted into the Lauge Hansen classification, e.g. Vasli (1957) 1.6 %, Klossner (1962) 1 %, Burwell & Charnley (1965) 3.7 %, Yde (1980) 1.2 %. In the present series, discounting the 22 impact fractures, there were 21 unclassifiable fractures (3.4 %). Very recently the classification criteria of the Lauge Hansen system have been revised (Yde 1980).

Several authors (Palmer 1950, Jergesen 1959, Olerud 1967, Hierton 1969, McDade 1975, Slätis 1979) have pointed out that Lauge Hansen's system, with its 13 subgroups, is too complicated for use in daily routine care, and I am of the same opinion.

Fracture-producing mechanism

Supination and eversion ?

According to Lauge Hansen the most common fracture-producing mechanism is outward rotation (eversion) of a supinated foot. This aetiological reasoning is based on cadaver experiments. Lauge Hansen tried to simulate what he said could happen when a person puts his body weight on his right foot, which is forced into a position of maximal supination, and by the body weight is fixed in this position, whereupon the body falls forwards and obliquely to the left, so that the body and leg rotate inwards in relation to the locked foot.

Patients, though, often give weight-bearing on a supinated foot without any outward rotation as the cause of injury. This would seem a reasonable mechanism in so called supination-eversion fractures - both in practice and theoretically. In studies during operation, Olerud (1979) demonstrated that on forced supination of the foot the talus is pressed into an outwardly rotated position. This may be explained by the mechanics of the joints of the forefoot. When this part of the foot is supinated, the navicular glides medially on the head of the talus (as can easily be observed on speciment or a demonstration skeleton). An abnormally high load transmitted via the forefoot and the navicular to the medial side of the fore part of the talus will rotate it outwards and press it against the lateral malleolus. Fracture-inducing overloading of a supinated foot can thus cause an "eversion fracture" of the fibula without the foot itself being everted at the moment of injury. This might also explain why a rupture of the anterior fibulotalar ligament simultaneous with a lateral malleolar fracture of the "eversion" type may be found (15 in the present material).

Lauge Hansen's theory of a combination of supination and eversion of the foot as a fracture-inducing mechanism may thus be questioned. Furthermore, Weber (1972) reported that he had seen on radiographs typical supination-eversion fractures that had occurred in skiing accidents where with certainty the foot had been in a pronated position at the time of falling.

The Danis-Weber system (AO classification)

The disadvantages of the Lauge Hansen system discussed above justify the use, instead, of the fracture classification system originally introduced by Danis (1949) and modified by Weber (1972). This

Table X:1 LAUGE HANSEN'S CLASSIFICATION OF ANKLE FRACTURES
Comparison between different clinical series

Type of fracture	Lindsjö 1980 (n=611)	Lauge Hansen 1942 (n=229)	Baek Kristensen 1953		Henke 1964 (n=223)	Yde 1980 (n=488)
			Randers series (n=232)	Control series (n=237)		
SA	20 %	16 %	16 %	7 %	6 %	20.1 %
SE	42 %	71 %	45 %	72 %	53 %	57.4 %
PA	17 %	5 %	16 %	12 %	21 %	8.2 %
PE	13 %	7 %	22 %	8 %	16 %	12.7 %
Unclassifiable	3.4 %	1 %	1 %	1 %	4 %	1.6 %

system is more appropriate for use in operative treatment. The grading of ankle fractures with respect to the level of the fibular fracture in relation to the joint space gives quick information about the risk of a syndesmotic injury and other specific joint injuries. Figure III:1.

In all type C fractures and in type B fractures with a lateral posterior tibial margin fragment the risk of syndesmotic injuries is 1/1. In type A fractures there is no risk of such injury.

This does not mean, however, that type A fractures are the least serious, type B somewhat more serious, and so on. The comparatively few operatively treated type A fractures in this series exhibited the poorest clinical results among the dislocation fractures, despite a low frequency of osteoarthritis. Many type A injuries with a high medial vertical or almost vertical fracture through the medial malleolus and compression of the distal articular surface of the tibia at the medial angle are on the border of impact fractures and are to be regarded as serious ankle injuries.

Regarding isolated transverse fractures through the medial malleolus, the opinions of Lauge Hansen and Weber differed. Lauge Hansen classified them as pronation fractures of the abduction or eversion type, whereas Weber placed them among the type A fractures and gave the mechanism as supination or a combination of supination and inversion. With the latter mode of injury, an isolated, almost horizontal fracture through the medial malleolus would rather be a shear fracture, a mechanism that is seldom discussed in these connections (Perkins 1946, Penrose 1966), and is not included in Lauge Hansen's experimental work.

No frequency figures for the different types of fractures in the AO classification in an unselected series appear to have been published previously. The present primary material give a good idea of what frequencies may be expected for these fracture types in a mixed urban and rural population of a kind similar to that in the area served by the University Hospital in Uppsala. Table X:2.

Table X:2 RELATIVE FREQUENCIES OF FRACTURE TYPES IN WEBER´S (AO) CLASSIFICATION

Ankle fractures (n=611)

Type of fracture	Men %	Women %	All patients %
AO:A	25	24	25
AO:B	52	60	56
AO:C	16	11	13
Impact fractures	4	3	4
Others	1	2	2

Accident frequency

In this material ankle fractures were most common among middle-aged and elderly patients. Most of these were women. The sex difference in the frequency of fractures was statistically almost significant. Many other authors have also found a larger number of female than male patients in the higher age groups (Lauge Hansen 1942, Hendelberg 1943, Magnusson 1944, Biström 1952, Baek Kristensen 1953, Vasli 1957, Cedell 1967, Weber 1972).

Among the younger patients there was a highly significant difference in frequency between the sexes. Most of the younger patients were men. This difference is probably due to occupational dissimilarities and to different choices of leisure activities. Table IV:3. It is possible that these sex differences in the frequency of ankle fractures in different age groups have now diminished to some extent with the appearance of more girls on foot-ball (soccer) fields and more middle-aged male joggers.

Treatment

Non-operative treatment

Just under half of the 611 ankle fractures, 266, were treated non-operatively. The reasons for not operating on these patients can be seen in Table IV:13. It was not within the frame of this investigation to follow up these patients. Moreover, the selection of patients for

operative or non-operative treatment was not randomized and thus the operatively and conservatively treated groups are not statistically comparable.

Open reduction and internal fixation

Increased knowledge about the normal and post-traumatic anatomy and function of the ankle joint (cf. Chapters II and III) has led to demands on exact reduction and rigid fixation of ankle fractures. It is difficult to satisfy these demands with closed, non-operative methods of treatment. The use of open reduction and internal fixation has therefore increased as the standard treatment for displaced and unstable fractures about the ankle. Many authors have reported improved results after operative treatment as compared with closed methods (Vasli 1957, Braunstein & Wade 1959, Klossner 1962, Henke 1964, Wilson & Skilbread 1966, Leitz 1966, Cedell 1967, Solonen & Lauttamus 1968, Colton 1971, Willenegger 1971, Weyand et al. 1974, Hughes et al. 1979, Müller, Bachman & Willenegger 1978).

The operation method used in the present series constitutes a further development of the principles recommended by Danis (1949) and introduced by the AO (ASIF) group (Arbeitsgemeinschaft für Osteosynthesfragen) (Müller et al. 1963, 1977, Weber 1972, Heim & Pfeiffer 1972). This method of precise open reduction and rigid internal fixation has been applied routinely in many European hospitals since the middle of the 1960s and in Uppsala since 1965. The small-fragment instrumentarium (Heim & Pfeiffer 1972) was increasingly used during the present study. Our experience of this development of the AO technique has been favourable.

Indications for operation

Palmer (1941, 1950, 1962) and Proctor (1954), among others, emphasized the importance of operating on unstable ankle fractures and of repairing and fixing the syndesmosis. In the opinion of Danis (1949) and Vasli (1957), as many fracture components should be fixed as will provide stability of the joint, so as to permit early postoperative exercises. Weber (1972) considered that every injury at the talocrural joint involving one or more ligamentous or bony lesions is an absolute indication for operative treatment. According to Olerud (1968), all ankle fractures with incongruity of joint surfaces should be regarded as cases for surgery. Both Weber and Olerud held the opinion that only in

the presence of general contraindications should it be decided not to operate.

In the individual fractures in the present series a decision to operate was made after an analysis of the injury based on the case history, clinical examination of the foot, radiography and general examination. If from the combined findings operation was indicated, this was planned as a primary measure without preceding attempts at closed reduction and non-operative treatment (cf. Chapter V).

Timing of operation

According to Weber (1972), ankle fractures should be operated on as soon as possible after the accident unless the patient's general condition or any local soft tissue changes indicate that it should be postponed. This view is shared by many other authors (e.g. McLaughlin & Ryder 1949, Willenegger 1961, Olerud 1968, Plaue & Hinz 1970, Müller, Allgöwer, Schneider & Willenegger 1977) and this was the main principle applied in the treatment of the present material. As such, in a large number of cases the operation was delayed because of swelling of soft tissues and skin complications.

Better clinical results were noted for patients who were operated on after some delay. This is probably connected mainly with the fact that high priority was given to the most serious fractures, which to the greatest possible extent were operated on during the first 8-10 hours after the accident. Other factors which may contribute to the better results in elective operations are that these are often performed by or under the supervision of a more experienced surgeon, that the ordinary staff are on duty and that most members of the surgical team are more rested than during emergency operations, which are often carried out at night.

If the operation cannot be performed immediately after the incident, in the case of major fractures with a risk of considerable swelling, at least five to six days should be allowed to elapse to give the swelling a chance to subside. Soft tissue swelling that still remains at the time of operation implies a threat to the microcirculation in the wound margins, giving a risk of wound complications.

Fixation of the syndesmosis

A suprasyndesmotic screw was used in 40 % of type B fractures and 80 % of type C. Henkemeyer, Burri & Bargon (1976) used a suprasyn-

desmotic screw in 15 of 42 cases of widening of the ankle mortise (35 %). Other authors recommend restraint with the use of suprasyndesmotic screws (Boettcher et al. 1970, Decker 1977). It is possible that some of the suprasyndesmotic screws used in the present series could have been avoided. There was no significant difference in the proportion of "excellent to good" results between the patients with type B injuries in whom suturing of the ligament alone was performed and those supplied with a suprasyndesmotic screw also. Neither did soft tissue calcification at the site of the screw appear to have given rise to symptoms. This may imply that a correctly positioned suprasyndesmotic screw at least did not do any harm even if in a few cases there was no strict biomechanical reason for its use.

Radiographic control of the reduction

In principle postoperative displacements were not accepted. For practical reasons, though, some minor displacements could be tolerated, but reoperation was often undertaken (cf. Chapter VI).

The surgeons stated that the reduction was exact in 90 per cent of the cases. After examination of the postoperative radiographs, however, the proportion of accurately reduced fractures was found to be 72 per cent. This discrepancy between the surgeons' opinion of the reduction result and the radiographic findings underlines the importance of a correctly performed and evaluated radiographic control at the operating table before the operation is completed, especially in cases with a posterior tibial fragment when the fragment has not been exposed and reduced under visual control.

Some minor displacements could not be found on radiographs taken at follow-up: in 27 cases a small displacement observed on postoperative films had disappeared, probably as a result of spontaneous reconstruction of the joint surfaces and of the cancellous bone at the distal end of the tibia and in the malleoli. A similar phenomenon has been observed by other authors (Hendelberg 1943, Henssge 1970, Müller, Plaas & Willenegger 1971, Nonnemann & Bräutigam 1977). The observation may be of interest from a prognostic aspect, but should of course not be taken as justification for lowering the demands for accurate reduction at operation.

Postoperative management

Postoperative exercises - plaster cast

The importance of early postoperative exercises has been stressed by several authors, including Danis (1949), Vasli (1957), Perkins (1958), Willenegger (1961), Burwell & Charnley (1965), Weber (1972) and Müller et al. (1963, 1965, 1977). Consistently performed training of movements without any external immobilization throughout the postoperative period (Weber 1972) requires large medical care resources. The patient has to remain hospitalized for a long period and after discharge he has to be kept under careful supervision. This form of treatment places great demands on the patient's capacity to co-operate and to understand instructions and exercise schedules.

In the present series the policy was primary postoperative exercises and subsequent application of a below-knee walking plaster (cf. Chapter V). This treatment is essentially the same as was recommended by Vaşli (1957). The clinical results with the use of this method were as good as those reported by Weber (1972) and Forudastan (1970). There were very few complications associated with the plaster - one pressure sore and one case of suspected hypersensitivity to the plaster.

In the whole material there were two clinically established thromboses that were referable to the ankle injury; one of these patients had a plaster cast - the other one had a PTB splint. Thrombosis giving rise to symptoms was thus rare. A tendency to thrombus formation would probably be counteracted by the early postoperative exercises. During the whole of the subsequent period the patients were up and about and fully mobile, which would also reduce the risk of circulatory disturbances caused by the plaster.

Weight-bearing in plaster

A rigidly internally fixed dislocation fracture is, in principle, capable of bearing weight in normal loading directions. During the course of healing the operatively treated ankle only needs to be protected against oblique, redisplacement-promoting loads. This is achieved in a simple manner by a below-knee plaster with a heel. The surgically treated patients were therefore, as a rule, allowed to bear weight in their plaster cast. Many patients found that the plaster gave them a sense of security, as was also evident in that after a time several of them walked without a stick or crutches.

In patients with extensive damage to articular surfaces, the postoperative treatment was chosen individually according to the nature of the injury.

Among patients in other series who did not carry out postoperative exercises and were not permitted to bear weight in the plaster cast (Cedell 1967), there was a highly significantly greater frequency of residual ankle swelling and calf muscle atrophy at follow-up than was found in the present series (cf. below).

Follow-up examination

The follow-up material was highly representative, including 95 per cent of the operatively treated fractures. Two patients were examined one year after the operation, 11 patients after 1.5 years and the remainder (314 patients) two to six years after the operation. These observation periods were sufficiently long for the clinical and radiographic results to have become "stabilized".

In patients who were followed up on two occasions, the results were somewhat better after the longer period, in contrast to the findings of Forudastan (1970) and Weber (1972).

Evaluation of clinical results

The absence of objectively observable sequelae constitutes the best indication that the function of the fractured ankle is completely restored. It is a common clinical experience, however, that a small number of patients have troublesome symptoms despite objective signs of restoration of the injured part of the body. When evaluating the advantages and disadvantages of a particular method of treatment, consideration should therefore be paid both to the patient's functional ability and subjective symptoms and to the findings at examination.

A combination of the subjective symptoms and objective findings yielded the following clinical results (cf. Chapter VIII):

Table X:3 COMBINED CLINICAL RESULTS
Operatively treated, followed-up ankle fractures (n=327)

	"Excellent"	"Good"	"Acceptable"	"Poor"
Dislocation fractures (n=305)	57 %	24 %	9 %	10 %
Impact fractures (n=16)	19 %	19 %	19 %	43 %
Combined shaft and ankle fractures (n=6)	1/6	1/6	3/6	1/6

Subjective symptoms and objective findings

In only half of the patients who felt that their ankle was swollen was an increase in circumference found at objective examination. This may possibly be related to impaired proprioception resulting from a functional disturbance of peripheral nerves. A similar incompatibility between subjective sensations and objective observations is also common after hand injuries and below-knee amputations, for example.

Only 71 per cent of the patients with restricted dorsal extension had a sensation of stiffness in the foot. In two-thirds of the patients with restriction of dorsal extension of up to 10^{o} this did not give rise to subjective symptoms. Reduction of the capacity for dorsal extension by up to 10^{o} thus does not appear to be of importance for the functional demands on the ankle placed by the majority of patients.

Pes plano-valgus

In conservatively treated patients residual unilateral pes plano-valgus is relatively common: Walheim & Akerman (1936) eight per cent, Hendelberg (1943) 20 per cent, Magnusson (1944) 14 per cent, Baek Kristensen (1953) 20 per cent.

In the present material the frequency was 1.3 per cent, which is considerably lower. With accurate reduction and rigid internal fixation this type of complication has virtually disappeared. In most reports on operatively treated materials this sequela is not mentioned at all.

Posterior articular surface bearing fragment

It has been claimed that the presence of a posterior fragment can be used as a prognostic criterion (Felsenreich 1931, Graff 1954, Willenegger 1961, Klossner 1962, Henke 1964, Cedell.1967, Henne & Müller 1968 Tauber et al 1971, McDaniel et al 1977, Nonneman & Bräutigam 1977, Niethard & Plaue 1977, Plaue 1978). This was also confirmed in the present study. The proportion of "excellent to good" clinical results was 81 per cent in patients with small non-surface bearing fragments, but 70 per cent in the cases with articular surface bearing fragments. The difference is almost significant. There was a highly significantly higher frequency of osteo-arthritis among the patients with large posterior fragments - both the perfectly reduced ones, and the cases with a slight displacement postoperatively - than among the other patients.

Posttraumatic osteoarthritis

The ankle is one of the most arthritis-resistant joints in the body (Funk 1976, Stauffer, Chao & Brewster 1977). Degenerative changes in this joint are practically always sequelae to an injury or disease. The development of arthritis after an ankle fracture is, in other words, a reaction to non-restoration of the anatomy and function of the joint.

Frequency

Information on the frequency of arthritis is lacking in many reports on clinical materials. When figures are given, it is sometimes difficult to see what criteria have been used. Reported frequencies of arthritis vary within relatively wide limits. For conservatively treated ankle fractures Magnusson (1944) found a frequency of 49.3 per cent, Burmeister (1963) 67.3 per cent, Stören (1964) 39 per cent, Leyendecker (1968) 33 per cent, and Tauber, Landholt & Willenegger (1971) 59 per cent. Klossner (1962) reported a figure of 42 per cent for operatively treated fractures and 38 per cent for those treated non-operatively. This difference is probably largely due to differences in the criteria of selection for the different forms of treatment - more severe cases were operated on and less serious ones were treated conservatively. In series of fractures operated on according to other principles than those of the AO group, Burwell & Charnley (1965) found an arthritis frequency of 37 per cent, Vasli (1957) 43 per cent, Cedell (1967) 23 per cent (SE fractures only) and Brodie & Denham (1974) 8.7 per cent.

The following figures have been reported for patients treated surgically by the AO technique: Willenegger (1961) found an arthritis frequency of 97 per cent among fractures with postoperative displacement and 8 per cent among those that were accurately reduced. Müller, Plaass & Willenegger (1971) found arthritis in 85.7 per cent of inadequately reduced fractures and in 9.7 per cent of those with exact reduction; the frequency of arthritis in the whole material was 26.8 per cent. Weber (1972) reported a frequency of 7.3 per cent, Luhnau (1972) 15.6 per cent, Renné & Mainhardt (1974) 9.2 per cent, Wolf & Klammer (1977) 12 per cent and Bargon & Henkemeyer (1977) 14.3 per cent (grades II-III). In the present material the frequency of arthritis among dislocation fractures was 14 per cent (cf. Chapter IX).

Statistical analysis of percentage figures from different materials

with different criteria of selection is not possible, but there is a distinct tendency towards a lower frequency of arthritis in series of fractures operated on according to the AO (ASIF) principles compared with conservatively treated series and those operated on by other methods.

Arthritis and type of fracture

The frequencies of arthritis in different materials have varied with different types of fractures. Table X:4.

Table X:4. THE FREQUENCY OF ARTHRITIS IN THREE FRACTURE SERIES OPERATED ON BY THE AO TECHNIQUE, DISTRIBUTED BY TYPE OF FRACTURE

	Müller, Plaass & Willenegger (1971)	Pankarter (1977)	Lindsjö (1980)
	%	%	%
AO:A	17.2	11.8	3.8
AO:B	13.2	13.0	11.5
AO:C	38.2	11.5	33.3

The difference in arthritis frequency between the different types of dislocation fractures in the present material is highly significant. The differences in the occurrence of arthritis in different types of fractures in the present material are not clearly evident in the other series. It is not certain that the criteria for arthritis are the same in the different materials. and dissimilarities in indications for operation may also contribute to the discrepancies. It is probable, however, that to a certain extent, the type of dislocation fracture is a discriminating factor for the tendency towards arthritis.

Among the impact fractures in this material the frequency was 50 per cent, which is higher than has been reported by other authors (Rüedi et al. 1968, Rüedi & Allgöwer 1969, Rüedi 1973, Dürig et al. 1978).

Arthritis and the patient's sex

Osteoarthritis following the ankle fracture was more common among the female patients. The difference in the frequency of arthritis

between middle-aged men and women in the present material was significant. The women of the age groups 45-64 years also showed the poorest clinical results of treatment. One possible reason for the higher frequency of arthritis and poorer clinical results in the middle-aged women might be a greater tendency to osteoporosis in menopausal women, which has often been observed during operation on middle-aged female patients. In the presence of osteoporosis it is more difficult to get a precise reduction and completely stable fixation.

Pseudarthrosis

In conservatively treated fracture series pseudarthrosis was a common complication, but with wider use of open reduction and rigid internal fixation it has now become exceptional. Baek Kristensen (1953) found that pseudarthrosis in the medial malleolus occurred in 5-10 per cent of conservatively treated fractures. In the present material there was no pseudarthrosis among the cases operated on strictly according to the AO principles. The two cases of pseudarthrosis in this series were due to technical faults and inadequate fixation. They healed after secondary rigid internal fixation with figure-of-eight tension band wiring and plate fixation, respectively. In no case did pseudarthrosis develop in the anterior tibial tubercle - a not uncommon complication in conservative treatment (Magnusson 1944).

Comparison with other series

Other operative methods

In 1957 Vasli published a series of 185 cases of ankle fractures from a Norwegian population operated on in the years 1946 to 1953. Cedell (1967) reported the results of operative treatment of 100 supination-outward rotation fractures from the south of Sweden treated surgically during the years 1958-1961. Both series are sampled from Scandinavian populations. It therefore seems of interest to compare their results with those of the present series.

The classification of subjective and objective clinical results suggested by Baek Kristensen (1953) and also used by Vasli (1957) and Cedell (1967) is more liberal than that of the present results. As subjectively good results, for example, Kristensen accepted slight symptoms during strain, and as objectively good results up to 50 per cent restriction of movement. The number of completely restored patients (restitutio ad integrum) was not reported. No meaningful

general comparison can therefore be made between the results in the present material and the "excellent", "good". "medium" and "acceptable" results in these other materials.

On the other hand, the advantages and disadvantages of the different methods may be elucidated by comparing the relative frequencies of individual post-traumatic and postoperative symptoms and examination findings, such as restriction of ankle joint motion, post-traumatic arthritis, persistent swelling of the ankle and atrophy of the calf muscles.

Vasli (1957) reported "pronounced" permanent swelling in 4 per cent and "trivial" swelling in 12 per cent, together 16 per cent. How this swelling was recorded - as objective measurements or a subjective feeling of swelling (cf. Chapter VIII) is not stated. Reduction of joint motion by more than 50 per cent was recorded in 9 per cent and post-traumatic arthritis in 43 per cent.

Cedell (1967) made a more elaborate and thorough report on his follow-up results, so a comparison of symptoms and signs is possible. There is an almost significantly smaller proportion of patients with restricted movement, a significantly smaller frequency of arthritis, and highly significantly smaller frequencies of ankle swelling and calf muscle atrophy in the present series. Table X:5.

Table X:5 COMPARISON OF TREATMENT RESULTS BETWEEN THE PRESENT SERIES AND THAT OF CEDELL (1967). SE FRACTURES.

	Cedell (1967) (n=100) %	Lindsjö (1980) (n=160) %
Limitation of movement	50	36
Increased ankle circumference	66	14
Decreased calf circumference	36	17
Arthritis	23	10

The two materials were recruited from similar populations. Both hospitals are located in medium-sized university towns with surrounding agricultural communities. Cedell's patients were, on the average, older than those of the present material and there is a time difference of about 15 years when the series were sampled, but these may not be the main reasons for the above-mentioned differences.

There were, though, a few major differences in the treatment of the patients in the two series, which may explain the contrasting results:

1. A more accurate and precise reduction in the present series,
2. Different techniques of internal fixation,
3. Different principles of syndesmotic fixation,
4. Different routines for postoperative treatment.

Concerning point 1, Cedell reported that "anatomical" reduction was achieved in 277 out of 406 fractures (SE II, III and IV), i.e., 68 per cent. Among corresponding factures in the present material there were 82 per cent (113/160) without any postoperative displacement. This difference in frequency is highly significant.

Point 2: For internal fixation Cedell used cerclage, staples, pins and small-threaded screws, which give good apposition. In the present series stability was achieved by the interfragmentary compression technique.

Point 3: The use of staples for syndesmotic fixation may not give sufficiently rigid fixation. The staples only support the anterior part of the syndesmosis, and in cases with a complete rupture this is not enough to guarantee stability in the ankle mortise while the ligaments heal. Furthermore, it may be difficult to apply staples without altering the position of the lateral malleolus in the fibular notch in the tibia.

Point 4: A non-rigid apposition technique puts a high demand on complementary external fixation for minimization of the risk of secondary re-rotation of the fracture fragments. In Cedell's patients the surgically treated ankle was immobilized in plaster immediately after the operation without prior postoperative exercises. The mean duration of plaster immobilization varied from 5.7 to 8.7 weeks. just under 50 per cent of the patients were allowed weight-bearing and then only during the last two weeks of plaster mobilization.

Thus, the higher frequency of post-traumatic arthritis in Cedell's series may be referable to the differences in the results and maintenance of primary reduction, which in turn are most probably attributable to differences in techniques of internal fixation. The higher frequency of ankle swelling, calf muscle atrophy and reduced joint movement can be explained by the lack of postoperative joint exercises and the use of non-weight-bearing plaster for a comparatively long time.

In experimental studies Salter (1980) has found much better healing of cartilage defects in joints under constant motion than in joints which are fixed in plaster of Paris.

Several of the drawbacks mentioned can be avoided by the use of biomechanically more appropriate internal fixation appliances. The AO compression technique undoubtedly gives better stability than staples, pins, cerclage and vitallium screws. Furthermore, the greater variety of fixation devices in the AO instrumentarium permits alternative solutions in different fracture combinations.

Weber's series

Weber (1972) presented a grading system with five points (0-4) for evaluation of six variables: pain, walking ability, activity, radiographic changes, range of movement in the talocrural joint and range of movement in the subtalar joint. The sum of the six scores was then used for placing the patient in one of the three groups "sehr gut" (very good), "gut" (good) or "schlecht" (bad). "Sehr gut" meant a score of 0 in all respects, i.e. restitutio ad integrum. By summarizing the variables in this way a quick and collective evaluation of the results could be made. Weber's system has also been applied by other authors (Forudastan 1970, Luhnau 1972, Henkemeyer 1975, Wolf & Klammer 1977, Hughes et al. 1979).

With the aid of a computer the present material was assessed according to Weber's scheme and the following comparison was made. Table X:6.

Table X:6 COMPARISON BETWEEN WEBER'S AND THE PRESENT SERIES

	Weber (1972)	Lindsjö (1980)
Percentage of "very good" and "good"	86.6	89.8

"Very good" and "good" combined correspond fairly closely to the sum of the "excellent", "good" and "acceptable" results in the present classification.

These figures should be interpreted with great reservation. The comparison should only be regarded as an arithmetical example,

indicating that the results for the two series are on approximately the same level. A direct comparison of the figures for the two series cannot be made, as the results for the present material were not classified from the beginning by Weber's system of result points.

Factors that affected the treatment results

The material was analysed with the help of AID (Automatic Interaction Detector program) in an attempt to determine what factors were of greatest importance for the final result (cf. Chapter VIII).

It was found that the most decisive factor for the result was the type of fracture. Table X:7 .

Table X:7 THE PERCENTAGE OF "EXCELLENT TO GOOD" RESULTS. Operatively treated follow-up ankle fractures (n=327)

	Type of fracture			
	AO:A	AO:B	AO:C	Impact fractures
	%	%	%	%
Men	56	89	94	43
Women	70	77	70	33

The second most decisive factor was the adequacy of the reduction. The difference in the frequency of "excellent to good" results between accurately and inadequately reduced fractures was highly significant. Table X:8.

Table X:8 THE ADEQUACY OF THE REDUCTION IN RELATION TO THE TREATMENT RESULT

	Accurately reduced fractures (n=217)	Inadequately reduced fractures (n=89)
Percentage of "excellent to "good" results	86.6	68.5

The third most decisive factor for the result was the sex of the patient. Table X:7.

Of these three most important factors, the surgeon is only able to influence the second one, namely, the adequacy of the reduction. Many authors have pointed out the significance of accurate reduction for a good end result (e.g. Magnusson 1944, Bonnin 1950, Palmer 1950, Bæk Kristensen 1953, Proctor 1954, Böhler 1957, Vasli 1957, Jergesen 1959, Burwell & Charnley 1965, Cedell 1967, Weber 1972, Danis 1979, Phillips & Spiegel 1979). Willenegger (1961) compared accurately and incompletely reduced cases from the same series and demonstrated a convincing difference in the treatment results, which is confirmed also in this investigation.

With the exact restoration of the anatomy of the joint, the biomechanical prerequisites for good function will be optimal. The best method of treatment for attaining this goal would seem to be accurate open reduction and rigid internal fixation.

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