ACTA ORTHOPAEDICA SCANDINAVICA
SUPPLEMENTUM 70

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OS CALCIS FRACTURES

BY

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Introduction

The treatment of intra-articular fractures of the os calcis often gives poor clinical results. It is commonly known that hardly any present day treatment will consistently produce good function. This is particularly so when the fracture involves the subtalar joint. Since the fractures are the result of violent trauma and occur in bone, consisting mainly of cancellous tissue, the damage takes the form of severe comminution. Therefore the articular involvement is deleterious and makes reconstruction very difficult or impossible. Furthermore in the course of the production of the fracture considerable surrounding soft tissue injury occurs. Because of this, many advocate a more conservative approach in the treatment, believing that the end results will not be different, even if the fracture is left to its own fate.

The present investigation deals with the anatomical appearance and the clinical end results of os calcis fractures which have been treated by various methods.

In order to obtain information about the degree of damage affecting the region of the os calcis, studies were undertaken on cadaveric specimens which were subjected to experimentally produced os calcis fractures. In these model experiments attempts have been made to study the fracture-mechanism, the magnitude of the force and the type of fracture related to the position of the foot at the time of injury. The lesions have been classified by radiographic and anatomical analysis.

Clinically, three different series of os calcis fractures treated by either, early mobilization without reduction, open reduction with attempts at reconstruction or early triple arthrodesis, have been compared with regard to the late end results. A statistical analysis of factors which may be significant for the final function of the foot are presented in terms of prognostic evaluation.

CHAPTER 1

Introduction to the Literature

The literature pertaining to injures and treatment of the os calcis is voluminous. In this section it is hoped to profitably give a brief introduction, with mention of the more important works.

In 1847 Malgaigne was the first to mention that fractures of the os calcis were compression fractures. Schmitt (1896) attempted to evaluate the static fracture force of some ten specimen but no exact data was given; the forces were said to vary between 500 and 2500 Kp. By his experiments he produced shearing fractures which Baer (1905) confirmed. Neither these authors nor Tietze (1908) were able in detail to analyze the effect of different positioning of the foot. Tietze however arrived at the conclusion that the type of fracture probably changes to a very high extent according to direction of the dynamic force. Some similar experiments have also been done by Paitre & Boppe (1935) and by Aurup (1958).

In the literature concerning the treatment and follow-up results of os calcis fractures many different types of treatment are described. These range from immobilization without reduction, closed reduction and to various operative procedures. The result and assessments vary considerably in the different series and for these reasons it is difficult to make valid comparisons and conclusions.

Immobilization without reduction. Felsenreich (1935), Bode (1937), Ahlberg (1940) and Nissen-Lie (1946) have all described the management of os calcis fractures utilizing only immobilization but without attempts at reduction.

Manual reduction. Closed reduction as a method of treatment was used by Cotton & Wilson (1908), McFarland (1937), Herman (1937), Laroyenne & Houot (1944), Page & Mumford (1945), Carothers & Lyons (1952), Wendt (1953), Barnhard & Odegard (1955) and by Steinkohl & Miethaner (1961). This method appears to have many current advocates.

Reduction with instruments. Several methods are described in the literature. Goff (1937) gave a good survey of those used until that date. The method generally in use is the technique described in 1929 by Böhler with traction through the tuber of the os calcis and counter-traction through the tibia. Counter-traction through the metatarsal bones was used by Arnesen (1939 and 1958), Hölund (1951), Aurup (1958) and by Aars & Bie (1961). Reduction of the depressed fragments by the use of a nail was recommended by Westhues (1934), Bürkle-de la Camp (1936), Lauritzen (1947), Zorn (1960) and by Maurer (1960).

Open reduction. This principle was initially advocated by the French surgeon Leriche (1922), who was the first to use screws or clamps for the osteosynthesis. This was also utilized and described by Simon & Stultz in 1928 and 1930 as well as by Stultz (1935) and Whittaker (1947). Lenormant (1928) and his co-workers were the first to insert bone grafts at open reduction. This technique was then independantly described by Palmer (1945 and 1948) who used traction through the tuber during the operation as did Sicard & Mutricy (1934). Since Palmer's account of his method in 1948 this method has come into general use. The largest series presented are those of Widén (1954). Good results have later been reported by Essex-Lopresti (1952), Maxfield & McDermott (1955), Allan (1955), Leonard (1957) and Maxfield (1936). Scandinavian reports with the recent use of this method are by Rosendahl-Jensen (1956) and Grewald et al (1961).

Primary arthrodesis. VanStockum (1912) seems to be the first one using subtalar arthrodesis as a primary treatment of os calcis fractures. Several others have later used this operation in severe os calcis fractures, amongst them, Wilson (1927), Gallie (1943), Armstrong (1943), Harris (1946 and 1963), Geckeler (1950), Becker (1951), Gollasch (1953), Lindsay & Dewar (1958), Ehalt (1957), Stultz et al (1960) and Hall & Pennal (1960). In some reports the arthrodesis includes not only the subtalar joint but also the joints between the talus and navicular, and the calcaneus and cuboid, in other words a triple arthrodesis. This method has been advocated among others by Conn (1935), Bankart (1942), Kiaer & Anthonsen (1942), Moberg (1951), Moberg & Erfors (1953), Brattström (1953) and Thompson and Friesen (1959).

Early physiotherapy without attempt at reduction. One of the first reports given of this type of treatment was by Roberts and Sayle Creer in 1946. Their patients were kept in bed for about two moths and treated with physiotherapy.

Essex-Lopresti in 1952 followed 70 patients in Roberts and Creer's series and found that 80% were back to work. He also found the subjective complaints of the patient to be stationary after 1.5 years. In 1952 he compaired the results of early physiotherapy with some other methods of treatment. Here he claimed that early physiotherapy was the best treatment for displaced fractures in patients over the age of 50, and in all those without displacement. Bertelsen & Hasner (1952) reported on 23 patients and mentioned some of the advantages of the method including the earlier return to work. Day (1950), DeBold & Stimson (1957), Brorson & Rosendahl-Jensen (1959), Barnhard (1963) and Kölle-Jörgensen (1963) in smaller series found no disadvantages of the method.

In material obtained from a Danish insurance company Rosendahl-Jensen in 1956 divided 485 intra-articular os calcis fractures according to the functional results of the different methods of treatment. He could not find any statistical difference between those treated by early physiotherapy, by plaster of Paris or by any surgical methods. The end result for all cases was that about 30% received a permanent disability rating.

Charnley recently (1957) has emphasized that very successful clinical results can be attained in those cases where the fracture is not reduced, and that most unsuccessful results follow attempts at open reduction.

The correlation between degree of displacement and the mobility of the subtalar joint, as well as the correlation between the tuber-joint angle and displacement of the fracture was pointed out by Lance, Carey & Wade (1963). In a series of 227 cases of intra-articular os calcis fractures, 20% of these were treated by early mobilization. The author claimed that fractures treated by early physiotherapy did better as to, hospital stay, work disability and final prognosis. They concluded that better results are obtained by early physiotherapy in those cases were there is no more than moderate displacement of the posterior articular facet.

EXPERIMENTAL SECTION

CHAPTER 2

Experimental Os Calcis Fractures on Autopsy Specimens

The os calcis fractures seen clinically usually arise from a sudden blow to the heel. This happens in two ways, either a person falls from a height, landing on his heels, or the floor explodes under him. In both cases the os calcis receives a sudden dynamic force.

Experimental technique

In order to study the effect of a sudden force against the heel, experiments have been made on autopsy specimens (fig. 1).

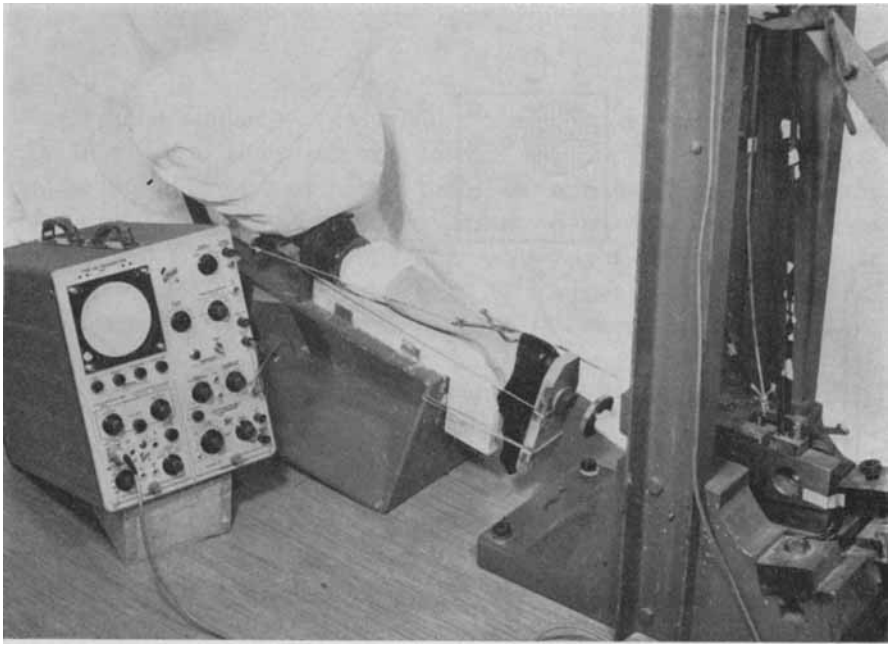


Fig. 1. Apparatus for producing experimental calcaneal fractures.

For this purposes legs exarticulated through the knee joint at autopsy have been used. The preparation was usually tested the same day it was taken or it was stored in a deep-freeze and thawed before the experiments. The preparation was fixed in a specially constructed steel retaining stand (A, fig. 2). The tibial condyles were levelled off in order to fit snugly against the plate (1) on the stand. The foot hanging free in the air was fitted with a suitable shoe (2). A wooden plate (3) was attached to the sole and heel of this shoe. On the light wooden plate a rubber bumper (4) was fixed. An Amsler pendulum-type impact machine (B) was used to produce the sudden force. On the hammer of this machine a thin tube (5) was mounted with a plate of duraluminum on its end (6). This plate strikes the rubber bumper on the wooden plate at the moment of impact. The pendulum and the retaining stand were so placed that the blow hit the leg at right angles to the wooden plate. In order to register the forces that act on the specimen, strain gauges were mounted on the tube (5). Through a special trigger device it was possible to register photographically on an oscilloscope (C) the impulses that occured at the moment of impact. On the oscilloscope the force will be seen as a function of time. (Fig. 3). Prior to the experiments a calibration against a known static load was made. The result of this procedure was also fed into the oscilloscope giving a known load line parallell to the base line. (Fig. 3).

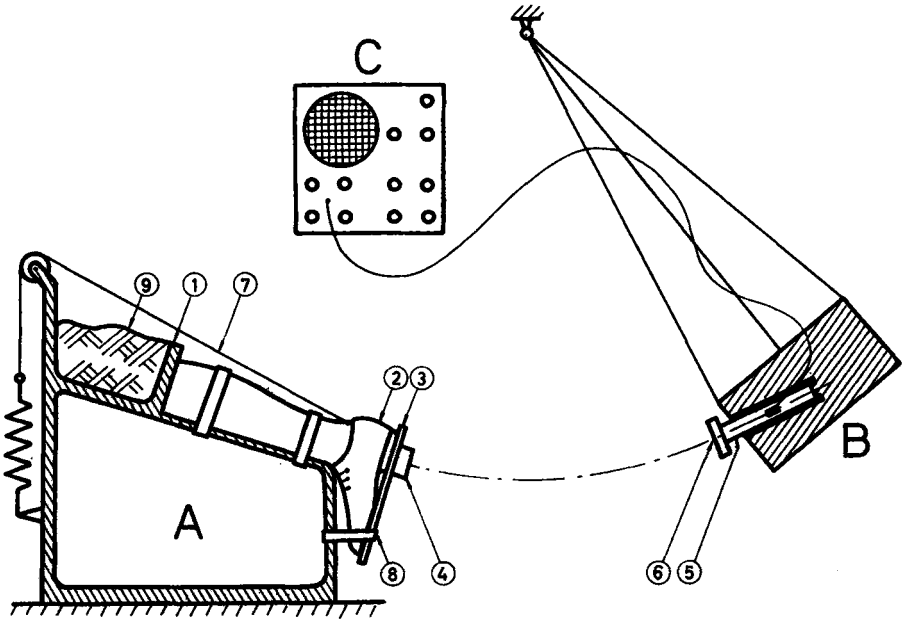


Fig. 2. Drawing of the apparatus seen in fig. 1.

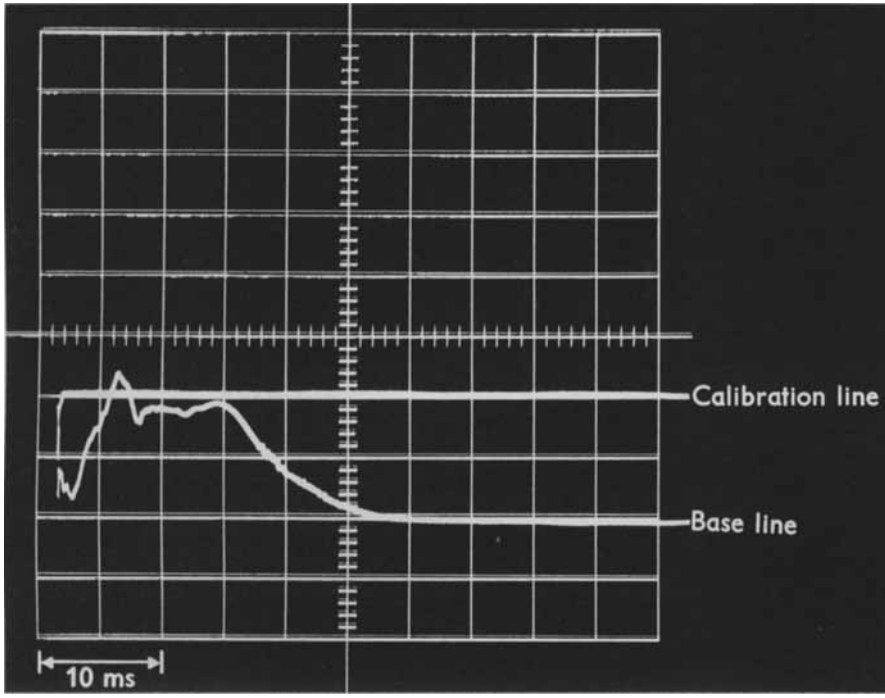


Fig. 3. Applied force as a function of time. (case no. 28)

The achilles tendon was held under tension by a special spring (Fig. 2: 7). In order to counteract this force a special device (Fig. 2: 8) was fixed to the anterior part of the foot. Through these arrangements the position of the foot could be varied. The stand on which the preparation was mounted (Fig. 2: 9) was given a total weight of 75 kilograms. It was placed on the floor but not fixed to it. Thus when the pendulum struck the preparation, as mentioned above, this stand could move on the ground.

The ultimate experimental set-up was based on a series of test-runs. During these it was found, among other things, that when the stand was fixed to the floor, os calcis fractures occurred of a type, not seen clinically. The same was true when the pendulum struck an unprotected heel. The type of fracture occurring in these latter case was a gross fracture in the plantar aspect of the tuber, with a mosaic pattern. Not until the stand was allowed to move freely against ground resistance and the specimen was secured in a shoe and plate did one succed in obtaining fractures similar to the ones seen clinically.

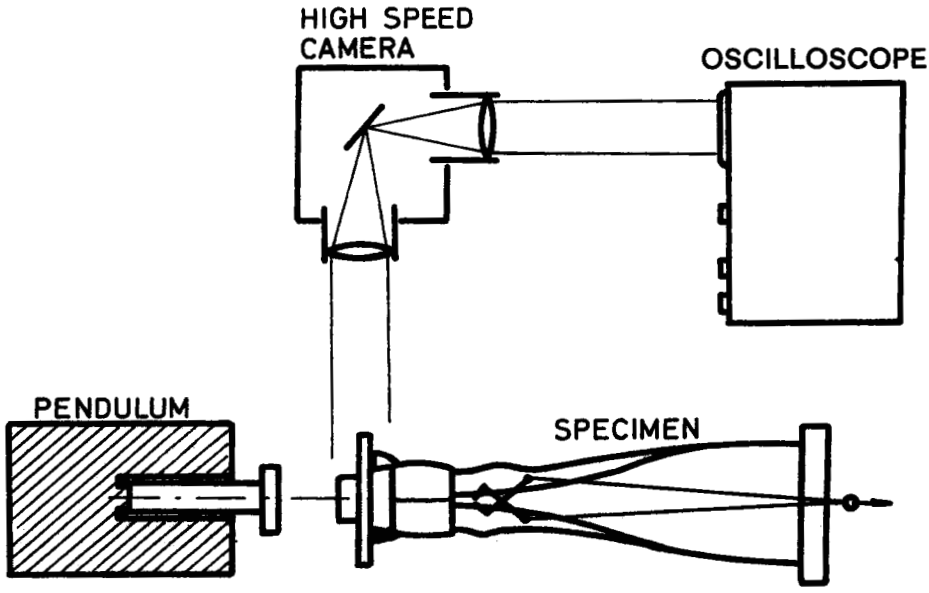
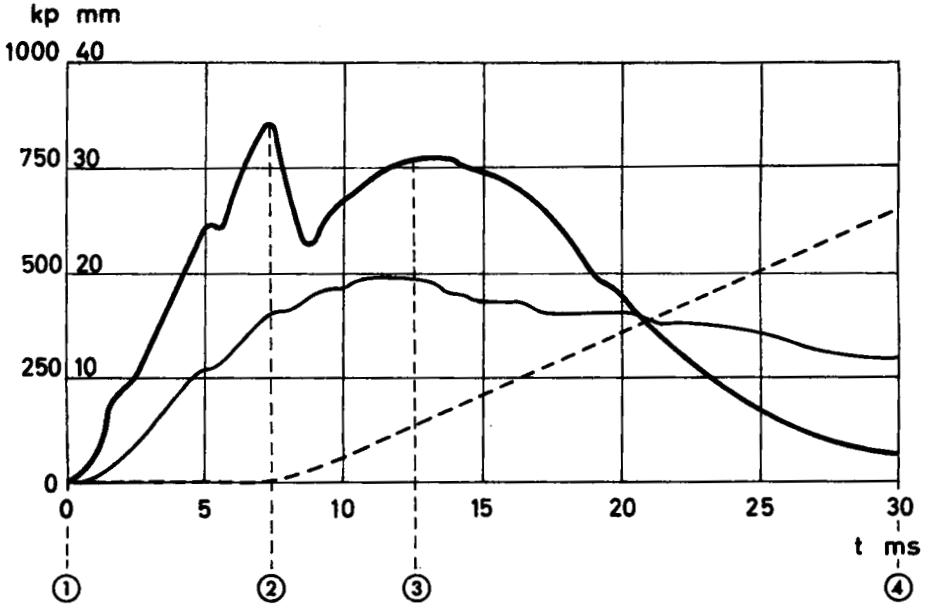


Fig. 4. Drawing illustrating the method of high speed photography during impact.

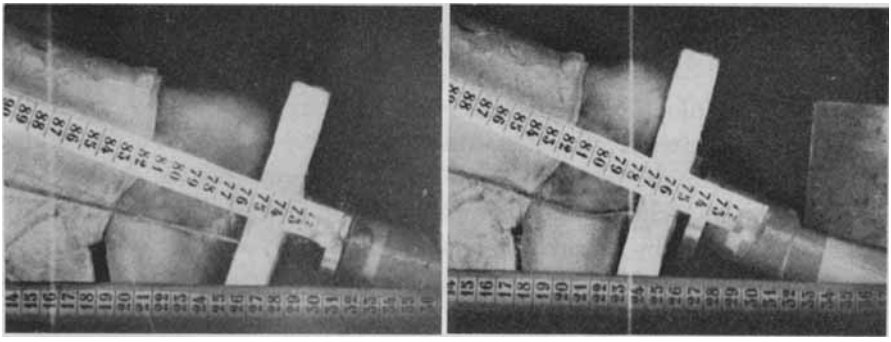


Force (Kp) as a function of time.

Compression of specimen (mm) as a function of time.

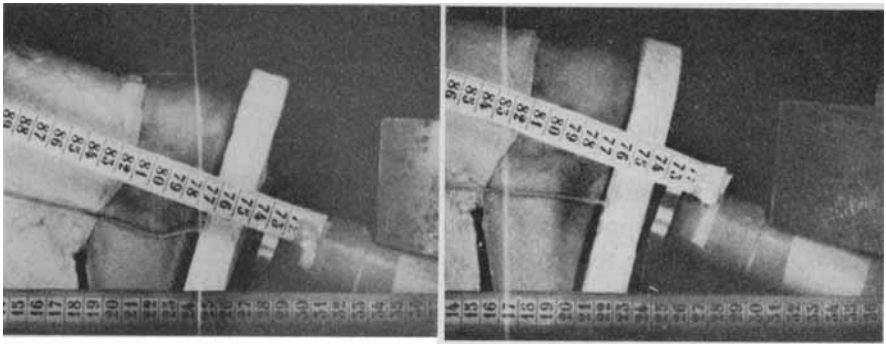
Displacement of retaining stand (mm) as a function of time.

Fig. 5. Composite graph showing the relationship between time, applied force, the degree of compression produced and displacement of the retaining stand. (Case No. 36)



① Start of impact.

② t = 7.4 ms
Force = 865 Kp
Compression of specimen = 16 mm
Displacement of retaining
stand = 0 mm



③ t = 12.7 ms
Force = 780 Kp
Compression of specimen = 19 mm
Displacement of retaining
stand = 6 mm

④ t = 30 ms
Force = 75 Kp
Compression of specimen = 12 mm
Displacement of retaining
stand = 27 mm

Lateral roentgenogram of the fractured specimen.

Fig. 6. Figures obtained at specific times ① ② ③ and ④ denoted on facing graph. The vertical white line across the pictures represents the force as recorded from the oscilloscope.

Pre- and post-experimental radiograms were taken of the specimens. The technique used for these radiograms has been described by Brodén 1949 (chapter 4 page 35). Some of the preparations were subjected to a further radiographic analysis with tomography. All these specimens were dissected after having been stored in a deep-freeze. The dissections were made with the specimens still frozen in order not to derange the fracture pattern. The dissected preparations were then all photographed.

The falling height of the pendulum and thereby its kinetic energy at the moment of impact was varied. From the earlier experiments the amount of energy needed to produce fractures of the os calcis were determined. It was also established that this variable amount of kinetic energy necessary to produce fractures was due to several factors among those the age and general condition of the skeleton as seen from the roentgenographic pictures.

The tensional force in the achilles tendon varied between 0—40 kilograms. Within these limits no gross difference in the pattern of the fractures were obtained. This tensional force helped to vary the position of the foot in the ankle and subtalar joints without giving it a rigid position.

In some experiments the impact was recorded with a high speed camera (type Kodak) with a maximum capacity of 3,000 frames/second. (fig. 4). This camera was equipped with two objectives at right angles to each other. This made it possible to register directly both the impact and the force-time relationship on the oscilloscope. It was also possible to determine the amount of compression occurring in the specimen and to study its relation to time and movement of the retaining stand. Along the longitudinal axis of the specimen a ruler was mounted. A second ruler was fixed on the floor. In this way it was possible to visualize the amount of compression in the heel, and the amount of motion of the stand after the moment of impact. In these cases the calibration was fed into the oscilloscope and recorded by the camera on the same film as the following experiment. Thus the white vertical line representing the force, seen in fig. 6, could be evaluated.

In figure 5 are shown the curves from such a representative experiment. These curves were produced from 70 pictures taken at the speed of 2,100 frames/second. In figure 6, four pictures from four different periods of the experiment are shown (marked 1—4 in fig. 5). Both from the curves in fig. 5 and from fig. 3 it is possible to demonstrate a bi-phasic course of the force line. In the beginning it rises steeply, turns downward for a moment only again to rise, but this time somewhat slower. During the first phase most of compression is occuring and probably also the fracture, at least to some extent. This view is supported by fig. 5 and in

this case the second phase probably corresponds to further compression of the bone and to the force displacing the 75 kilogram retaining stand. It is possible to interpret from the pictures how the stand is beginning to move during this second phase (fig. 5). It is also seen that most of the impact period is spent within 30 milliseconds. After the maximum total compression is recorded, some rebound occurs in the soft tissues. The remaining deformity will be due to the fracture of the os calcis.

Type of experimental fractures

Altogether the final experimental series which could be evaluated comprised of 36 cases. The fractures that occured were classified with regard to the antomical appearance as seen on radiograms as well as from anatomical dissections. In table 1 are recorded pertinent data from all the final experiments.

Based on the results obtained from this experimental investigation it was found possible to classify the fractures on anatomical, roentgenological and patho-mechanical grounds into four main types. The fracture types have also been clossified according to Widén (p. 42) and to Palmer (p. 43).

Type I. (fig. 7).

Fractures of type I occurred when the foot was pronated at least 10 degrees and dorsiflexed 5—10 degrees through the talo-crural joint. The fracture pattern seen in these cases was composed of a main shearing fracture extending from the plantar and medial aspect of the os calcis forward, cranially and laterally to just behind the posterior articular facet. This fracture runs lateral to the posterior facet into the sinus tarsi which is fragmented.

Usually, the os calcis is separated into two fragments; one smaller antero-medial carrying all the articular facets and displaced caudal and medial in relation to the second and larger postero-lateral fragment.

This type of fracture corresponds clinically to group V according to Widén's classification.

Type II (fig. 8).

Fractures of type II occurred when the foot was in mid position of the subtalar joints and zero or at most 5—15 degrees plantar flexion of the talocrural joint.

The fracture pattern seen in these cases was composed of a main shearing fracture through the posterior articular facet running in to the sinus tarsi, which was fragmented, and a longitudinal fracture in the lateral

Table 1. Factors involved in the production of experimental os calcis fractures.

No.	Age	Achilles-tension (Kp)	Position of the foot, in degrees:				Maximum force (Kp)	Fracture group	Type of fracture	Authors classification
			dorsiflexion	plantar flexion	supination	pronation				
1	74	20	—	10	10	—	—	VII	2	IV
2	57	20	—	10	—	—	—	VI	2	II
3	83	30	10	—	—	5	—	VI	1	III
4	74	40	10	—	—	5	—	VI	1	III
5	59	10	—	10	15	—	—	VII	2	IV
6	25	30	—	10	15	—	—	VII	2	IV
7	84	10	10	—	—	10	—	V		I
8	72	40	—	10	5	—	—	VI	2	II
9	60	10	—	10	10	—	—	VII	2	IV
10	58	30	—	10	15	—	—	VII	2	IV
11	38	10	—	15	15	—	—	VII	2	IV
12	50	20	10	—	—	5	—	VI	1	III
13	34	10	—	10	10	—	—	VII	2	IV
14	55	10	—	10	—	—	—	VI	2	II
15	77	30	—	10	15	—	—	VII	2	IV
16	89	10	10	—	—	5	—	VI	1	III
17	70	30	5	—	—	10	—	V		I
18	63	20	5	—	—	5	—	VI	1	III
19	64	—	10	—	—	—	—	VI	1	III
20	73	10	5	—	—	10	—	V		I
21	65	30	—	10	10	—	1040	VII	2	IV
22	73	10	—	10	—	—	1160	VI	2	II
23	84	20	10	—	—	—	850	VI	1	III
24	84	10	—	10	—	—	885	VII	2	IV
25	82	—	—	—	—	—	695	VII	1	III
26	82	10	—	10	—	—	885	VII	2	IV
27	80	20	5	—	—	10	855	V		I
28	75	20	5	—	—	—	880	VI	2	III
29	76	—	—	—	—	—	1110	VI	2	II
30	76	—	—	10	10	—	840	VII	2	IV
31	57	20	5	—	—	—	1075	VI	1	III
32	62	30	5	—	—	5	1125	VI	1	III
Experiments with high speed camera at the moment of impact.										
33	73	—	5	—	—	—	700	VII	2	III
34	75	—	5	—	—	—	600	VI	2	III
35	79	—	—	5	5	—	825	VII	2	IV
36	78	—	—	—	—	—	865	VII	2	IV

wall of the os calcis. Usually, in this type of fracture the os calcis is separated into a antero-medial fragment carrying part of the posterior facet and a postero-lateral fragment carrying the lateral part of this facet. This latter part very often is compressed and tilted in relation to the main antero-medial fragment, producing a dislocation within the posterior articular facet. This type of fracture corresponds clinically to Group VI or VII according to Widén's classification, and to type 2 according to Palmer's classification.

Type III. (fig. 9).

Fractures of type III occurred when the foot was in midposition with regards to the subtalar joint while there was 5—10 degrees of dorsiflexion in the talocrural joint.

The fracture pattern seen in these cases was again composed of the shearing fracture through the posterior articular facet into the sinus tarsi which was fragmented. The lateral wall on the larger postero-lateral fragment is fractured at the level of the posterior facet. This latter fracture runs behind the posterior facet, which becomes depressed in relation to the remainder of the large postero-lateral fragment.

This type of fracture corresponds clinically to group VI or VII according to Widén's classification, and to type 1 acording to Palmer's classification.

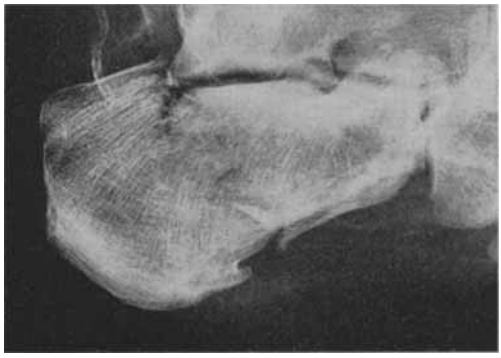
Type IV. (fig. 10).

Fractures of type IV occurred when the foot was supinated at least 10 degrees and plantar flexed 5—15 degrees through the talocrural joint.

In these cases the shearing fracture runs close to the medial border of the posterior articular facet into the sinus tarsi which is fragmented. There also exists, in this type, a fracture running from the sinus tarsi along the lateral wall of the tuber.

The main postero-lateral fragment carrying the entire posterior articular facet, is compressed, thus creating a diastasis between the talus and the facet.

This type of fracture corresponds clinically to group VII according to Widén's classification and to Palmer's type 2.



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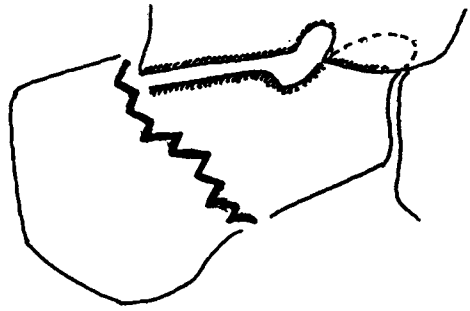

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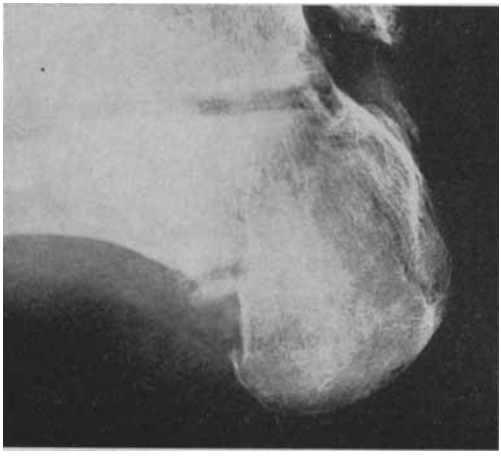

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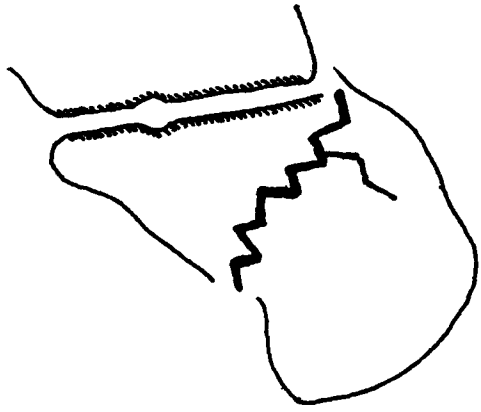

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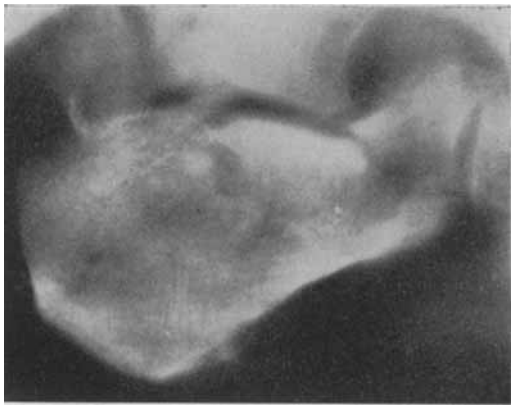
Fig. 7. Fracture of type I (case no. 7): a) lateral view. b) projection I. c) tomogram d) dissected specimen seen from above.



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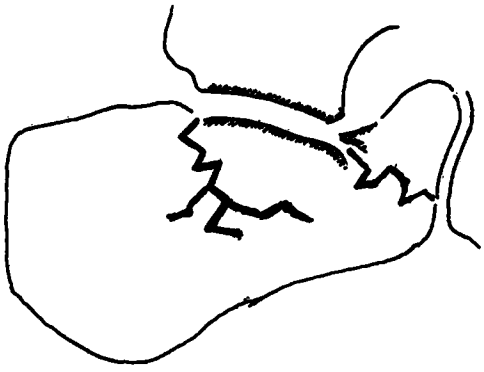

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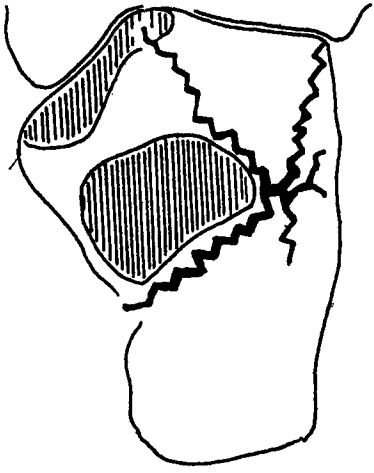

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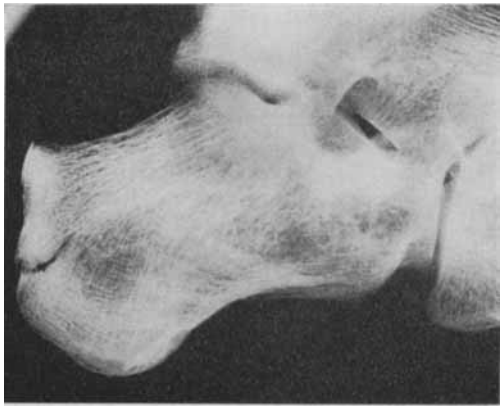

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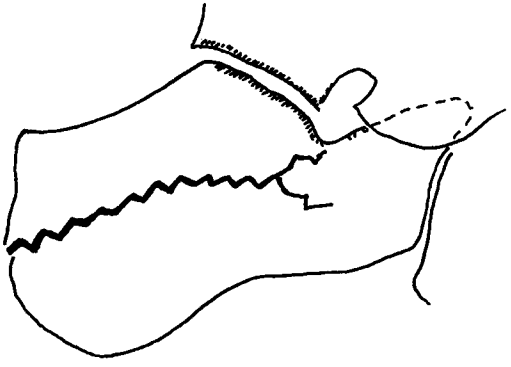

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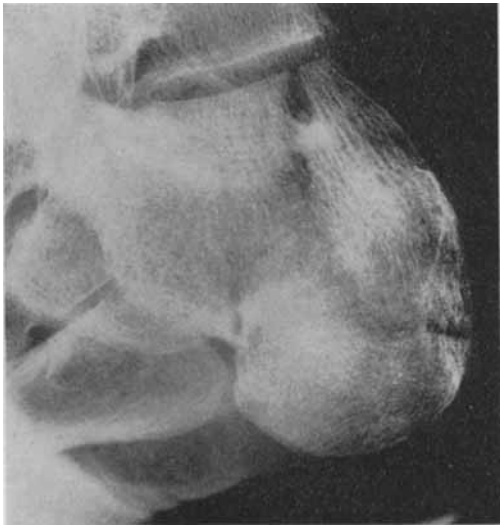

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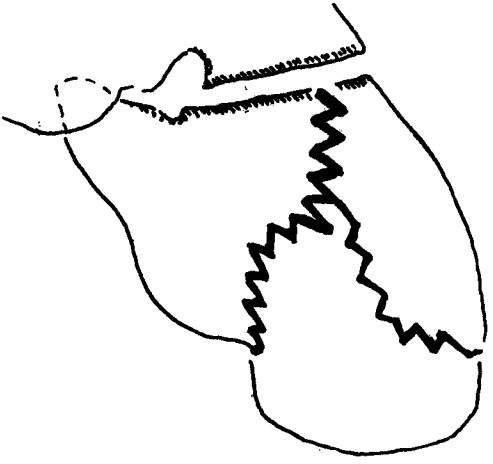

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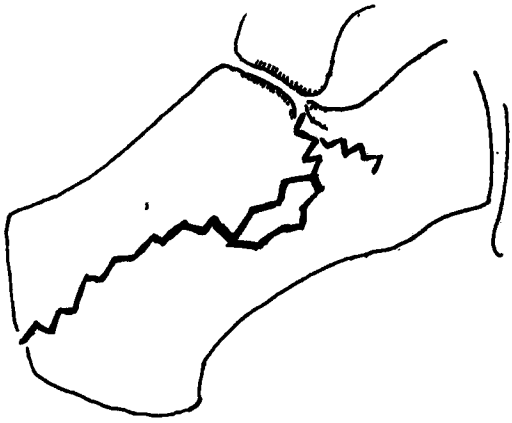
Fig. 8. Fracture of type II (case no. 14): a) lateral view. b) projection I. c) tomogram. d) dissected specimen seen from above.

c



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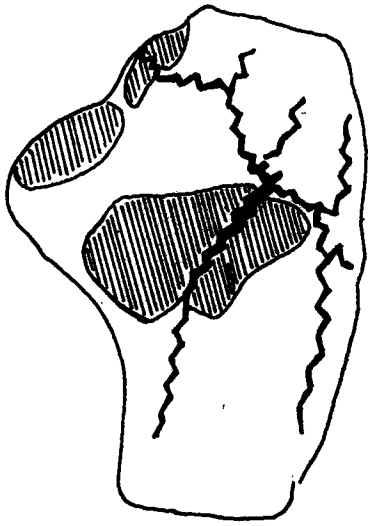

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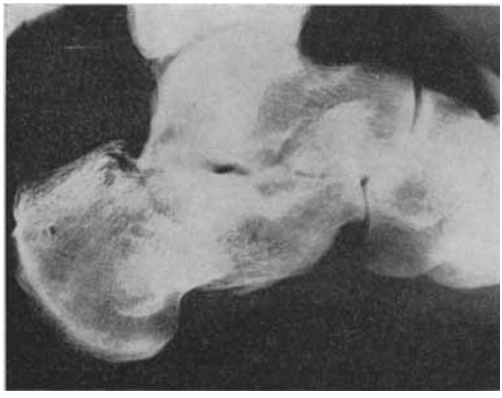

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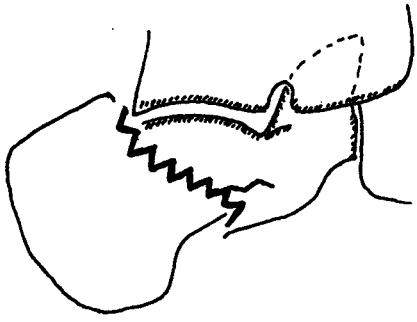

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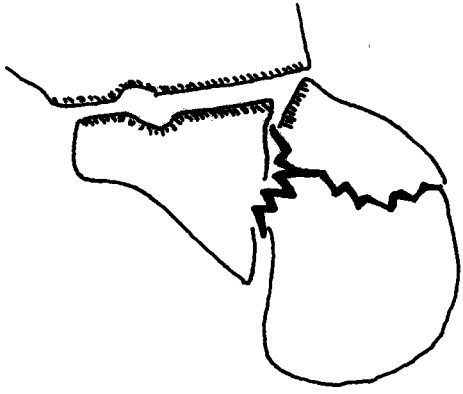

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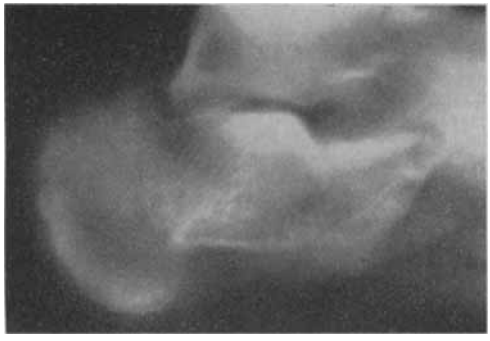
Fig. 9. Fracture of type III (case no. 12): a) lateral view. b) projection I. c) tomogram. d) dissected specimen seen from above.



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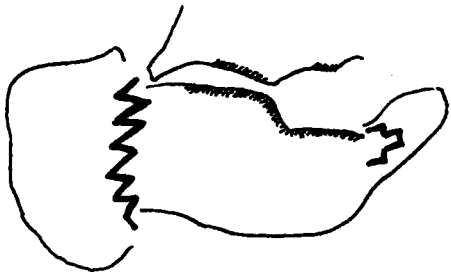

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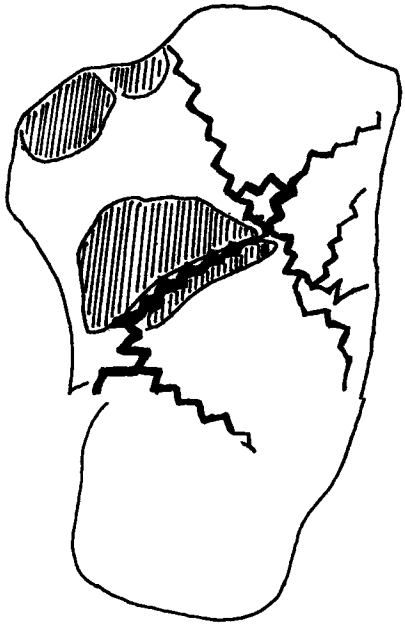

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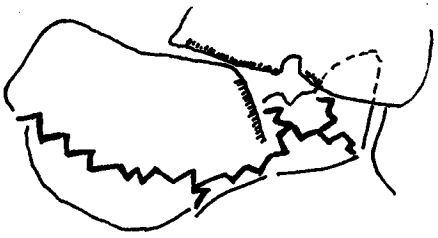

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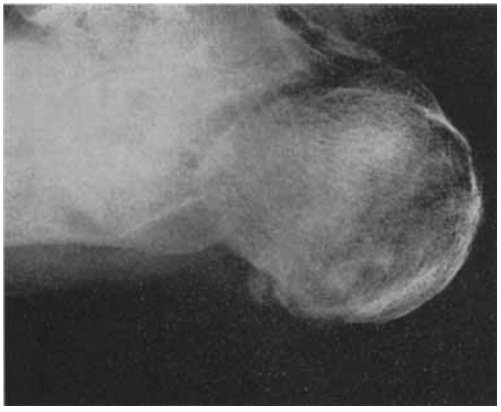

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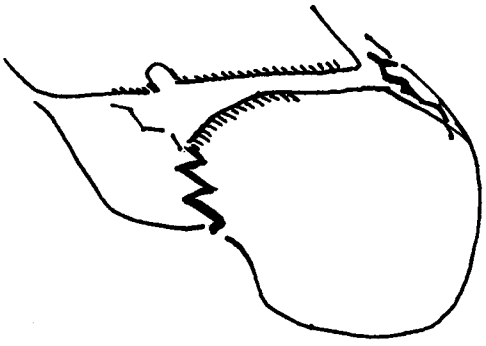

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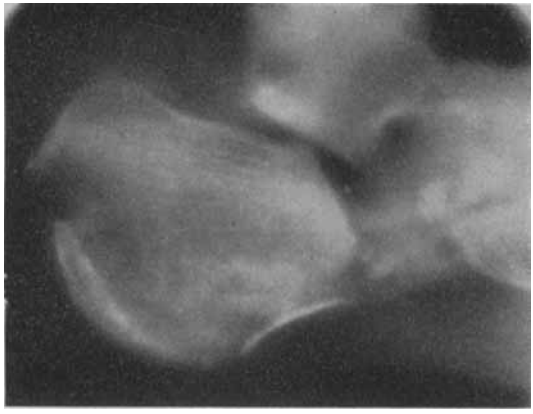
Fig. 10. Fracture of type IV (case no. 11): a) lateral view b) projection I c) tomogram d) dissected specimen seen from above.



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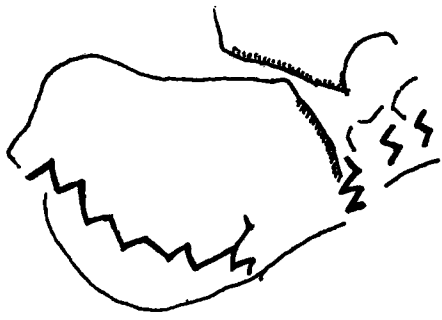

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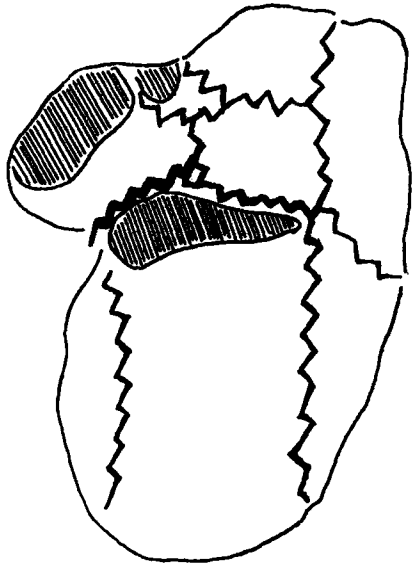

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Attempts at explanation of the fracture mechanism.

When a force acts on the os calcis this bone will be compressed against the talus. Dependent on the direction of the force, i. e. the position of the foot at the moment of impact, different parts of the posterior articular facet in the talo-calcaneal area will sustain the trauma. If the force is of sufficient magnitude it will fracture the os calcis.

At the moment of impact the os calcis is forced against the talus. If the force is great enough it will produce a fracture which tends to separate the os calcis in two parts, one antero-medial including the sustentaculum tali and one postero-lateral including the tuber. Thus the os calcis nearly always is separated into two halves. This main fracture has been called the shearing fracture. The direction of this fracture appears to be dependent on the position of the foot at the moment of impact. If the foot is supinated the shearing fracture tends to run more medial (see figure 11). In these cases the resistance against the talus will then come from the greater postero-lateral fragment carrying the main part of the posterior articular facet. If the remaining force is of sufficient magnitude a compression fracture of the postero-lateral fragment will eventually occur if the lateral wall of this fragment also is fractured. (figure 10).

If the foot is held in pronation the force will act with maximum force lateraly in the subtalar joint and the shearing fracture thus will run more lateral as seen in figure 11. In these cases (figure 7) no further compression will occur as the talus usually will act on the facet carrying

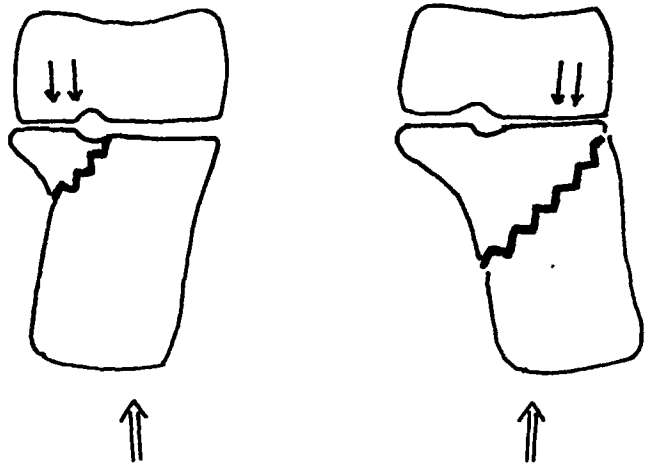


Fig. 11. Posterior views of the right foot showing the direction of the shearing fractures of the os calcis in supination (A) and pronation (B).

antero-medial fragment which can slide downwards without meeting any greater resistance.

Between these two borderlines the shearing fracture seems to run somewhere through the posterior articular facet. Again in these cases a compression will occur of the facet carrying the postero-lateral fragment in the same manner as just mentioned, i. e. there must also be a fracture of the lateral wall of the os calcis (figure 8 and 9). The main antero-medial fragment, together with the sustentaculum tali and medial part of the separated posterior articular facet, can slide downwards against practically no resistance.

In all the experiments the sinus tarsi was fragmented. The fragmentation of this part can be due to several factors and the shape of the talus is one of them.

The tilting of the articular facet however, probably depends on the fact that the ligaments in the sinus tarsi are strong and always, without exception, were found uninjured at the dissections. These ligaments keep the small fragments together and in their aproximate relations to the talus. The articular facet on the other hand lacking such ligamentous support can be tilted downwards to obtain a more vertical direction. One other possibility is of course that there is a rebound mechanism by which the smaller fragments are first depressed to the same degree as the talus; at the moment of rebound they again move upwards, still being attached to the talus.

CLINICAL SECTION

CHAPTER 3

Survey of the Material.

Since the early nineteen-fifties early active exercise has along with other forms of treatment, been included in the management of fractures of the calcaneus at the Surgical Department of Akademiska Sjukhuset in Uppsala. Thus, during the period from January 1952 until July 1956, 16 out of 26 patients with fracture of the calcaneus received early exercise therapy. The results of this form of treatment during that period were favourable. In many cases the functional end results were satisfactory, as the author himself has been able to confirm in a follow-up examination of these patients. This series however, in addition to being too small, had the disadvantage of being selected which disqualified it for a critical follow-up study. In order that the efficacy of the method might be tested on completely unselected material, it was decided that from the middle of 1956 all patients with fractures of the calcaneus coming under the care of the Department, unless contraindicated by special features, were to be uniformly treated with active exercises started at an early stage. The intention was to provide us with an unselected, uniformly treated series as a basis for subsequent clinical evaluation. Fairly soon it became evident, however, that we could not expect to collect a sufficiently large series within a reasonable period of time. In the face of this, it proved necessary to turn to other sources to secure more material for the planned study. From earlier investigations, the Surgical Department at Akademiska Sjukhuset had positive experience in the cooperation of surgical departments in other parts of Sweden.

There were two conditions which we felt were essential in making a study of this kind feasible.

1. The method of treatment should not present any problems and permit a standard procedure to be followed.

2. In conducting the study, one must be able to rely upon the intimate cooperation and active interest of the surgeons from other departments who have undertaken to assist in the investigation.

Both these requirements were satisfied in the present investigation.

Table 2 presents the hospitals which cooperated in this investigation and illustrates the distribution of cases placed at the author's disposal in

Table 2. Geographic distribution of total series

Center and date	Number of patients	Number of fractures	Number of patients treated by operation or plaster fixation
Uppsala—Enköping Oct. 1956—1959	32	33	3
Linköping May 1957—1959	8	9	3
Norrköping May 1957—1959	18	20	1
Karlstad June 1957—Jan. 1960	8	9	1
Karlskoga May 1957—1959	5	5	1
Falun May 1957—1959	12	14	2
Sala—Sandviken 1957—Jan. 1960	11	12	2
Gävle 1957—1959	23	27	1
Söderhamn—Ljusdal 1959—Jan. 1960	5	5	—
Östersund 1959	9	10	1
Luleå 1957—1959	12	12	—
	143	156	15*)

*) This number includes the 6 cases of bilateral fracture in which one side was treated by operation or plaster fixation.

each instance with respect to the number of fractures that were treated and the time of their treatment. Originally three more surgical departments from other parts of Sweden contributed material, but these cases were excluded as they were found to have been subject to selection. For various reasons, the collection of material from the different departments was begun at different times, but on the whole the investigation comprises the 3 year period 1957—59.

The total series includes 143 patients with 156 fractures of the calcaneus, which means that bilateral fractures occured in 13 cases.

The table further shows that 15 patients have been treated by other methods. In 6 cases this was occasioned by complications or other injuries situated close to the fracture site, which made active exercise impossible. Three cases were mistakenly treated by other methods. In 6 cases of bilateral fractures, eventually one side was treated by plaster fixation or operation, for reasons which will be further discussed in chapter 7 (p. 64).

CHAPTER 4

Radiographic Examination

Ordinary lateral and semi axial roentgenograms usually do not reveal in detail the extent of injury in the fractured os calcis.

From roentgenologic studies of clinical and experimental fractures of the calcaneus the author has formed the impression that roentgenograms taken with Brodén's projection I and II provide the most valuable information for clinical evaluation of the fracture. The method is based on the fact that the posterior articular facet constitutes the surface of a cone whose axis forms an angle of about 30 degrees with the long axis of the foot.

The technique, according to Brodén (1949), is as follows:

Projection I: The patient supine. Leg and foot are turned 45 degrees inwards with right angle flexion at the ankle joint. The central ray is directed against a point 2—3 cm. caudoventrally to the lateral malleolus. Four pictures are taken with the tube angled 40, 30, 20 and 10 degrees, respectively, towards the head.

The picture taken with the tube angled 40 degrees shows the anterior part of the talocalcaneal joint, the picture with the tube angled 10 degrees reproducing the posterior part. Some of the pictures (generally those with the tube angled 30 or 20 degrees), make the articulation between the sustentaculum and the talus visible.

Projection II: The patient supine. Leg and foot are turned 45 degrees outwards with right angle flexion at the ankle joint. The central ray is directed against a point 2 cm. caudoanteriorly to the medial malleolus with the tube angled about 15 degrees towards the head. It is suitable to take 3 pictures with a difference of 3—4 degrees. One of these will, as a rule, be perfect.

Tomography as an aid in analysis of os calcis fractures has earlier been used by Peter R. *et. al* (1961) and Grewald, I. *et al* (1961).

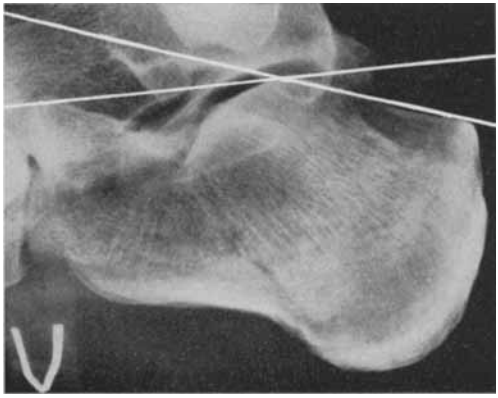
Initially in the investigation a number of fractures were studied with tomography, but the value of such evidence appeared insufficient to justify the amount of work examination by this technique would require. In addition, it would have been impossible to ensure a uniform roentgen examination of the entire series if tomography had been selected as a standard procedure, since many of the hospitals which contributed to the material did not have tomographic equipment at their disposal.

All patients included in the series which has been presented were subjected to roentgen examination on the first day of admission to hospital or within a few days of injury, and on one or two subsequent occasions

during the convalescent period. In connection with our follow-up study, all but two of the patients (cases no. 55 and no. 56) were again subjected to roentgen examination. The examination included in all cases one lateral view, one semiaxial view, and roentgenograms taken with Brodén's special projections. In every unilateral case a lateral roentgenogram was taken also of the normal foot.

The tuber-joint angle

The so-called tuber-joint angle, introduced by Böhler, has been defined as the complement of an angle formed by two lines, one of which is drawn between the upper margin of the anterior process and the upper margin of the lateral portion of the posterior articular facet; the other is drawn along the upper margin of the tuberosity (see fig 12 a and b). According to



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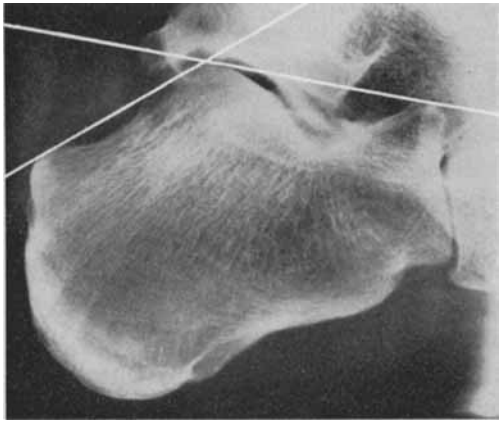


b

Fig. 12 Case no. 76. Demonstrating the tuber-joint angle on fractured (a), left foot and normal (b), right foot.

Böhler, the normal value of this complementary angle varies between 20 and 40 degrees. In intra-articular fractures of the calcaneus, it is often decreased and in some cases it may be entirely obliterated or present a negative value.

In the present series, the tuber-joint angle was measured in every roentgen examination. The measurements were accurate within one degree.

In order to estimate a possible effect on the observed values, arising from the technique of examination, the following analysis was made:

Five different examiners took one roentgenogram each of the injured and uninjured foot in four patients. Following this the tuber-joint angle was measured. The outcome of this analysis, designed to assess the error of the method, was that the variation in the values measured in the same foot never exceeded 3 degrees. The standard deviation for the values measured in the same foot was for the four patients:

In the fractured foot: 1.02, 0.71, 0.97 and 0.71 degrees respectively.

In the opposite foot: 0.87, 1.22, 0.81 and 1.30 degrees respectively.

On the whole we find that the error of the method, if evaluation is based on a single judgment, amounts to 0.95 degrees and therefore is of little consequence in comparison with the individual variations in the tuber-joint angle.

The tuber-joint angle provides a numerical expression of the degree of deformation of the calcaneus. With respect to this numerical value, however, we must take into account that its individual variations normally range between 20 and 40 degrees, according to Böhler. The diminution of the tuber-joint angle in comparison with the uninjured side must therefore be regarded as a more exact indication of the degree of compression of the fractured calcaneus. In all cases included in the present series, roentgenograms of the uninjured foot were on some occasion made in conjunction with roentgen examination of the fractured foot. The diminution of the tuber-joint angle could thus be defined. Since no exact information is available to determine what the normal variations of the tuber-joint angle are, and whether the values for the right and left foot in the same individual normally show appreciable individual variations, a random selected series of 25 healthy individuals was obtained.

In each case both feet were examined by one and the same examination. The highest observed value for the tuber-joint angle was 45 degrees, the lowest 20 degrees. No appreciable difference existed between the left and right foot (mean difference 32.5—32.3 degrees, standard deviation 1.6, and maximum variation between right and left foot was 3 degrees).

Displacement of the posterior articular surface

From anatomical studies of experimental fractures of the calcaneus (see chapter 2) and roentgenologic study of the clinical material, the author has found displacement of the posterior articular facet, resulting from the fracture which runs diagonally through the posterior articular surface, to be one of the most characteristic features of intra-articular frac-

tures of the calcaneus. This displacement is best evaluated on the basis of roentgenograms taken with Brodén's projections. The majority of cases in the present series were examined by this technique at the time of injury and the entire series again at follow-up. It was found that any initial displacement of the posterior articular surface on the whole persisted, and that physical therapy had failed to have much effect upon the degree of displacement. The follow-up roentgenograms show a certain filling in and rounding out of the fracture edges.

Evaluation of the degree of displacement of the posterior articular surface on the basis of roentgenograms is somewhat uncertain, since it is influenced by subjective criteria. In an attempt to eliminate this subjective element, the series has been evaluated not only by the author, but by four other judges quite familiar with the problems involved. As it was impossible to express the degree of displacement in a numerical value, the series was based on the roentgenograms, exemplified in fig. 13 and 14. These were divided into two groups characterized by moderate displacement (+) or considerable displacement (++) respectively.

With typical examples of moderate and considerable displacement as their criteria, the four other judges performed an independent grading of the material. The series at their disposal comprised of 88 cases of unilateral intra-articular fractures of the calcaneus. The results of this evaluation are set down in table 3.

Fig. 13. Case no. 76. Demonstrating moderat displacement (+) of the posterior articular facet.

Fig. 14. Case no. 57. Demonstrating considerable displacement (++) of the posterior articular facet.

The table shows that a unanimous judgment was reached in 65 out of the 75 cases with displacement. As for the 10 cases in which opinions differed, it can be noted that one case which the author assigned to be in the group with moderate displacement, according to the majority verdict, belonged in the group with considerable displacement. We may conclude that the evaluation is reliable, provided it is carried out by someone familiar with the problems involved.

Table 3. Evaluation of the degree of displacement of the posterior articplar surface.

Author's evaluation	Majority evaluation (author and 4 other judges)			Unanimous evaluation
	0	+	++	
0	13	–	–	13
+	–	39	–	34
++	–	1	35	31

0=no displacement
+=moderate displacement
++=considerable displacement

CHAPTER 5

Statistical Methods

The following formulae have been employed in the statistical calculations:

Notation. Number of patients = n.

Mean: $\bar{x} = \frac{\sum x_i}{n}$,

where x_i denotes the $_i$th patient.

Standard deviation:

$$\text{S. D.} = \sqrt{\frac{\sum (x_i - \bar{x})^2}{n-1}}$$

Standard error of the main:

$$\text{Mean} = \frac{\text{S. D.}}{\sqrt{n}}$$

and in comparisons between two groups x and y:

$$\sigma_{\bar{x}-\bar{y}} = \sqrt{\frac{\sum (x_i - \bar{x})^2}{(n_x - 1)\, n_x} + \frac{\sum (y_i - \bar{y})^2}{(n_y - 1)\, n_y}}$$

Standard weighted percentages: $\sum W_j P_j$.

where P_j is the percentage in the $_j$th subgroup,

W_j is the weight of the $_j$th subgroup, and $\sum W_j = 1$.

Weighted percentages are applied when comparing groups differing in the distributions. The weights, W_j, are chosen to correspond approximately to the number of patients in the respective sub-groups.

Confidence intervals

Confidence intervals corresponding approximately to the 95 % level are given in some tables, as

$$\bar{x} - \bar{y} \pm 2\, \sigma_{\bar{x}-\bar{y}}$$

Significance levels

The significance analyses are given in conjunction with the tables. As a rule, however, only "significant" results are presented. The term "significant" is used in accordance with the following convention. If an observed difference between two percentages (or two means) is of such a magnitude that the probability P of obtaining a difference at least as great as the observed value is greater than 0.05 (where the null hypothesis is assumed to hold), then that observed difference is said to be non-significant.

If $0.01 < P \leq 0.05$, the difference is said to be (probably) significant and is marked*.

If $0.001 < P \leq 0.01$, the difference is said to be significant and is marked**.

If $0.001 \geq P$, the difference is said to be (highly) significant and is marked***.

Significance tests

The following significance tests were used:

1. In percentage differences: χ^2-test usually with one degree of freedom.
2. In mean differences: the t-test if $n < 20$ but usually normally distributed

$$C.\ R. = \frac{\bar{x} - \bar{y}}{\sigma_{\bar{x}-\bar{y}}}$$

3. In differences between standard weighted percentages:

$$\sum W_j (P_{xj} - P_{yj})$$

a normally distributed critical ratio is produced:

$$R. = \frac{\sum W_j (P_{xj} - P_{yj})}{\sqrt{\sum W^2{}_j \frac{n_{xj} P_{xj} + n_{yj} P_{yj}}{n_{xj} + n_{yj}} \left(100 - \frac{n_{xj} P_{xj} + n_{yj} P_{yj}}{n_{xj} + n_{yj}}\right) \left(\frac{1}{n_{xj}} + \frac{1}{n_{yj}}\right)}},$$

where n_{xj} and n_{yj} correspond to the number of patients in the compared sub-groups.

CHAPTER 6

The Follow-up Series

The follow-up investigation took place during the latter part of 1960 and the early part of 1961. Of the patients included in table 2 those who had been subjected to plaster fixation or operation were excluded from the follow-up, with the exception of the 6 cases of bilateral fracture in which one side was treated with early exercise. Thus 134 patients remained. Out of this number, 5 had died. Of the remaining 129 patients, 121 or 93.8 %, were available for clinical examination. Since 11 of the patients in the follow-up series had bilateral fractures, the total number of followed-up fractures was 132.

Classification

Almost every author who has ever written about fractures of the calcaneus, has his own views on classification of the material. The author has chosen to adopt Widén's classification, mainly for the purpose of providing a basis for comparison of the present series, treated with early exercise, with a series subjected to a standard form of operative treatment.

Table 4. Classification (according to Widén) of fractures included in total series

Classification according to Widén	Number of fractures included in follow-up	Number of fractures not included in follow-up	Total
A. Groups I—IV	22	8	30
B. Group V	15	1	16
Group VI	59 (Palmer's Type 1:39 Type 2:20)	4	63
Group VII	36 (Palmer's Type 1:16 Type 2:20)	11	47
Total	132	24	156

The classification of the present series is illustrated by table 4. In order to present an over-all picture of the material, the series was broken down into the followed-up and non followed-up fractures.

Since earlier studies in a majority of cases have demonstrated that extra-articular fractures of the calcaneus seldom give rise to persisting disability, these fractures have been collected within one group A, corresponding to Widén's fracture groups I—IV. Of the 22 fractures in this part of the series which were included in the follow-up, the majority were referable to group II, i. e. fracture of the medial tubercle.

The other main division comprise fractures through the body of the calcaneus. This group B has in Widén's classification been divided into 3 subgroups:

Group V: The shearing fracture runs behind and below the posterior articular facet or upwards towards the posterior facet without causing any displacement of the posterior articular surface.

Group VI: The shearing fracture runs into the lateral portion of the posterior articular facet and causes depression of the lateral fragment.

Group VII: The shearing fracture runs a more medial course and causes depression of the whole or major portion of the posterior articular facet.

As shown in table 4 followed-up fractures belonging to groups VI and VII have been subdivided into Palmer's type 1 and type 2. Palmer (1948) subdivided the secondary compression fractures into two main types:

1. The articular fragment, more or less deeply impacted into the subjacent bone, was 1—1.5 cm in height and equal to the articular surface in length.
2. The articular fragment extended posteriorly to include the upper part of the tuber, whereby the tuber was split in two portions, which gaped apart posteriorly.

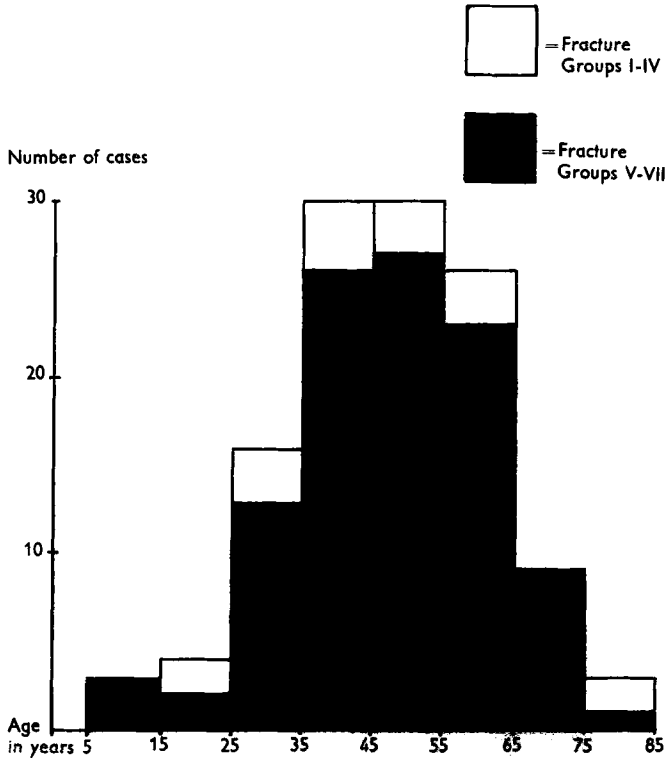
Fractures assigned to groups V—VII are in the present study designated as intra-articular fractures.

Of the 110 unilateral fracture included in the follow-up, 61 involved the right and 49 the left side.

Age and sex distribution

The age distribution of the follow-up series is illustrated by diagram 1. The bulk of the material is concentrated within the age groups between 30 and 60. Seen as a whole, the age distribution shows good general agreement with the figures presented by other authors (Widén, Ahlberg, Gollach, Arnesen). The average age of the entire follow-up series is 47.3 years.

Diagram 1. Distribution of follow-up series with respect to age and fracture groups



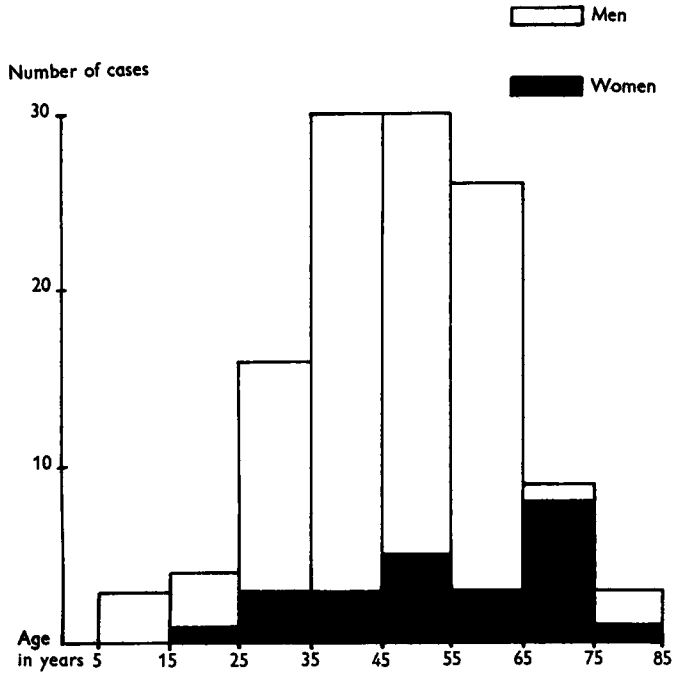
Number of cases:									
Groups I—IV	0	2	3	4	3	3	0	2	Total 17
Groups V—VII	3	2	13	26	27	23	9	1	„ 104
Total	3	4	16	30	30	26	9	3	„ 121

(cases with bilateral fractures referable to two different groups have been assigned to the higher group)

The distribution of the sexes is illustrated in diagram 2. Twenty-four or 19.8 %, of the patients are women. This percentage is about the same as in Widén's series, but somewhat higher than the figures reported by other authors (Ahlberg 14.1 %, Gollach 9 %). The average age for women is somewhat higher than for men (54.4 as against 45.9 years).

From these two diagrams it is further evident that the milder and the more severe forms of fracture are fairly evenly distributed over the different age groups. By contrast we find that the majority of women are referable to the higher age groups.

Diagram 2. Sex and age distribution of follow-up series



Number of men	3	3	13	27	25	23	1	2	Total	97
Number of women	0	1	3	3	5	3	8	1	„	24
Total	3	4	16	30	30	26	9	3	„	121

Mode of injury

Most of the calcaneal fractures in this series were caused by falls from a height. The mode of injury varies, however, with respect to fracture group. Almost half of the patients assigned to fracture groups I—IV, representing the milder forms of fracture, incurred their injuries in traffic accidents or had their foot crushed. In one case the fracture was due to an accident with explosives.

The more severe forms of fracture, assigned to groups V—VII, are almost without exception the result of a fall from heights varying from 0.5 to 8 metres. A rough estimation of the average falling height for men and women shows that there is a difference: for men, the average heights is 3.4 metres, for women 1.3 metres. The highest average falling height, 4.3 metres, is found for the 6 cases of bilateral, intra-articular fracture.

Concomitant injuries

Twenty-nine of the patients in the follow-up series had incurred other substantial injuries simultaneously with the calcaneal fracture. This amounts to 23.9 %, approximately the same incidence as reported by Ahlberg and Arnesen. Both Widén and Olofsson, (1940) on the other hand, report a considerably lower incidence of concomitant injuries (8.3 and 8.7 % respectively).

The following injuries were noted:	
Vertebral fracture (single or multiple)	5 cases
Pelvic fracture	4
Fracture of the femoral neck	2
Femoral fracture	1
Fracture of the condyle of the knee	3
Lower leg fracture	1
Malleolar fracture	3
Metatarsal fracture	2
Fracture of the radius	8 (including one case of bilateral fracture)
Fracture of the wrist	2 cases
Costal fracture	1

Treatment

The great majority of patients (112 out of 121 that were followed up), were hospitalized for some time following injury. Treatment was based on the following principles.

1. Bed rest with the injured foot elevated.
2. Active exercises initiated on the first or second day following injury, under the supervision of a physical therapist. The exercises were designed to aid articular mobility in the entire foot.

Swelling of the soft tissues around the fracture site and the pain normally experienced during the first few days following injury required caution in the beginning; after about one week the range of mobility could be gradually increased and patients were instructed in active exercises designed to improve the total range of mobility, with the emphasis on pronation and supination. After their discharge from hospital the patients were allowed to be up and walk on crutches without weight-bearing. The patient continued with active exercises, often supervised by a physical therapist. Weight-bearing was permitted by individual standards, but as a rule after 7—9

weeks. A little over half of the patients used an arch support type for some time after weight-bearing was allowed.

The treatment of outpatients was on the whole carried out along similiar lines.

Length of hospitalization

The majority of patients with extra-articular fractures were hospitalized even though there was no actual indication for hospital treatment.

The average length of hospitalization for patients with intra-articular fractures is illustrated by the table below.

We find that the average length of hospitalization for cases with unilateral intra-articular fractures not associated with other substantial injuries is 15,8 days — a little more than 2 weeks. This may seem a high figure, but the length of hospitalization is largely due to the fact that the patients in this series were intentionally kept in hospital as long as possible in order to guarantee uninterrupted exercise therapy, in particular during the immediate post-injury period.

For the 12 cases with unilateral fractures of the calcaneus associated with other injuries tending to prolong hospitalization, the average hospitalization time is, naturally, considerably longer (43.8 days). For the 11 cases of bilateral fracture the average length of hospitalization is 38.5 days.

Table 5. Average hospitalization time for patients with intra-articular fractures.

	Number of cases	Average hospitalization time in days (range)
A. Unilateral fractures		
1. Without other substantial injuries	77	15.8 (2—53)
2. With concomitant injuries prolonging hospitalization	12	43.8 (14—95)
3. Outpatient care	4	0
B. Bilateral fractures	11	38.5 (7—102)

Follow-up procedure

All patients included in the follow-up series were examined by the author in person. About one third of those in the series were subjected to repeated examinations. For this follow-up examination the patients were

as a rule requested to come to the hospital where they had been treated. Here a subjective history was taken and the patient subjected to clinical and roentgenographic examination. In a few isolated cases the follow-up examination took place in the patient's home or at his place of work, in which case roentgen examinations were taken at a later date at the nearest hospital. The subjective history was intended to determine the presence of pain at rest and following use, and the type of function producing pain. The history further included any information about swelling around the injured ankle following use, stiffness, and the patient's subjective evaluation of walking function on both flat and rough surfaces. Finally the patient was required to evaluate his occupational fitness.

For the purpose of the follow-up analysis, the subjective evaluation of function were graded according to a system which is essentially identical with that of Widén. The following four gradations were used.

1. *Excellent:* No subjective symptoms and unimpaired occupational fitness following recovery.

2. *Good:* Negligible subjective symptoms causing no impairment of occupational fitness. The symptoms which were tolerated for classification of the results as "good" were very slight and took the form of "weather sensitivity" or an occasional twitch in the lateral aspect of the foot following maximum exertion.

3. *Fair:* Moderate subjective symptoms consisting of pain following exertion. Many of the patients assigned to this group reported transient stiffness of the injured foot in the morning and swelling of the ankle following use. These patients have returned to their former employment, but in most cases the symptoms required a certain restriction of activity at work. They did consequently not regain full occupational fitness.

4. *Poor:* Pronounced symptoms. Pain following even slight use with difficulty in walking on rough surfaces. Stiffness of the joint and swelling around the joint after moderate use. As a rule there is a loss of occupational fitness and many of these patients have been forced to turn to less strenuous work.

"Excellent" and "good" results were designated as *favourable* with respect to function, "fair" and "poor" results as functionally unfavourable.

This grading is naturally influenced by the author's subjective views, but on the whole one may say that the essential difference between unfavourable and favourable functional results lies in the total absence of any restriction of occupational fitness in the latter group.

The clinical examination included inspection of the injured foot and comparison with the opposite side. In addition, the patient's gait and his ability to walk on his toes and heel were evaluated. Any valgus or varus

deformity was recorded, and as well as any broadening of the heel region. Pain on pressure and any sensory or circulatory impairment in the injured foot was also noted as well as hammer toe deformity and callous formation. The girth of the calves was measured at the greatest part and measurements were made to determine the mobility of the subtalar and talocrural joints.

On the basis of the roentgenograms taken at the time of injury and at follow-up, the tuber-joint angle was measured and compared with the value for the opposite foot. The roentgenograms further served to identify remaining displacement and deformation of the subtalar articular surface and to detect any signs of degenerative arthrosis.

The fractures of primary clinical interest are those involving the joint, which in this series have been assigned to group V—VII. The follow-up results which are subsequently presented are primarily based on this type of fracture. Table 6 shows the distribution of the entire follow-up series with respect to fracture groups and functional results.

In order to create a homogeneous group of unilateral intra-articular fractures, the following cases were excluded from the series:

1. All 17 cases assigned to groups I—IV.
2. Unilateral fractures assigned to groups V—VII with severe concomitant injuries which had an unfavourable effect on the end results. In this series there were 8 such cases.
3. Bilateral fractures in which both were classified in any of the groups V—VII.

By these eliminations we obtain a series consisting exclusively of unilateral intra-articular fractures, and comprising 90 cases in all.

This series has been designated the "Comparative series".

Table 6. Distribution of follow-up series with respect to fracture groups and functional results.

Functional results	Fracture groups I—IV	Fracture group V	Unilateral fractures		Bilateral intra-articular fractures	Total
			Fracture groups VI—VII			
			Without concomitant injuries causing functional impairment	With concomitant injuries causing functional impairment		
Excellent	15	12	20	1		48
Good	2	1	25	3		31
Fair			18	2	2	22
Poor			14	2	4	20
Total	17	13	77	8	6	121

We find from table 6 that 79 patients in the entire follow-up series present favourable functional results, which amounts to 65.3 %. If we consider only the patients within the comparative series, the corresponding figures are 58 and 64.4 % respectively.

Length of follow-up

Experience from several major follow-up studies of calcaneal fractures indicates that the interval between injury and follow-up should not be less than 2 years. Some authors (Essex-Lopresti, Lindsay & Dewar) maintain, on the other hand, that a follow-up period of 1½ years is sufficient and that no subjective deterioration of the patient's condition appears to take place after that time.

In the present series the length of the follow-up period varies from 1 to 4½ years. For 81.5 % of the series the time of follow-up is 1½ years or more. Of the 22 patients for whom the length of follow-up has varied between 1 and 1½ years, all but three had returned to work at least 6 months prior to follow-up. The prolonged occupational disability in those 3 cases was largely due to other factors. In the majority of cases, therefore, function of the injured foot had been tested under normal conditions for at least 6 months before the follow-up took place.

Since the interval between injury and follow-up varies between such a wide range (1—4½ years) and for part of the series has been relatively short, it will be of interest to compare the length of the observation period in relation to the different functional results. Table 7 illustrates the distribution of the series in this respect.

We find from this table that the period of follow-up varies from 12 to 53 months. We cannot detect any tendency for the results to vary with follow-up periods of different length.

Table 7. Length of observation period (and range) in months within different groups. "Comparative series"

Functional results	Length of observation period average time in months (and range)				Number of cases		Total
	Fracture group V		Fracture groups VI—VII		Fracture groups V	VI—VII	
Excellent	28.5	(15—46)	29.3	(12—49)	12	20	32
Good	42.0		26.3	(12—53)	1	25	26
Fair			25.4	(12—39)		18	18
Poor			29.6	(14—49)		14	14
Total	29.5	(15—46)	27.5	(12—53)	13	77	90

CHAPTER 7

Follow-Up Results

A. Extra-articular fractures of the calcaneus.

The follow-up series includes 17 cases of unilateral fracture assigned to groups I—IV, 11 of them referable to group II which comprises fractures of the medial tubercle. The functional results in these cases were invariably favourable and none of the 4 patients insured under the Workmens Compensation Act were found to have any persisting disability. The period of occupational disability had been relatively short. Fifteen of the patients returned to full employment within 3 months of injury, the remaining two patients within 4 months. On the basis of the objective findings all patients were rated as fully recovered. These results are entirely consistent with those reported by other authors, regardless of the method of treatment (Essex-Lopresti, Widén and others).

B. Unilateral intra-articular fractures of the calcaneus.

The follow-up results presented in this section refer to the cases comprising the Comparative Series, i. e. unilateral fractures assigned to fracture groups V—VII. The criteria by which this comparative series was selected from the total follow-up series are evident from table 6 on page 45. This selection procedure provided a fairly large and well defined series of intra-articular fractures, permitting comparison of the objective findings in each individual case with the normal state as evidenced by the uninjured foot.

Subjective symptoms

Although the follow-up period in the present series is fairly short, judging from the results of previous investigations, the author considers it sufficient for the purpose of this study. Essex-Lopresti, for instance, states that no appreciable change in the results occurs after $1^1/_2$ years. Lindsay and Dewar found in a follow-up series of 147 intra-articular fractures of the calcaneus, with an average length of follow-up of 8 years,

that the subjective symptoms had been stabilized between 16½ and 19½ months following injury. In only 9 cases did they find that any impairment of the patients' condition had taken place at a later date.

We may recall, at this point, that for 80 % of cases in the follow-up comparatives series the length of follow-up was established as 1½ years or more.

The most common, and apparently the most persistent symptom of which the patients complain is pain in the foot when walking on rough surfaces or following use. The pain is almost invariably localized to the region around the lateral malleolus, in particular the anterior aspect. The severity of the symptoms is naturally dependent on the patient's activity. An elderly person or a young individual with sedentary work has lesser demands on good function of the foot than someone performing strenuous activity, and may consequently experience less discomfort from the injured foot. In the comparative series 60 % of the patients complained of pain in the foot brought on by strenuous activity or by walking on rough ground. This percentage covers such symptoms in its entire range and consequently includes even those patients with only occasional complaints of pain: In many of these cases the symptoms were slight and did not impair the patients occupational fitness, nor did they require any appreciable restriction of recreational activities. In a little over 20 % of cases, the patient complained of symptoms described as "rheumatic pain", brought on by changes in the weather. In a number of cases this constituted the sole subjective discomfort.

Gait

At follow-up the patients were examined with respect to their gait and their ability to walk on the toes. A patient's gait was designated as limping if he walked with a distinct limp, or showed a disturbance of gait in which the foot strikes the ground in a stiff and inelastic manner. Patients who walked without an obvious limp but were unable to walk on the toes were classed as having an impaired gait.

The table below shows the distribution of the comparative series with respect to gait and functional results.

This table shows that 67 out of the 90 cases, or 74.4 % had an entirely normal gait at the time of follow-up. The patients with the least favourable results in this respect, i. e. those who limp and are unable to walk on the toes, constitute 10 % of the series.

The correlation between gait and functional results is very high. We find that of 67 cases with normal gait 57 are referable to the groups designated by excellent or good functional results, whereas only one of

Table 8. Distribution of cases with respect to gait and functional results

Functional results	Normal gait on flat surface and ability to walk on toes	Normal gait on flat surface but inability to walk on toes	Limping on flat surface and inability to walk on toes	Number of cases
Excellent	31	1		32
Good	26			26
Fair	10	6	2	18
Poor		7	7	14
Total	67	14	9	90

the cases with impaired gait has been classed as a good functional result. The difference observed between the group with normal gait and the one with impaired gait with respect to the functional results is statistically significant (***). It should be noted that all cases with favourable functional results present a normal gait except one.

Widén observed almost identical percentages of impaired gait in his follow-up study of unilateral fractures. The incidence found in Gollasche's series is 20 %.

Atrophy of the calf muscles

The treatment of the present series of fractures of the calcaneus by active and passive exercises initiated at an early stage was designed to prevent or minimize the development of atrophy, in particular of the calf muscles, as a result of immobilization.

During the follow-up examination, the girth of the calves on both the injured and the healthy side was measured at their greatest circumference. A difference of girth exceeding 1 cm. was registered as atrophy. Five cases had to be excluded for various reasons, including varices. The distribution

Table 9. Distribution of cases with respect to muscular atrophy and functional results.

Functional results	Decrease in girth of the calf in relation to normal side		Number of cases
	None or not exceeding 1 cm	Exceeding 1 cm	
Excellent	31	1	32
Good	21	3	24
Fair	11	5	16
Poor	6	7	13
Total	69	16	85

of the remaining cases with respect to the presence or absence of muscular atrophy and the functional results is illustrated by table 9.

We find that 69 out of 85 cases (81,2 %) present no evidence of muscular atrophy at the time of follow-up.

A strong correlation exists between muscular atrophy and functional results. Thus we find that 75.4 % of the 69 cases without appreciable atrophy were referable to the group presenting excellent or good functional results, as against only 25.0 % of the 16 cases with evidence of atrophy. This difference is statistically significant (***).

In Ahlberg's series of 111 fractures of the calcaneus subjected to various forms of treatment, no significant difference was found with respect to muscular atrophy between the cases treated with early exercises and those treated by other methods. In Widén's series of cases mainly treated by operation, on the other hand, a significant correlation emerged between functional results and muscular atrophy.

Broadening of the heel

In its acute stage, intra-articular fracture of the calcaneus is always associated with considerable swelling and discoloration of the heel region, in particular its lateral aspect. When this edema has subsided some increase in the breadth of the heel portion persists in most cases, because of the fact that the fracture has caused some deformation of the heel bone. This increase in breadth has on the whole remained constant on comparison of the roentgenograms taken at the time of injury and at follow-up. It would seem, therefore, that early exercise therapy has had no effect in this respect.

The breadth of the calcaneus was measured in both feet with a caliper at a point immediately below the tip of the lateral malleolus. The difference in breadth between the two feet was recorded. Table 10 shows the observed values in this series, differentiated into one group with an increase of breadth of less than 1 cm. and one group with an increase of 1 cm. or more, correlated with the functional results.

It is to be noted that almost exactly half of the series presents an increase of breadth of 1 cm. or more.

There is a correlation between broadening of the heel and functional results. The observed difference is statistically significant (**).

Widén found in his series, evaluated by identical criteria, no significant difference. Aars and Bie reported "moderate or marked lateral thickening" in somewhat over half of a series treated with traction according to Arnesen's method.

Table 10. Distribution of cases with respect to broadening of the heel and functional results.

Functional results	Increase in breadth		Number of cases
	< 1 cm	≥ 1 cm	
Excellent	22	10	32
Good	15	11	26
Fair	5	13	18
Poor	2	12	14
Total	44	46	90

Valgus deformity

Due to the shortening and broadening of the heel resulting from fractures of the calcaneus with serious joint involvement, it is virtually impossible to rely upon roentgenographic evidence in order to determine the presence or absence of appreciable valgus deformity with a reasonable degree of certainty. In the present evaluation of this factor the author has adopted the following procedure. With the patient standing barefoot on a level surface, the heel region in both feet was inspected from the rear. Evaluation of valgus deformity was based on comparison of the injured with the uninvolved side.

Table 11 shows the incidence of persiting valgus deformity and the distribution of such cases in relation to the functional results.

The table shows that valgus deformity in comparison with the uninjured side is present in 21 cases, or 23.3 % of the series. In 8 more cases valgus deformity was diagnosed, but this was about equal to that found in the uninvolved foot.

There is a fairly strong correlation between valgus deformity and functional results. Persisting valgus deformity is found in only 4 of the 58

Table 11. Distribution of cases with respect to valgus deformity and functional results.

Functional results	Valgus deformity of fractured foot	No valgus deformity or deformity equal on both sides	Number of cases
Excellent	1	31	32
Good	3	23	26
Fair	4	14	18
Poor	13	1	14
Total	21	69	90

cases with favourable functional results, as against 17 out of 32 cases with unfavourable results. The difference (relating to valgus deformity and functional results) is statistically significant (**).

On this point the results are on the whole consistent with those reported by other authors. In the majority of earlier studies a clear correlation was established between poor functional results and persisting valgus deformity (Cotton, Wilson, Paitre and Boppe, Aars and Bie).

Mobility of the talocrural joint

When the foot is placed so that the talocrural joint assumes a middle position, its long axis forms an angle of 90 degrees with the longtitudinal axis of the lower leg. On maximum plantar flexion of the foot a simultaneous movement in the metatarsal joints contributes to the mobility of the talocrural joint. This component can be ascertained without difficulty by measuring plantar flexion from the posterior or anterior lateral margin of the foot in relation to the longtitudinal axis of the lower leg. For the purpose of determining dorsiflexion and plantar flexion of the talocrural joint in relation to the range of mobility on the uninjured side, the following measuring technique was adopted:

The patient assumed the supine position. The longtitudinal axis of the lower leg was marked by a line drawn from the head of the fibula to the laeral malleolus. One arm of a protractor was placed along this line, with the other arm placed along a line following the lateral margin of the heel region. An acute angle was graded as dorsiflexion and an obtuse angle as plantar flexion. The same technique has been used by Ahlberg and Widén, among others.

Several authors (Hansen, 1942, Magnusson, 1942, Widén) have found a certain difference between the sexes with respect to dorsal and plantar

Table 12. Distribution of unilateral fracture cases with respect to mobility of the talocrural joint and sex

		Fractured foot								Uninjured foot	Number of cases
		Mobility in degrees							Mean value in degrees	Mean value in degrees	
		0°	5°	10°	15°	20°	25°	30°			
Dorsiflexion	Men	1	12	39	19	2			10.6	12.0	73
	Women		7	9	1				8.2	9.7	17
Plantar flexion	Men				2	25	24	21	24.3	27.7	73
	Women					5	4	8	25.9	29.7	17

flexion, in that women presented a somewhat higher value for plantar flexion and the men for dorsiflexion. In table 12 the series has been differentiated by sex. The tables give the mean values for dorsiflexion and plantar flexion in the uninjured foot and the observed values in the fractured foot for the sexes separately.

This table shows that plantar flexion following fracture of the calcaneus appears somewhat more affected in the female group.

Table 13 illustrates both the mobility on dorsiflexion and on plantar flexion and the total range of movement at the talocrural joint in comparison with the uninjured side.

It emerges from this table that the mobility of the talocrural joint has on the whole been fairly well maintained in comparison with the mobility on the uninjured side. An increase of the mobility, such as Watson-Jones (1943) found in a number of cases, has not been observed in a single case in this series. If we consider only those cases in which the loss of mobility exceeded the error measurement of 5 degrees, we find a decrease of 10 degrees or more in the total range of movement in 28 out of 90 cases, or 31.1 %. The table further shows that this loss of mobility is largely due to a decrease of plantar flexion.

A correlation exists between mobility of the talocrural joint and the functional results. This emerges from the fact that 48 out of the 62 cases with equal mobility on both sides, or a loss of mobility not exceeding 5 degrees, representing the error of measurement, present favourable functional results (77.4 %) as against 10 out of 28 (35.7 %) cases with a loss of mobility amounting to 10 degrees or more. This difference is statistically significant (***).

Table 13. Distribution of cases with respect to mobility of the talocrural joint in comparison with the uninjured side and functional results

Functional results	Mobility of the talocrural joint in comparison with uninjured side						Number of cases
	Dorsiflexion		Plantar flexion		Total range of movement		
	Identical or decreased by at most 5°	Decreased by 10° or more	Identical or decreased by at most 5°	Decreased by 10° or more	Identical or decreased by at most 5°	Decreased by 10° or more	
Excellent	32		31	1	27	5	32
Good	26		25	1	21	5	26
Fair	18		14	4	11	7	18
Poor	11	3	5	9	3	11	14
Total	87	3	75	15	62	28	90

Mobility of the subtalar joint

Function of the subtalar joint is of particular interest following intra-articular fractures of the calcaneus, since the injury primarily affects the subtalar joint but often also involves the calcaneocuboid joint.

In terms of anatomy, the subtalar joint consists of a posterior portion articulating between the talus and the calcaneus, and an anterior part articulating between the talus-calcaneus and the cuboid bone. The anterior portion also forms part of Chopart's joint. The motion in these two joints occurs simultaneously about a common axis, and in terms of mechanics the joint may be regarded as a functional unit. The common axis runs from the inferior posterolateral margin of the calcaneus forward, upward and medially through the neck of the talus. The movement at this joint is a complex one, consisting on the one hand of inversion-adduction-plantar flexion, here designated as supination and on the other of eversion-abduction-dorsiflexion, here designated as pronation. In measuring the range of pronation and supination in the anterior part of the foot, the mobility of the subtalar joint is added to the range of motion of Chopart's joint and the tarso-metarsal joints. Wilson (1925) has pointed out that a partial or total loss of mobility at the subtalar joint results in a compensatory increase of the mobility of the metatarsal joints.

The mobility of the subtalar joint at the time of follow-up was measured as follows:

The patient was placed in the prone position with the foot in the middle position between pronation and supination and between dorsiflexion and plantar flexion. In this position the midline was marked by a line drawn on the calf and the heel. From this position pronation and supination movements were performed and the total angle was measured to within 5 degrees. Through this procedure one eliminates the component contributed by the movements at the metartarsal joints when pronation and supination of the anterior part of the foot are measured on the plantar surface.

In the following sections the results of these measurements will be designated as the mobility of the subtalar joint.

The total range of pronation and supination was measured in the following way:

The patient was placed in the supine position with the foot in the middle position. A protractor was placed on the plantar surface of the foot at the level of the metatarsal heads, and the angle formed between the protractor and a plane perpendicular to the longtitudinal axis of the leg was measured.

On comparing the results of the two techniques used to measure pronation and supination of the foot, we find that in many of the cases which show a loss of mobility on measurement with the first method, mobility is also decreased when the total range of pronation and supination is measured. This is illustrated by table 14.

Table 14. Distribution of cases with respect to range of pronation and supination as measured in the anterior part of the foot and in the heel

Measured in the heel	Measured in the anterior part of the foot			Number of cases
	Abolished	Restricted	Normal	
Abolished	2	18	—	20
Restricted	—	28	6	34
Normal	—	—	36	36
Total	2	46	42	90

These results show that in the majority of cases, or 18 out of 20, a total loss of mobility at the subtalar joint coincides with a restriction of mobility on measurement of the total range of pronation and supination in the foot. This may be interpreted as a compensatory increase in mobility at the metatarsal joints. The table also illustrates that the normal mobility of the subtalar joint coincides with normal values for the total range of pronation and supination of the foot.

Since fracture of the calcaneus primarily involves the subtalar joint, the values resulting from measurement in the heel where chosen as a criterion of the follow-up results. The same procedure was followed by Widén, which facilitates comparison with his series.

Table 15 shows the distribution of the series with respect to mibility at the subtalar joint and functional results.

If we regard mobility at the subtalar joint as abolished if it does not exceed 5 degrees, we find a total loss of mobility in 20 out of the 90 cases, amounting to 22.2 %. There is a marked correlation between mobility of the subtalar joint and functional results. On the 58 cases presenting favourable functional results, mobility at the subtalar joint is abolished only in 4 cases. In 32 cases of unfavourable results 16 showed abolition of subtalar movement. The difference is statistically significant (***). It further emerges from this table that the mean mobility in the group marked by excellent functional results has been fairly well maintained in comparison with the mean value observed in the uninjured foot, in direct contrast to the values presented by the group with poor functional results.

Table 15. Distribution of cases with respect to range of mobility of the subtalar joint, mean mobility in comparison with the uninjured side, and functional results

Functional results	Fractured foot							Uninjured foot	Number of cases
	Mobility of the subtalar joint						Mean mobility in degrees	Mean mobility in degrees	
	0°–5°	10°	15°	20°	25°	30°			
Excellent	2	1	5	6	16	2	20.9	26.2	32
Good	2	6	7	9	1	1	15.6	24.2	26
Fair	6	5	3	3	1		10.8	25.0	18
Poor	10	2	2				5.4	25.7	14
Total	20	14	17	18	18	3	15.2	25.3	90

In view of the normal variations in the mobility of the subtalar joint, the loss of mobility as compared with the uninjured foot in each individual case will provide a more exact measure of the true mobility at the subtalar joint. Table 16 presents the values estimated for this loss of mobility in the present series in relation to the functional results.

We find from this table that normal mobility, i. e. equal to the mobility on the uninjured side, is observed in 36 out of the 90 cases. We can again discern a correlation with the functional results. Of the 58 cases with favourable functional results, 34, or 58.6 %, presented a mobility equal to that of the normal side. The corresponding figures for the two groups representing unfavourable functional results are 2 out of 32 cases, or 6.3 %. This difference is statistically significant (***).

Table 16. Distribution of cases with respect to mobility of the subtalar joint, as compared to the uninjured foot, and functional results

Functional results	Loss of mobility in comparison with uninjured foot						Number of cases
	0°–5°	10°	15°	20°	25°	30°	
Excellent	23	6	2	1			32
Good	11	9	6				26
Fair	2	8	2	5	1		18
Poor		1	2	6	4	1	14
Total	36	24	12	12	5	1	90

Tuber-joint angle

The tuber-joint angle, as defined earlier (p. 36), is a relative measure of the degree of compression in fractures of the calcaneus. Satisfactory roentgenologic evidence of this aspect was available for 85 of the 90 cases in the comparative series. For 3 further cases roentgenograms were taken at the time of injury, but no follow-up pictures were available. As appears in a previous section, a standard roentgen procedure was followed at the various hospitals, but the quality of the roentgenograms varied from place to place. Nevertheless, the roentgenograms permit evaluation of the features which are of interest for the purpose of this investigation. The absence of plaster casts to obscure the roentgenograms has proved of particular advantage in the measurement of the tuber-joint angle.

Table 17 presents the distribution of the series, differential into 3 subgroups according to the size of the tuber-joint angle at follow-up, with respect to the functional results.

Table 17. Distribution of cases with respect to tuber-joint angle at follow-up and functional results.

Functional results	Tuber-joint angle at follow-up			Number of cases
	neg.—0°	1°—10°	> 10°	
Excellent	4	4	21	29
Good	4	6	15	25
Fair	4	5	8	17
Poor	8	2	4	14
Total	20	17	48	85

The results set down in this table show that of 48 cases with a tuber-joint angle exceeding 10 degrees, 36, or 75.0 % present favourable functional results. In 37 cases with a tuber-joint angle of 10 degrees or less, the corresponding incidence is 18 or 48.6 %. The difference of 26.4 % is statistically significant (*). These figures are approximately the same as those reported by Widén from his operated series, and by Aars and Bie from a series treated by traction ad modum Arnesen.

The values found for the tuber-joint angle at the time of follow-up varied in the present series between +29 degrees and —25 degrees. At the time of injury the values ranged between +32 degrees and —12 degrees. The mean value for the total series is 9.3 degrees at the time of follow-up, as against 12.5 degrees at the time of injury. This secondary compression has also been noted by other authors (Böhler, Gollasch, Widén).

Table 18. Distribution of cases with respect to functional results and mean tuber-joint angle at time of injury and at follow-up

Functional results	Mean value (and range) in degrees		Mean diminution at follow-up (and range) in degrees	Number of cases
	At time of injury	At follow-up		
Excellent	17.8 (-7 −+32)	14.8 (-11−+29)	3.0 (0−10)	29
Good	12.5 (-10−+26)	10.6 (-12−+26)	1.9 (0− 6)	25
Fair	10.7 (-6 −+25)	7.9 (-8 −+22)	2.8 (0− 8)	17
Poor	3.9 (-12−+24)	-1.9 (-25−+22)	5.8 (1−15)	14
Total	12.5 (-12−+32)	9.3 (-25−+29)	3.2 (0−15)	85

From table 18 it is evident that the secondary diminution of the tuber-joint angle varies from 0 to 15 degrees. The table further illustrates the incidence of such secondary compression in the groups differentiated by functional results. The mean values for the different groups present fairly large variations. The mean value for the group with least satisfactory function (poor results) is considerably lower than the mean value for the total series (3.2 degrees).

The normal variations of the tuber-joint angle have in the present series been established as ranging from 20 to 45 degrees. In view of these large normal variations, the diminution of the tuber-joint angle in comparison with the uninvolved side should provide a more exact measure of the degree of compression in each individual case. Since roentgenograms of the uninjured side were available for the entire comparative series, it was possible to estimate this difference.

Table 19. Distribution of cases with respect to functional results and diminution of tuber-joint angle at follow-up in comparison with the uninjured foot

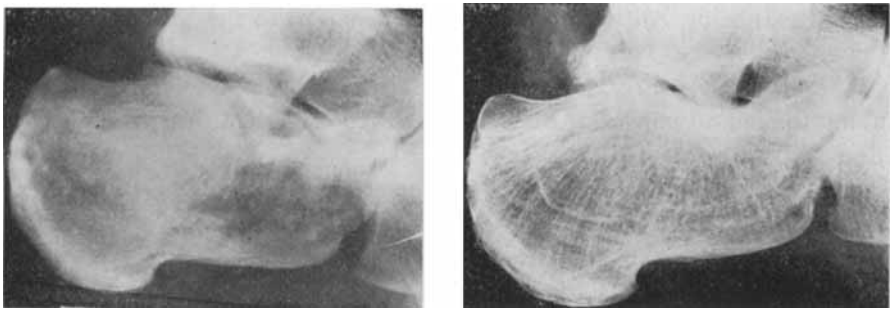
Functional results	Diminution at follow-up in comparison with uninjured foot					Mean diminution at follow-up in degrees	Number of cases
	≦ 10°	11°−20°	21°−30°	31°−40°	> 40°		
Excellent	8	8	8	5		19.7	29
Good	1	11	11	1	1	21.4	25
Fair	1	8	3	4	1	24.3	17
Poor		4	2	4	4	32.6	14
Total	10	31	24	14	6	23.2	85

Table 19 presents the distribution of the series with respect both to the diminution of the tuber-joint angle in comparison with the uninjured foot and to the functional results.

For 9 of the 10 cases in which the diminution of the tuber-joint angle did not exceed 10 degrees in comparison with the uninjured foot — i. e. cases with minimal compression of the calcaneus — the functional results were favourable. If we consider the cases with considerable compression, as expressed by a diminution of the tuber-joint angle, in comparison with the healthy side, of more than 30 degrees, we find favourable functional results for 7 out of 20, or 35.0 %. The mean diminution of the tuber-joint angle in comparison with the uninjured foot at follow-up is largest for the group with least favourable (poor) results. These results merely confirm our previous observation that a higher degree of compression of the bone, as measured by the tuber-joint angle, coincides with less favourable functional results.

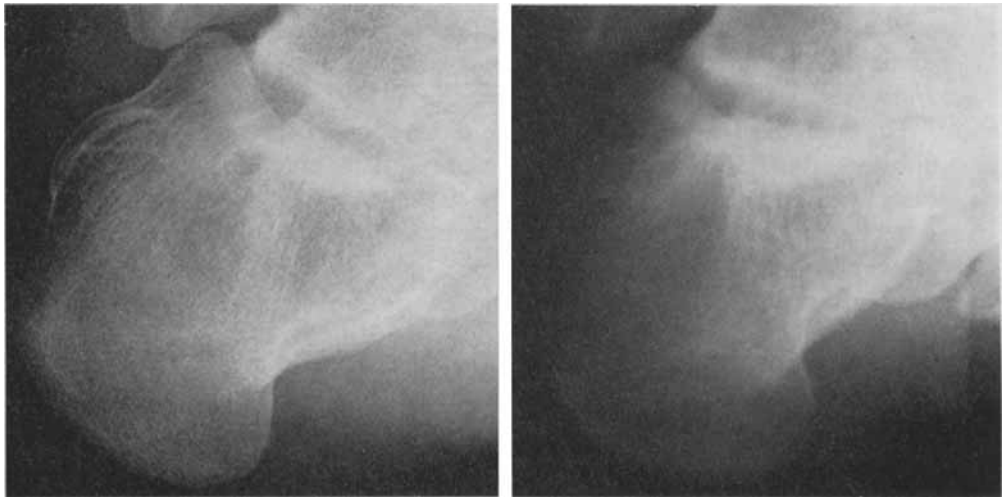
Arthrosis of the subtalar joint

The roentgenologic evidence of arthrosis of the subtalar joint with consequent deformity consists in narrowing of the joint space, marginal osteophytes, and structural changes in the adjacent bone. In the present series evaluation of this factor has presented a problem, mainly because these fractures are associated with initial deformity of the posterior articular facet. Diagnosis and evaluation of changes due to arthrosis is fraught with difficulties, even if entirely satisfactory roentgenograms are available. Especially useful is projection I of Brodén, which provides a fairly reliable picture of marginal osteophytes. With these projections we were able to demonstrate marginal excrescences suggestive of oesteophytes in almost two-thirds of the series, by comparing the injured and uninvolved foot.



a b

Fig. 15. Results (b) 7 years after original injury (a) treated by eexcercise only (non followed-up).



a b

Fig. 16. Case no. 33. At time of injury (a), at follow-up 4 years later (b). Projection 1.

Any displacement of the posterior articular surface has on the whole persisted in this series, but in the majority of cases the notch on the articular facet is less sharply outlined, indicating reorganization of this area. (fig. 15 and 16).

Other objective findings.

The calcaneo-cuboid joint. In 11 of the 90 cases, the original films showed fracture lines entering the calcaneo-cuboid joint. Six of these cases were classified as unfavourable.

Peroneal tendon. Four patients had marked tenderness over the peroneus longus tendon behind the lateral malleolus. In two of these cases, the roentgenogram showed a marked broadening of the tuber, close to the lateral malleolus. All these four patients belonged to the functional group "poor".

Sensory disturbances. In two cases the patients complained of numbness along the lateral border of foot. Both showed a marked broadening of the heel and were classified as "poor".

Oedema. About 25 % of the patients complained of swelling of the injured foot with exertion. Due to the fact that the follow-up examinations were performed at different hours of the day, it was difficult to obtain comparable measurements. Nearly all the cases complaining of this symptom belonged to those classified as "poor".

Healing. All cases showed roentgenological signs of healing. No case of thrombosis or other complication was recorded.

C. Bilateral intra-articular fractures of the calcaneus.

In 1952 a 42-year old man was treated at the Surgical Department of Akademiska Sjukhuset in Uppsala for bilateral fracture of the calcaneus. One side was treated by early exercises, the opposite side by plaster fixation. The functional results in this case were considerably better for the fracture treated by exercise therapy than on the side which had been immobilized in plaster. Earlier studies have established that poor functional results are obtained for bilateral fractures of the calcaneus with serious joint involvement, regardless of the form of treatment. Both our experience with the aforementioned case and earlier experiences made us decide at the beginning of this investigation that in all cases of bilateral intra-articular fracture one side would be subjected to early exercise therapy, while the other side would be treated by plaster fixation or operation. It was further decided that the side which from the roentgenograms presented the more serious injury, would become the subject for exercise therapy. During the period covered by this investigation, a total of 8 cases of bilateral fracture with serious joint involvement presented. In the majority of these cases the tuber-joint angle was on both sides obliterated or negative. In two cases both feet were treated by exercise therapy, for different reasons.* Of the 6 remaining cases, 3 were treated by unilateral plaster fixation and the other 3 by arthrodesis. One of the latter cases was still undergoing treatment at the time of follow-up and has consequently not been included in the follow-up series. Thus 5 cases remain in which one side was treated by early exercises, while the other side was immobilized in plaster or subjected to arthrodesis. On follow-up all 5 cases subjected to this treatment presented unfavourable functional results. The subjective symptoms were in all cases severe. On the whole, though, the symptoms were less pronounced on the side which had been subjected to exercise therapy. All 5 patients were occupationally handicapped, one of them to the extent that occupational rehabilitation was required. Four of the 5 cases were insured and received benefits for disability rated at 15—33⅓ %. The objective evidence concerning mobility of the talocrural and subtalar joints, muscular atrophy, gait etc., failed to establish any clear difference between feet treated with exercise, plaster fixation, or operation.

Widén reports equally poor results from his series, with the exception of one case. This was a 14-year old boy with bilateral fractures which were both treated by operation. In this case full recovery of function resulted. Moberg's series (p. 86) of patients treated by arthrodesis includes 4 cases in which operation was performed bilaterally. These all present poor functional results and permanent disability.

* One of these was not followed-up.

CHAPTER 8

Factors of Prognostic Relevance with respect to Follow-up Results

At the time of admission to hospital, the following factors were recorded: fracture group (p. 42), type of fracture (p. 42), age and sex (p. 43), tuber-joint angle in the injured foot (p. 36), diminution of the tuber-joint angle as compared to the injured foot (p. 37), and degree of displacement of the posterior articular surface (p. 37).

The following analysis is intended to determine the relevance of these factors with respect to certain variables characterizing the follow-up results, i.e. functional results, gait, muscular atrophy, mobility of the subtalar and talocrural joints, and residual disability entitled to insurance benefits.

Since our follow-up investigation had established that functional results were consistently favourable for extra-articular fractures assigned to groups I—IV, these were excluded from the present evaluation. Also excluded were the 6 patients with bilateral calcaneal fractures and involvement of the articular surfaces on both sides, which formed a separate group. Of the 90 cases of unilateral intra-articular fractures comprising the "comparative series", the 13 cases placed in fracture group V to some extent form a special class. They will be accounted for in tables 20 and 21 only, and are excluded from the further analysis. As roentgenologic data were incomplete for two cases, belonging to groups VI and VII, the comparative series is for the purpose of this evaluation restricted to 75 cases.

Men and women will be accounted for separately. In the introductory tables, one factor at a time has been correlated both with the subjective functional results and with the follow-up results. For the factors found to have a strong bearing on the follow-up results, subsequent tables present a more detailed analysis.

Relevance of fracture group and type of fracture

The difference between fracture groups VI and VII lies in the more lateral orientation of the shearing fracture in the former group, with

compression mainly involving the lateral portion of the posterior articular surface. In the cases assigned to group VII the shearing fracture strikes the posterior articular surface further medially, producing depression of the greater portion of the posterior articular surface in relation to the medial fragment. A feature common to both fracture groups is displacement of the posterior articular facet, in contrast to group V in which the shearing fracture runs into the articular surface without causing any displacement.

Table 20 shows the distribution of cases with respect to fracture group, sex and functional results.

Table 20. Distribution of cases with respect to fracture group, sex, and functional results

Functional results	Men			Women		
	Group V	Group VI	Group VII	Group V	Group VI	Group VII
Excellent	11	8	5	1	5	1
Good	1	13	6		4	1
Fair		11	5		1	1
Poor		7	6		1	
Total	12	39	22	1	11	3

From this table, group V stands out by its uniformly favourable functional results. As regards the other two fracture groups, no appreciable difference can be discerned in the functional results for either sex.

It appears, therefore, that there is no demonstrable difference between fracture groups VI and VII with respect to the functional results. Prognosis for fracture group V is significantly (***) better than for fracture groups VI and VII.

The figures presented in table 21 indicate the relative frequency of favourable follow-up results, as defined above, in the relevant fracture groups. No distinction as to sex is made.

The designations "Excellent and Good" functional results have been defined earlier (p. 48), as having "Normal gait". (p. 52). The designation "No muscular atrophy" implies that a decrease in the girth of the calf muscles not exceeding 1 cm in comparison with the uninjured side was accepted. "Normal mobility of the subtalar joint" and "Normal mobility of the talocrural joint" indicate that the deviation from the range of movement in the uninjured foot did not exceed 5 degrees.

We find from this table that all variables are consistently more favourable for the cases assigned to group V than for the other groups. The difference between group V on the one hand and groups VI and VII on

Table 21. Relative frequency (percentage) of favourable follow-up results, as represented by *certain characteristics, within the subgroups differentiated* by fracture group.

Characteristic of follow-up results	Group V		Group VI		Group VII	
	Characteristic/ subgroup	%	Characteristic/ subgroup	%	Characteristic/ subgroup	%
Excellent+good functional results	13/13	100	30/50	60.0	13/25	52.0
Normal gait	12/13	92.3	37/50	74.0	16/25	64.0
No muscular atrophy	13/13	100	38/46	82.8	16/24	66.7
Normal mobility of subtalar joint	11/13	84.6	15/50	30.0	9/25	36.0
Normal mobility of talocrural joint	12/13	92.3	34/50	68.0	14/25	56.0
No residual disability entitling insurance benefits	4/4	100	19/29	65.5	10/13	76.9

the other is significant both with respect to the percentage of excellent and good functional results (**) and for normal mobility of the subtalar joint (**). These results further justify the dissociation of group V from groups VI and VII, as has been done in the following tables. Group VI and VII, on the other hand, present no material difference with respect to any of the result variables.

Table 22 shows the distribution of cases with respect to functional results and sex when the series is differentiated into Palmer's (1948) fracture types 1 and 2. Both in this table and those to follow, the cases comprising group V have been excluded, for the reasons stated above.

We may conclude from this table that the male group presents no appreciable differences. As for the women, favourable functional results are found in all cases classified as type 1 fractures, but it should be noted that the number of cases is insufficient to permit any definite conclusions. The difference is probably significant (*).

Functional results	Men		Women	
	Type 1	Type 2	Type 1	Type 2
Excellent	8	5	6	
Good	13	6	4	1
Fair	10	6		2
Poor	10	3		1
Total	41	20	10	4

Table 22. Distribution of cases with respect to type of fracture, sex, and functional results.

Table 23. Relative frequency (percentage) of favourable follow-up results, as represented by certain characteristics, within the subgroups differentiated by type of fracture.

Characteristic of follow-up results	Fracture type 1		Fracture type 2	
	Characteristic/ subgroup	%	Characteristic/ subgroup	%
Excellent+good functional results	31/51	60.8	12/24	50.0
Normal gait	36/51	70.6	17/24	70.8
No muscular atrophy	37/47	78.7	17/23	73.9
Normal mobility of subtalar joint	18/51	35.3	6/24	25.0
Normal mobility of talocrural joint	32/51	62.7	16/24	66.7
No residual disability entitling insurance benefits	22/30	73.3	7/12	58.3

Table 23 presents the relative frequency of favourable follow-up results when the series is differentiated into type 1 and type 2 fractures, but undistinguished as to sex.

It can be concluded from this table that there is no appreciable difference between type 1 and type 2 fractures with respect to any of the result variables.

Relevance of age and sex

Widén (1954) found in his series of operated patients a certain difference in the results with respect to the age of the patient. With the age limit in his series set at 50, satisfactory functional end results for 77.4 % of cases in the younger age groups, as against 52.0 % for patients over 50 years of age, implying a statistically significant difference. Essex-Lopresti (1952), claiming that operation produced poor end results in patients over 50, advocated early active exercise for these elderly patients.

Table 24 shows the functional results for men and women differentiated into several age groups. All 75 cases are included in fracture groups VI or VII.

Of the 14 women included in this series, 11 showed favourable functional results. The corresponding figures for men are 61 and 32 respectively. This does not amount to a statistically significant difference.

If we divide the series into two age groups, with the limit set at 50, we find favourable functional results for 9 out of the 10 older women (over 50 years of age), as against 2 out of 4 in the group of younger women. It is possible that this represents a random difference, but the number of cases is too small to warrant any definite conclusions concern-

Table 24. Distribution of cases with respect to age, sex, and functional results

Functional results	Age in years and sex																						Number of cases
	< 26		26–30		31–35		36–40		41–45		46–50		51–55		56–60		61–65		66–70		> 70		
	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	
Excellent	—	—	2	—	—	—	2	—	2	1	3	—	3	2	1	2	—	—	—	1	—	—	19
Good	—	—	—	1	1	—	3	—	2	—	4	—	4	—	4	—	—	1	1	—	—	3	24
Fair	1	—	2	—	1	—	2	—	2	—	1	1	2	—	4	—	1	—	—	1	—	—	18
Poor	—	—	—	—	2	—	2	1	1	—	2	—	1	—	4	—	1	—	—	—	—	—	14
Total	1	—	4	1	4	—	9	1	7	1	10	1	10	2	13	2	2	1	1	2	—	3	75

Summary of table 24

Functional results	Men		Women	
	≤ 50 years	> 50 years	≤ 50 years	> 50 years
Excellent	9	4	1	5
Good	10	9	1	4
Fair	9	7	1	1
Poor	7	6	1	—
Total	35	26	4	10

ing the relevance of the age factor. An alternative explanation of the favourable functional results for elderly women may be that their activities are more restricted in comparison with both the younger women and the older male group, and their functional requirements thus lower.

If we review the results in the male series, we find favourable functional results in 19 out of the 35 men of 50 years or younger, which amounts to 54.3 %. In the group over 50 exactly half of the men, or 13 out of 26, showed favourable functional results. The difference has no statistical significance. If we set the age limit at 46, we find favourable functional results for 48.0 % of the younger men and 55.5 % of the older age group. This difference also falls short of statistical significance and we may therefore concluded that the present material provides no evidence to suggest that the age factor is of decisive importance as regards men.

With the age factor accounted for, no significant difference can be demonstrated between the sexes. Nevertheless, the observed differences are sufficiently large to warrant a differentiation according to sex in the following account.

Table 25. Relative frequency (percentage) of favourable follow-up results, as represented by certain characteristics, within the subgroups differentiated by age.

Characteristic of follow-up results	50 years and younger		Over 50 years	
	Characteristic/ subgroup	%	Characteristic/ subgroup	%
Excellent+good functional results	21/39	53.8	22/36	61.1
Normal gait	29/39	74.4	24/36	66.7
No muscular atrophy	29/38	76.3	25/32	78.1
Normal mobility of subtalar joint	15/39	38.5	9/36	25.0
Normal mobility of talocrural joint	29/39	74.4	19/36	52.8
No residual disability entitling insurance benefits	16/25	64.0	13/17	76.5

Table 25 illustrates what bearing age has on the variables characterizing the follow-up results. No distinction of sex is made.

We may conclude from this table that there is no appreciable difference between younger and older patients with respect to the relevant characteristics. Not even the largest percentage difference, referring to mobility of the talocrural joint, (74.4 % versus 52.8 %) is significant. The table tends to support our impression that the demands on function are lower for elderly patients than in the younger age group, since the percentage of excellent and good functional results, expressing a relatively more subjective rating of function, is higher among the older patients, whereas variables permitting a more objective grading, specifically normal gait and normal mobility of the subtalar and talocrural joints, show a higher percentage in the younger age groups.

Relevance of the tuber-joint angle

The tuber-joint angle, as defined earlier, is a relative measure of the degree of compression in fractures of the calcaneus, depending on the normal, pre-injury value in each individual case.

If we divide the series into 3 subgroups according to the size of the tuber-joint angle, and compare these subgroups with respect to sex and functional results, we obtain the figures set down in table 26.

In the male group, we find favourable functional results for 22 out of 33 cases with a tuber-joint angle exceeding 10 degrees, contrasting with an incidence of 10 out of 28 cases with a tuber-joint angle of 10 degrees or less. The difference is statistically significant (*), suggesting that this factor does have a bearing upon prognosis.

Table 26. Distribution of cases with respect to tuber-joint angle at time of injury, sex and functional results

Functional results	Tuber-joint angle in degrees					
	Men			Women		
	neg.—0°	1°—10°	>10°	neg.—0°	1°—10°	>10°
Excellent	3	1	9		2	4
Good	1	5	13	1	1	3
Fair	4	5	7		1	1
Poor	7	2	4			1
Total	15	13	33	1	4	9

Table 27 presents the relative frequency of favourable follow-up results in the subgroups differentiated according to tuber-joint angle. No distinction of sex is made.

If we disregard the insurance cases without residual disability, we find that the table presents a uniform tendency for all result variables in that the incidence of favourable results increases with a higher value for the tuber-joint angle. A comparison of the group presenting a tuber-joint angle exceeding 10 degrees with, at the other extreme, the cases in which the tuber-joint angle is zero or negative, yields significant (*) differences with respect to the percentage of excellent and good functional results, normal gait, and absence of muscular atrophy, while the differences for normal mobility of the subtalar and talocrural joints emerge as clearly significant (**).

Table 27. Relative frequency (percentage) of favourable follow-up results, as represented by certain characteristics, within the subgroups differentiated by the tuber-joint angle at time of injury.

Characteristics of follow-up results	Tuber-joint angle in degrees					
	Neg.—0°		1°—10°		>10°	
	Characteristic/ subgroup	%	Characteristic/ subgroup	%	Characteristic/ subgroup	%
Excellent+good functional results	5/16	31.3	9/17	52.9	29/42	69.0
Normal gait	7/16	43.8	11/17	64.7	35/42	83.3
No muscular artophy	6/13	46.2	13/17	76.5	35/40	87.5
Normal mobility of subtalar joint	0/16	0	2/17	11.8	22/42	52.4
Normal mobility of talocrural joint	6/16	37.5	8/17	47.1	34/42	81.0
No residual disability entitling insurance benefits	6/9	66.7	3/7	42.9	20/26	76.9

Relevance of diminuted tuber-joint angle in comparison with the uninjured foot

Roentgenograms of the uninjured foot had at some point during our investigation been taken in all cases included in the present analysis, which permitted us to define any diminution of the tuber-joint angle in relation to the uninjured side. Since individual variations of the normal value range from 20 to as much as 45 degrees, one might expect this measure to provide a more reliable indication of the degree of compression of the fractured calcaneus than the one value for the tuber-joint angle in the injured foot only.

We found in a previous section (p. 62) that functional results in cases with widely differing values for the tuber-joint angle in the fractured and uninjured foot were somewhat less favourable than in cases with only slightly varying values. This difference was not statistically significant, however.

In table 28 the series has been divided into two subgroups according to the degree of diminution of the tuber-joint angle in comparison with the uninjured foot, with the limit set at 20 degrees, and this value has been correlated to the functional results. In this instance, too, the series has been differentiated by sex.

We find from this table that functional results were favourable for somewhat less than half of the men, or 14 out of 32, with diminution of the tuber-joint angle exceeding 20 degrees. Of the 29 men with a diminution of the tuber-joint angle of 20 degrees or less, 18 had favourable functional results. A certain difference does exist, consequently, but it has no statistical significance. For the women we find favourable functional results in all 3 cases presenting a diminution of the tuber-joint angle exceeding 20 degrees, while of the 11 cases with a diminution of 20 degrees or less, 8 presented favourable functional results.

Table 28. Distribution of cases with respect to initial diminution of tuber-joint angle in comparison with uninjured foot, sex, and functional results.

Functional results	Initial diminution in comparison with uninjured foot			
	Men		Women	
	$\leq 20°$	$> 20°$	$\leq 20°$	$> 20°$
Excellent	7	6	5	1
Good	11	8	3	2
Fair	7	9	2	
Poor	4	9	1	
Total	29	32	11	3

The above results indicate that diminution of the tuber-joint angle in comparison with the uninjured foot, as a measure of the degree of compression of the calcaneus, does not constitute a decisive factor with respect to the functional results.

Table 29 shows the relative frequency of favourable follow-up results within the two subgroups differentiated by the degree of diminution of the tuber-joint angle.

Table 29. Relative frequency (percentage) of favourable follow-up results, as represented by certain characteristics, within the subgroups differentiated by initial diminution of tuber-joint angle in comparison with the uninjured foot

Characteristic of follow-up results	Initial diminution in comparison with uninjured foot			
	≦ 20°		> 20°	
	Characteristic/ subgroup	%	Characteristic/ subgroup	%
Excellent+good functional results	26/40	65.0	17/35	48.6
Normal gait	32/40	80.0	21/35	60.0
No muscular atrophy	34/38	89.5	20/32	62.5
Normal mobility of subtalar joint	18/40	45.0	6/35	17.1
Normal mobility of talocrural joint	31/40	77.5	17/35	48.6
No residual disability entitling insurance benefits	15/21	71.4	14/21	66.7

We can in this table discern a significant (*) difference with respect to the result variables referring to muscular atrophy and mobility of the subtalar and talocrural joints. The value for the tuber-joint angle in the fractured foot (table 27) appears to have greater prognostic relevance than the diminution of the tuber-joint angle in comparison with the uninjured foot (table 29).

Relevance of displacement of the posterior articular surface

Both at the time of injury and at follow up all cases included in the present series were subjected to roentgenographic examination with Brodén's oblique projections, providing a basis for evaluating any displacement of the posterior articular surface. A relatively moderate depression of the posterior articular facet, as measured by the tuber-joint angle, does not exclude the possibility of a considerable displacement of the posterior

articular surface. As appears from the chapter on roentgenologic procedure (p. 37), it has been impossible to express the degree of displacement in exact numerical values and the series has for the purpose of this evaluation, been divided into two subgroups marked by moderate displacement and considerable displacement respectively. The distribution of cases within the subgroups is illustrated by table 30.

Table 30. Distribution of cases with respect to degree of displacement, sex, and functional results

Functional results	Degree of displacement			
	Men		Women	
	Moderate displacement (+)	Considerable displacement (++)	Moderate displacement (+)	Considerable displacement (++)
Excellent	12	1	3	3
Good	14	5	5	
Fair	3	13	1	1
Poor	2	11		1
Total	31	30	9	5

The table shows that 26 out of the 31 men with moderate displacement (+), or 83.9 %, presented favourable results, as against only 20.0 % or 6 out of the 30 men with considerable displacement (++). It is evident that there is a material difference between the two groups with respect to the functional results. The differences are statistically significant. (***).

As for the women, the number of cases is again insufficient to warrant any conclusions. We may note, however, that functional results were favourable for all but one of the cases with moderate displacement.

The high degree of correlation between degree of displacement and functional results which emerges from this table, is fully consistent with the uniformly favourable functional results presented by patients in fracture group V. As we know, these fractures are characterized by the absence of displacement of the posterior articular facet. In view of the favourable functional results for group V patients, it seems reasonable to assume that the degree of displacement must be the decisive factor. The results presented in the above table undoubtedly provide a strong indication that this factor has a bearing upon prognosis.

Table 31 shows the relative frequency of favourable follow-up results in the two subgroups differentiated by the degree of displacement.

Table 31. Relative frequency (percentage) of favourable follow-up results, as represented by certain characteristics, within the subgroups differentiated by the degree of displacement.

Characteristic of follow-up results	Degree of displacement			
	Moderate (+)		Considerable (++)	
	Characteristic/ subgroup	%	Characteristic/ subgroup	%
Excellent+good functional results	34/40	85.0	9/35	25.7
Normal gait	37/40	92.5	16/35	45.7
No muscular atrophy	36/38	94.7	18/32	56.3
Normal mobility of the subtalar joint	20/40	50.0	4/35	11.4
Normal mobility of the talocrural joint	33/40	82.5	15/35	42.9
No residual disability entitling insurance benefits	18/23	78.3	11/19	57.9

We find from this table that the difference between the two subgroups is most marked with respect to the percentage of excellent and good functional results (85.0 % — 25.7 % = 59.3 %) (***). With the exception of residual disability entitling one to insurance benefits, the differences are also strongly significant (***) for the remaining result variables. It would seem that the degree of displacement has a stronger bearing upon prognosis than any of the other factors which have been taken into account.

In the preceding sections we have estimated the correlation between, on the one hand, functional results and favourable follow-up results, as characterized by excellent and good functional results, normal gait, absence of muscular atrophy, normal mobility of the subtalar joint, normal mobility of the talocrural joint, and absence of residual disability entitling one to insurance benefits, and, on the other hand, each one of the following factors: fracture group, type of fracture, age and sex, absolute value of tuber-joint angle, diminution of tuber-joint angle in comparison with the uninjured foot, and degree of displacement of the posterior articular facet. We shall now proceed to analyze the functional follow-up results with respect to certain combinations of the above mentioned factors. Since the degree of displacement emerged definitely as the most relevant factor, the series has been differentiated by this criterion. No distinction as to sex is made.

It is evident from table 32 that within the subgroup characterized by moderate displacement (+) no appreciable differences exist with respect to age, fracture group and type of fracture, diminution of tuber-joint angle

Table 32. Functional results correlated with age, fracture group, type of fracture, initial diminution of tuber-joint angle in comparison with the uninjured foot, and absolute tuber-joint angle in fractured foot, in cases with

moderate displacement (+)

Functional results	Age in years		Fracture group		Type of fracture		Initial diminution of tuber-joint angle		Tuber-joint angle in fractured foot		Total cases
	≤50	>50	VI	VII	1.	2.	≤20°	>20°	≤10°	>10°	
Excellent	9	6	10	5	10	5	10	5	3	12	15
Good	7	12	14	5	14	5	14	5	5	14	19
Fair	3	1	3	1	1	3	3	1	1	3	4
Poor	2	0	2	0	2	0	1	1	1	1	2
Total	21	19	29	11	27	13	28	12	10	30	40

Table 33. Functional results correlated with age, fracture group, type of fracture, initial diminution of tuber-joint angle in comparison with the uninjured foot, and absolute tuber-joint angle in the fractured foot, in cases with

considerable displacement (++)

Functional results	Age in years		Fracture group		Type of fracture		Initial diminution of tuber-joint angle		Tuber-joint angle in fractured foot		Total cases
	≤50	>50	VI	VII	1.	2.	≤20°	>20°	≤10°	>10°	
Excellent	1	3	3	1	4	0	2	2	3	1	4
Good	4	1	3	2	3	2	0	5	3	2	5
Fair	7	7	9	5	9	5	6	8	9	5	14
Poor	6	6	6	6	8	4	4	8	8	4	12
Total	18	17	21	14	24	11	12	23	23	12	35

in comparison with the uninjured foot, and tuber-joint angle in the fractured foot. From table 33 we find that the same observation holds true for the cases presenting a considerable degree of displacement (++).

If the degree of displacement is adopted as a basis for prognosis with respect to the functional (follow-up) results, data on the other factors are of no account. Not even the tuber-joint angle in the fractured foot, a factor which in the preceding analysis (table 26) was found to be significant, appears to have any tendency to influence prognosis.

This is explained by the correlation existing between the degree of displacement and the absolute value for the tuber-joint angle, as is evident from tables 32 and 33.

These 30 out of the 40 cases with moderate displacement (+), or 75.0 %, present a value for the tuber-joint angle exceeding 10 degrees, as against 12 out of 35 cases (or 34.3 %) with considerable displacement (++). The difference (75.0 % — 34.3 % = 40.7 %) is statistically significant (**).

Similarly we find from the tables that 70.0 % of cases with moderate displacement present a diminution of the tuber-joint angle in comparison with the uninjured foot of 20 degrees or less, as against an incidence of 12 out of 35 (34.3 %) of the cases with considerable displacement. This difference, too, is significant.

We may now proceed to study the relevance of the remaining factors within subgroups with the same degree of displacement. In tables 34 and 35 we find the relative frequency of favourable follow-up results, as

Table 34. Relative frequency and percentage of favourable follow-up results, as represented by certain characteristics, within different factor group in cases with *moderate displacement* (+)

Characteristic of follow-up results	Factor group									
	Age in years		Fracture group		Type of fracture		Initial diminution of tuber-joint angle		Tuber-joint angle in fractured foot	
	≤ 50	> 50	VI	VII	1.	2.	≤ 20°	> 20°	≤ 10°	> 10°
Excellent + good functional results	16/21 76.2	18/19 94.7	24/29 82.8	10/11 90.9	24/27 88.9	10/13 76.9	24/28 85.7	10/12 83.3	8/10 80.0	26/30 86.7
Normal gait	19/21 90.5	18/19 94.7	27/29 93.1	10/11 90.9	24/27 88.9	13/13 100	26/28 92.9	11/12 91.7	9/10 90.0	28/30 93.3
No muscular atrophy	19/20 95.0	17/18 94.4	26/27 96.3	10/11 90.9	25/26 96.2	11/12 91.7	25/26 96.2	11/12 91.7	9/10 90.0	27/28 96.4
Normal mobility of subtalar joint	11/21 52.4	9/19 47.4	13/29 44.8	7/11 63.6	14/27 51.9	6/13 46.2	17/28 60.7	3/12 25.0	2/10 20.0	18/30 60.0
Normal mobility of talocrural joint	20/21 95.2	13/19 68.4	26/29 89.7	7/11 63.6	21/27 77.8	12/13 92.3	25/28 89.3	8/12 66.7	7/10 70.0	26/30 86.7
No residual disability entitling insurance benefits	10/14 71.4	8/9 88.9	12/16 75.0	6/7 85.7	14/17 82.4	4/6 66.7	13/16 81.3	5/7 71.4	2/4 50.0	16/19 84.2

defined earlier, within different factor groups. From these tables we may conclude, among other things, that the age factor presents an appreciable difference only with respect to normal mobility of the talocrural joint. In both subgroups the frequency of normal mobility in this respect is somewhat higher in the younger age group than in the older group. This difference does not have statistical significance, however.

Not the slightest tendency towards appreciable differences with respect to any of the result variables can be discerned for the different fracture groups or for the different types of fracture.

With regard to the tuber-joint angle, we note a lower incidence of muscular atrophy when the diminution of this angle in comparison with the uninjured foot does not exceed 20 degrees. The difference is not statistically significant. Otherwise the subgroups differentiated by tuber-joint

Table 35. Relative frequency and percentage of favourable follow-up results, as represented by certain characteristics, within different factor group in cases with *considerable displacement* (++)

Characteristic of follow-up results	Factor group									
	Age in years		Fracture group		Type of fracture		Initial diminution of tuber-joint angle		Tuber-joint angle in fractured foot	
	≦50	>50	VI	VII	1.	2.	≦20°	>20°	≦10°	>10°
Excellent+good functional results	5/18 27.8	4/17 23.5	6/21 28.6	3/14 21.4	7/24 29.2	2/11 18.2	2/12 16.7	7/23 30.4	6/23 26.1	3/12 25.0
Normal gait	10/18 44.4	6/17 35.3	10/21 47.6	6/14 42.9	12/24 50.0	4/11 36.4	6/12 50.0	10/23 43.5	9/23 39.1	7/12 58.3
No muscular atrophy	10/18 55.6	8/14 57.1	12/19 63.2	6/13 46.2	12/21 57.1	6/11 54.5	9/12 75.0	9/20 45.0	10/20 50.0	8/12 66.7
Normal mobility of subtalar joint	4/18 22.2	0/17 0	2/21 9.5	2/14 14.3	4/24 16.7	0/11 0	1/12 8.3	3/23 13.0	0/23 0	4/12 33.3
Normal mobility of talocrural joint	9/18 50.0	6/17 35.3	8/21 38.1	7/14 50.0	11/24 45.8	4/11 36.4	6/12 50.0	9/23 39.1	7/23 30.4	8/12 66.7
No residual disability entitling insurance benefiits	6/11 54.5	5/8 62.5	7/13 53.8	4/6 66.7	8/13 61.5	3/6 50.0	2/5 40.0	9/14 64.3	7/12 58.3	4/7 57.1

angle present no particularly interesting differences. It should be noted, though, that there is a marked difference for the absolute value of the tuber-joint angle in the fractured foot with respect to normal mobility of the subtalar joint, which has a frequency of 33.3 % in cases with considerable displacement and of 40.0 % in cases with moderate displacement. The frequency of normal subtalar mobility is significantly (**) higher among cases with a value of more than 10 degrees for the tuber-joint angle in the fractured foot.

In an analogous manner the series has been differentiated with respect to the factor which, next to the degree of displacement, appears to be most relevant, i.e. tuber-joint angle in the fractured foot. The distribution of the series thus differentiated is illustrated in tables 36 and 37.

Table 36. Functional results correlated with age, fracture group, type of fracture, initial diminution of tuber-joint angle in comparison with the uninjured foot, and degree of displacement of the posterior articular surface, in cases with *tuber-joint angle exceeding 10 degrees* (at time of injury)

Functional results	Age in years		Fracture group		Type of fracture		Initial diminution of tuber-joint angle		Degree of displacement		Total cases
	≦50	>50	VI	VII	1.	2.	≦20°	>20°	(+)	(++)	
Excellent	8	5	10	3	10	3	11	2	12	1	13
Good	7	9	12	4	13	3	12	4	14	2	16
Fair	7	1	6	2	6	2	7	1	3	5	8
Poor	4	1	4	1	4	1	5	0	1	4	5
Total	26	16	32	10	33	9	35	7	30	12	42

The following observations emerge from these tables. In the group with a tuber-joint angle of more than 10 degrees the functional results are more favourable for the older patients (over 50 years of age) than for the younger age group. The difference is not significant, however, and does not agree with the results in the group with a tuber-joint angle of 10 degrees or less, which shows a higher incidence of favourable functional results in the younger age group.

The factors: fracture group, type of fracture and diminution of tuber-joint angle in comparison with the uninjured foot have no appreciable prognostic relevance for the functional results when the series is different-

iated with respect to the tuber-joint angle in the injured foot. With regard to the degree of displacement, on the other hand, the tables yield appreciable differences. Thus prognosis is significantly (**) more favourable for cases with moderate displacement (+) as compared to cases with considerable displacement (++), both in the group with a tuber-joint angle of more than 10 degrees and in the group with a value of 10 degrees or less.

This confirms that the degree of displacement is the factor of greatest prognostic relevance for the functional results.

In tables 38 and 39 the same differentiation of the series with respect to tuber-joint angle in the fractured foot is retained for the purpose of estimating the prognostic relevance of the different factor groups with respect to the variables characterizing the follow-up results, apart from the prognostic relevance which can be ascribed to the tuber-joint angle factor.

Table 37. Functional results correlated with age, fracture group, type of fracture, initial diminution of tuber-joint angle in comparison with the uninjured foot, and degree of displacement of the posterior articular surface, in cases with *tuber-joint angle of 10 degrees or less* (at time of injury)

Functional results	Age in years		Fracture group		Type of fracture		Initial diminution of tuber-joint angle		Degree of displacement		Total cases
	≦ 50	> 50	VI	VII	1.	2.	≦ 20°	> 20°	(+)	(++)	
Excellent	2	4	3	3	4	2	1	5	3	3	6
Good	4	4	5	3	4	4	2	6	5	3	8
Fair	3	7	6	4	4	6	2	8	1	9	10
Poor	4	5	4	5	6	3	0	9	1	8	9
Total	13	20	18	15	18	15	5	28	10	23	33

As could be expected, the degree of displacement is found to have such bearing upon the prognosis, both in the group with a tuber-joint angle not exceeding 10 degrees and in the group with a value of more than 10 degrees (table 38 and 39 respectively). The displacement factor shows significant differences with respect to excellent and good functional results and normal gait both in table 38 and in table 39 and with respect to normal mobility of the subtalar joint in table 39. As to the result variables "No muscular atrophy" and "Normal mobility of the talocrural joint", no statistical significance is admittedly elicited if we consider the differences in tables 38 and 39 separately, but the tendency towards

Table 38. Relative frequency and percentage of favourable follow-up results, as represented by certain characteristics, within different factor group in cases with *tuber-joint angle of 10 degrees or less* (at time of injury)

Characteristic of follow-up results	Factor group									
	Age in years		Fracture group		Type of fracture		Initial diminution of tuber-joint angle		Degree of displacement	
	≦ 50	> 50	VI	VII	1.	2.	≦ 20°	> 20°	(+)	(++)
Excellent+ good functional results	6/13 46.2	8/20 40.0	8/18 44.4	6/15 40.0	8/18 44.4	6/15 40.0	3/5 60.0	11/28 39.3	8/10 80.0	6/23 26.1
Normal gait	8/13 61.5	10/20 50.0	10/18 55.6	8/15 53.3	9/18 50.0	9/15 60.0	4/5 80.0	14/28 50.0	9/10 90.0	9/23 39.1
No muscular atrophy	7/13 53.8	12/17 70.6	11/16 68.8	8/14 57.1	10/15 66.7	9/15 60.0	5/5 100	14/25 56.0	9/10 90.0	10/20 50.0
Normal mobility of subtalar joint	2/13 15.4	0/20 0	1/18 5.6	1/15 6.7	0/18 0	2/15 13.3	1/5 20.0	1/28 3.6	2/10 20.0	0/23 0
Normal mobility of talocrural joint	7/13 53.8	7/20 35.0	8/18 44.4	6/15 40.0	6/18 33.3	8/15 53.3	3/5 60.0	11/28 39.3	7/10 70.0	7/23 30.4
No residual disability entitling insurance benefits	2/7 28.6	7/9 77.8	4/9 44.4	5/7 71.4	5/8 62.5	4/8 50.0	0/0	9/16 56.3	2/4 50.0	7/12 58.3

variation apparent in both tables can be claimed to add up to a significant difference between moderate and considerable displacement for these two variables.

The remaining factors (age, fracture group type of fracture and diminution of tuber-joint angle in comparison with the uninjured foot) yield no significant differences, which means that the observations resulting from tables 36 and 37 are consistent with the impression we received from tables 38 and 39.

From the preceding analysis of factors to be taken into account in the primary evaluation of fractures of the calcaneus in terms of clinical management, we may conclude that the degree of displacement of the posterior articular surface is the decisive factor in this respect; the degree

Table 39. Relative frequency and percentage of favourable follow-up results, as represented by certain characteristics, within different factor group in cases with *tuber-joint angle exceeding 10 degrees* (at time of injury)

Characteristic of follow-up results	Factor group									
	Age in years		Fracture group		Type of fracture		Initial diminution of tuber-joint angle		Degree of displacement	
	≦50	> 50	VI	VII	1.	2.	≦20°	> 20°	(+)	(++)
Excellent+ good functional results	15/26 57.7	14/16 87.5	22/32 68.8	7/10 70.0	23/33 69.7	6/9 66.7	23/35 65.7	6/7 85.7	26/30 86.7	3/12 25.0
Normal gait	21/26 80.8	14/16 87.5	27/32 84.4	8/10 80.0	27/33 81.8	8/9 88.9	28/35 80.0	7/7 100	28/30 93.3	7/12 58.3
No muscular atrophy	22/25 88.0	13/15 86.7	27/30 90.0	8/10 80.0	27/32 84.4	8/8 100	29/33 87.9	6/7 85.7	27/28 96.4	8/12 66.7
Normal mobility of subtalar joint	13/26 50.0	9/16 56.3	14/32 43.8	8/10 80.0	18/33 54.5	4/9 44.4	17/35 48.6	5/7 71.4	18/30 60.0	4/12 33.3
Normal mobility of talocrural joint	22/26 84.6	12/16 75.0	26/32 81.3	8/10 80.0	26/33 78.8	8/9 88.9	28/35 80.0	6/7 85.7	26/30 86.7	8/12 66.7
No residual disability entitling insurance benefits	14/18 77.8	6/8 75.0	15/20 75.0	5/6 83.3	17/22 77.3	3/4 75.0	15/21 71.4	5/5 100	16/19 84.2	4/7 57.1

of compression of the fracture, as measured by the tuber-joint angle in the fractured foot only, ranking second in importance. Neither the age of the patient, on the one hand, nor fracture group or type of fracture appear to be of decisive importance. The fact that the degree of displacement is the decisive factor implies that our evaluation of these fractures can be based on reliable roentgenographic evidence. The personal opinion of the author is that the degree of displacement is best visualized with Brodén's projection I.

CHAPTER 9

Comparison with Other Series

Impartial evaluation and comparison of the therapeutic results of different fracture series represents a major problem. The many variations presented by fractures of the calcaneus, and their divergent classification do not always permit comparison of different series. The criteria for evaluation may likewise vary between different series. A case which one author might class as "good" may be graded as "fair" by another. In the majority of studies the follow-up results are based on a personal follow-up examination, but occasionally they are derived from a combination of personal investigations and questionnaires. Undoubtedly different series vary with respect to the severity of the fractures, since a number of hospitals have practiced selection of their material. In addition, it is likely that the results are to some extent influenced by the length and the period to which collection and treatment of the series are referable. In a number of series the results are derived from evaluation for insurance purposes only. Due to the wide variety of regulations in this respect, a comparison of certain series is feasible only within one and the same country. There is a fairly wide divergence of opinion between different series as to what constitutes an adequate follow-up period. In order to ensure a fair and objective comparison of the results in different series, therfore, the following requirements should be satisfied.

1. The series should be referable to approximately the same period of time.
2. The series should be equated with respect to such variables as may influence prognosis.
3. Classification of the series should permit comparison of the fractures with respect to their severity.
4. Unless the length of the follow-up period is found to be irrelevant to prognosis, this factor should not present substantial differences and should perferably be equated.
5. Evaluation of the functional results should be based on similar critera.

As has been stressed in a previous section, our interest is primarily directed towards intra-articular fractures which present varying functional results following different forms of treatment in different series. In the following section is presented a comparison between the present series, as representing treatment by early exercise, and two other series subjected to operative treatment. To date the largest series of fractures of the calcaneus treated by open reduction has been published by Widén in 1954. Comparison with his series is greatly facilitated by the fact that classification and follow-up procedure in the present series are set up along similar lines. The second comparison will be based on cases treated by triple arthrodesis, included in the series published by Moberg in 1953. For the purpose of the present comparison some additions have been made to the series. For reasons which will be discussed in a later section, comparison with this series will be limited to results derived from evaluation for insurance purpose.

With a view to ensuring an optimal degree of objectivity in our comparisons, the series will be differentiated by the size of the tuber-joint angle. Because of technical difficulties in connection with roentgenographic evaluation, it proved unfeasible to differentiate the series according to the degree of displacement of the posterior articular surface, as would have been preferable. On the other hand, a significant correlation was established in a previous chapter between the size of the tuber-joint angle and the functional results.

In 1954 Widén published the results of a follow-up study of 132 patients with fracture of the calcaneus. His series was derived from two Stockholm hospitals and consisted of patients treated during the years 1944—1950. Part of the series had been referred for treatment by other Stockholms hospials. As appears from table 40, intra-articular fractures of the calcaneus (groups VI—VII) were for the greatest part treated by open reduction according to Palmer's method. Widén's tabular presentation of the series provides data on age and sex distribution, classification of fractures, tuber-joint angle at time of injury and at follow-up, and in the majority of cases permits an estimation of the diminution of the tuber-joint angle in relation to the uninjured foot. No data is available, on the other hand, on the degree of displacement of the posterior articular surface prior to follow-up. The follow-up results in Widén's series which permit comparison with the present series are the following: degree of function, gait, muscular atrophy, mobility of the subtalar and talocrural joints, and results as evaluated for insurance purposes.

Table 40. Distribution of cases comprising Widén's, Moberg's, and present series, with respect to fracture group, form of treatment, unilateral and bilateral involvement, and unilateral involvement associated with other disabling injuries.

Fracture series				Fracture group			Total cases	Insured cases included in groups
				I–IV	V	VI–VII		VI–VII
Widén	Open reduction	Unilateral fractures		—	—	**56**	56	33
		Bilateral fractures		—	—	6	6	
		Unilateral fractures with concomitant injuries		—	—	3	3	
	Other operative treatment or conservative treatment	Unilateral fractures		31	20	13	64	
		Bilateral fractures		—	—	1	64	
		Unilateral fractures with concomitant injuries		—	2	—	2	
Department I of Sahlgrenska Sjukh.	Moberg: Reduction + triple arthrodesis in two stages	Unilateral fractures		—	—	**26**	26	22
		Bilateral fractures		—	—	4	4	
		Unilateral fractures with concomitant injuries		—	—	3	3	
	Other operative treatment or conservative treatment	Unilateral fractures		9*	3*	48	60	
		Bilateral fractures		5*	—	1	6	
		Unilateral fractures with concomitant injuries		4*	—	7	11	
Present series	Early exercise therapy	Unilateral fractures		17	13	**77**	107	42
		Bilateral fractures		—	—	1	1	
		Unilateral fractures with concomitant injuries		—	2	5	7	
	Plaster fixation or operative treatment	Unilateral fractures		—	—	1	1	
		Bilateral fractures		—	—	5	5	

* Specially selected cases.

Moberg and Erfors published in 1953 a preliminary report on the results of triple arthrodesis in the treatment of intra-articular fractures of the calcaneus. This report was based on a series of 15 cases treated by this operation during the years 1947—51. It appeared from this report that while the preliminary results had left a favourable impression, the relatively short period of observation did not permit any definitive conclusions to be drawn, nor allowed for a final evaluation of results from the insurance point of view. The author has been fortunate in being allowed to study the relevant material, which has been enlarged by additional cases treated by triple arthrodesis up to and including 1955 at Surgery Department I at Sahlgrenska Sjukhuset; during the years 1947—55 a total of 110 patients were admitted with fractures of the calcaneus. Tables 40 and 41 illustrate the distribution in time and the various methods of treatment which have been used for these patients.

A review of case records, operation reports, and roentgenograms revealed that of the total of 125 fractures treated at Surgery Department I during the relevant period, 98 were intra-aritcular fractures referable to groups V—VII according to Widén's classification. Since all case records and, with a few exceptions, all roentgenograms were available, a comparative study provided a reliable classification of this series.

The following procedure has been adopted for triple arthrodesis. During the first week the injured foot is elevated and a pressure dressing applied to reduce soft tissue edema about the fracture site. This is followed by

Table 41. Distribution of fractures of the calcaneus treated at surgical department I of Sahlgrenska Sjukhuset, Gothenburg, over the period 1947—55.

Year	Number of patients	Number of fractures			Form of treatment			
		Intra-articular	Extra-articular	Total	Arthrodesis	Open reduction	Other operations	Plaster fixation
1947	15	17	1	18	6	—	2	10
1948	7	6	1	7	1	—	—	6
1949	16	17	—	17	7	—	—	10
1950	9	8	2	10	5	—	1	4
1951	11	7	5	12	5	—	—	7
1952	10	9	3	12	3	—	1	8
1953	15	12	6	18	4	3	1	10
1954	11	10	2	12	3	4	—	5
1955	16	12	7	19	3	2	—	14
Total	110	98	27	125	37	9	5	74

closed reduction similiar to Böhler's method and percutaneous fixation of the fracture with Rissler nails. Following plaster immobilization for a period of 4—6 weeks, the patient is rehospitalized for the final arthrodesis operation, which follows the standard procedure for triple arthrodesis, with removal of the cartilage and the articular surfaces between calcaneus, talus, navicular and cuboid bones. Following this second operation, the foot was immobilized in plaster for an additional 12—14 weeks.

Table 41 shows that 37 operations for arthrodesis were performed during the relevant period, in 4 cases bilaterally. A review of the case records discloses that indications for arthrodesis existed in 10 more cases, but was contra-indicated for various reasons (residential disqualification, poor general condition of the patients, etc.).

As roentgen analysis with Brodén's projections has been carried out in only a few of Moberg's cases, evaluation of the degree of displacement of the posterior articular surface is not feasible. For the majority of cases, on the other hand, roentgenograms are available which permit an estimation of the tuber-joint angle. Since analysis of the present series in an earlier section has demonstrated a correlation between functional results and tuber-joint angle (p. 71), the series compared here have been differentiated by this criterion. The comparison includes only those cases which are marked in heavy print in table 40 (p. 86), representing unilateral uncomplicated fractures referable to groups VI—VII.

It is evident from table 42, that while the distribution with respect to tuber-joint angle is similar for Widén's and Moberg's series, the present series shows a fairly marked disparity. The cases presenting a tuber-joint angle exceeding 10 degrees amount in the present series to 56 %, as against 29 % in Widén's series. The difference between these percentages is statistically significant (**). In this respect the present series has an initial advantage. This stresses the necessity of paying particular attention to the differentiation by tuber-joint angle in comparing the series with respect

Table 42. Distribution of cases with respect to tuber-joint angle at time of injury. Widén's, Moberg's and present series

Series	Tuber-joint angle at time of injury			Data missing	Total cases
	neg.—0°	1—10°	>10°		
Widén	24	13	15	4	56
Moberg	12	6	5	3	26
Present series	16	17	42	2	77

to the follow-up results. For this reason the series will for each comparison be differentiated into three subgroups on the basis of the observed values for the tuber-joint angle. It might be feared that the operated cases in Widén's series, which belong to the group presenting the most favourable values for the tuber-joint angle, have a far greater incidence of considerable displacement than the present series. It should be stressed, however, that the roentgen technique with which it is possible to identify and evaluate displacement of the posterior articular facet, was not adopted until the latter part of 1948 and has at the very most been used in a fourth of that part of Widén's series which is included in the present comparison. Analysis of the degree of displacement in relation to the functional results in the present series has furthermore elicited a correlation between the size of the tuber-joint angle and the degree of displacement, which means that for the purpose of this comparison the value for the tuber-joint angle in the injured foot may be substituted for the degree of displacement. Thus, within the respective subgroups, differentiated by tuber-joint angle, Widén's and the present series will be considered comparable to a certain degree.

It should be stressed, however, that the degree of displacement has a bearing upon prognosis even after the tuber-joint angle has been eliminated as a factor. This has been shown in tables 36, 37, 38 and 39. We may not assume, therefore, that we have found the ideal solution if we take only the tuber-joint angle into account. The question arises whether there is any reason to suspect that Widén's series and the present one are at variance with respect to degree of displacement within the subgroups differentiated by tuber-joint angle. As appears from tables 36 and 37, the present series showed a marked correlation between degree of displacement and tuber-joint angle values. For Widén's series no record has been made of the initial degree of displacement at the time of follow-up (Widén op. cit., p. 71, table 19). The incidence of considerable displacement among the operated cases was found to amount to 65.7 % at follow-up.

This percentage is derived from the total series of operated cases. The distribution of this series is illustrated in table 43 which also includes the corresponding figures for the present series.

In Widén's series, the cases with considerable displacement have not been differentiated by tuber-joint angle. It should be noted, however, that the present series shows an entirely different distribution with respect to tuber-joint angle values. Since the following analysis is intended to compare the results of the two series within the respective subgroups differentiated by the tuber-joint angle, the figures of the present series

Table 43. Distribution of fractures with displacement of the posterior articular surface with respect to tuber-joint angle at time of injury.
Criterion for testing equation of Widén's and present series with respect to degree of displacement

	Tuber-joint angle at time of injury			Data Missing	Number of cases	
	Neg.—0°	1°—10°	>10°			
Widen's Series (Operated patients)						
1. Unilateral fractures	26	12	16	4	58	
2. Bilateral fractures	4	3	2	—	9	
Total	30	15	18	4	67	
Considerable (++) displacement at follow-up					44	65.7%
Present Series						
1. Unilateral fractures	16	17	42	—	75	
Considerable (++) displacement at time of injury	13	10	12	—	35	
Percentage of considerable displacement	81.2	58.8	28.6			46.7%
2. Bilateral fractures						
a. Treated by early exercise	4	2	1	—	7	
b. Treated by plaster fixation or operation	3	1	1	—	5	
Total	7	3	2		12	
Percentage of considerable displacement	100	100	0			83.3%

should be equated so as to permit comparison with Widén's figures. On the basis of the percentage distribution of cases with considerable displacement within the respective tuber-joint angle subgroups, it is possible to estimate what the percentage of such cases would have been in the present series if this had had the same distribution as Widén's total operated series. The following expression is used for this calculation:

$$\frac{26 \cdot 81.2\% + 12 \cdot 58.8\% + 16 \cdot 28.6\% + 4 \cdot 100\% + 3 \cdot 100\% + 2 \cdot 0\%}{26+12+16+4+3+2} = 63.1\%$$

We find that the percentage of 63.1 in the present series is only slightly lower than Widén's percentage of 65.7. Widén's series is obviously at a disadvantage, despite the fact that the displacement percentage in his

series refers to the time of follow-up and in the present series to the time of injury.

It can be expected that the percentage at the time of injury in Widén's series must be higher, since it is reasonable to assume that operation has succeeded in reducing the degree of displacement.

Despite this differentiation of the series by tuber-joint angle values, it is unlikely that the two series are fully equated. Initial conditions in Widén's series have been less favourable, which should be taken into account when we interpret the results of our analysis.

The question arises whether a differentiation according to the diminution of the tuber-joint angle in relation to the uninjured foot would have provided a better basis for comparison than the differentiation adopted here, based on the value for the tuber-joint angle in the injured foot. Further analysis shows that if the distribution of the present series had been equated to Widén's series with respect to the diminution of the tuber-joint angle in relation to the uninjured foot, the incidence of displacement in the present series would amount to only 53.6 % as against 65.7 % in Widén's series. This fully confirms that the value for the tuber-joint angle in the injured foot is the preferable criterion for differentiation.

If we wish to evaluate whether the age and sex factors in Widén's, Moberg's, and the present series are comparable for the purpose of this analysis, we find an average age of 48, 45.5, and 48.5 years, respectively. The age distribution is fairly well equated. The percentage of women is somewhat higher in the present series than in the other two (19 % as against 11 % in Widén's and 4 % in Moberg's series).

Widén's series permits a differentiation of the material into fracture groups VI and VII, but this provides an identical percentage distribution with respect to functional results. The same is true for the present series.

In the following section, comparisons will primarily be drawn between the follow-up results of Widén's and the present series. Comparison will be based on the follow-up results presented in Widén's study and the results which have been presented for the present series in the preceding chapters. Comparison of Widén's and the present series is, as mentioned earlier, based on a differentiation of the material into three subgroups representing different values for the tuber-joint angle.

A similar comparison with Moberg's series did not prove feasible, since his series has not been subjected to follow-up examination, with the exception of data relevant to insurance adjustment. It must be noted that his series, though appearing small, consits only of about one third of the total patients seen, since only the most severe intra-articular fractures are included.

Table 44. Functional results in different subgroups. Widén's and present series

Functional results	Tuber-joint angle					
	Widén's series			Present series		
	neg.—0°	1—10°	> 10°	neg.—0°	1—10°	> 10°
Excellent	7	4	5	3	3	13
Good	7	4	6	2	6	16
Fair	5	3	3	4	6	8
Poor	5	2	1	7	2	5
Total	24	13	15	16	17	42

Table 44 shows the distribution of Widén's and the present series with respect to the tuber-joint angle. In Widén's series data on this aspect is missing in 4 cases, in the present series in 2 cases.

With respect to the length of follow-up the two series show considerable variation. The average follow-up period in Widén's series is considerably longer than in the present series (49.7 months and 27.8 months, respectively). From table 45 it appears that the length of follow-up is not dependent on the value for the tuber-joint angle at the time of injury, nor does any correlation appear between length of follow-up and functional results. Thus, in Widén's series, the groups representing excellent and good functional results have an average follow-up period of 48.9 months, as against 51.2 months for the groups with fair and poor results. The corresponding figures in the present series are 27.6 and 28.1 months, respectively. Within Widén's and the present series the period of obser-

Table 45. Average length of observation period in months in different subgroups. Widén's and present series

Subgroup	Tuber-joint angle at time of injury					
	Widén's series			Present series		
	Neg.—0°	1°—10°	> 10°	Neg.—0°	1°—10°	> 10°
Entire comparative group	47.0	53.8	50.6	28.1	21.1	30.5
Excellent+good functional results	43.6	55.3	51.2	34.0	20.9	19.7
Fair+poor functional results	51.8	51.6	49.0	25.5	21.3	34.6
Normal mobility of subtalar joint	47.3	43.0	52.7		24.5	31.3
Loss of mobility at subtalar joint	46.9	47.3	50.1	28.1	20.6	29.4

vation is on the whole equally long for patients with favourable or unfavourable results.

The same observation is made if we compare the length of follow-up for cases with normal and impaired mobility of the subtalar joint, respectively, as is evident from table 45.

This agreement suggests that the variations with respect to length of follow-up between Widén's series and the present series may be disregarded.

The percentage of favourable (excellent and good) functional results is somewhat higher in Widén's series than in the present series. This holds true for each of the tuber-joint angle subgroups. The three subgroups differentiated by tuber-joint angle present the following differences:

Table 46. Relative frequency and percentage of favourable follow-up results, as represented by certain characteristics, within the subgroups differentiated by tuber-joint angle at time of injury. Widén's and present series

Characteristic Follow-Up Results	Widén's Series						Present Series					
	Tuber-Joint Angle											
	neg.—0°		1°—10°		> 10°		neg.—0°		1°—10°		> 10°	
	Characteristic/subgroup	%	Characteristic/subgroup	%	Characteristic/subgroup	%	Characteristic/subgroup	%	Characteristic/subgroup	%	Characteristic/subgroup	%
Excellent+good functional results	14/24	58.3	8/13	61.5	11/15	73.3	5/16	31.3	9/17	52.9	29/42	69.0
Normal gait	16/24	66.7	10/13	76.9	11/15	73.3	7/16	43.8	11/17	64.7	35/42	83.3
No muscular atrophy	16/20	80.0	8/12	66.7	11/12	91.7	6/13	46.2	13/17	76.5	35/40	87.5
Normal mobility of subtalar joint	3/24	12.5	2/13	15.4	3/15	20.0	0/16	0	2/17	11.8	22/42	52.4
Normal mobility of talocrural joint	15/24	62.5	10/13	76.9	9/15	60.0	6/16	37.5	8/17	47.1	34/42	81.0
No residual disability entitling insurance benefits	9/14	64.3	5/9	55.6	7/8	87.5	6/9	66.7	3/7	42.9	20/26	76.9

Tuber-joint angle neg. or 0° 58.3—31.3 = 27.0 %
Tuber-joint angle 1°—10° 61.5—52.9 = 8.6 %
Tuber-joint angle >10° 73.3—69.0 = 4.3 %

None of the differences reaches statistical significance. In order to be able to evaluate a possible difference between the series, however, these three differences have been summarized so as to construct a standard weighted mean of the differences. This calculation has provided the single mean value $\frac{27.0 + 8.6 + 4.3}{3} = 13.3$ %. We find that this percentage likewise falls short of statistical significance (95 % confidence interval 13.3± 18.6 %).

A comparative analysis between the two series, designed to estimate the relative frequency of favourable follow-up results, (as defined earlier) within the subgroups differentiated by tuber-joint angle, provides the figures set down in table 46.

This comparison between the two series demonstrates favourable percentage in Widén's series. A significance analysis of the 18 percentage differences between the two series, however, fails to elicit a significant difference for any one of the subgroups differentiated by the tuber-joint angle. If we calculate the mean of the three percentage differences for each characteristic of the follow-up results, we arrive at the following tabulation (table 47).

Table 47. Standard weighted percentages and differences of characteristics representing favourable follow-up results. Widén's and present series

Characteristic of follow-up results	Widén's series	Present series	Difference (per cent)	Standard error of the difference (per cent)	Difference between Widén's and present series for tuber-joint angle neg.—0°	Standard error of the difference (per cent)
Excellent+good functional results	64.4	51.1	13.3	9.3	27.0	16.1
Normal gait	72.3	63.9	8.4	8.3	22.9	15.9
No muscular atrophy	79.5	70.1	9.4	8.6	33.8	16.8
Normal mobility of subtalar joint	16.0	21.4	−5.4	7.3	12.5	8.5
Normal mobility of talocrural joint	66.5	55.2	11.3	8.3	25.0	16.1
No residual disability entitling insurance benefits	69.1	62.2	6.9	12.1	−2.4	20.3

No significant difference exists. From the column denoting the mean error it is evident that the percentage observed for the difference between the two series is uncertain.

A comparative analysis of functional results is not feasible where Moberg's series is concerned, since no follow-up is available, with the exception of such results as are relevant from the insurance point of view. Both in Moberg's and Widén's series the lapse of time following injury has been sufficient for a final adjustment to be made in all cases which had been entitled to disability benefits. In order to compare the three series of insurance cases in this respect, the same differentiation by the tuber-joint angle as before has been adopted. Table 48 shows the distribution of the three series at the time of injury.

Table 48. Distribution of insurance cases with respect to tuber-joint angle at time of injury. Widén's, Moberg's, and present series.

Series	Tuber-joint angle at time of injury			Total cases	Data on tuber-joint angle missing
	neg.–0°	1°–10°	> 10°		
Widén (followed-up + not followed-up)	14+0	9+1	8+0	33+1	2+0
Moberg (not followed-up)	10	5	5	22	2
Present series (followed-up + not followed-up)	9+0	7+1	26+0	42+3	0+2

Widén's series includes one additional case and the present series 3 such cases, for which insurance data are available but which for various reasons were not included in the follow-up. The table shows that the relative frequency of cases with a tuber-joint angle exceeding 10 degrees is higher within the present series.

A comparison of the three insurance series five years following injury, with respect to the degree of disability as rated for insurance purposes within the subgroups differentiated by tuber-joint angle, provides the figures set down in table 49. In the present series the follow-up period has in many cases been relatively short, but as disability benefits are

Table 49. Distribution of insurance cases entitled to disability benefits over a period of five years or more, with respect to tuber-joint angle at time of injury. Widén's, Moberg's, and present series

Series		Tuber-joint angle at time of injury						Total cases		Data for tuber-joint angle missing
		neg.–0°		1°–10°		>10°				
		no.	%	no.	%	no.	%	no.	%	
Widén	no disability	9	64.3	6	60.0	7	87.5	22	68.8	2
	disability	5	35.7	4	40.0	1	12.5	10	31.2	0
Moberg	no disability	1	10.0	1	20.0	2	40.0	4	20.0	1
	disability	9	90.0	4	80.0	3	60.0	16	80.0	1
Present series	no disability	6	66.7	4	50.0	20	76.9	30	69.8	1
	disability	3	33.3	4	50.0	6	23.1	13	30.2	1

awarded for several years at a time, it has been possible to evaluate the degree of disability.

No significant difference is elicited between Widén's series and the present series with respect to the percentage of individuals entitled to disability benefits.

The comparison presented in the preceding pages, between two series of calcaneal fractures treated by different methods, has shown that prognosis does not vary significantly for a series treated by open reduction (Widén's series) and a series subjected to early exercise therapy (present series). In interpreting the results of comparison between Widén's series and the present series it should be noted, however, that prognosis is more favourable for Widén's series, even though the difference is not significant. In addition, the period of follow-up has been longer in Widén's series, and it is likely that the incidence of considerable displacement in his series has been higher, implying an initial disadvantage.

Nevertheless we may conclude that within the subgroups presenting a tuber-joint angle of more than 10 degrees, there is not even a tendency towards more favourable results in Widén's series as compared with the present one. Within this group results tend to be more favourable in the present series with respect to gait, and mobility of the subtalar and talocrural joints. In this case, however, the results may to some extent be influenced by the length of follow-up.

However, within this subgroup it is primarily the cases with moderate displacement which account for the favourable prognosis. An interpretation worth considering is that cases with moderate displacement treated by early exercises regain satisfactory mobility and that their prognosis is equally as favourable as cases treated by open reduction. It would seem, on the other hand, that early exercise therapy in cases with considerable displacement produces less favourable results than open reduction. A conclusive answer to these questions might be provided by a study based on a new series, requiring a record of the initial degree of displacement, standardization of the length of follow-up, and random selection of the cases to be treated by either open reduction or early exercises.

CHAPTER 10

Evaluation of Results of Different Therapeutic Methods for Fractures of the Calcaneus, in Terms of Insurance Rating

In view of the varying principles of evaluation followed by insurance companies in different countries, comparison with insurance series outside the country has little value. Scandinavian sources report the incidence of permanent disability ensuing from fracture of the calcaneus as varying from 8 to 30 % (Olofsson 1940, Kiaer and Antonson 1942, Widén 1954, Rosendahl-Jensen 1956 and others). Rosendahl-Jensen reported in 1956 on a Danish insurance series including a total of 465 intra-articular fractures of the calcaneus, followed up over a period of at least 8 years. He found permanent disability in 29.7 % of all cases, and twice as much disability in cases treated by secondary arthrodesis as in those treated conservatively or with some form of traction. Olofsson published a study in 1940 which was based on a series derived from the records of the National Insurance Board for the years 1924—1933. His observations included two five-year periods. During the first of these periods the majority of cases had received conservative treatment, whereas treatment in the latter period had been predominantly active, mainly in the form of reduction ad modum Böhler. No appreciable difference between the two five-year periods could be established. Olofsson found that half of his calcaneal fractures had healed without residual disability, one fourth had temporary disability and one fourth permanent disability. The average degree of disability was 17 %. Olofsson's failure to classify his fractures, and his inclusion of bilateral fractures makes it difficult to compare his series with those of other authors.

Among other Swedish studies of calcaneal fractures evaluated in terms of insurance rating we find Ahlberg's series, which includes both cases treated by conservative methods (exercise therapy or plaster fixation), and cases treated by different surgical techniques. Widén's report of insurance cases is based on a series which for the greater part was subjected to

uniform surgical treatment, consisting of open reduction. Moberg and Erfors' report on triple arthrodesis in the treatment of calcaneal fractures was based on too short a period of follow-up to permit any definitive conclusions in terms of insurance rating.

The disability rating of Widén's and the present series.

It would be useful to include a comparison of the present series in terms of insurance rating with Widén's operated series of cases subjected to uniform surgical treatment. In Widén's series, so much time had elapsed since injury that the insurance companies have come to a final adjustment of disability claims. The data relevant to this comparison are derived from a review of the insurance records of all individuals in the two series who had made application for disability benefits. All insurance records were still available for inspection.

The following comparison will be concerned with unilateral intra-articular fractures of the calcaneus and is designed to determine the frequency and degree of disability, the length of hospitalization, the period of total occupational disability, and the patient's final state of occupational fitness.

The two insurance series on which this comparison will be based consists exclusively of men. The average age in Widén's insurance series is 46.3 years and in the present series 46.6 years. No differentiation of the series by either fracture groups or tuber-joint angle has been carried out.

In the insurance series which Widén presented in his 1954 study and compared with insurance cases from Ahlberg's series, the length of follow-up varied between 2 and 8 years. All cases included in Widén's insurance series were for the purpose of the present comparison re-examined on the basis of their insurance records.

Diagram 3 A shows the insurance rating of Widén's series at the time of follow-up in 1952. Due to the varying length of follow-up, the number of cases subjected to insurance rating decreases with each year that passes. Diagram 3 B shows the disability rating following final adjustment of all insurance claims. It is evident from this figure that the actual frequency of disability in Widén's series is considerably higher than appears from his original presentation (diagram 3 A). The proportion of cases with a final rating of permanent disability is found to be about twice as large. In this retrospective analysis we have also taken into account any complaints from patients whose claims for insurance benefits were denied despite residual symptoms. Widén's series included two patients who had protested the insurance company's decision, but only one of them suc-

Diagram 3 A

Disability rating of Widén's insurance series at follow-up in 1952.

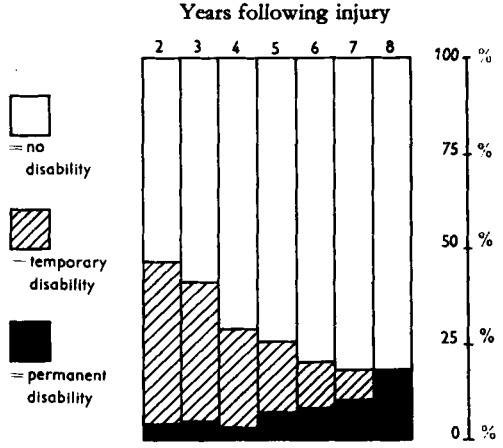
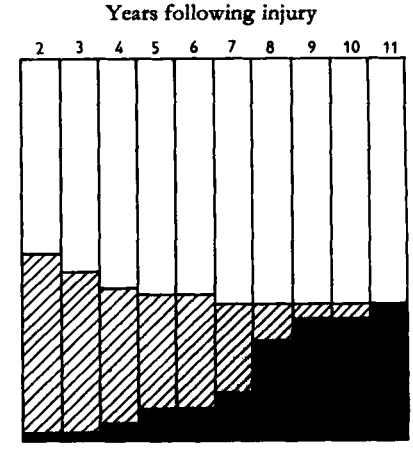


Diagram 3 B

Final adjustment of disability rating in Widén's insurance series.



Number of cases:																				
No disability	27	29	28	24	13	10	5		26	29	31	32	32	33	33	33	33	33
Temporary disability	22	18	10	6	2	1	0		24	21	18	15	15	12	5	2	2	0
Permanent disability	2	2	1	2	1	1	1		1	1	2	4	4	6	13	16	16	18
Total	51	49	39	32	16	12	6		51	51	51	51	51	51	51	51	51	51

ceeded in securing a provisional prolongation of the temporary disability benefits.

Widén's insurance series of 51 cases includes 17 patients subjected to some form of treatment other than open reduction. As we are interested in evaluating the results for cases subjected to uniform surgical treatment separately, these have been collected into a separate series. It consists of 34 cases referable to fracture groups VI and VII. Their distribution over these fracture groups (and their insurance rating) is illustrated by Diagram 4 A.

Diagram 4 B provides a similar presentation of the insurance cases included in the present series and referable to fracture groups VI and VII, 45 cases in all. Despite the short follow-up period of the present series, it has been possible to follow the pertinent cases over a period of five years with respect to their insurance rating.*)

Diagram 4 A and 4 B show the incidence of temporary and permanent disability in the two insurance series at varying intervals following injury.

*) Example: Case no 58, injured Aug. 1958, 15 % disability benefit secured until May 1, 1964.

Diagram A

Final adjustment of disability rating for operated patients in Widén's insurance series.

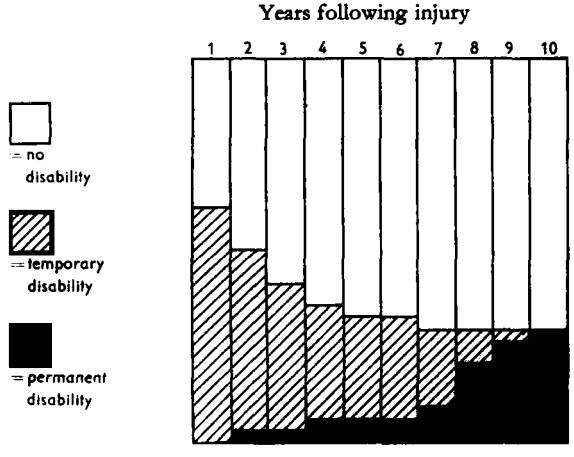
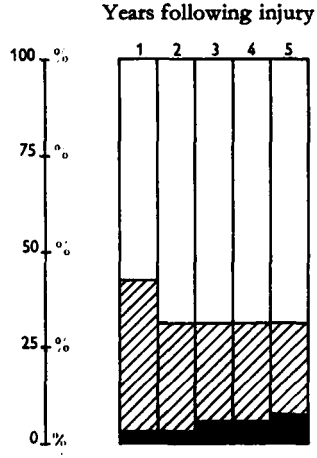


Diagram B

Disability rating of precent insurance series during first five years after injury.



Number of cases:															
No disability	13	17	20	22	23	23	24	24	24	24	26	31	31	31	31
Temporary disability	21	16	13	10	9	9	7	3	1	0	18	13	12	12	11
Permanent disability	0	1	1	2	2	2	3	7	9	10	1	1	2	2	3
Total	34	34	34	34	34	34	34	34	34	34	45	45	45	45	45

In Widén's series we find that from 5 years after injury only one of the cases awarded provisional benefits is subsequently transferred to the group without residual disability. The other cases with provisonal disability benefits are at some later stage granted a permanent disability pension. We further find that in one case final adjustment of the patient's disability rating did not take place until more than 9 years following injury. It would seem, therefore, that in a series of this type a stationary condition is reached in terms of insurance rating on the average after about 4 years. As appears from diagram 4 B the insurance rating of the present series has from 2 years after injury undergone no appreciable changes. Those cases which 2 years following injury are in receipt of provisional disability benefits, are still collecting them by the end of the 5-year period, unless they have already been granted a permanent disability pension by that time. For all insurance cases in the present series which at the time of follow-up were in receipt of provisional disability benefits, functional results were found to be unfavourable (fair or poor) at follow-up. This evaluation was confirmed on subsequent revision of their disability rating.

It is hardly likely that the condition of these patients will improve as far as function is concerned, and we may reasonbly assume, therefore, that they will sooner or later become eligible for a permanent disability pension.

On the basis of the insurance series compared here, it may be interesting to estimate how the degree of disability changes in relation to the time elapsed since injury. Since the number of cases entitled to disability benefits decreases with the years, the average degree of disability for the total insurance series should show a similar decrease. This assumption is confirmed by table 50.

Table 50. Mean disability in per cent for total insurance series at varying intervals following injury. Widén's, and present series.

Series	Years after injury									
	1	2	3	4	5	6	7	8	9	10
Widén	13.4	6.4	5.1	4.1	3.8	3.7	3.4	3.5	3.5	3.5
Present series	7.9	4.1	4.1	4.1	4.1					

During the first year following injury, the average degree of disability is lower in the present series in comparison with Widén's series. This obviously reflects the observation emerging from diagram 4 A and B that the rate of disability during the first years following injury is higher in Widén's series. From 2 years after injury the present series shows no further changes and from then on any difference with Widén's series is negligible.

Table 51 shows the average degree of disability estimated only for those cases who at varying intervals following injury were still in receipt of insurance benefits.

Table 51. Mean disability in per cent for insurance cases entitled to disability benefits at varying intervals following injury. Widén's, and present series.

Series	Years after injury									
	1	2	3	4	5	6	7	8	9	10
Widén	21.7	12.8	12.3	11.7	11.8	11.5	11.7	12.0	12.0	12.0
Present series	18.7	12.9	12.9	12.9	12.9					

It emerges from this table that the degree of disability as estimated in relation to the number of cases receiving insurance benefits has undergone no appreciable changes in either of the series from 2 years after injury onwards. We also find that there is no appreciable difference between the 2 series. The average degree of disability ranges from 12 to 13 %, which is somewhat lower than the 17 % reported by Olofsson. One reason for this may be that Olofsson's series includes both bilateral fractures and cases with concomitant injuries. Even though no final adjustment of insurance ratings has been effected yet in the present series, we may expect the final degree of disability for this series to remain at an average of 13 %. In the majority of cases the provisional disability rating remains unchanged or is lowered by the final adjustment.

From the sociomedical point of view it may be interesting to establish the length of hospitalization and total occupational disability. Table 52 presents a comparison of the two series in these respects.

Table 52. Duration of hospitalization and total occupational disability. Insurance cases in Widén's, and present series.

Series	Number of cases	Hospitalization mean time in days and (range)		Total occupational disability mean time in days and (range)	
Widén	34	23.0	(7—88)	210.0	(89—365)
Present series	45	20.5	(0—80)	156.0	(71—390)

In these respects the two series show some variation. The average length of hospitalization for the present series may seem relatively high, but the patients were intentionally kept in hospital as long as possible to ensure an uninterreputed course of intensive physical therapy during the early post-injury period.

The degree of disability following fracture of the calcaneus is highly variable dependent on the patient's occupation. A patient with a sedentary job, such as an office worker, is obviously less handicapped by his injury than someone engaged in heavy manual labour, as, for instance, a construction worker. Our findings in the two compared series show that about 90 % of the patients were engaged in heavy labour prior to injury. It may be interesting, therefore, to determine how many of those who are still receiving insurance benefits were forced to turn to lighter work

because of residual symptoms resulting from their injury. By combining the data from the respective follow-up examinations with those derived from the insurance records, including so-called "employers' reports", it was possible to arrive at a fairly reliable estimate of actual occupational fitness in each individual case. As a rule the injury has in these series caused a reduction of occupational fitness, with a consequent loss of income which is not fully covered by the disability benefits. A typical example is the construction worker who has been unable to return to his former occupation and has been forced to accept a less active and less profitable job.

Series	Total number of cases with disability	Occupationally handicapped
Widén	10	6
Present series	14	9

Table 53. Disability constituting occupational handicap in insurance cases. Widén's and present series.

Table 53 shows that roughly 2 out of 3 were reduced to lighter work, In a number of cases, consequently, disability benefits are paid to patients who, judging by employers' reports, on the whole have suffered no loss of income within their former occupation. In these latter cases the disability benefits are more or less equal to "smart-money"*. As to insurance cases not eligible for a permanent disability pension, the insurance records show that 3 patients in Widén's and the present series, were forced to change their occupation because of residual symptoms following injury.

Under the Swedish Workmen's Compensation Act, insurance benefits are paid as long as occupational fitness is reduced by at least 10 % in the estimate of the insurance company. In the series of calcaneal fractures presented here, disability rating was centralized at the insurance companies and performed on the basis of uniform criteria.

Our comparison has shown that there is no appreciable difference between Widén's series and the present series, except for the fact that the average period of total occupational disability appears to be shorter for cases treated by early exercises. However, the severity of the fractures in the insurance cases of Widén's series appear to be intermediate between the most severe type in Moberg's series, and those of the author's present insurance series. For these reasons it has not been possible to significantly compare these groups.

* Payment for inconvenience, pain and suffering.

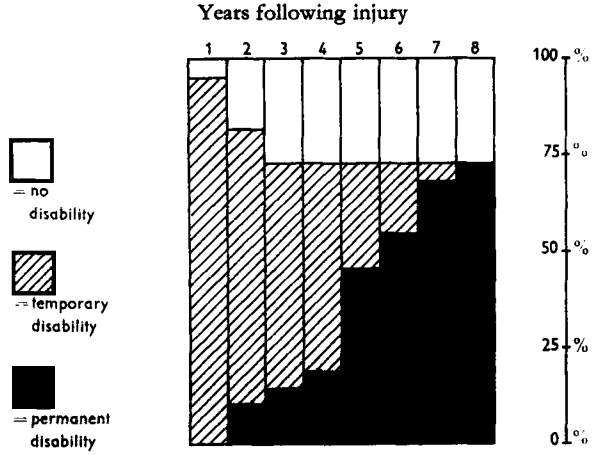
The disability rating of Moberg's series.

As already shown in chapter 9. Moberg's cases were treated in an entirely different manner. Closed reduction with traction and pinning and later triple arthrodesis were performed. The age in this series does not differ from the two other series. However, the cases are selected and consist of only the severest third of the total number of intra-articular fractures admited to hospital during the years in question. Only 37 of 98 cases are included and of this number, 22 were insurance cases. This makes comparison with the other two series difficult and as well no detailed follow-up is available. However, the result from the insurance point of view, can be followed in the cases covered by insurance..

A similar presentation as for the other two insurance series has been made for Moberg's insurance cases in diagram 5, which illustrates the incidence of full recovery, temporary disability, and permanent disability at varying intervals following injury. We find from this diagram that during the first year after injury all but one of the patients were in receipt of insurance benefits. From 3 years after injury onwards all cases still collecting benefits will continue to do so, the provisional benefits being gradually replaced by permanent disability pensions. In one case this was

Diagram 5

Final adjustment of disability rating in Moberg's series.



Number of cases:								
No disability	1	4	6	6	6	6	6	6
Temporary disability	21	16	13	12	6	4	1	0
Permanent disability	0	2	3	4	10	12	15	16
Total	22	22	22	22	22	22	22	22

delayed until 8 years following injury. Altogether, 73 % of this series are classified as permanently disabled, which is about twice as high as the rate observed in Widén's series and the expected rate in the present series.

Mean disability (in per cent) for the total insurance series following injury will for one to seven years after injury (at varying intervals) drop as follow: 50.5, 12.7, 10.8, 10.8, 10.6, 10.2, 10.2.

It is also of interest to see that in those difficult cases of Moberg five years after injury the average disability rating is 14 % in his series compared with 11.8 % for Widén's and 12.9 % for the present series.

The time in hospital is prolonged in the 22 cases, being 57.8 days as an average (range 32 — 95). The total occupational disability is 337.6 days (mean) with a range of 113 — 615 days. The working capacity was diminished in only 10 of the 16 patients who received permanent disability payments. The remaining 6 patients were able to return to their former occupation.

CHAPTER 11.

Summary and Conclusion

In an attempt to classify the os calcis fractures according to anatomical principles and in order to elucidate the pathomechanics of these injuries, the author has experimentally produced such fractures on post mortem material.

Preparations consisting of the lower limb and foot were subjected to a sudden force striking the heel from beneath with varied positions of the foot. During the experiments strain-gauges registered the force as a function of time.

Different types of os calcis fractures were produced resembling those seen clinically. The position of the foot at the moment of impact appeared to be the most important factor governing the type of fracture obtained. Some of the experiments were followed with a high speed camera which simultaneously registered both the force and the course of the fracture as well as the degree of the compression in the os calcis. In the experiments detailed here the force necessary to produce a fracture varied between 600 and 1200 Kp. It is possible to explain the fracture mechanism by correlating experimental results with roentgenograms and anatomical findings at dissection.

The trauma causing a severe os calcis fracture not only produces the fracture itself but also to a great extent injures the soft tissues. Therefore immobilizing the foot for a prolonged period of time makes the restoration of the muscular and circulatory physiology of the extremity more difficult and nullifies the beneficial effect aimed at by attempted reconstruction of the normal anatomy of the injuried bones.

The author has analysed unselected clinical material of os calcis fractures that have been treated with early physical therapy. This was done in an attempt to evaluate what results this conservative treatment could produce for different types of os calcis fractures and which factors were of importance for the prognosis.

The clinical material in the present investigation was taken from some 15 surgical departments in Sweden during the period June 1956 — January 1960. With very few exceptions all cases of os calcis fractures occuring in these departments during this period were treated in a similar way with early mobilization without attempts at reduction. The follow-up was conducted on an individual personal basis during the latter part of 1959 and early 1960. During this time 121 patients were examined. (93.8% of the available total).

The end result of a group of unilateral intra-articular os calcis fractures (90 patients) was of special interest. The follow-up period for the majority of these patients was more than 18 months. In this group of unilateral intra-articular fractures a good correlation exsisted between the subjective patient complaints after the injury and with the more objectively registered end results of the function of the foot. Those patients which were graded as excellent showed a normal gait and a normal, or near normal, mobility in the talocrural and subtalar joints.

The following factors which were subjected to detailed analysis are of presumable prognostic value: the fracture group (according to Widén), type of fracture (according to Palmer), age and sex, the tuber-joint angle and the degree of displacement in the posterior articular facet of the os calcis. It has been shown that a most significant factor in determining the end results is whether the fracture includes the posterior articular facet or not. The degree of displacement of the posterior articular facet is *one* measure of the severity of the fracture. In judging the degree of displacement the author has adopted the roentgenological technique set forth by Brodén. If the material is divided into three groups according to the degree of displacement of the posterior articular facet (none, moderate, considerable) it is shown that the displacement factor was of greater prognostic significance than the tuber-joint angle. This latter measurement is the one presently in general use in the grading of the severity of os calcis fractures. This present analysis has not shown age, sex, fracture-group and type of fracture to be of any prognostic significance in unilateral intra-articular fractures.

The end results of the present clinical series were compared to other series, one of which was treated with open reduction, the other with triple arthrodesis. In this comparison the material of the present series had to be classified according to the magnitude of the tuber-joint angle, in order that the differences in degree of severity between the various series could be compared. It would have been better and more instructive if this comparison could have been made on the degree of displacement. This how-

ever was not possible since the necessary roentgenograms, taken at special and significant angles, were not available in all the three series.

It was possible to compare the end results of the present series to that treated by open reduction. It was found that the results were better in the group with severe os calcis fractures (tuber-joint angle neg. —0°) when they were treated by open reduction. As for the less severe group (tuber-joint angle exceeding 10 degrees) one finds better results in those treated by early physical therapy. One explanation for this may be that in the group "tuber-joint angle exceeding 10 degrees" there are fewer cases with considerable displacement, and thus in this group the hazards of prolonged immobilization make the result of the operation inferior.

The comparison with the series that was treated by early triple arthrodesis was based only on insurance judgements. It appeared here that both early physical therapy and open reduction gave better results than an arthrodesis; on the other hand, these cases were considered the severest of those that were admitted to the hospital during that interval.

Through the co-operation of the various insurance companies it was possible for the author, in the two operatively treated series, to follow the insurance judgement in those cases. This investigation showed that it sometimes takes up to 11 years before the insurance companies finally have settled an injury of this type. It was also found that those cases that had a temporary disability rating, 4 — 5 years after the injury, would in all probability eventually get a permanent disability rating. The average time of working incapacity is lower for those patients with these fractures treated by early physical therapy. On the other hand the average degree of disability in the three series compared, is about equal. The incidence of permanent disability is, however, greatest in the series treated by triple arthrodesis, being twice as common as in the other two series.

On the basis of the experimental studies of os calcis fractures combined with review of clinical material treated by early physiotherapy (and comparison with two other differently treated series) the author makes the following recommendations:

It is necessary to perform a thorough roentgen examination with special attention to the degree of displacement in the subtalar joint; this is essential in order to form an initial specific opinion about the fracture and to further plan the specific treatment. Fractures not involving the posterior articular facet ought to be treated with early mobilization without weight bearing thereby reducing both the duration of treatment and the time of hospital stay.

As for the intra-articular fractures with none or moderate displacement in the posterior joint facet the same treatment is preferable to presently

available operative methods of treatment. The early mobilization is best carried out during the first few days in hospital.

In the fracture with a more severe displacement an open reduction may give a better result, but in these cases early physiotherapy also can give sufficiently good results to warrant its use instead of the operative treatment.

In conclusion the author believes that open reduction in combination with early physiotherapy is probably the treatment of choice in those cases of os calcis fractures with considerable displacement in the posterior articular facet.

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CASE REPORTS

Key to the Tabulation of Case Reports*

("Comparative Series")

1. Case number
2. Age in years
3. Sex
4. Fracture-group (according to Widén)
5. Fracture-type (according to Palmer)
6. Degree of dislocation slight = (+) or considerable = (++)
7. Tuber-joint angle of uninjured foot (in degrees)
8. Tuber-joint angle of injured foot initially (in degrees)
9. Tuber-joint angle of injured foot at follow up (in degrees)
10. Defference of tuber-joint angle between uninjured foot and injured foot initially (in degrees)
11. Difference of tuber-joint angle between uninjured foot and injured foot at follow up (in degrees)
12. Normal gait and ability to walk on toes
13. Normal gait on flat surface but inability to walk on toes
14. Limping on flat surface and inability to walk on toes
15. Mobility of the subtalar joint, difference between uninjured and injured foot (in degrees)
16. Mobility of the talocrural joint, difference between uninjured and injured foot (in degrees)
17. Atrophy of the calf muscles (in cm.)
18. Valgus deformity
19. Broadening of the heel (in cm.)
20. Disability benefit in per cent (insurance cases)
21. Observations time (in months)
22. Hospitalization time (in days)
23. Total loss of working capacity (in days)
24. Functional results.

* This table comprises only the unilateral, intra-articular fractures dealt with in the "comparative series". Cases 1—17 consist of extra-articular fractures discussed in chapter 7, p. 47. Cases 116—121 consist of bilateral intra-articular fractures discussed in chapter 7 p. 61.

Table 54. Tabulation of Case Reports.

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
18	60	♂	V		0	37	21	20	16	17	+			10	0	0	—	0		46	6	117	Exc.
19	29	♂	V		0	38	28	28	10	10	+			5	0	0	—	½		44	11	88	Exc.
20	53	♂	V		0	35	21	21	14	14	+			0	0	0	—	½	0	42	11	113	Good
21	31	♂	V		0	36	20	14	16	22	+			0	0	0	—	½		42	3	83	Exc.
22	14	♂	V		0	28	26	26	2	2	+			0	0	0	—	0		39	13	56	Exc.
24	12	♂	V		0	45	30		15		+			0	0	0	—	0		32	0	43	Exc.
25	44	♂	V		0	35	20	18	15	17	+			0	0	0	—	½	0	25	6	117	Exc.
26	38	♀	V		0	35	10		25		+			5	5	0	—	½		24	0	74	Exc.
27	14	♂	V		0	34	28	27	6	7	+			0	0	0	—	0		21	5	51	Exc.
28	40	♂	V		0	28	15	14	13	14	+			5	5	½	—	½	0	19	19	114	Exc.
30	40	♂	V		0	37	32	29	5	8	+			0	0	0	—	0	0	17	2	80	Exc.
31	77	♂	V		0	37	8	0	29	37		+		15	10	½	+	1		18	9	102	Exc.
32	41	♂	V		0	35	26	26	9	9	+			5	0	0	—	½		15	7	123	Exc.
33	36	♂	VI	1	++	41	18	14	23	27	+			5	5	0	—	½−1	0	51	25	140	Good
34	49	♂	VI	1	+	35	0	−3	35	38	+			10	5	½	—	1		47	20	193	Exc.
35	57	♂	VI	2	++	20	−7	−9	27	29		+		25	10	½	+	1.5		40	28	115	Poor
36	36	♂	VI	1	+	24	16	13	8	11	+			10	0	½	—	½	0	41	31	144	Good
38	46	♂	VI	1	+	37	28	27	9	10	+			5	0	0	—	½	0	42	4	90	Exc.
39	39	♂	VI	1	+	42	20	18	22	24	+			0	0	0	—	½−1	0	40	5	84	Exc.
40	48	♀	VI	2	+	30	13	11	17	19	+			10	0	0	—	1−1.5		39	0	136	Fair
41	56	♂	VI	2	+	28	20	20	8	8	+			10	5	—	+	1.5	0	40	15	138	Good
42	45	♂	VI	1	++	32	20	12	12	20	+			10	5	½	+	1.5	10	37	9	350	Fair
43	40	♂	VI	1	++	27	13	9	14	18			+	20	10	1.5	+	1.5	15	36	12	129	Poor
44	75	♀	VI	1	+	35	−10	−12	45	47	+			10	5	1	—	1.5		41	13	115	Good
45	26	♂	VI	2	+	31	20	16	11	15	+			20	5	1	—	½−1	10	34	18	138	Fair
46	26	♂	VI	2	+	41	21	20	20	21	+			0	0	0	—	½	0	36	10	100	Exc.
47	22	♂	VI	1	++	39	25	22	14	17		+		10	10	1.5	—	1.5		36	28	118	Fair
48	64	♀	VI	1	+	31	22	20	9	11	+			0	0	0	—	½		29	20	74	Good
49	71	♀	VI	1	+	33	11	5	22	28	+			10	10	0	—	1		32	28	148	Good
50	41	♂	VI	1	+	23	18	16	5	7	+			0	0	0	—	½		32	4	90	Exc.
51	56	♂	VI	1	++	32	−4	−7	36	39			+	15	15	2	+	1.5	10	28	14	167	Poor
52	54	♂	VI	2	+	28	16	14	12	14	+			0	0	0	—	½−1		29	39	93	Exc.
53	50	♂	VI	1	+	35	15	11	20	24		+		20	5	½	+	1	10	29	12	115	Poor
54	27	♀	VI	2	+	26	10	9	16	17	+			5	0	0	—	½		26	7	95	Good
55	66	♀	VI	1							+			5	0	0	—	½		28	17	117	Exc.
56	72	♀	VI	1							+			10	5	0	—	½		28	19	53	Good
57	46	♂	VI	1	++	31	23	21	8	10	+			5	5	0	—	1	0	28	11	104	Fair
58	35	♂	VI	1	+	36	4	3	32	33		+		20	15	½	+	1.5	15	27	9	71	Poor
59	38	♀	VI	2	++	33	24	22	9	11		+		25	10	½	—	½−1		27	9	59	Poor
60	67	♀	VI	1	+	38	20	16	18	22	+			5	10	0	—	1		28	10	93	Exc.
61	56	♀	VI	1	+	39	29	22	10	17	+			0	0	0	—	½		24	27	151	Exc.
62	62	♂	VI	2	++	26	7	6	19	20		+		20	10	1	+	1.5		27	10	164	Fair
63	60	♂	VI	1	++	35	10	5	25	30			+	20	10	1	+	1.5	0	25	42	94	Fair
64	56	♂	VI	2	++	35	10	8	25	27		+		20	10	0	—	1	10	21	7	198	Fair
65	52	♂	VI	2	+	32	3	3	29	29	+			15	5	0	—	1		22	5	73	Good
66	46	♂	VI	2	++	20	−6	−10	26	30	+			15	10	2	+	1.5	0	24	13	87	Good
67	35	♂	VI	1	+	27	14	12	13	15	+			15	0	1	—	1	0	20	25	131	Good
68	48	♂	VI	1	+	37	16	11	21	26	+			5	0	0	—	½	0	25	28	121	Exc.
69	43	♂	VI	1	+	31	11	8	20	23	+			5	0	½	—	½	0	20	9	150	Good
70	66	♂	VI	1	+	26	15	14	11	12	+			0	0	0	—	½	0	18	8	157	Good
71	39	♂	VI	2	++	34	0	0	34	34		+		25	0	1.5	—	½	10	30	6	128	Fair
72	49	♂	VI	1	+	39	22	18	17	21	+			5	0	0	—	½	0	18	6	147	Good
73	45	♂	VI	1	+	30	15	13	15	17	+			15	0	—	—	1	0	18	7	96	Good
74	57	♂	VI	1	++	31	0		31		+			10	5	—	—	1.5	0	17	53	119	Fair
75	56	♂	VI	1	++	33	−4	−9	37	42			+	25	20		+	2		18	25	181	Poor
76	51	♂	VI	1	+	40	19	17	21	23	+			10	5	0	—	½−1	0	15	17	112	Good
77	47	♂	VI	1	++	34	3	1	31	33	+			15	10	0	+	1		16	10	66	Good
78	52	♂	VI	1	++	31	−1	−3	32	34	+			20	5	1.5	—	1	0	16	46	175	Exc.
79	54	♂	VI	2	+	28	12	11	16	17	+			10	0	1	—	1		14	0	64	Good
80	55	♀	VI	1	++	22	6	2	16	20	+			10	10	0	—	1		15	41	229	Exc.
81	58	♀	VI	1	+	34	20	18	14	16	+			10	0	0	—	1		14	15	123	Exc.
83	38	♂	VI	1	++	30	14	11	16	19	+			10	0	0	—	½−1	0	13	80	321	Fair
84	42	♂	VI	2	+	32	4	0	28	32	+			15	5	1.5	—	½	10	18	10	97	Fair
86	42	♀	VI	1	++	34	20	12	14	22	+			10	10	0	—	1		12	12	98	Exc.
88	51	♂	VI	1	++	37	20	18	17	19		+		10	5	1.5	+	1.5	15	49	14	238	Poor
89	73	♀	VII	1	+	31	20	16	11	15	+			5	10	1	—	½		53	7	86	Good
90	57	♂	VII	1	+	38	20	18	18	20	+			5	0	1	—	1	0	48	50	150	Exc.
91	26	♂	VII	1	+	30	18	8	12	22	+			0	0	0	—	½−1	0	49	8	135	Exc.
92	51	♂	VII	2	+	28	−7	−11	35	39	+			15	10	0	—	1-1.5	0	42	20	71	Exc.
93	40	♂	VII	1	++	29	18	16	11	13			+	25	5	½	+	½		42	10	264	Poor
94	59	♂	VII	1	+	32	17	12	15	20		+		10	10	2	—	½	15	15	17	109	Fair
95	32	♂	VII	1	++	39	18	18	21	21	+			5	0	0	—	1.5		37	15	182	Fair
96	40	♂	VII	1	++	42	20	20	22	22	+			5	0	1.5	—	½−1	0	37	15	140	Good
97	41	♂	VII	1	++	21	−3	−18	24	39		+		15	10	1.5	+	1.5		34	4	269	Poor
98	27	♂	VII	2	++	38	−6	−8	44	46	+			20	5	0	—	1	0	36	15	104	Fair
100	35	♂	VII	2	++	32	−5	−13	37	45			+	30	20	1.5	+	1.5	15	29	47	346	Poor
101	47	♂	VII	1	++	33	7	0	26	33		+		20	10	1.5	+	1.5	15	26	31	217	Poor
102	57	♂	VII	2	++	38	10	8	28	30	+			10	0	2	—	1.5	0	27	13	185	Good
103	36	♂	VII	2	+	35	10	10	25	25	+			5	0	0	—	½−1		23	19	87	Exc.
105	50	♂	VII	1	+	22	2	−3	20	25	+			15	0	½	—	½		22	37	81	Good
106	59	♂	VII	1	+	27	3	0	24	27	+			10	10	½	—	1	0	20	23	162	Good
107	54	♀	VII	1	++	45	9	5	36	40	+			10	0	½	—	1		17	6	125	Exc.
108	51	♂	VII	1	++	25	−3	−7	28	32			+	10	15	—	+	1.5	0	18	35	390	Fair
109	42	♂	VII	2	+	36	28	26	8	10	+			5	0	0	—	½		18	6	68	Exc.
110	59	♂	VII	2	++	25	−12	−24	37	49			+	20	15	2	+	2		16	95	413	Poor
111	55	♂	VII	1	++	34	4	2	30	32		+		10	10	2	—	1.5		14	31	182	Fair
112	63	♂	VII	1	++	37	−11	−25	48	62			+	20	15	½	+	2		14	5	325	Poor
113	69	♀	VII	2	++	25	6	6	19	19	+			15	5	½	—	1		12	14	67	Fair
114	52	♂	VII	1	+	32	16	15	16	17	+			5	0	0	—	½−1	0	14	5	86	Good
115	59	♂	VII	2	+	40	26	26	14	14	+			5	5	0	—	½−1	0	12	32	182	Good
Additional insurance type cases (case no. 123 and 124 not followed-up)																							
87	41	♂	VI	2		25	9												0	14	54	237	Good
123	66	♂	VI																20	—	0	273	—
124	55	♂	VI																0	—	10	91	—