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From the Departments of Surgery and Orthopaedic Surgery,
University Hospital, Uppsala

TIBIAL FRACTURES TREATED BY AO COMPRESSION OSTEOSYNTHESIS

Experiences from a five year material

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INTRODUCTION

The treatment of tibial fractures has varied during the last decades. In Sweden active surgical therapy (Lauritzen 1949, Johansson 1953) has alternated with periods with a more conservative approach. After Bergentz & Thureborn (1957) had demonstrated an increased risk of healing disturbances and complications with an increased frequency of operative treatment in tibial fractures, there was a period when in this country more conservative therapeutic principles were followed for these fractures. These disadvantages of surgical treatment, especially with internal fixation with metallic material, had also been pointed out previously by Böhler (1953) and Watson-Jones (1955). Hedenberg & Pompeius (1959), however, found a low complicazion frequency and a reduction by about 50% of the length of time spent in hospital with osteosynthesis of oblique fractures. Solheim (1960) reported good results from stable internal fixation followed by immediate mobilization. This form of treatment was developed on account of the poor functional results observed after conservative treatment and after open operation followed by external fixation with plaster. In a follow-up study of a series of tibial fractures, Hjelmstedt (1961) found an unsatisfactory functional result in 25% and a poor final result in 6% with these forms of therapy. He therefore advocated a wider use of stable internal fixation, which allows immediate postoperative mobilization.

Several authors have reported poor results and a high frequency of complications in comminuted transverse fractures treated openly by internal fixation. Bauer, Edwards & Widmark (1962) considered it probable, however, that the greater frequency of complications in these fractures was not due to the open treatment in itself but was rather a consequence of the greater severity of the trauma, with damage to soft tissues. They recommended, therefore, that aetiological factors be taken into consideration when comparing different fracture series.

The relatively poor final functional results of conservative fracture therapy and the high frequency of complications following operative treatment led to the formation of the now well-known AO group in Switzerland in 1957 (Müller 1961) for the purpose of mastering these problems. On the foundations already laid by Lambotte, Danis, Charnley, Krompecher, Eggers, Küntscher and others, the AO group developed methods for stable internal osteosynthesis allowing immediate postoperative mobilization (Müller, Allgöwer & Willenegger 1965). Their treatment consists, in principle, in exact apposition of the fragments combined with compression by screws alone or screws and plating techniques, or with intramedullary nailing afterreaming of the medullary cavity.
In England Hicks (1959, 1969) also supports the same principles and stresses the value of immediate post-operative functional excercises.

After reports on the results of the AO group, internal fixation with compression techniques has been used to a large extent in the treatment of tibial fractures at the University Hospital in Uppsala since 1965. The aim has been to test this method and its value as a routine procedure in a surgical clinic. In this paper we will describe our experiences from extensive clinical trial during a five-year period and at the same time present the final results of a follow-up study. A further aim of our study has been to consider this type of fracture from certain socio-medical aspects.

Chapter I

THE MATERIAL AND ITS CLASSIFICATION

During the years 1965-1969 compression osteosynthesis by the AO method was used for treatment of 129 patients with tibial fractures at the Departments of Surgery and Orthopaedic Surgery of the University Hospital in Uppsala. Six of the patients had bilateral fractures; the number of fractures treated was thus 135. No pseudarthroses were included in the material.

In Table 1 the relative frequency of compression osteosynthesis is given. Only fractures leading to admission to hospital are included. In 1965, when trial of the method first began, the frequency was only 41%. One year later it had already risen to 87%. During the following years a reduced frequency was noted.

TABLE I.

Tibial fractures 1965-1969 and the frequency of compression osteosynthesis by the A0 method.

	Total no. of fractures	No. with A0 compression osteosynthesis	Percent with A0 compression osteosynthesis
1965	39	16	41
1966	45	39	87
1967	40	28	70
1968	42	28	67
1969	39	24	62
Total	205	135	66

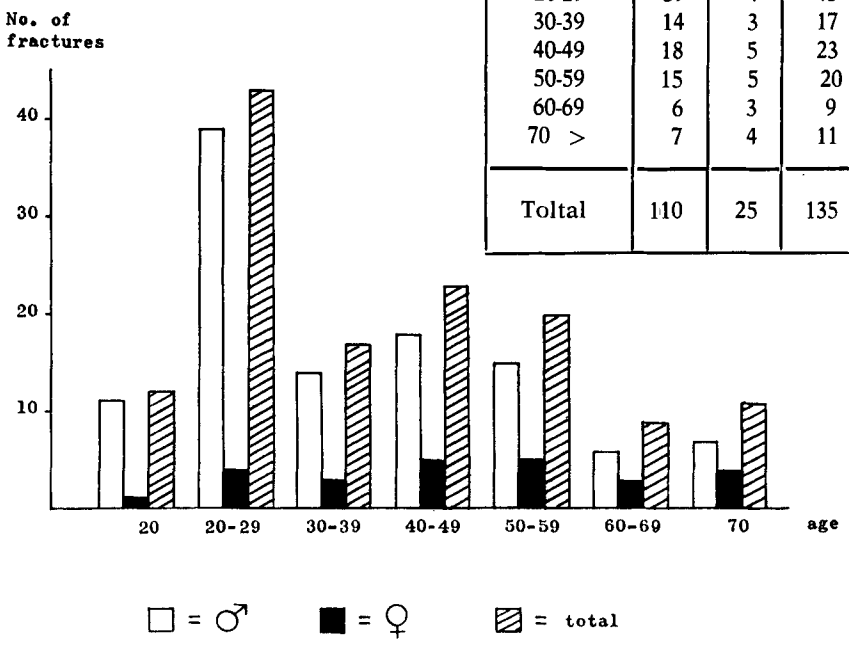
The reason for this was partly that the range of indications for this method of treatment had been narrowed, and partly that other methods such as primary intramedullary nailing and transfixations as described by Vidal-Adrey (1970), with the Hoffmann apparatus, had come into increasing use.

The age and sex distributions of the patients are given in Table 2. As in other series of similar type, the male patients predominated, comprising 81%. Whereas the women were fairly evenly distributed between the age groups, among the men the age group 20-29 years was clearly predominant, this age group being affected most by accidents during sports and traffic accidents.

We have chosen to classify the fractures both anatomically, i.e. according to their anatomical level, and clinically as suggested by Edwards (1965). The distribution of the fractures by

TABLE 2. *Age and sex distributions.*

Age	♂	♀	Σ
< 20	11	1	12
20-29	39	4	43
30-39	14	3	17
40-49	18	5	23
50-59	15	5	20
60-69	6	3	9
70 >	7	4	11
Toltal	110	25	135



anatomical level is given in Table 3. The different anatomical levels are illustrated in Fig. 1. The purely diaphyseal fractures

TABLE III.

Distribution of the fractures by anatomical level.

Type of fracture	No.	%
1. Proximal metaphysis	6	4.5
2. Diaphysis	99	73.0
3. Diaphysis + distal metaphysis	20	15.0
4. Diaphysis + distal articular surface	10	7.5
Total	135	100

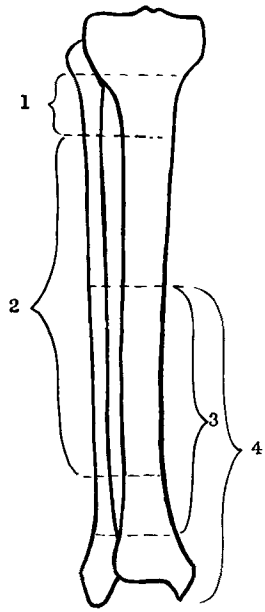


FIGURE 1.

predominate, representing 73% of all the tibial fractures. Table 4 shows the distribution into clinical groups. 95% of the fractures fall within the groups 1, 4 and 5, i. e. dislocated longitudinal closed fractures and dislocated transverse closed and open fractures. One-third of the fractures were open; of the longitudinal fractures 12% were open, and of the transverse 45%.

TABLE IV.

Distribution of the fractures by clinical group (according to Edwards).

	No.	%
1. Dislocated longitudinal closed	44	33
2. Dislocated longitudinal open	6	4
3. Non-dislocated longitudinal open	—	—
4. Dislocated transverse closed	46	34
5. Dislocated transverse open	38	28
6. Non-dislocated transverse open	—	—
7. Non-dislocated transverse closed	1	1
8. Non-dislocated longitudinal closed	—	—
Total	135	100

Comminuted fractures were found mainly in group 5, i.e. among the dislocated transverse open types, two-thirds of which were comminuted (Table 5). Classified as comminuted fractures were those with an intermediate fragment comprising at least half the circumference.

An evaluation of the primary dislocation was not possible, since the most severe dislocations were generally reduced immediately on admission to hospital, before the first roentgenological examination.

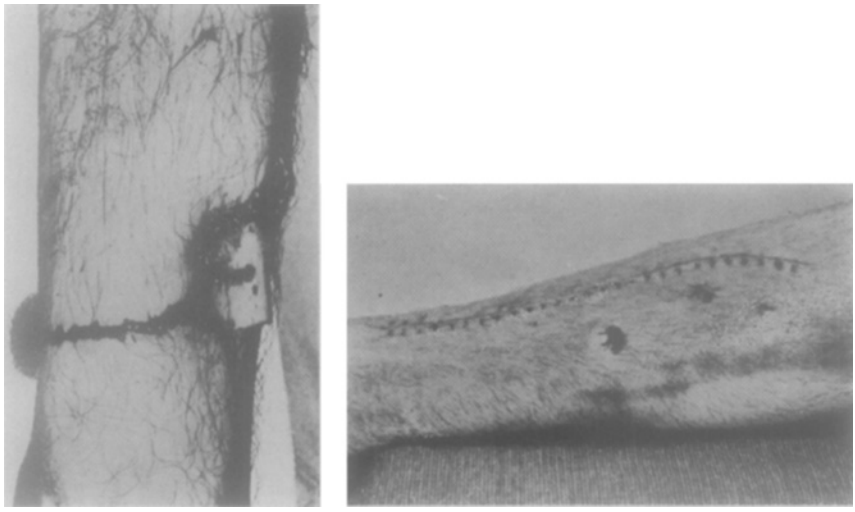
Hereinafter the fractures will be reported essentially in four groups, viz. longitudinal closed and open and transverse closed and open.

TABLE V.

Number and percentage of comminuted fractures in different clinical fracture groups.

Type of fracture	No. of fractures	No. of comminuted fractures	% comminuted fractures in each group	% comminuted fractures in whole material
Dislocated longitudinal closed	44	3	7	2
Dislocated longitudinal open	6	—	0	0
Dislocated transverse closed	46	12	26	9
Dislocated transverse open	38	25	66	19
Non-dislocated transverse closed	1	—	0	0
Total	135	40		30

The fracture types are clearly correlated to cause of injury and type of violence. As seen in Table 6, traffic accidents and football injuries were the main causes of direct violence to the tibia. In the whole material traffic accidents predominated as the cause of the fracture (over 40%). Of the traffic accident victims the majority were pedestrians or moped or motor-cycle riders.



a b

FIGURE 2. Open simple transverse fracture in a 22-year old football player. Treated with a compression plate. Ten days after the accident (b) there were good conditions of healing both as regards the operation incision and the site of the perforation, which was left open for secondary granulation. Postoperative course satisfactory.

Injuries occuring at work comprise only 17% in the table, but were in reality a few per cent more, as a number of the fractures from traffic accidents were sustained at work. Football accidents completely dominated the group of fractures sustained during sports. The fact that only 3 of the fractures were caused during skiing is explained by the geographical location of the hospital.

TABLE VI.

Causes of fracture and type of violence.

		Indirect violence	Direct violence	Total	%
Traffic accidents	Pedestrians	—	23	23	
	Cyclists	1	6	7	
	Moped and motorcycle riders	2	15	17	
	Automobile drivers	—	9	9	
	Automobile passengers	1	1	2	
	Total traffic accidents	4	54	58	43
Accidents at work	Forestry work	7	3	10	
	Industrial and building work	3	4	7	
	Other work	3	3	6	
	Total accidents at work	13	10	23	17
Accidents at sports	Football	—	15	15	
	Skiing	3	—	3	
	Other sports	3	—	3	
	Total accidents at sports	6	15	21	16
Various	Fall at same plane, at home	14	—	14	
	Fall at same plane, on the street	8	—	8	
	Fall from height (stairs, ladder etc.)	5	—	5	
	Other causes of injury	5	1	6	
	Total various accidents	32	1	33	24
Total		(41%)	(59%)	135	100

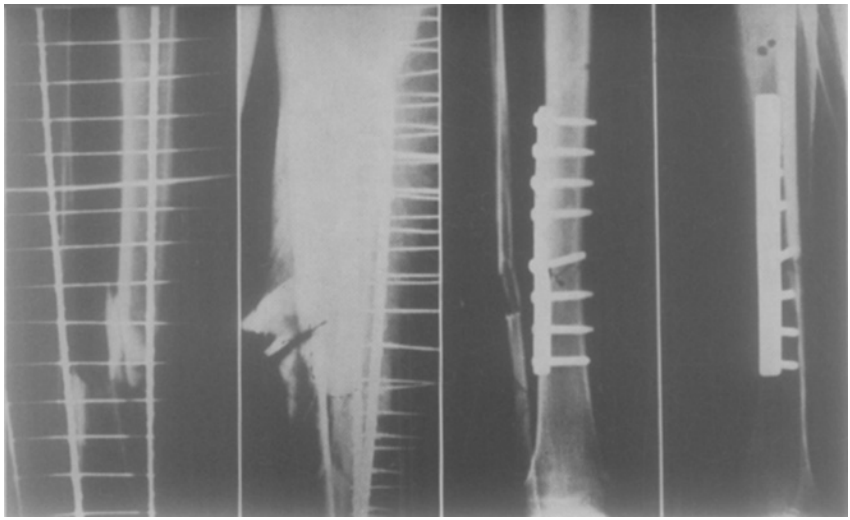


FIGURE 3. Comminuted open transverse fracture of grade III (according to Matter) (a). An intermediate fragment about 3 cm long, lying transversally (b) is embraced in a lateral plate osteosynthesis (c + d). Adequate stability. The length of the healing time was satisfactory and the patient was able to bear full weight on the leg 6 months after the accident.

FIGURE 4. The soft tissues were severely lacerated on the medial side of the tibia. An area of skin measuring about 5 x 5 cm was missing. Tension-free suturing of skin opened at the accident and of the operation incision resulted in the postoperative condition shown in the figure to the left. The greater part of the skin defect was later repaired by a split skin graft, and the remaining part over cortical bone underwent secondary granulation after chiselling of the superficial cortical bone.

TABLE VII.

Relation between type of violence and extent of injury.

			Longitudinal fractures	Transverse fractures
Indirect violence	Closed fractures	Total	42	—
		With skin contusion	1	—
		With other severe injury	—	—
	Open fractures	Total	6	1
		With skin perforation	6	1
		With skin laceration	—	—
		With muscle injury from the trauma	—	—
		With other severe injury	—	—
Direct violence	Closed fractures	Total	2	47
		With skin contusion	—	21
		With other severe injury	—	6
	Open fractures	Total	—	37
		With skin perforation	—	—
		With skin laceration	—	37
		With muscle injury from the trauma	—	16
		With other severe injury	—	16

In Table 7 the extent of the injury is related to the type of violence sustained. Only in one case did indirect violence result in a transverse fracture. Direct violence caused transverse fractures in all cases except two. That direct violence usually also involves high-energy trauma is evident by the fact that severe soft

TABLE VIII.

Multiple injuries.

22 transverse fractures with other severe injuries.

Pedestrian	10	20 traffic accidents
Cyclist	1	
Moped + motorcycle riders	1	
Automobile drivers	8	
Others	2	

a b c

FIGURE 5. Comminuted fracture with a lateral wedge fragment fixed with a compression plate and a separate compression screw (b). The ideal position of the osteosynthesis material resulted in early and reliable healing of the fracture.

tissue injuries and other severe injuries only occurred in these cases. Further, high-energy trauma seems, on the whole, to be synonymous with more severe traffic injuries. Of the 22 (17% of the whole material) transverse fractures with one or more other severe injuries, 20 were caused in traffic accidents (Table 8).

In the open fractures, the damage to skin and soft tissues has been classified according to Matter (1970) as follows:

Grade 1: Skin perforation from the internal route (Fig. 2).

Grade 2: Skin perforation.

Grade 3: Skin and muscle laceration trauma by the external route (Figs. 3 and 4). Of the open fractures in this series, 7 were of grade 1, 21 of grade 2 and 16 of grade 3.

Chapter II

THE TREATMENT AND THE HEALING COURSE

Principles of treatment.

The type of fracture chosen for surgical treatment by the AO method was a dislocated longitudinal or transverse fracture - whether the fracture was closed or open.

The aim was anatomical and functional restoration by means of stable internal fixation, initially with a metal plate and/or screws. Fig. 5 illustrates an ideal healing course.

The principles recommended by the AO group (Müller et al. 1965) were followed as far as possible. Every attempt was made to undertake immediate operative treatment, i.e. within 8-10 hours after the accident. Of the 135 fractures, 115 were operated on immediately - in general within 8 hours after the accident (see Table 3). Only 20 (15%) underwent operation at a later stage. Osteosynthesis was generally postponed (for more than 5 days) in cases with extensive injuries to the skin and soft tissues, or when immediate osteosynthesis was contraindicated by other severe physical injuries.

The need for early operation meant that to a large extent different surgeons on duty carried out the treatment, which was often performed in the evening or during the night. A total of about 15 surgeons thus operated on this series of patients.

Operative technique.

Wherever possible an anterior incision just lateral to the anterior tibial margin was used. Reduction was performed after cleaning of the fragment surfaces with the aid of bone-holding forceps or temporary application of cerclage. In most of the fractures a compression plate combined with compression screws

was used, together with a stabilizing neutralization plate. Only 3 closed longitudinal fractures were treated with screws alone. The compression or neutralization plate as a rule, applied to the medial surface of the tibia. A requirement for this was that the skin should be undamaged or at least should show only a clearly delimited contusion. In occasional cases the plate was applied to the lateral tibial surface. Great weight was placed on primary drainage of the wound by the high vacuum principle (Redon-Jost). An atraumatic skin suture technique as described by Allgöwer was used. Tension on the skin was always avoided and in a few cases where there was a risk of skin tension a relieving incision was made dorsally, with division of the underlying fascia. In injuries involving considerable damage to soft tissues the wound was very carefully cleaned and any devitalised tissue removed. In several such cases open treatment of the wound surfaces was carried out despite the use of internal fixation. Care was taken, however, to see that the osteosynthesis material was always covered with soft tissue.

In 7 fractures the osteosynthesis was combined with primary bone transplantation; these were 2 closed and 5 open comminuted transverse fractures.

In 2 cases the plate osteosynthesis was not planned as the definitive treatment but only as temporary fixation for about two months prior to intramedullary nailing.

Postoperatively the treated limb was placed in an elevated position. Only limited movements were allowed in the first three days, but thereafter a gradually increasing pattern of exercises, mainly active, were encouraged under the supervision of a physiotherapist. The vacuum drainage was removed after a maximum of 48 hours or when the drainage had ceased. Great importance was also placed on the control of swelling, both by pharmacological agents such as Tanderil® and Hygroton® (or Lasix®)* and by moderate compression of the soft tissues with an elastic stocking of the Sigvaris type. In certain suitable cases a patellar-tendon bearing (PTB) walking splint was used, which rendered an elastic stocking necessary. Full weight-bearing was usually allowed after 10-14 weeks, but before this was permitted healing

* Tanderil® Geigy (oxyphenbutazone), Hygroton® Geigy (chlorthalidone) and Lasix® Hoechst (furosemide).

signs on the roetgenogram in the form of filling of the fracture gaps were required.

In 3 patients plaster splintage was applied immediately after the operation - in 2 patients because of epilepsy and psychosis and in 1 patient in whom the osteosynthesis was considered primarily to be not fully stable.

The positions of the fractures immediately after osteosynthesis are presented in Table 9, graded as follows:

1) An ideal position, the fracture line is just visible on the roentgenogram.
2) On the rontgenogram the fragments show a practically correct position, with good contact between them. Part of the fracture line is visible, however, up to a width of 0.5 mm.
3) Diastasis with a gap more than 0.5 mm wide between the fragments around the greater part of the circumference of the bone (see Fig. 11).

TABLE IX.

Survey of times of operation and position of fracture postoperatively.

	Total	Position after osteosynthesis		
		1	2	3
Osteosynthesis immediately	115	85*	27	3
Osteosynthesis postponed (> 5 days)	18	17	1	—
Osteosynthesis after delayed healing	2	1	1	—
Total	135	103	29	3

* = 2 patients with non-definitive osteosynthesis, i.e. later intramedullary nailing planned.

For definition of positions 1, 2 and 3, see text above.

Postoperative course

In most cases the primary postoperative course was uncomplicated. Two patients developed fat embolism, however. One was a patient with bilateral open fractures, which had been operated on immediately. This patient died after 17 days, and

autopsy revealed bronchopneumonia and fat embolism (see case histories, case 3). The second patient with fat embolism had also sustained bilateral fractures. He overcame this complication, however, and the fractures healed. This patient died 3 years later of carcinoma of the stomach.

Venous circulatory disturbances gave no problems. In no case were there any clinical signs of deep thrombosis. Obviously subclinical thromboses cannot be excluded, since phlebography was not performed. This finding may be regarded as remarkably favourable, however, in consideration of the fact that Hjelmstedt (1968) found a relatively high frequency of serious thromboembolic complications in a series of tibial fractures.

78 fractures (58% of the whole material) healed with no complications (Table 10). A further 31 fractures (23%) healed with only minor disturbances.

It was found that the anatomical level of the fracture seemed to be of importance for the healing course (Table 11). All proximal metaphyseal fractures healed with no disturbances. These were only 6 in number, however. More severe healing disturbances occurred in diaphyseal fractures (19%) and in fractures involving both the diaphysis and distal metaphysis (25%). Healing at these levels without any complications occurred in 59 and 50%, respectively. Only 10% of the diaphyseal fractures combined with a fracture of the distal articular surface were affected by severe healing disturbances, but on the other hand only 40% of this category healed with no complications at all.

All factors disturbing the course of healing are related to the clinical fracture groups in Table 12. The relatively large number of healing disturbances in this table is explainable by the fact that more than one disturbance occurred in several of the fractures.

Certain complications which did not prolong the healing time appreciably have been designated as mild disturbances. Assigned to this category are thus secondary skin healing (Fig. 6), metallosis (low-virulence infection) (Fig. 7), superficial virulent infection, mild marginal necroses, and instability (irritation callus) (Figs. 8-11). Classified in the group of severe disturbances are deep virulent infection, bending and fracture of the plate, refractures, skin necrosis and delayed healing. (For examples, see case histories).

TABLE X.

Summary of the healing courses.

Type of fracture	No disturbances	Mild disturbances	Severe disturbances	Total
Longitudinal closed fractures	31 (70%)	11 (25%)	2 (5%)	44
Longitudinal open fractures	4 (67%)	1 (16,5%)	1 (16,5%)	6
Transverse closed fractures	24 (51%)	13 (28%)	10 (21%)	47
Transverse open fractures	19 (50%)	6 (16%)	13 (34%)	38
Total	78 (58%)	31 (23%)	26 (19%)	135

TABLE XI.

Fracture level and healing course.

Anatomical fracture type	No disturbances	Mild disturbances	Severe disturbances	Total
Proximal metaphysis	6 (100%)	—	—	6
Diaphysis	58 (59%)	21 (21%)	20 (20%)	99
Diaphysis + distal metaphysis	10 (50%)	5 (25%)	5 (25%)	20
Diaphysis + distal articular surface	4 (40%)	5 (50%)	1 (10%)	10
Total	78 (58%)	31 (23%)	26 (19%)	135

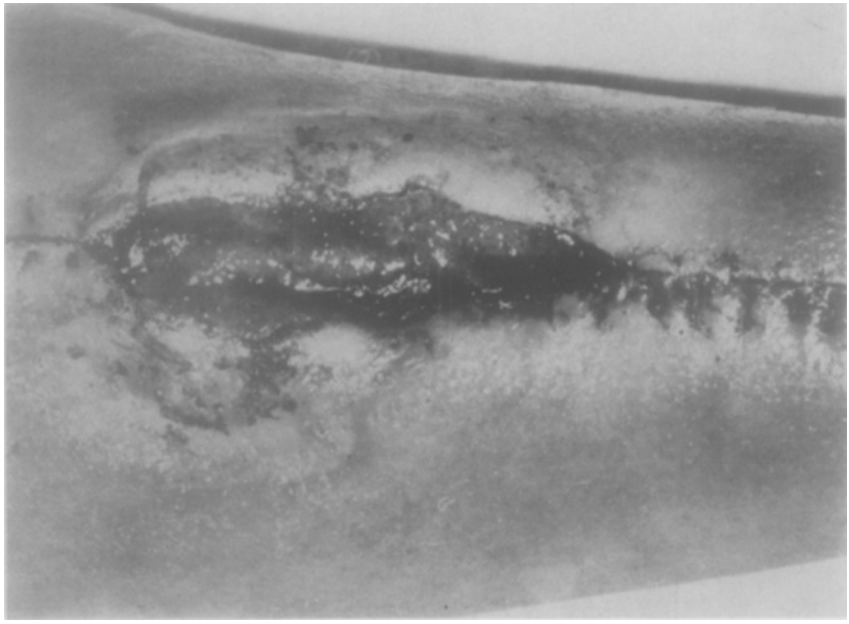


FIGURE 6. A 60-year old man with a comminuted closed transverse fracture. An earlier secondarily healed soft tissue injury (3rd degree burn) on the anterior aspect of the lower leg prevented primary closure of the wound. The wound was left open for secondary granulation. Healing of the fracture and skin was satisfactory.

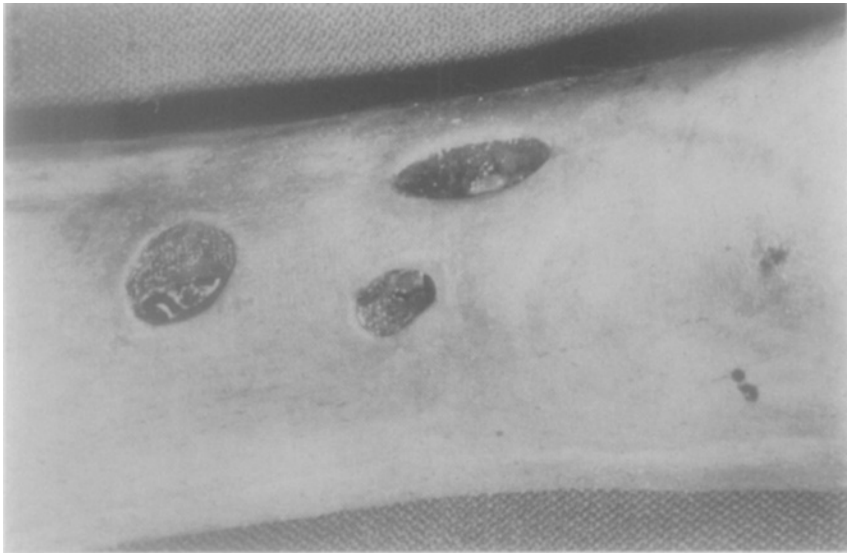
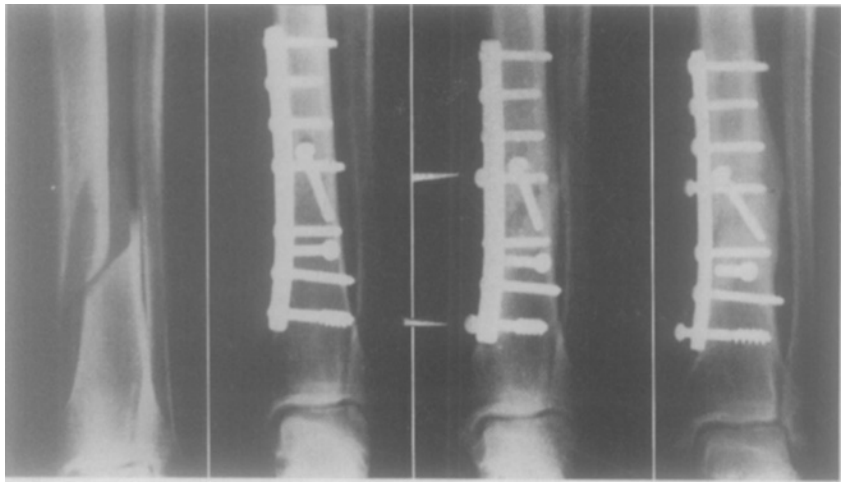


FIGURE 7. Metallosis and skin necrosis in a forestry worker after 1 month's work in the forest. It is possible that pressure from his boots may have been a contributory cause. After removal of the osteosynthesis material 8 months after operation for a comminuted fracture there was rapid healing. The patient was supplied with a walking plaster for 6 weeks, after which he was able to return to his forestry work.

TABLE XII.

All types of healing disturbance in relation to clinical classification.

	Longitudinal closed fractures	Longitudinal open fractures	Transverse closed fractures	Transverse open fractures	Total
	44	6	47	38	135
Metallosis or low-virulence infection	4	—	7	3	14
Virulent infection, superficial	—	1	—	1	2
Virulent infection, deep osteomyelitis	—	—	1	6	7
Necrosis of wound margin	5	1	3	3	12
Other skin necrosis	1	—	2	2	5
Necrosis over osteosynthesis material	1	—	3	2	6
Irritation callus	2	—	7	2	11
Only loosened screw	—	—	1	3	4
Loosened screw + refracture	—	—	1	—	1
Plate fractured or bent	1	1	3	6	11
Refracture after removal of plate	1	—	2	1	4
Delayed healing	—	—	1	4	5
Delayed healing after removal of plate	—	—	—	1	1
Amputation	—	—	—	1	1
Clinical signs of thrombosis	—	—	—	—	—

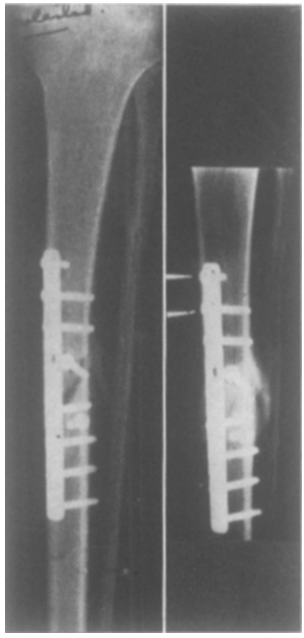


a b c d

FIGURE 8. A relatively short oblique fracture fixed with a neutralization plate and two compression screws (b). On examination after 2 months (c) it was noted that two screws had loosened, and that irritation callus was present on the lateral side of the tibia. It was recommended that no weight should be borne on the leg, and the fracture subsequently healed with bridging callus laterally and filling of the fracture gap.

a b c

FIGURE 9. A relatively short oblique fracture fixed with a compression plate only. In figure (c) a deficiency of cortical contact on the lateral side of the tibia is seen, indicating a risk of instability. That the fracture is in fact unstable is revealed (c) by the relatively large amount of callus on the lateral side of the tibia.



a b

FIGURE 10. A comminuted transverse fracture with poor contact of the fragments after plate osteosynthesis. The upper compression screw is seen to coincide with the fracture gap (a). On examination after 2 months instability was revealed by the relatively large amount of callus development laterally. Furthermore, the upper two screws had loosened (b).

An interesting development in the healing course is illustrated in Fig. 12. Here there is ideal fracture healing in the tibia, but a distinct pseudarthrosis in the fibula. (Subjectively the patient only experienced some occasional tenderness).

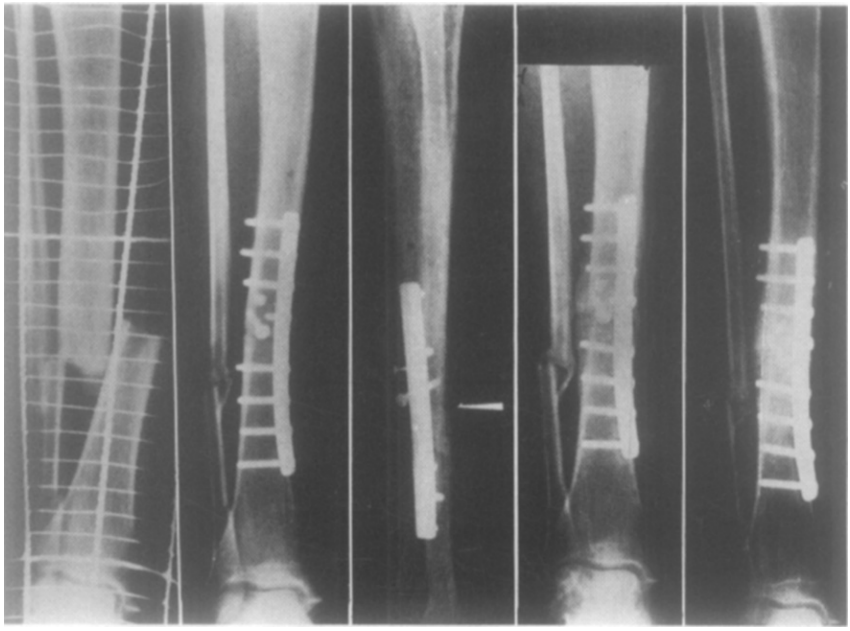
The frequencies of mild and severe healing disturbances in different types of fracture are given in detail in Table 13 and summarized in Table 10.

Serious healing disturbances occurred to the greatest extent in transverse open fractures (34%). Open transverse comminuted fractures with muscle damage showed a particularly difficult healing course. Practically none of these fractures healed without any complications at all, and in two-thirds of them the complications were severe. On the other hand there were fewer and

TABLE XIII.

The frequencies of different degrees of healing disturbance in different types af fracture.

Type of fracture	No disturbance		Mild disturbance		Severe disturbance		Total	
	No.	%	No.	%	No.	%	No.	%
Longitudinal closed, simple	28	68	11	27	2	5	41	100
Longitudinal closed, comminuted	3	100	—	—	—	—	3	100
Longitudinal open, simple	4	67	1	17	1	16	6	100
Longitudinal open, comminuted	—	—	—	—	—	—	—	—
Transverse closed, simple without skin contusion	14	64	3	13	5	23	22	100
Transverse closed, simple with skin contusion	6	46	6	46	1	8	13	100
Transverse closed, comminuted without skin contusion	—	—	2	50	2	50	4	100
Transverse closed, comminuted with skin contusion	4	50	2	25	2	25	8	100
Transverse open, simple without muscle damage	9	82	1	9	1	9	11	100
Transverse open, simple with muscle damage	2	100	—	—	—	—	2	100
Transverse open, comminuted without muscle damage	8	42	3	16	8	42	19	100
Transverse open, comminuted with muscle damage	—	—	2	33	4	67	6	100
Total	78	58	31	23	26	19	135	100



a b c d e

FIGURE 11. Lack of stability and increased callus. The plate (b) seems to have been applied somewhat tensely. This has resulted in lack of contact of the cortical bone laterally. Also on the lateral roentgenogram there is a 1 mm wide gap dorsally. There was a risk of instability in this fracture. The patient was supplied with a plaster for 2 months, during which time bridging callus developed, especially on the lateral side of the tibia (b). Mature bone reconstruction is seen on the roentgenogram taken 16 months after accident.

less severe disturbances to healing in the longitudinal fractures. This is natural, since such fractures are generally caused by relatively mild indirect violence.

To a large extent the healing disturbances necessitated secondary operations or of other measures. No fewer than 42 secondary measures were thus taken during the healing of 135 fractures. A fairly large number of these measures were relatively simple, however, such as the application of plaster or other splintage, with or without removal of the osteosynthesis material, or intramedullary nailing, which in all cases was preceded by reaming of the medullary cavity. Further, in some patients

reoperation was performed more than once. The indications for secondary measures in different fracture groups are given in Table 14. Since healing disturbances were most common in open transverse fractures, the frequency of secondary measures was also highest in this group.

a b

FIGURE 12. Primarily a transverse fracture, which was fixed with a compression plate. Early mobilization and training of the ankle joint function meant that the fibula was unable to heal but instead developed a hypertrophic pseudarthrosis. This was still unchanged 2 years after removal of the plate (b).

The indications for secondary operations are related to the types of measures undertaken in Table 15. The most common reasons for secondary treatment were infection, refracture and delayed healing.

Metallosis with or without low-virulence infection did not constitute any severe problem. On the other hand a few patients developed infections of high virulence which considerably delayed the healing course. The virulent infections are presented in Table 16. The superficial infections were mastered without difficulty with a relatively short period of antibiotic therapy

TABLE XIV.

The indication for secondary measures in different fracture groups.

Indication	Longitudinal fractures	Transverse closed fractures	Transverse open fractures	Total
Primarily planned reoperation		1	1	2
Necrosis	1	1	1	3
Postoperative skin defect			3	3
High-virulence infection	1	2	8	11
Instability	1	3		4
Pseudarthrosis, delayed healing		2	4	6
Refracture with intact osteosynthesis		1		1
Refracture, fractured plate	2	2	4	8
Refracture after removal of plate	1	2	1	4
Total	6	14	22	42

TABLE XV.

Types of secondary measures related to the indications for such measures.

Indication \ Type of operation or measure	Skin transplantation	Plaster or splint	Removal of osteosynthesis material + plaster or other splintage	Intramedullary nailing with or without bone graft	Drainage	Removal of sequestrum with or without bone graft	Charnley or Hoffmann transfixation with or without bone graft	Bone graft alone	Amputation	Total
Primarily planned reoperation				2						2
Necrosis	1		2							3
Postoperative skin defect	3									3
Virulent infection		1	2		3	3	1		1	11
Instability		3		1						4
Pseudarthrosis, delayed healing				4			1	1		6
Refracture, intact osteosynthesis		1								1
Refracture, fractured plate			1	7						8
Refracture after removal of plate		3		1						4
Total	4	8	5	15	3	3	2	1	1	42

TABLE XVI.

Degree of severity of the infection in relation to clinical classification.

Fracture type		Superficial infection	Deep infection	Osteomyelitis w. sequestrum	Total
Longitudinal fractures	(50)	1 (2%)	—	—	1 (2%)
Transverse fracture closed	(47)	—	—	1 (2%)	1 (2%)
Transverse fractures open simple	(13)	—	1 (8%)	—	1 (8%)
Transverse fractures open comminuted	(25)	1 (4%)	2 (8%)	3 (12%)	6 (24%)
Total	(135)	2 (2%)	3 (2%)	4 (3%)	9 (7%)

after culture and resistance determination. Of the 7 cases (6 open fractures) of deep infection, 4 developed into osteomyelitis with sequestral formation, these predominantly occurring in open comminuted fractures. One patient with a closed fracture. however, developed a postoperative skin necrosis which later gave rise to osteomyelitis (see case 8 in the case histories).

Among the three patients with deep infections without direct signs of osteomyelitis, the healing course was somewhat prolonged in one patient with an open transverse fracture combined with a femoral fracture (case 20). In the patient who died of fat embolism (case 3), it cannot be entirely excluded that infection might have been a contributory cause of death. Injuries to blood vessels and nerves in association with extensive muscle necrosis led to infection in one patient (case 15). The loss of soft tissue was so extensive that amputation had to be performed.

All cases of osteomyelitis healed with an acceptable final result (see cases 2, 4, 8 and 16 in the case histories).

Those healing disturbances which most often occurred and prolonged the patient's inability to return to work were caused by instability of the osteosynthesis. Regarded as signs of this instability were irritation callus and loosening or breaking of screws, while bending or fracture of a plate was considered rather to indicate deficient bone contact or unsatisfactory compression. The frequencies of these complicating factors are presented in Table 17. It is seen that the osteosyntheses showed deficiencies in considerably more transverse than longitudinal fractures.

In general the osteosynthesis material was allowed to remain in situ for at least 12 months. In elderly patients ($>$ 75 years old), however, it was left in place permanently, provided it was causing no trouble. Often in patients with healing disturbances the plate and screws had to be removed before the intended time. Relatively often a new osteosynthesis was then undertaken - in most cases with intramedullary nailing. The times of removal of the osteosynthesis material in different fracture groups, in fractures with and without healing disturbances and in fractures with mild and severe healing disturbances are shown in Tables 18, 19 and 20.

The total duration of hospitalization is given for the different fracture groups in Table 21. Further, the following mean periods

TABLE XVII.

Instability and deficient bone contact in different groups.

Fracture type		Instability		Deficient bone contact		Instability + deficient bone contact	
Longitudinal closed fractures	(44)	2 (5%)	2 (4%)	1 (2%)	2 (4%)	3	4 (8%)
Longitudinal open fractures	(6)	—		1 (17%)		1	
Transverse closed fractures	(47)	10 (21%)	16 (19%)	2 (4%)	6 (7%)	12	22 (26%)
Transverse open fractures	(38)	6 (16%)		4 (11%)		10	
Total	135	18 (13%)		8 (6%)		26	

TABLE XVIII.

Times of removal of the osteosynthesis material.

Fracture type / Plate in situ (mths)		12	12-18	18-24	24	Osteosynthesis mat. still in place	
						Alive	Dead
Longitudinal closed fractures	(44)	12 (27%)	13 (30%)	7 (16%)	—	8 (18%)	4 (9%)
Longitudinal open fractures	(6)	2 (33%)	2 (33%)	—	—	2 (33%)	—
Transverse closed fractures	(47)	13 (28%)	13 (28%)	7 (15%)	2 (14%)	12 (25%)	—
Transverse open fractures	(38)	9 (24%)	9 (24%)	4 (10%)	4 (10%)	10 (26%)	2 (5%)
Total	(135)	36 (27%)	37 (28%)	18 (13%)	6 (4%)	32 (24%)	6 (4%)

TABLE XIX.

Times of removal of the osteosynthesis material in fractures with and without healing disturbances.

Plate in situ for	Fractures without healing disturbances	Fractures with healing disturbances	Total
< 12 months	9 (25%)	27 (75%)	36
> 12 months or osteosynthesis material still in place	67 (72%)	26 (28%)	93
Dead, osteosynthesis material still in place	3 (50%)	3 (50%)	6

of hospitalization as well as the median values were found for the different fracture groups (includes all hospital stays):

	Mean values	Median values
Longitudinal closed fractures	15 days (4-43 days)	12 days
» open »	26 days (6-59 days)	10 days
Transverse closed fractures	30 days (5-173 days)	20 days
» open »	44 days (7-210 days)	18 days

It is seen that the need for hospital care becomes more prolonged with an increasing degree of severity of the fractures. In order to shed further light on the length of time in hospital required for different types of fractures the cumulated curves in Fig. 13 have been plotted. It is evident here that over 50% of the patients with longitudinal fractures left hospital after 2 weeks. Of the patients with transverse closed fractures, just over 50% were discharged after 3 weeks. Of those with open transverse fractures 50% were discharged after 4 weeks. 95%

TABLE XX.

Mean times for removal of the osteosynthesis material in fractures with and without healing disturbances.

Fracture type	No disturbance		Mild disturbances		Severe disturbances		Total no. of fractures with osteosynthesis material removed	Osteosynth. material still in place
	Mean time mths.	No. ( )	Mean time mths.	No. ( )	Mean time mths.	No. ( )		
Longitudinal closed fractures	15	22 (—)	13,4	8 (—)	5,25	2 (—)	32	12
Longitudinal open fractures	10,75	2(—)	17	1 (—)	6	1 (1)	4	2
Transverse closed fractures	15,5	10 (—)	15,3	9 (1)	10,7	10 (5)	35	12
Transverse open fracture	17,7	13 (—)	15,3	5 (1)	8,2	9 (7)	27	11

( ) = fractures in wich the primarily applied osteosynthesis material was replaced by other osteosynthesis material.

TABLE XXI.

Total period of hospitalization.

Fracture type \ Weeks	< 1	1-2	2-3	> 3	Total
Longitudinal closed fractures	4 (9%)	24 (55%)	8 (18%)	8 (18%)	44 (100%)
Longitudinal open fractures	1 (17%)	2 (33%)	—	3 (50%)	6 (100%)
Transverse closed fractures	3 (6%)	15 (32%)	8 (17%)	21 (45%)	47 (100%)
Transverse open fractures	—	7 (18%)	8 (21%)	23 (61%)	38 (100%)
Total	8 (6%)	48 (35%)	24 (18%)	55 (41%)	135 (100%)

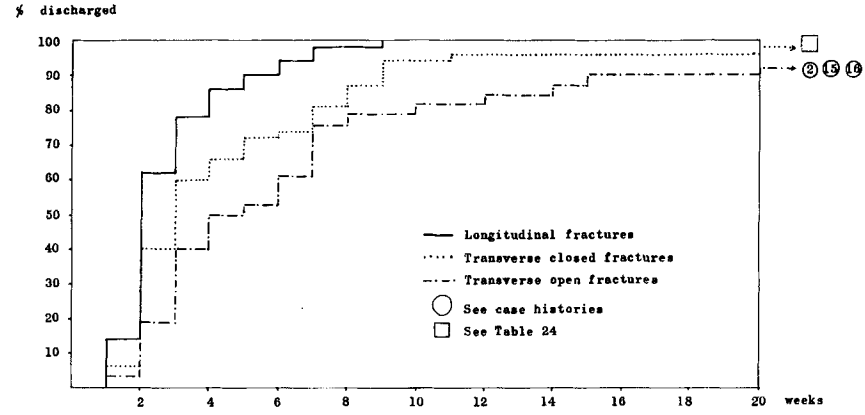


FIG. 13 - *Total period of hospitalization. Cumulated percentage discharged after different times.*

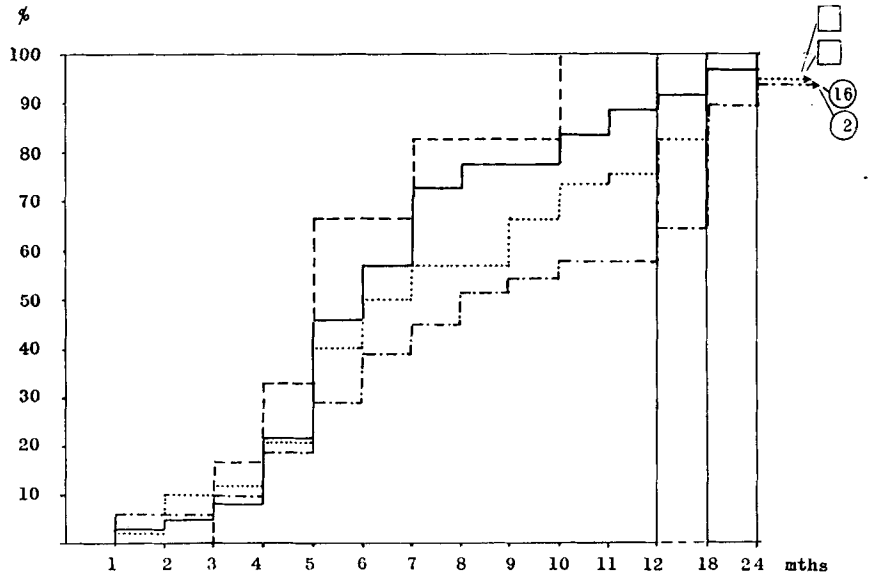


FIG. 14 - *The time on the sick-list. Cumulated percentage returned to work. For symbols see Fig. 13.*

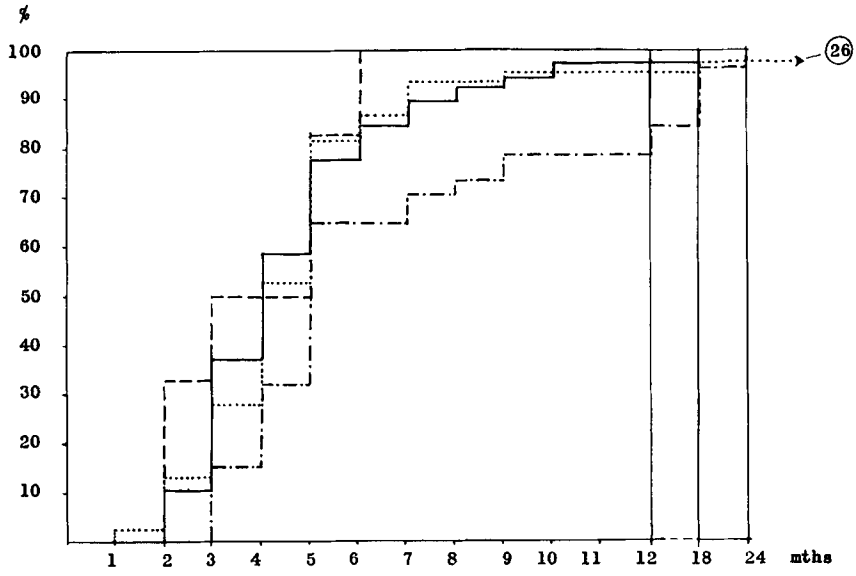


FIG. 15 - *The time from accident to full weight-bearing. Cumulated percentage. For symbols see Fig. 13.*

of the respective fracture groups had been discharged after 7, 11 and over 20 weeks. It should be noted that in the calculations the total duration of hospitalization was used, i.e. the primary length of time in hospital in connection with the osteosynthesis plus the hospitalization for removal of the osteosynthesis material and for treatment of any healing disturbances.

It is difficult to report any definite healing time after this type of osteosynthesis, since the fractures cannot be regarded as definitively healed until a certain period has elapsed after removal of the osteosynthesis material. We have therefore chosen to use as parameters for the healing time the length of time from the accident to return to work (the time on the sick-list) and the time from the accident to full weight-bearing, when from clinical and roentgenological criteria the fractures were considered to be sufficiently well consolidated to bear weight (see Figs. 14 and 15). Full weight-bearing before 2.5 to 3 months should not, however, be regarded as a sign of healing but rather means that the patient did not follow the doctor's instructions. The

degree of severity of the fractures is also evident from these curves. After 6 months 50% of the patients with longitudinal fractures and closed transverse fractures had returned to work. Patients with open transverse fractures did not reach the 50% level in this respect until 2 months later. All patients with longitudinal fractures had gone back to work after 24 months. The 90% level was reached after 18 months on the sick-list even for the group with open transverse fractures. There is some discrepancy between the curves for the time on the sick-list and the time before full weight-bearing, due to the fact that in a certain number of cases healing disturbances which prolonged the length of time on the sick-list had occurred after the patient had begun to bear weight on the fractured leg.

Among patients who suffered severe healing disturbances and were on the sick-list for more than 12 months, alcoholics and persons with psychic abnormalities were clearly overrepresented. No fewer than 44% of the severe healing disturbances fall within this combined group (11 patients).

TABLE XXII.

Number of fractures with healing disturbances necessitating secondary operation, and the number of measures per reoperated fracture.

Secondary operations	Longitudinal fractures (50)	Transverse closed fractures (47)	Transverse open fractures (38)	Total (135)
Number (%)	3 (6%)	13 (28%)	14 (37%)	30 (22%)
1 sec. op.	1	11	7	18
2 sec. op.	2	2	4	8
3 or more op.	—	—	3	3

From these studies of the aetiology and healing of these fractures, three main types of clinical course can be distinguished:

1) Low-energy indirect violence causing longitudinal fractures (closed or open). Treatment with osteosynthesis in these cases is relatively straightforward. Few complications occur in the postoperative course and these are relatively easily treated. The duration of hospitalization and the length of time on the sick-list are short.

2) Low-energy direct violence causing transverse fractures, which usually are closed and more seldom comminuted. A higher demand for stability of the osteosynthesis is required here. Healing disturbances and indications for secondary operations are more frequent. The length of time on the sick-list and the duration of hospitalization are also therefore generally longer.

3) High-energy direct violence, causing transverse fractures. These are often open, comminuted and to a high degree complicated by soft tissue injuries. Patients with such tibial fractures not seldom have other severe physical injuries. The osteosynthesis is often difficult, with a high demand on stability. Healing disturbances requiring one or more secondary measures occur relatively often (compare Table 22). The lengths of time on the sick-list are often long and demands on hospital care considerable.

At times our situation regarding hospital care was such that healing disturbances could not always be met with adequate measures at the right time, which in many cases may have prolonged the duration of hospitalization and inability to return to work. This was especially true for some cases of osteomyelitis, which in its chronic, relatively untroublesome state had to wait for the final sequestrotomy (cases 2, 8 and 16).

Discussion

In the case histories all of the poorest healing courses are described (26 patients). Of these fractures 3 were caused by indirect violence and 15 by high-energy violence. The latter cause of injury predisposes markedly to delay in healing. However,

there are other factors of importance for the healing course, namely technical factors in the osteosynthesis operation and the personality of the patient. Especially with the AO method both of these factors have their particular significance, since this method is based on the best possible internal stability and absence of external fixation in order to allow early but also sensible postoperative mobilization for restoration of normal function.

Obviously infection also constitutes a factor which may delay the definitive healing, but in our series this had no appreciable effect on the length of time before union of the fracture itself.

TECHNICAL FACTORS IN THE OSTEOSYNTHESIS OPERATION. It is of great importance that the basic principles regarding the incision, the positioning and fitting of the plate and positioning of the screws should be followed. In three of the patients with osteomyelitis skin necrosis had occurred over the plate. In two of these the skin incision had been made much too far medially. Primary injuries to the skin certainly contributed to the extent of the necrosis and it cannot be stressed too strongly that any tension or pulling on the margin of the skin during the operation increases the risk of necrosis. In this connection it should be pointed out that because of the risk of necrosis the plate should not be applied beneath heavily bruised skin.

When applying the plate against the tibia the plate should not be more curved than the tibial contour, and neither should the compression be so strong as to cause further bending of the plate. In such cases the fracture gap will increase in size in the cortex of the side away from the plate, so that the osteosynthesis will depend mainly upon the metal plate. This will then bend to a small degree at each muscle contraction. The same situation occurs in fracture diastasis - all elements of force then pass via the plate and cause bending. This occurs very easily in transverse fractures, especially of the comminuted type, and is the cause of fracture of a screw or plate (as many as 9 patients reported in the case histories). Sometimes this instability is manifested in the form of loosened screws (3 cases in this series). Defects in the cortical bone, if left untreated, will lead to reduced stability and an increased strain on the plate, and in these cases a primary bone transplantation should be performed whenever possible,

even if the fracture is an open one. This was done in certain patients in the present series, and in the presentation of the results it is seen that these patients are in fact to be found among the group « healing without disturbance » or « healing without severe disturbances ».

If it is seen on the roentgenogram postoperatively that the osteosynthesis is instable, i.e. that it is only resting on the plate, additional splintage, e.g. with a PTB splint or plaster, should be applied intermittently.

THE PATIENT'S PERSONALITY. This term embraces here the general mental state and psychic abnormalities including the misuse of alcohol. In order to carry through the AO therapy satisfactorily the patient must be made familiar with its principles and follow the advice given. It has been found that alcoholics, in particular, especially under the immediate influence of alcohol, disregard all advice, and the same applies from time to time to patients with other forms of psychic abnormalities. In actual fact these patients behave as if they have not been injured at all. Under such circumstances the osteosynthesis will obviously not hold. Among the 26 patients with serious healing disturbances there were no fewer than 11 in this category. It would seem highly advisable, therefore, to provide such patients with complementary external plaster fixation.

INFECTION. Infection is a very serious complication. With early, active treatment, however, it seems possible to master this problem to a large extent. In the present series the treatment of infection, consisting of excision of necrotic tissue, open or closed drainage — often in combination with a cancellous bone graft —, and administration of antibiotics, gave satisfactory results in all cases. It is important, however, that as long as it is contributing to the stability of the fractured bone, the osteosynthesis material should remain in situ until the fracture itself has united.

REFRACTURE. The risk of refracture after removal of the osteosynthesis material has been pointed out as a disadvantage of the AO method. There are two causes of refracture — one is that the initial fracture has not yet healed satisfactorily, and

the other is that the bone has weakened to such an extent by the presence of the plate that a fracture can easily occur, especially where a screw-hole comprises a weak point. In our series there were three cases of refracture after removal of the osteosynthesis material. All were associated with trauma of only a slight degree. One of these patients showed a dislocation, and retrospective examination of the roentgenograms established that the fracture had not been completely united at the time of removal of the osteosynthesis material. In one patient a small fissure had developed at the site of the previous fracture. In the third patient no fracture line could be seen at first, even though the patient had pain; not until after about one month was a crack observed close to the site where callus formation had appeared. In both of these two latter patients the treatment comprised only the use of crutches, with no weight-bearing on the refractured leg.

Refracture prior to removal of the plate, thus combined with fracture of the plate, must be considered to be caused by instability due to an inferior osteosynthesis associated with poor healing and excessive weight-bearing. In comminuted fractures a primary bone graft should contribute to early bone formation and stability before the plate sustains its fatigue fracture.

The complications — instability and refracture — were treated successfully by intramedullary nailing preceded by reaming of the medullary cavity. In practically all cases this was followed by only a short further period on the sick-list. An interesting finding concerning these cases of late nailing is that as regards the fracture level the indications for nailing can be widened considerably in that the new endosteal bone already formed gives good support for the nail in a region where otherwise the medullary cavity would have been considered too wide for successful treament with a Küntscher nail.

The numerous healing disturbances in the group of comminuted transverse fractures indicate that careful evaluation should be made in such fractures as to their suitability for plate osteosynthesis. In those cases where such osteosynthesis is considered safe, i.e. with no increased risk of infection, a modified technique may be used with fixation of the fragments by a short plate. This plate will hold the fragments in position during the development of periosteal and endosteal bone formation. After 8-12 weeks the

plate can be removed, and the fracture can then be firmly fixed with an intramedullary nail after medullary reaming. With such a method the length of time before the patient can return to work should be considerably reduced.

In tibial fractures of the types most difficult to treat, i.e. comminuted fractures with considerable damage to soft tissues, the suitability of internal fixation with plate osteosynthesis must be questioned. The associated soft tissue injury is treated more easily and safely by the use of transfixation of the fracture fragments by the method of Charnley or Vidal & Adrey.

Chapter III

FOLLOW-UP EXAMINATION

Material

Of the 129 patients with 135 fractures, 118 patients with 122 fractures were followed up (see Table 23). As mentioned previously, one patient with bilateral fractures died of fat embolism and bronchopneumonia 17 days after the operation. An additional 7 patients with 8 fractures died before their follow-up examination. The causes of death in these cases were studied and in none of these 7 patients did the fractures or osteosyntheses have any relationship with the causes of death. Three patients with 3 fractures were not available for follow-up, the reasons being that one had left the country, and two were leading a vagrant life with no fixed address. Such persons appear to be overrepresented in a fracture series. The fact that only 3 out of 121 patients were missing from the follow-up material may therefore be regarded as satisfactory (97.5% followed up).

Of the 118 patients followed up, 6 were excluded from the presentation of the results on account of other injuries or diseases which rendered the evaluation difficult or impossible. Details of the reasons for exclusion of these patients are given in Table 24.

Table 25 gives the number of fractures followed up in the different clinical fracture groups, and Table 26 the interval between operation and follow-up examination.

At the follow-up examination a record was made of any subjective symptoms in the ankle, any aching or pain in the fracture area, difficulties in walking and the degree of activity at work and in sports compared with that prior to the accident. The objective examination included the condition of the skin

on the lower leg and foot, examination for any deformity, muscular atrophy or swelling, and testing of the range of movements of the ankle joint. These nine parameters were classified into three grades, A, B and C as shown in Table 27. It is seen that for assignment to grade A very stringent criteria were required, since function equivalent to that of the intact side was demanded. The conditions for assignment to grade B may also be regarded as

TABLE XXIII.

Patients and fractures undergoing final evaluation of the results of the treatment.

	Patients	Fractures
Whole material	129	135
— Died in hospital	1	2
— Died before follow-up examination	7	8
— Not attainable for follow-up	3	3
Followed up	118	122
— Excluded because of other disease or injury complicating evaluation of the function of the lower extremities	6	6
Evaluable, followed up	112	116

very good. The knee function has not been included in this table, since it showed no abnormalities except in one patient (case 16). Neither are pronation and supination in the subtalar joint included in the table, since this function was also unimpaired in all cases, most probably due to the fact that plaster immobilization was only used exceptionally and for short periods.

TABLE XXIV.

Fractures which were followed up but were excluded from the final results.

	Patient	Fracture	Excluded because of	Complication	Reoperation	Results of follow-up exam. Ex-cell-ent	Good	Ac-cep-table	Poor
1.	A.L. 48 yrs	Long. closed simple	Talipes equinus after prev. ischias with paresis	Instability	—		X		
2.	I.A. 58 yrs	Transv. closed comminuted	Soft tissue injury in thigh and knee. Vascular damage in popliteal fossa	—	—			X	
3.	D.A. 74 yrs	Transv. closed comminuted	Ca. prostate. Confined to bed	Metallosis + instability and bending of plate	Plaster			X	
4.	I.Z. 53 yrs	Transv. open comminuted	Fracture of femoral neck. Necrosis of head of femur	Pseudarthrosis	Bone transplantation			X	
5.	Y.P. 47 yrs	Transv. open comminuted	Fractures of talus and metatarsus	Metallosis	—		X		
6.	H.P. 22 yrs	Transv. open comminuted bilat.	Arterial, muscular and skin damage. Amputated	Infection Amputation	Hoffmann fixation, amputation revisional ops.				X

TABLE XXV.

Distribution of the evaluable followed up fractures into different clinical groups.

Fracture type	No.	
Longitudinal closed	37	
Longitudinal open	6	
Transverse closed, simple	33	42
Transverse closed, comminuted	9	
Transverse open, simple	11	31
Transverse open, comminuted	20	
Total	116	

TABLE XXVI.

The interval between operation and follow-up examination of the evaluable fractures.

Time after op.	No.
4-5 years	41
3-4 years	20
2-3 years	32
1-2 years	23
Total	116

TABLE XXVII.

Definition of parameters in the follow up examination.

		Parameter	A.	B.	C.
Subjective complaints	1	Ankle joint symptoms	0 or negligible	Moderate. Some functional reduction	Severe. Clear functional reduction
	2	Aching or pain in fracture area	0 or slight symptoms on exertion	Moderate symptoms	Severe symptoms Pain at rest.
	3	Difficulty in walking	0	Mild subj.symptoms	Severe symptoms. Limp
	4	Work and sports	Unchanged activities	Works as before. Finished with some sport	Stopped working because of injury
Objective findings	5	Skin condition	Normal	Slightly discoloured	Ulcer or fistula, persistent infection
	6	Deformity	0	Slight, not noticeable	Considerable, noticeable, shortening > 1 cm
	7	Muscular atrophy	0-1 cm	1-2 cm	> 2 cm
	8	Swelling (mall.)	0-1 cm	1-2 cm	> 2 cm
	9	Movement of ankle joint, dorsi- and plantarflexion	Limitation 0 or < 5°	Limitation 5-10°	Limitation > 10°

Results

The results concerning each of the nine parameters in Table 27 are presented in Tables 28-36.

SUBJECTIVE SYMPTOMS FROM THE ANKLE (Table 28). Very seldom did any of the patients complain of symptoms from the ankle joint at the follow-up examination. Two patients, however, had ankle joint symptoms of such a degree that they were assigned to grade C. One of them had a closed longitudinal tibial fracture combined with a fracture of the distal articular surface. The roentgenogram at follow-up showed some arthrosis in the talocrural joint. The patient with the closed transverse fracture, who had fairly severe persistent symptoms from the ankle joint, was a 62-year old man with moderate arthrosis in the ankle.

TABLE XXVIII.

Subjective ankle joint symptoms.

Fracture type	A.		B.		C.	
Long. closed	34(94%)		2(5%)		1(3%)	
Long. open	5(83%)		1(17%)		—	
Transv. closed, simple	2(97%)	8%	—		1(3%)	3%
Transv. closed, comm.	9(100%)		—		—	
Transv. open, simple	11(100%)	97%	—	6%	—	
Transv. open, comm.	18(90%)		2(10%)		—	
Total	109(94%)		5(4%)		2(2%)	

ACHING AND PAIN IN THE FRACTURE AREA (Table 29). In no case were symptoms of this type severe giving rest pain.

TABLE XXIX.

Aching and pain in the fracture area.

Fracture type	A.		B.		C.
Long. closed	35(95%)		2(5%)		—
Long. open	5(83%)		1(17%)		—
Transv. closed, simple	29(88%)	91%	4(9%)	9%	—
Transv. closed, comm.	9(100%)		—		—
Transv. open, simple	9(82%)	84%	2(18%)	16%	—
Transv. open, comm.	17(85%)		3(15%)		—
Total	104(90%)		12(10%)		—

TABLE XXX.

Walking ability.

Fracture type	A.		B.		C.
Long. closed	36(97%)		—		1(3%)
Long. open	6(100%)		—		—
Transv. closed, simple	33(100%)		—		—
Transv. closed, comm.	7(100%)		—		—
Transv. open, simple	10(91%)	84%	1(9%)	6%	—
Transv. open, comm.	16(80%)		4(20%)		—
Total	110(95%)		5(4%)		1(1%)

WALKING ABILITY (Table 30). The only patient with some difficulty in walking was the patient mentioned above with a diaphyseal fracture and a distal fracture of the articular surface. Otherwise there were only slight difficulties, in patients who had had open transverse fractures.

WORK AND SPORTS (Table 31). None of the patients were forced to change their work after the fracture. One patient, however, who developed osteomyelitis with a long healing course, reached retirement age before the osteomyelitis was fully healed. 12% of all patients followed up finished with some form of sport after the accident. This was probably not due to the fracture in all cases, however; a number of football players, for example, were 5 years older by the time of the follow-up examination and had limited their activities in this respect.

SKIN CONDITION (Table 32). The total absence of severe skin lesions is probably associated with the fact that all osteomyelites healed — although relatively long treatment was required in some cases — and that there were no clinical signs of venous circulatory disturbances. The occasional cases of mild skin symptoms seen at follow-up comprised slightly tender skin in and around the operation scar over the tibia and moderate induration over the plate (metallosis) in patients who had not yet had their osteosynthesis material removed.

DEFORMITY (Table 33). More marked deformity was only seen in two patients. One was a female patient who at the time of the fracture was 80 years old. This patient had a severe open comminuted fracture and at operation it was not observed that an external rotation of about 30° was produced at the osteosynthesis. Healing occurred without delay, however, Subjectively the patient had very little discomfort from the deformity. The reason might be limited demand because of her age. The other patient had shortening by 2 cm. (case 2).

MUSCULAR ATROPHY (Table 34). More pronounced atrophy of the muscles of the lower leg occurred in only one patient, with an infected pseudarthrosis (case 16). Other muscular atrophies were hardly noticeable, but were only evident on careful measurements of the calf circumference.

TABLE XXXI.

Ability to work and participate in sports.

Fracture type	A.		B.		C.
Long. closed	36(97%)		1(3%)		—
Long. open	6(100%)		—		—
Transv. closed, simple	28(85%)	88%	5(15%)	12%	—
Transv. closed, comm.	9(100%)		—		—
Transv. open, simple	10(88%)	74%	1(9%)	26	—
Transv. open, comm.	13(65%)		7(35%)		—
Total	102(88%)		14(12%)		—

TABLE XXXII.

Skin condition.

Fracture type	A.		B.		C.
Long. closed	37(100%)		—		—
Long. open	6(100%)		—		—
Transv. closed, simple	28(85%)	87%	5(15%)	12%	—
Transv. closed, comm.	9(100%)		—		—
Transv. open, simple	10(91%)	88%	1(9%)	13%	—
Transv. open, comm.	71(89%)		3(15%)		—
Total	107(92%)		9(8%)		—

TABLE XXXIII.

Deformity.

Fracture type	A.		B.		C.	
Long. closed	37(100%)		—		—	
Long. open	6(100%)		—		—	
Transv. closed, simple	33(100%)		—		—	
Transv. closed, comm.	9(100%)		—		—	
Transv. open, simple	11(100%)	84%	—	10%	—	6%
Transv. open, comm.	15(75%)		3(22%)		2(10%)	
Total	111(95%)		3(3%)		2(2%)	

TABLE XXXIV.

Muscular atrophy.

Fracture type	A.		B.		C.	
Long. closed	32(86%)		5(14%)		—	
Long. open	4(67%)		2(33%)		—	
Transv. closed, simple	30(91%)	90%	3(9%)	10%	—	
Transv. closed, comm.	8(89%)		1(11%)		—	
Transv. open, simple	9(75%)	85%	2(18%)	11%	—	4%
Transv. open, comm.	17(89%)		11(10%)		1(5%)	
Total	100(86%)		15(13%)		1(1%)	

SWELLING (Table 355). Slight swelling of the injured leg was observed at follow-up examination in 15%. In 3 patients the swelling was more marked. The patient with more marked swelling after a closed longitudinal fracture was an 81-year old man with no subjective symptoms. The swelling after one of the closed transverse fractures was also noted in an elderly patient, who had had refracture and fracture of the plate, however (case 22). In the other patient with a closed transverse fracture the swelling developed after 4 months in plaster, so treated because of a refracture (case 17). The absence of swelling in the majority of patients is associated with the absence of clinical thromboses in this series.

ANKLE MOVEMENT (Table 36). Perhaps the most noteworthy finding at the follow-up examination was the good function of the ankle joint, which was completely unimpaired in 83% and good in a further 16%. The only patient with a more marked limitation of this range of movements was the patient who was treated with plaster postoperatively because of some unreliability of the stability of the osteosynthesis. This patient had no subjective symptoms at follow-up, however.

By summarizing all follow-up parameters, a complete picture of each fracture was obtained. Designated as excellent or restitutio ad integrum were such fractures for which all follow-up parameters were assigned to grade A. Designated as good were those fractures for which one or more parameters were graded as B. Those fractures for which one of the parameters was assigned to grade C but which essentially gave no subjective symptoms were regarded as acceptable. Designated as poor were the results of those patients with objective and subjective functional symptoms and with one or more of the parameters graded as C. A definitely poor final result was obtained only in case 15, but in this patient, however, an unequivocal evaluation of the fracture treatment alone was rendered impossible by other injuries (see Tables 24, 37 and 38) and is excluded from the final result.

As a whole the final functional result must be considered very satisfactory. None of the patients' final conditions could be regarded as poor. Nine of the patients had an acceptable and 91% an excellent final result, even though very stringent criteria for a perfect result were used.

TABLE XXXV.

Swelling.

Fracture type	A.		B.		C.	
Long. closed	33(89%)		3(8%)		1(3%)	
Long. open	6(100%)		—		—	
Transv. closed, simple	24(73%)	67%	7(21%)	28%	2(6%)	5%
Transv. closed, comm.	4(44%)		5(56%)		—	
Transv. open, simple	10(91%)	90%	1(9%)	10%	—	
Transv. open, comm.	8(90%)		2(10%)		—	
Total	95(82%)		18(15%)		3(3%)	

TABLE XXXVI.

Ankle movements.

Fracture type	A.		B.		C.	
Long. closed	33(89%)		4(11%)		—	
Long. open	6(83%)		1(17%)		—	
Transv. closed, simple	30(91%)	90%	3(9%)	10%	—	
Transv. closed, comm.	8(89%)		1(11%)		—	
Transv. open, simple	7(64%)	68%	3(27%)	29%	1(19%)	3%
Transv. open, comm.	14(70%)		6(30%)		—	
Total	96(83%)		19(16%)		1(1%)	

TABLE XXXVII.

Results of follow-up examination with respect to all parameters.

Fracture type	Excellent		Good		Acceptable		Poor	Total	
Longitudinal closed	25(68%)		11(30%)		1(2%)		—	37	
Longitudinal open	4(67%)		2(33%)		—		—	6	
Transverse closed, simple	17(52%)	48%	13(40%)	45%	3(8%)	7%	—	33	42
Transverse closed, comminuted	3(33%)		6(67%)		—		—	9	
Transverse open, simple	8(73%)	45%	2(18%)	36%	1(9%)	19%	—	11	31
Transverse open, comminuted	6(30%)		9(45%)		5(25%)		x)	20	
Total	63(54%)		43(37%)		10(9%)			116	
	91%								
	100%								

x) One patient amputated but excluded because of other injury (case 15).

TABLE XXXVIII.

Healing disturbances and reoperations in relation to results of follow-up examination.

Healing disturbances and reoperations	Excellent	Good	Acceptable	Poor	Total	
No disturbance	45	21	5	—	71	89
Slight disturbance, no reoperation	6	11	1	—	18	
Slight disturbance, reop., intramed. nail	—	1	—	—	1	
Slight disturbance, other reop.	2	2	—	—	4	
Severe disturbance, no reop.	2	—	—	—	2	
Severe disturbance, reop., intramed. nail	7	4	2	—	13	
Severe disturbance, other reop.	1	4	2	—	7	
Total	63	43	10	—	116	

The relatively numerous healing disturbances thus had no appreciable effect on the final result. It is evident from Table 38 that among the 22 patients with more severe healing disturbances who were included in this follow-up series, the final result in 10 was classified as excellent, in 8 as good and in 4 as acceptable. Four of the patients with more severe healing disturbances are not included, for the following reasons: 1 had died (case 3); 2 had other severe injuries (cases 5 and 15); and 1 had prostatic cancer with metastasis (case 26).

Chapter IV

GENERAL DISCUSSION

Compression osteosynthesis in the treatment of fractures is used with the aim of attaining a better final result than is often achieved with closed reduction and plaster fixation. The principle underlying compression osteosynthesis is that with stable internal fixation of the fracture during the healing course, external fixation is usually obviated. The early painlessness and the stability are utilized for very active and functional treatment throughout the whole phase of bone healing. Compression osteosynthesis would seem to be especially valuable in tibial fractures, in which fixation with plaster splintage sometimes results in functional impairment of the ankle joint or, in occasional cases, in Sudeck's atrophy. The method aims at exact anatomical restoration, which in tibial fractures will give the best guarantee against late symptoms due to deformities.

The roentgenological picture in the bone healing following compression osteosynthesis has been described by Danis (1949) and is designated « soudure autogene », i.e. a slow disappearance of the fracture gap without development of roentgenologically visible periosteal callus. Histological studies made by Schenk and Willenegger (1963, 1964, 1967) have shown the importance of so called primary bone healing, i.e. secondary osteones growing directly over the fracture gap. In microangiographic investigations of the bone healing in compression osteosynthesis (e.g. Olerud & Danckwardt-Lilliestrom 1968, 1971; Danckwardt-Lilliestrom, Lorenzi & Olerud 1970) it has been questioned whether the intracanalicular bone formation is solely responsible for the so called clinical consolidation. Information on the stability produced by different types of bone healing would be of great value. Fixation that is too rigid may have a retarding effect on the healing process. A central component of the operative treatment is the compression of the fragment surfaces, a factor which

can hardly promote healing in any other sense than that it increases the stability of the osteosynthesis (Müller 1963). Perren et al. (1969) have shown that after an initial moderate fall the compression decreases slowly to about 50% of the initial pressure after about 2 months. Under controlled experimental conditions there are thus good prerequisites for relatively good maintenance of the compression, which will favour primary bone healing. In clinical practice, especially in comminuted fractures, however, there is a risk that ideal compression conditions will not be achieved. Further, when the fragment surfaces are uneven, there is no guarantee that well applied compression will be retained during the long period required for undisturbed formation of new bone. Practical experiences of external compression with transfixation by the method of Vidal & Adrey (1970) have shown that the compression applied primarily is often not sustained.

The present work comprises a study of a series of tibial fractures treated essentially in accordance with the principles recommended by the AO group for compression osteosynthesis. The follow-up material is relatively small compared, for example, with fracture materials presented by Böhler (1953) and Nicoll (1964). To our knowledge, however, no similar study of tibial fractures treated with compression osteosynthesis has been published previously, and it was therefore considered of value to present these results.

From one important angle this whole fracture material lacks some uniformity in that the fractures were treated by a relatively large number of surgeons (about 15) with varying degrees of experience. This may have influenced the healing courses, but on the other hand demonstrates the possibility for a clinic not solely intended for this purpose to apply the therapeutic principles of compression osteosynthesis. However, even if the technical performance and the treatment of the fractures may have varied somewhat, the follow-up examination did comprise a uniform evaluation, since all components of this examination were carried out by the authors personally.

We found that this method of treatment, despite the fact that it was associated with a fairly high frequency of healing disturbances and relatively long periods before the patient could return to work, led to a very good final result. The time on the sick-

list is an unreliable parameter as this is dependent partly on the morale of the patient and partly on the cooperation of the employer. By using the classification of Edwards, some grouping according to the type of trauma is also obtained automatically. As a rule the longitudinal fractures represent low-energy trauma and the comminuted type trauma of high-energy. When evaluating the consolidation and healing times and the healing disturbances, the type of trauma clearly plays a decisive role in the grouping of our results. In every presentation where the healing course is to be evaluated it is of great importance to take into consideration the type of trauma.

In general the AO treatment of tibial fractures in comparison with other methods did not change the time the patients were on the sick-list. Edwards (1965) showed in 95% of his material a somewhat shorter healing time than was noted in this material. The results, however, cannot correspond exactly, as Edwards defines healing time as the period from the accident to clinical stability. As this definition is not suitable in our material, we have instead chosen the time from the accident to the moment when the patient can go back to work as the healing parameter.

The basic reasons for the good final results were with all probability the exactness of the anatomical reconstruction and the functional postoperative management. We consider of especial importance an exact apposition of the fragments, which will prevent angulation, shortening and rotational deformity. Attention to this factor will certainly have explained the fact that only very few patients with late subjective symptoms, and also few patients with objective functional limitations in the extremity were seen at the follow-up examination.

In *longitudinal fractures* (as a rule caused by low-energy trauma) good healing results have been reported from both conservative and operative treatment (Hedenberg & Pompeijus 1959; Bauer, Edwards & Widmark 1962; Edwards & Nilsson 1965). With conservative treatment of these fractures, e.g. with the more and more widely accepted PTB plaster (Sarmiento 1967) there is, however, in our experience, a tendency towards healing with shortening and not seldom outward rotation. Even if these deformaties are moderate and do not initially affect the function of the limb, they may constitute a risk of late symptoms. A rotational deformity need not be of high degree in order very soon

to reduce the function in certain positions. For example, skiing is rendered very difficult by an outward rotation deformity of 15° in the tibia, since when the feet are placed in parallel, knee-bending becomes impossible (Olerud 1970). We thus consider that also in these fractures, which are regarded as easily treated, compression osteosynthesis may well lead to a more favourable result than conservative management, both in the short and long view, and especially in patients with high demands. A prerequisite for this, however, is that the surgeon should have good theoretical and practical knowledge of the operative method, so that the final result shall not be impaired by healing disturbances.

In *transverse fractures,* which more often are comminuted and open (usually caused by high-energy trauma), the mode of treatment is more difficult to choose. In these cases both conservative treatment and conventional osteosynthesis not seldom require a long period of plaster fixation, frequently more than 5-6 months, sometimes as long as 12 months. This long period of time considerably increases the risk of reduced function in the extremity after completion of the therapy.

Extended plaster treatment may give late symptoms not only from the joints but also from the muscles and tendons as well as from the circulatory systems.

Concerning the joints, it is a well known fact that the longer the plaster cast period, the more likely that permanent stiffness of the joints will occur. In tibial fractures the upper and lower ankle joint react with reduced dorsal extension and limited pro- and supination. The knee joint on the other hand is seldom affected and when it is, only to a negligible degree. Fibrosis around joints and in the joint capsule may be one cause. Narrow joint spaces on X-ray pictures sometimes reveal that the joint cartilage might be damaged. Experimental studies have shown a tendency to vascularization of cartilaginous joint surfaces even after as short a period of plaster fixation as 4 weeks (Wigren & Olerud 1971). Therefore it is not surprising that in tibial fractures due to high-energy trauma, needing extended plaster cast treatment, the function of the ankle joint will become impaired. It seems probable that the lower ankle joint would be effected first. The early functional exercises, which have been an important part of the fracture treatment in the present material, have eliminated this cause of ankle joint stiffness.

An immediate effect of plaster immobilization is atrophy of muscles and also tendons with accompanying adhesions around gliding surfaces etc. This phenomenon certainly impairs motility. However, we believe that on muscle injury concomitant with the fracture a hard irremissible fibrous scar tissue will easily develop, especially when the leg is placed for a long time in a plaster cast. This scar tissue contributes to the joint stiffness to a greater extent with increasing injury. Early functional treatment prevents this scarring and the muscle tissue contracture can be kept under control with an almost unaffected joint function. We consider that in the present material this explanation is most relevant to the good ankle function even in the most complicated types of fractures. If it were possible to predict a short healing time for a fracture, conservative treatment might still be favourable, but in a fracture with a potentially long healing time operative treatment would be wiser because of the risk of joint stiffness.

Moderate muscular atrophy was noted in only a few cases. There is no available information in the literature for comparison, but there seems to be no doubt that the frequency of muscular atrophy will be much lower in a series of tibial fractures with greater postoperative mobilization.

The stable fixation of the tibial fracture according to the AO method also gives the best prerequisite for the circulation within the leg. The surgical procedure itself reduces the local tissue tension by the evacuation of the haematoma. The functional exercises not only facilitate the venous blood return and the lymphatic circulation but also stimulate the arterial blood supply. This type of treatment should therefore minimize the risk of thrombosis. Clinical thrombosis, now and then a reality in conservatively treated tibial fractures, was not found in the present material. Hjelmstedt (1968) found 10,7% late circulatory disturbances after plaster cast treatment in a group with a total of 76 tibial fractures. In no fewer than 44.7% were thromboses revealed by phlebography. Pulmonary emboli occurred in 5.3%.

A phlebographic study of the present material would be of great interest.

The stable fixation of fracture fragments is also very important if infection has developed. The intensive local treatment

which is often required in such cases is made much easier.

In order to illustrate further what great advantages can be achieved with the principles of anatomical reconstruction and functional postoperative management, it may be mentioned that in Böhler's large, mainly conservatively treated material from 1953 there was limitation of the range of movement of the ankle joint in 14% in closed fractures and in 70% in open fractures. Further, Burwell (1971) reported a series of tibial fractures treated with conventional plate osteosynthesis and plaster. After the severe fractures in this series there was pronounced stiffness of the ankle joint in 19.5%. In both of these series it is probable that the reduced ankle function was caused largely by the factors of tissue damage and plaster fixation. Recently Hicks (1971) reported good functional results from rigid fixation allowing joint excercises and other leg activities throughout the bone healing period.

In comparison to Edwards' (1965) « prospective » series of tibial fractures, which were on the whole treated in a conventional manner with reposition and plaster cast and ostosynthesis combined with plaster cast, the present series shows somewhat better end results (see Table 39) provided that similar classifi-

TABLE XXXIX.

Fracture type	Classified as	Prospective serie Edwards 1965		Present serie Olerud Karlström	
		No. Pat.	%	No. Pat.	%
Longitudinal	E G	41	89	42	98
	F P	4	11	1	2
Transv. closed	E G	54	87	39	93
	F P	8	13	3	7
Transv. open	E G	32	76	25	81
	F P	10	24	6	19
Total	E G	127	82	106	91
	F P	22	18	10	9

E G = Edwards group « Good »
Our groups « Excellent » and « Good ».

F P = Edwards groups « Fair » and « Poor »
Our groups « Acceptable » and « Poor ».

cation has been used. Probably it is the exact anatomical reduction which gives the better result in the group longitudinal fractures as this fracture type does not need very long time in plaster cast. In the transversal fracture groups the free movement of the ankle joint during the bonehealing period certainly plays a predominant role.

The follow-up study of our series gives a good all-round picture of the types of fracture, the healing course and final result. The lengths of time in hospital and on the sick-list were relatively long, especially in the open fractures. What can be done to shorten these times in the more severe fractures, reduce the healing disturbances and possible improve the end result? Firstly, the type of trauma should be evaluated before the start of treatment, since the prognosis seems to be largely dependent upon the force of the violence. From our exerience in this respect the indications for different kinds of treatment may be summarized as follows.

With the good prognosis for healing of *longitudinal fractures* caused by low-energy trauma, the method of treatment in this type of fracture may be chosen according to the surgeon's own experience and the resources available. There is an indication for operation, however, in cases with angulation, shortening or rotational deformity, which cannot be remedied conservatively. Even if the surgical procedure is easiest in the early phase, there is no extreme hurry in performing the operation in these cases.

In *simple transverse diaphyseal fractures* with no appreciable soft tissue damage, primary intramedullary nailing should be chosen in preference to plate osteosynthesis if open treatment is achieved. Intramedullary nailing after reaming of the medullary canal allows full weightbearing at a very early stage, and the interval before the patient can return to work is reduced considerably. As mentioned previously, in certain cases temporary plate fixation replaced about 2 months later by intramedullary nailing should come into increasing use, especially in open transverse diaphyseal fractures — not too comminuted — with no severe soft tissue injuries. In the patients with secondary intramedullary nailing in our series, the fractures healed without complications, with only one exception.

Comminuted closed fractures with minor soft tissue injuries can often be successfully treated by compression osteosynthesis with a plate.

In the most severe fractures, i.e. mainly in *open fractures of grade 3*, transfixation by the method of Charnley (1948) or Vidal & Adrey (1970) seems to have some advantages over plate osteosynthesis. Our results from these transfixation methods in the last two years have been very promising.

Infection rate: Six of the seven infections in the present series occurred in primary open fractures. One patient died of fat embolism in a very early phase. One infection had a disastrous result, namely amputation (case 15). All the others healed after adequate therapy, though in a few cases the time on the sick-list was considerable. We believe that infection in rigidly fixed fractures should not be considered too poor risks for operative treatment, as all infections with the exception of the case mentioned above healed. This opinion is shared by Hicks (1971).

On the other hand, experience from the infections has also taught us that plating may not be the ideal treatment in severe fractures. The transfixation procedures mentioned above give a good alternative. These methods also permit the same advantages concerning intensive after-treatment as rigid implants. No further devascularization of cortical bone over and above that caused by the trauma itself will occur. The bone healing process will thus probably start earlier.

The most severe disturbances in the healing of fractures treated by plate osteosynthesis, next to infections, may be said to be caused by lack of stability or, in other words, the fact that the rigidity of the osteosynthesis has been overestimated by the surgeon or the patient. We consider, therefore, that there is good motivation for increased use of intermittent plaster fixation for periods of 4-6 weeks alternating with a few weeks without plaster, for exercising the limb, in cases where the osteosynthesis is not quite perfect, or of more continous external fixation if for any reason the cooperation of the patient in the postoperative management seems uncertain. For the patient's comfort and to prevent stiffness of the knee joint, a PTB plaster may be used.

Refracture after removal of the plate did not cause any serious trouble, as can be seen from the Case Histories.

The difficulties encountered in the treatment of certain fractures and our experiences from the analysis of this series have convinced us that the treatment of the most severe fractures

caused by high-energy trauma should be centralized. This has been advocated previously by Edwards (1965). The transport of patients with such fractures seldom offers difficulty, especially if a plastic air cushion splint is used. This simple and relatively inexpensive aid not only is a temporary splint but also protects soft tissues and counteracts shock and swelling.

We are well aware that AO compression osteosynthesis is a difficult technique, which demands exact indications, considerable staff and health service resources and careful postoperative management. The good final result which we have achieved with AO screws and plates is not due solely, however, to the almost ideal construction of the osteosynthesis material, but must be attributed largely to the theoretical knowledge and practical skill of the surgeons in question. A similar opinion has been expressed by members of the AO group, to whom much of the developmental work in this field is to be ascribed. Though the so called AO method has become for us one of the main weapons against the numerous problems and difficulties which are undeniably often present in tibial fractures, we have to face the limitation of the method which concerns especially the risk of an extended healing time; however, infection seems to be well manageable under stable conditions in the fracture area and does not appear to give large problems. In spite of this, there is reason to agree with Wade (1970) in his statement that osteosynthesis with a compression plate is not a defensible general routine method in tibial fractures.

Chapter V

CONCLUSIONS

1. In a 5-year series of tibial fractures treated with compression osteosynthesis by the AO method, the frequency of healing disturbances was relatively high, due mainly to overestimation of the stability of the osteosynthesis. Because of these complications the over-all healing time is fairly long and often extended.

In order to obtain satisfactory results from AO compression osteosynthesis, both theoretical knowledge of the method and a good surgical technique are required.

2. Beside exact apposition of the fracture fragments and as stable an osteosynthesis as possible, careful supervision of the postoperative management is of great importance.

Complementary external fixation can then be applied in time if necessary.

3. Certain patients (alcoholics and patients with psychic abnormalities) should always have a period of plaster fixation postoperatively, or be treated entirely along conservative lines.

4. In cases with inferior osteosynthesis and/or signs of instability, intermittent plaster fixation should be used to a relatively wide extent.

5. In a stable osteosynthesis any infections respond more readily to treatment.

6. Open fractures with no severe soft tissue injuries can be treated as closed fractures.

7. Longitudinal fractures without dislocation are treated most suitably by conservative measures.

Longitudinal fractures with dislocation, which cannot be treated satisfactorily with conservative measures, are suitable for treatment with compression osteosynthesis.

8. Nondisplaced transverse diaphyseal fractures are best handled with external fixation by plaster cast.

Closed displaced transverse diaphyseal fractures difficult to handle properly with plaster cast should preferably be treated with intramedullary nailing after reaming of the medullary cavity, either immediately or after about one week of traction.

9. Open transverse diaphyseal fractures with moderate soft tissue injuries might be fixed primarily with a short plate (as these never should be primarily nailed) and then treated secondarily with intramedullary nailing after about 2 months.

10. Closed and also open transverse metaphyseal fractures are treated with advantage by compression osteosynthesis.

11. If well managed, AO rigid osteosynthesis with postoperative active functional exercises as leading principles gives a high percentage of excellent and good end results, even in high-energy compound fractures. Neither Sudeck's atrophy nor « fracture disease » occurred in this series and no clinically manifest circulatory disturbances of thrombotic origin were observed.

12. In the most severe fractures, i.e. comminuted diaphyseal and metaphyseal fractures with extensive skin and soft tissue injuries, transfixation (by the Vidal & Adrey or the Charnley-AO method), seem preferable to compression osteosynthesis with a plate and screws.

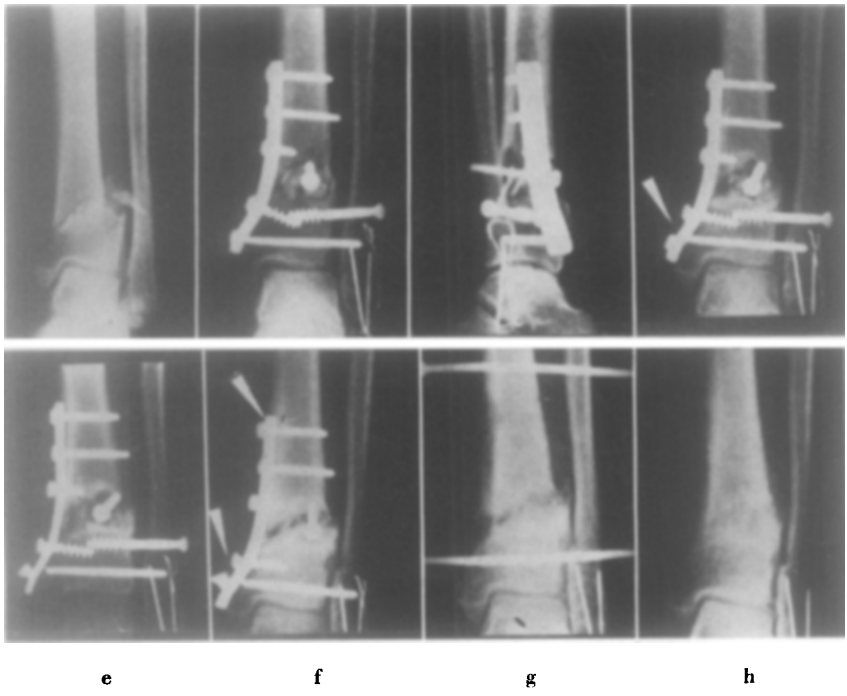
SUMMARY

A 5-year material of 135 tibial fractures treated with compression osteosynthesis by the AO method is presented. 59% of the fractures had been caused by direct trauma. 45% were caused in traffic accidents. The material included a relatively high proportion of comminuted fractures (30%). 32% were open fractures.

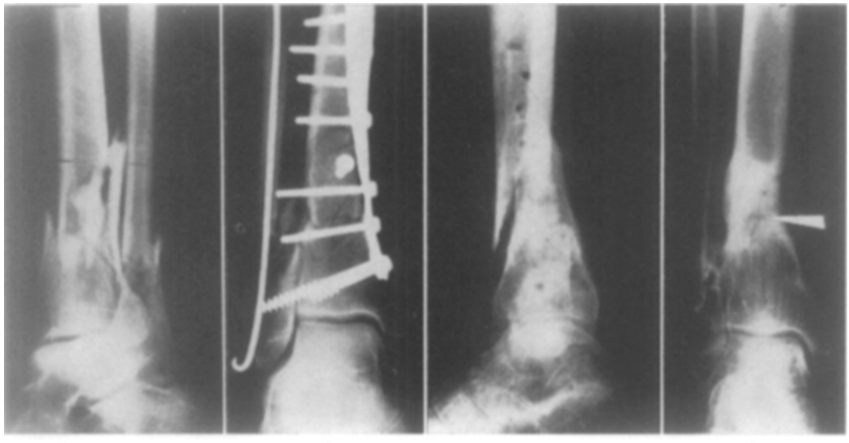
The treatment and healing course are reported for all fractures, and 97.5% of the whole material underwent a follow-up study. There was a relatively high frequency of healing disturbances, and the intervals before which the patients were able to return to work were rather long. In 19% of the fractures the healing disturbances were assessed as severe and demanded further surgical procedures. Nevertheless the final results at the follow-up examination were found to be excellent. Despite the stringent criteria laid down when grading the results, 91% were classified as excellent or good and the remaining 9% as acceptable. Among the patients for whom a final evaluation could be made, no poor result was noted. The good results may be ascribed largely to the excellent ankle joint function which was generally maintained, even in cases with a protracted healing course. This in turn is attributable to the careful postoperative management with emphasis on mobilization.

The risk of an extended healing course with the AO compression technique indicates the necessity for a very careful selection of patients and fractures as suitable for this special treatment.

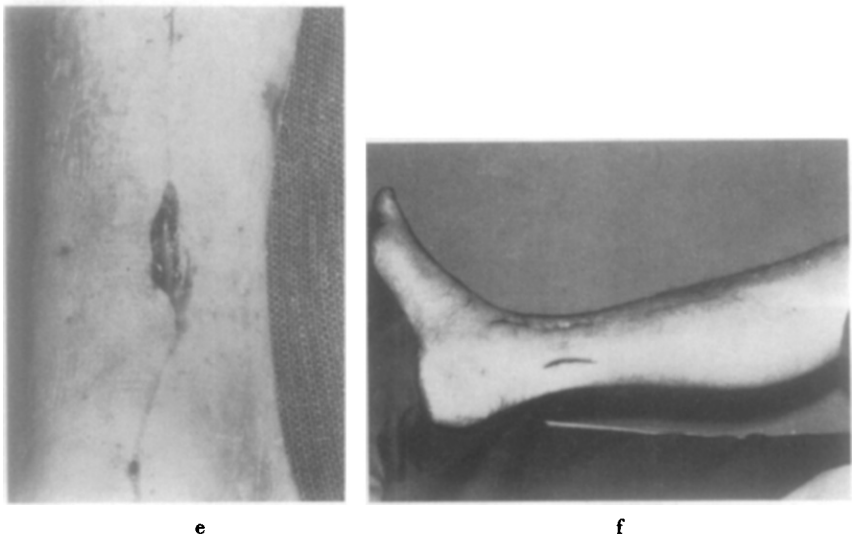
CASE HISTORIES OF PATIENTS WITH FRACTURES WITH SEVERE HEALING DISTURBANCES



CASE 1. After the osteosynthesis both the distal tibia and the fibula showed a satisfactory position (b, c). After a time fracture of a screw (d) and pseudarthrosis became evident (e). Yet a further screw fracture occurred (f). A bone graft and transfixation according to Charnley (g) resulted in definitive bone healing (h).



a b c d



e f

CASE 2. A crush fracture of the distal metaphysis (a); after osteosynthesis (b). On account of skin necrosis and infection the plate was removed 5 months after the accident, after which the fracture showed some deformity (c). Osteomyelitis developed; gradually, however, a constant, small amount of secretion from a fistula was found to arise from a sequestrum in a small cystic cavity (arrow at d). After sequestrotomy and a cancellous bone graft there was definitive healing.
As a result of skin necrosis the plate is exposed (e). A relieving incision and a double-based skin flap gave only temporary covering (f).

1. E. W. 170817, caretaker

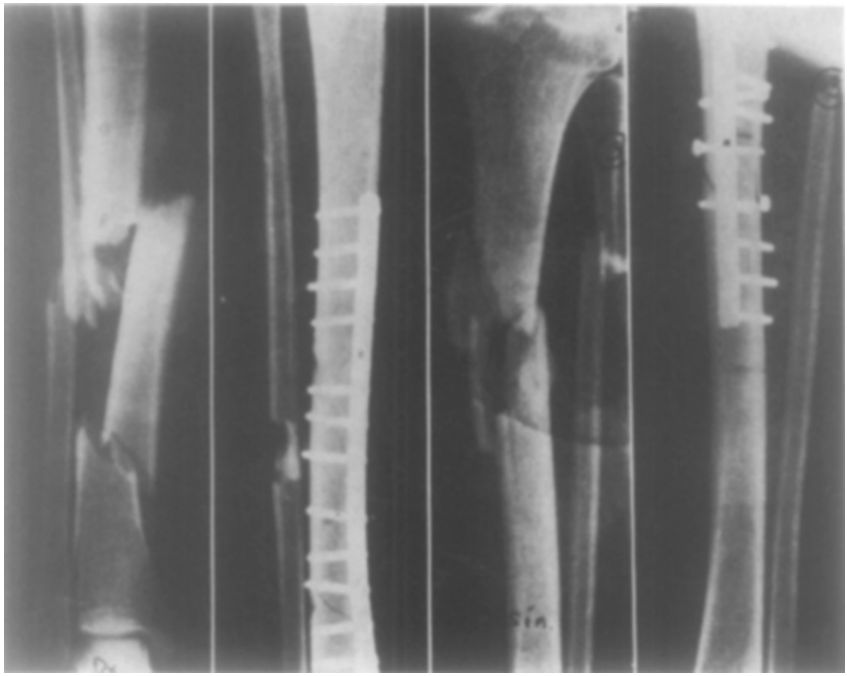
Accident 26.11.65. Crushed between a lorry and a wall.
Open distal left tibio-fibular fracture.
Op. 26.11.65: AO osteosynthesis with plate and screws. The skin injury was left open. A skin graft was planned. The patient *discharged himself* from hospital against advice, however, on 15.12.65 He probably bore weight on the leg earlier than the 3 months which he stated.
X-ray 18.8.66: *Fractured screw.* Aching and pain in fracture region.
Unable to work at times.
X-ray 8.3.67: Dislocation of the fracture with some varus deformity.
X-ray 14.12.67: Distinct pseudarthrosis.
Op. 7.2.68: Removal of osteosynthesis material + bone graft + Charnley compression osteosynthesis.
21.3.68: Removal of Charnley material.
X-ray 11.4.68: Good callus formation. Able to work full-time since 1.7.68.
Followed up 5 years after the accident: Condition of leg good (1 cm shortening, slight varus deformity).

2. S. S. 060124, mechanic

Accident 21.5.66. Collided with a car while riding a moped. Open comminuted distal tibial and fibular fracture on right side.
Op. 21.5.66: Open reduction + AO osteosynthesis + bone graft. Some *necrosis* over the plate postoperatively.
Op. 29.6.66: Skin graft.
X-ray 3.8.66: Fracture in good position, good callus formation. In Sept. '66 he developed a purulent infection after bathing. Admitted 29.9.66. Staph. aureus cultured. Treatment: Ekvacillin®. Healing took place gradually. Readmitted 27.10.66 with infection.
Op 26.10.66: Removal of osteosynthesis material.
X-ray 2.11.66: *Refracture* with small dorsal angulation deformity and some shortening. Plaster applied. The deformity was accepted. Secretion from the wound. Treated with Lincocin®.
X-ray 23.2.67: Sclerosis around the fracture.
The Lincocin was discontinued in June 1967. Increased secretion after 2 weeks. Lincocin therapy recommenced.
X-ray 8.11.68: Decalcification, cystic radiolucent areas. Slowly discharging fistula.
Op. 11.11.68: Exploration of fistula. No sequestrum.
X-ray 11.9.70: Marked sclerosis. Culture: Staph. albus + coli.
Op. 15.9.70: Removal of sequestrum + bone graft. Lincocin® therapy. Secretion gradually ceased. Treated in hospital with local antibiotic therapy.
4.12.70 healed.
Followed up 5 years after the accident. Condition of fractured leg acceptable. 2 cm shortening observed on X-ray examination. No swelling, no atrophy. Normal mobility in the ankle. No sign of infection.

3. K. K. 930520, retired

Accident 2.8.66. Knocked down by a car while walking.
Severe shock. Fractured ribs - right V and VII and left VI. Bilateral open comminuted tibial fractures.
Op. 2.9 - 3.9.66: Open reduction + AO osteosynthesis bilaterally. The operation took 7.5 hours! Unconscious postoperatively.
4.9.66: Skull roentgenograms and carotid angiograms showed nothing abnormal.
5.9.66: Tracheotomized.
9.9.66: Signs of infection in *left tibia*. Gas gangrene suspected. Culture: coli. Transferred to Dept. of Infectious Diseases.
X-ray chest: Bilateral infiltrations.
Died 1.9.66: *Autopsy*: Fat emboli in brain and lungs + bronchopneumonia. Cause of death: Pneumonia in combination with fat embolism, caused by injuries.

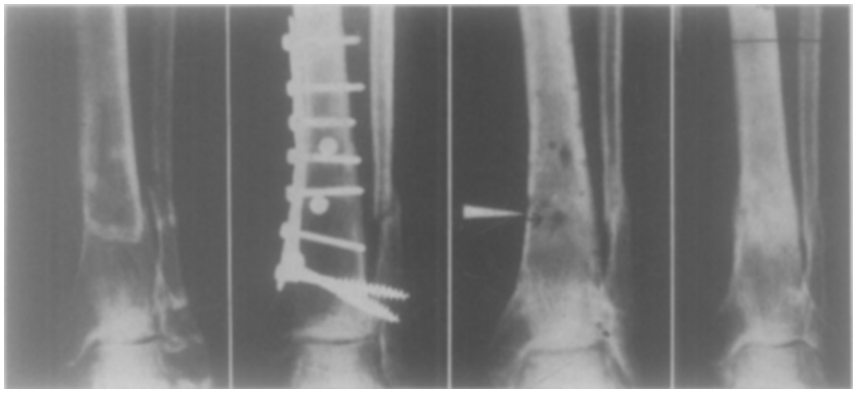


a b c d

CASE 3. A bilateral open comminuted tibial fracture; a + b = right side, c + d = left side.

4. R. A. 210910, building worker

Accident 20.10.66. Collided with a car while riding a moped. Unconscious on admission. Recovered consciousness relatively quickly. Alcohol intoxication. Open low comminuted left tibial fracture.
Op. 21.10.66: Open reduction + osteosynthesis with AO compression plate. A small skin defect was left over the anterior tibial tendon.
Op. 2.11.66: Partial skin graft.
Postoperative infection. Culture: Staph. aureus. Treated with Lincocin^{R}. 5.12.66 Flush-drainage. The skin was healed on 30.12.66.
X-ray 13.1.67: Fracture showed good position. Further ulceration. Growth of Staph. aureus. Lincocin® treatment continued, and Bacimycin® given locally. Secretion at times. A fistula gradually developed.
X-ray 20.7.67: osteitis.
Op. 9.8.67: Excision of osteitic area + bone graft. Postoperatively, plaster fixation and Lincocin®. No recurrence of infection.
The roentgenograms showed gradual healing. Taken off the sick-list on 28.9.68. Followed up 5 years after the accident: Condition good. Slight limitation of ankle movements. No secretion.



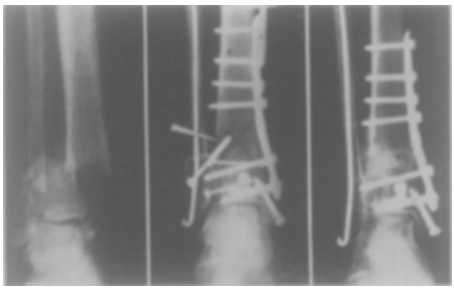
a b c d

CASE 4. Open distal tibial fracture. (a) The day of the accident, (b) after osteosynthesis. Osteitis developed (c) and was treated sucessfully with excision of the osteitic area and a bone graft. The leg was still free from infection four years after this operation.

5. I. Z. 040830, housewife

1959 cardiac infarction.
Accident 21.2.67. Fell from a hayloft on to a cement floor.
Low open tibial and fibular fractures on right side + fracture through medial malleolus + medial fracture of neck of femur on right side.

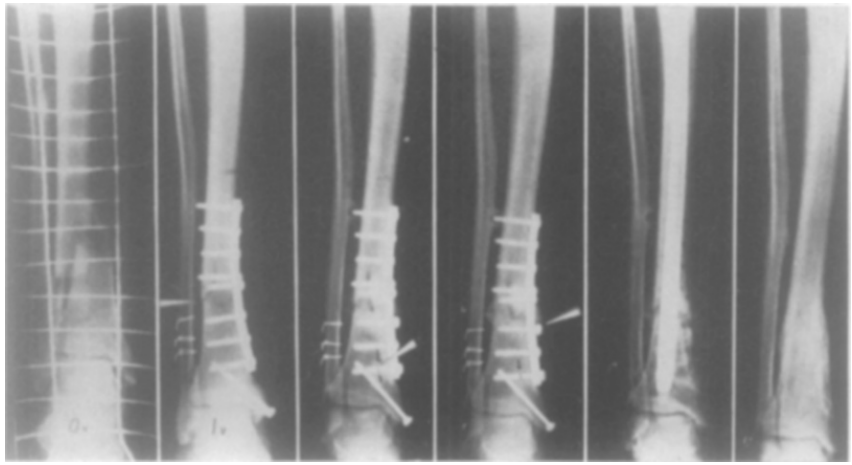
Op. 21.2.67: Open reduction + AO osteosynthesis of tibial and fibular fractures + fixation of medial malleolus with a screw. A lateral relieving skin incision was left open. The fractured femoral neck was treated by traction.
Op. 22.3.67: Johansson nailing of the fractured femoral neck. The skin and soft tissues of the lower leg had healed.
Postoperative roentgenograms satisfactory. Mobilized with the aid of walking supports.
X-ray Oct. 67: Pseudarthrosis in the tibia.
Op. 30.10.67: Removal of some screws + cancellous bone graft.
X-ray 26.1.68: Increasing callus formation. 5.9.68 fracture healed.
Followed up 4.5 years after the accident: Evaluation difficult owing to necrosis of femoral head after the fracture of the femoral neck + arthrosis of the knee. No definite symptoms from the tibial fracture. Full mobility in the ankle joint.
Included in Table 24.



CASE 5. Open distal tibial fracture. The screw marked by the arrow (b) showed signs of instability, and pseudarthrosis was therefore suspected. This screw was therefore removed, and at the same time a bone graft was performed (c). This gave complete stabilization of the fracture and the subsequent course was satisfactory.

6+7. L. H. 451218, carpenter

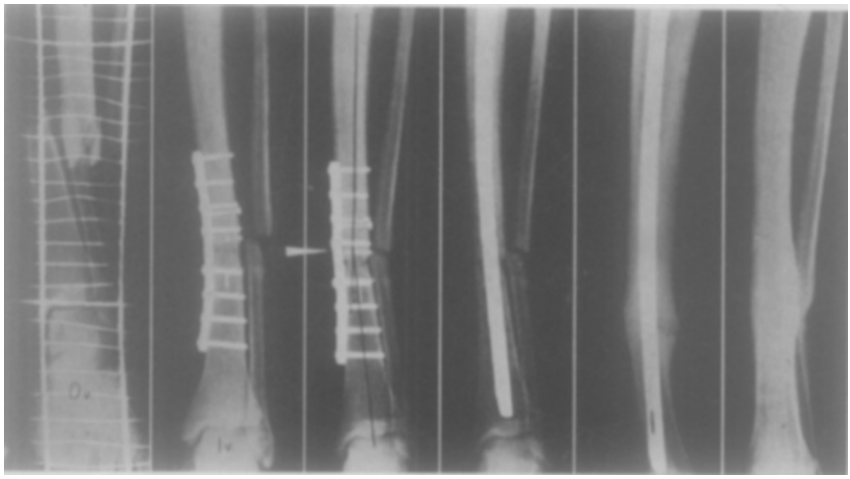
Accident 16.3.67. Automobile collision, driver.
Bilateral open comminuted tibial fractures + right-sided fracture of both malleoli + luxation fracture of right talus.
Op. 16.3.67: AO synthesis bilaterally. The wounds were left partly open. The skin and soft tissue injuries healed after some skin grafts. Discharged with a PTB plaster on 11.5.67.
Despite the PTB plaster refracture occurred, with *fracture of the plate*, in the left tibia (6) on 10.8.67.
Op. 14.8.67: Removal of AO plate and screws + intramedullary nailing after reaming of the medullary cavity.



a b c d e f

CASE 6 A. The right tibia in bilateral open fractures (a). The plate is bent to much too large an extent, giving poor cortical contact laterally - see arrow (b). Instability is manifested by loosening and fracture of a screw (c + d). Because of the endosteal callus, good stability was obtained by intramedullary nailing (e). Weight could be borne on the leg almost immediately. The definitive condition after extraction of the nail 2 years after nailing (f).

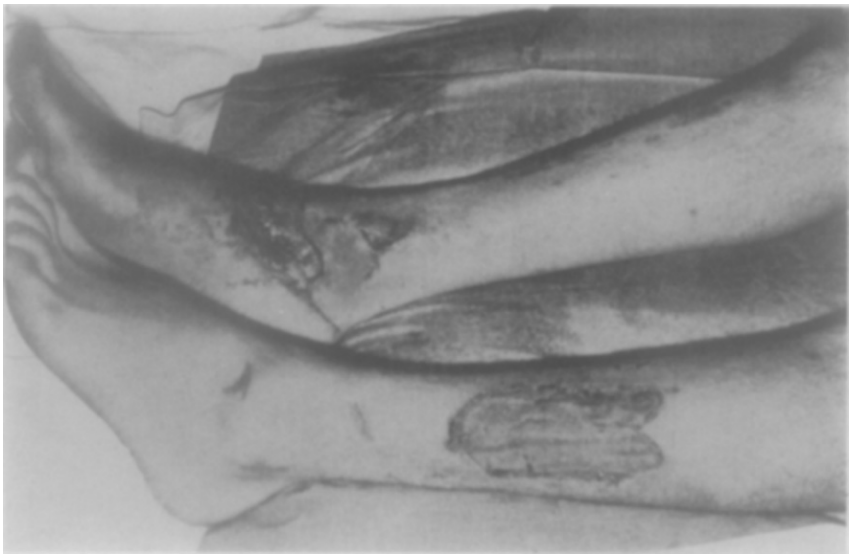
The fracture was stable postoperatively. Weight-bearing on the left leg was started after a few days. In the right tibia the fracture was still visible and very little callus had formed.
X-ray 23.2.68: *Fractured screw in right tibia* (7)
X-ray 5.4.68: Resorption around the plate and screws. Pseudarthrosis.
Op. 16.4.68: Removal of plate and screws + intramedullary reaming and intramedullary nailing.
The fracture was stable postoperatively. Bore weight on the leg after a few days. Started work 1.8.68 after roentgenograms had shown increasing callus bilaterally.
X-ray 31.7.69: Fractures healed.
Op. 15.4.70: Removal of intramedullary nail bilaterally.
Followed up 3.5 years after the accident: Both legs in good condition. Moderate pain in right foot. Working full-time as before.



a b c d e f

CASE 6 B. The left tibia in bilateral open fractures. Open comminuted fracture (a). Here also there is poor lateral contact (b), resulting in fracture of the plate after 5 months (c). The complication was treated with intramedullary reaming and nailing (d). Immediate weight-bearing was possible, and after a short time there were no symptoms. Considerable callus developed, however, with only slow disappearance of the fracture gap (e). No further measures were taken apart from extraction of the intramedullary nail, which operation was undertaken 2½ years after insertion of the nail (f).

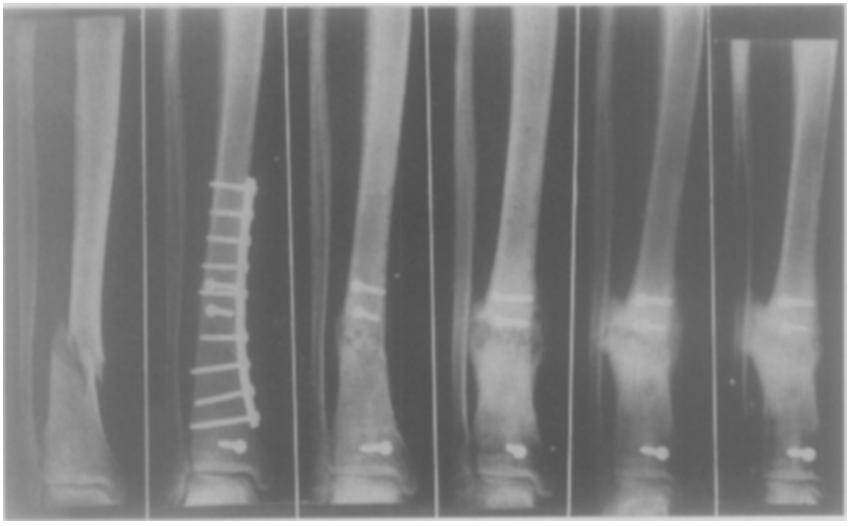
CASE 6 C. Photograph taken on the day after the accident, showing the extent of the soft tissue damage. A relieving incision is seen on the dorsal side of the left leg.



CASE 6 D. The wound surfaces which had been left open were subjected to split skin grafts performed in a few sessions, giving rapid definitive healing of the soft tissue injuries.

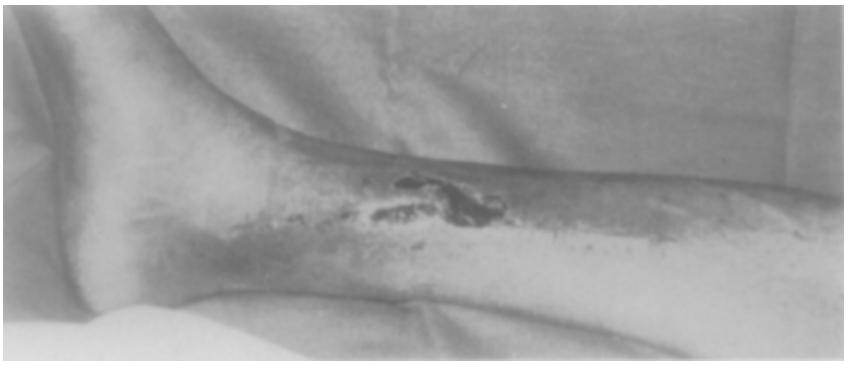
8. L. J. 281209, seaman

Accident 9.8.67. Under the influence of alcohol. Fell and hit his right leg against the edge of a metal plate. Closed tibial fracture. Some skin contusion.
Op. 9.8.67: AO osteosynthesis (the skin incision was clearly not made according to the principles of this treatment).
Postoperative marginal necrosis. After 1 month necrosis over the plate (see Fig.). Treatment: Lincocin^{R} + elevation of limb. Culture: Staph. aureus. Culture Dec. 67 negative. Slow healing of the wound.
Febr. 67, purulent secretion. Culture: Staph. albus.
Op. 12.12.68: Removal of plate and screws. The upper and lower compression screws were left in situ. A sequestrum in the fracture was excised. Plaster applied postoperatively and left on until 20.3.68, after which weight-bearing was increased gradually.
X-rays: Abundant callus, cavity seen anteriorly in the fracture.
Full weight-bearing since 1.9.68.
X-ray 17.1.69: Good callus formation. Started work 50% 14.2.69. 100% from 14.6.69.
Followed up 4½ years after the accident: Condition good. Slight swelling. No ulcer or secretion the last 2 years. Normal ankle mobility.



a b c d e f

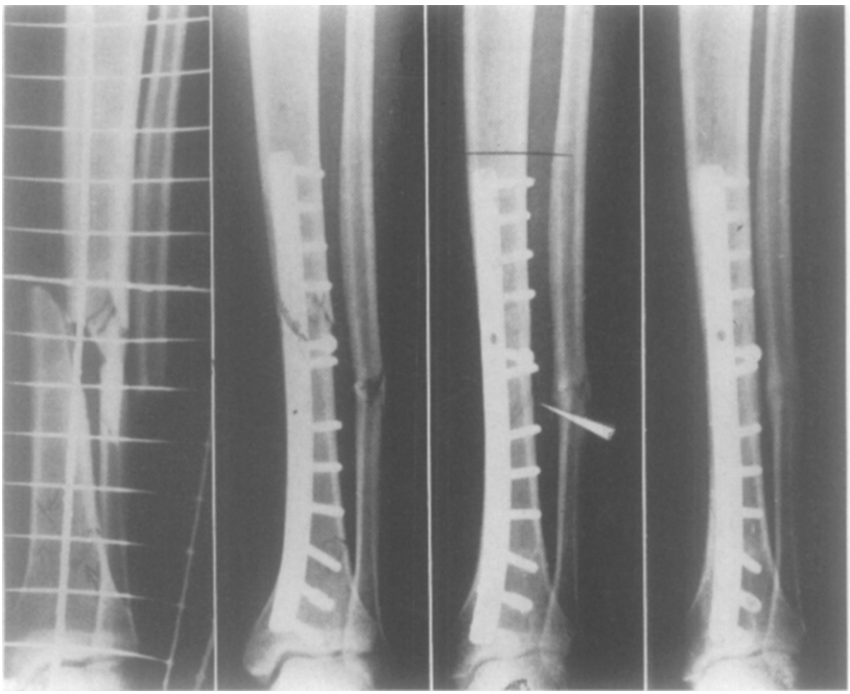
CASE 8 A. Primarily closed tibial fracture caused by direct trauma (a). The osteosynthesis was apparently satisfactory (b). Skin necrosis occurred postoperatively, however (see further under 8 B). The osteosynthesis material was removed after only 6 months and a sequestrum was removed (c), and plaster was then applied for six weeks. The large amount of callus indicated an irritating agent, but complete healing occurred with no further complications (f).



CASE 8 B. The surgeon in this case had not observed the prescribed rules concerning the position of the incision, as is evident in the photograph - the incision lies over the medial tibial surface. The skin necrosis comprises parts of the skin lying laterally to the incsion. On shedding of the necrotic areas the plate is exposed.

9. R. Z. 170123, factory worker

Accident 21.3.67. A heavy box fell on his left lower leg.
Closed comminuted tibial and fibular fractures + skin contusion.
Op. 21.3.67: AO plate osteosynthesis.
Initially no complications. X-rays satisfactory. Aug. 67, full weight-bearing. Started work as before in Nov. 67.
8.12.67: *Fell on ice.* Walked home. Subsequently had pain in left tibia. X-ray: Refracture. No dislocation. Plate intact. Was given crutches with no weight-bearing on left leg.
Full weight-bearing 22.2.68.
X-ray: Visible fracture but good callus.
Started work 11.3.68.
X-ray 31.10.68: Fractures healed.
Op. 14.2.69: Removal of plate and screws.
Followed up 3.5 years after the accident: Condition of leg excellent.

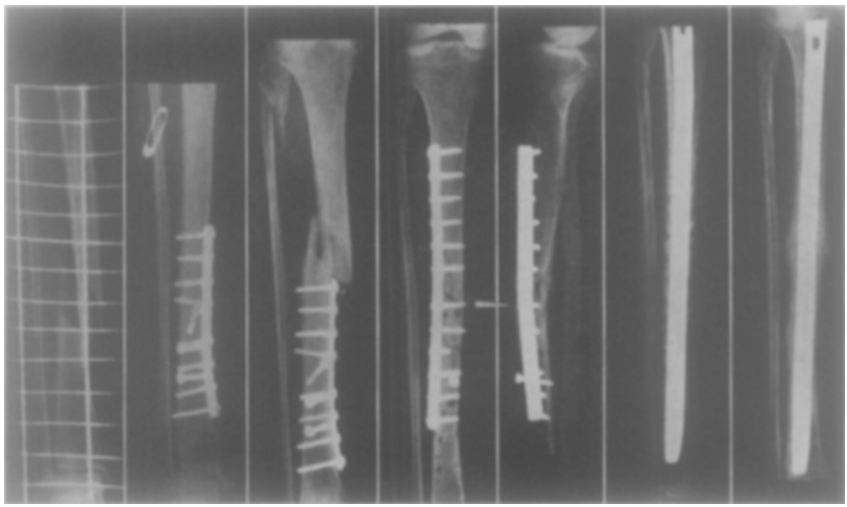


a b c d

CASE 9. Closed comminuted tibial fracture with fissures extending to the distal metaphysis (a). The plate osteosynthesis is essentially satisfactory (b). Further trauma 9 months after the first accident. Roentgenograms showed a refracture — see arrow (opposite the arrow at c) — but no signs of disturbance of the osteosynthesis material. Roentgenograms 2 months later showed good callus (d).

10. D. N. 210605

Nov. 67 right tibial fracture. Operation - AO osteosynthesis with plate and screws. The fracture healed with no complications. Removal of plate planned for autumn 69.
Accident 30.8.69. *Under the influence of alcohol.* Fell at home, and probably sustained further trauma. Now had an *open oblique fracture* over the old plate. Only skin perforation. *Because of alcoholic condition and marked swelling, she was treated primarily with traction.*
Op. 22.9.69: Removal of plate and screws. Osteosynthesis with 12-hole plate.
X-ray postoperatively: Almost exact fracture position. Discharged 2 weeks after operation.
Considerable *misuse of alcohol* after discharge from hospital. Slow callus formation. 50% weight- bearing 30.1.70. She probably bore full weight on the leg, however, when intoxicated.
Pain in the leg since Feb. 70.
X-ray 13.3.70: Fractured plate and refracture of tibia.



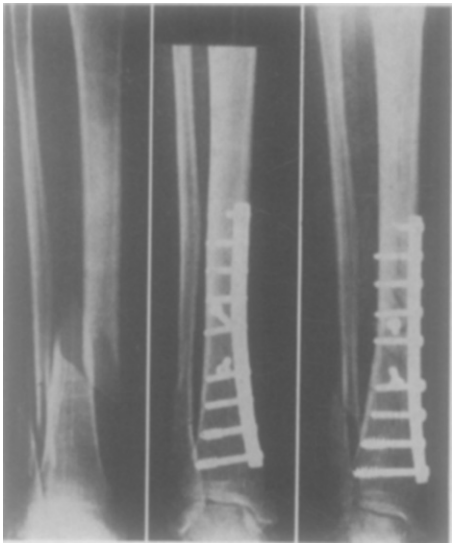
a b c d e f g

CASE 10. A relatively short oblique fracture with a fissure through the distal metaphysis (a). Treated with a neutralization plate and compression screws (b). Further trauma 1 year 10 months after the first accident, causing a splinter fracture above the plate (c). A new neutralization plate was applied (d). After a further 2 months the plate fractured (e). This was removed and intramedullary reaming and nailing were performed (f). After a further 12 months there was good consolidation of the fracture (g).

Op. 19.3.70: Removal of plate and screws, intramedullary nailing after reaming of the medullary cavity. The fracture was then stable. Full weight-bearing after a few days.
Follow-up examination 1 year after the second accident: Condition of leg excellent.
One month later sustained a fracture of a tibial condyle. Admitted to a clinic for alcoholics.

11. L. N. 310402, bookseller

Accident 15.2.67. Tripped on the edge of the pavement, under the influence of alcohol. Fell with his right leg beneath him. *Did not come to the hospital until 16.2.67.*
Closed distal longitudinal tibio-fibular fracture. Considerable swelling of soft tissues.
Op. 27:2.67: AO osteosynthesis with plate and screws.
X-ray postoperatively: Tibial fracture in exact position.
Started some weight-bearing after about 2 weeks. Aching and pain on weight-bearing.



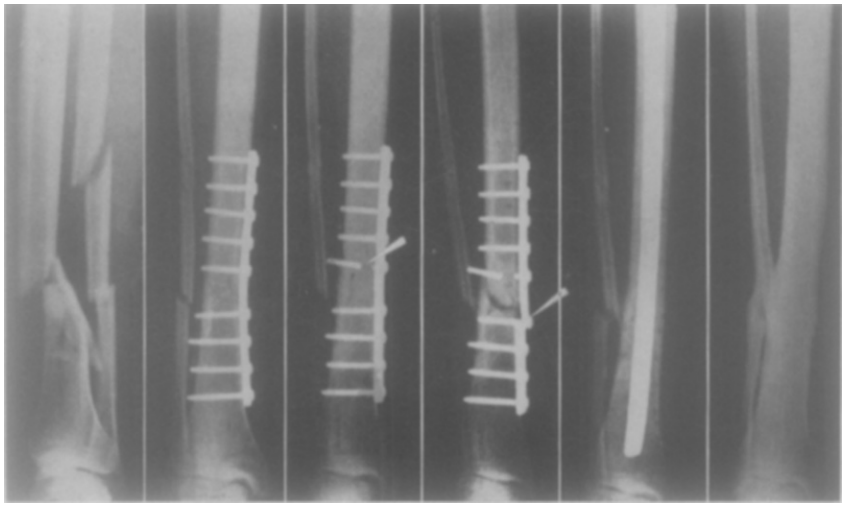
a b c

CASE 11. A relatively short oblique fracture (a), treated with a neutralization plate and compression screws (b). Weight-bearing too early caused dislocation of the fracture with a suggestion of valgus deformity (c). A fracture of the plate occurred, and after removal of the plate fixation was complemented by plaster splintage for 1 month.

X-ray 7.4.67: Slight valgus angulation and slight dislocation in the fracture.
11.4.67: Closed reduction. Some improvement of the fracture position. PTB splint applied. *Despite instructions, the patient soon put full weight on the leg without the splint.*
X-ray 10.8.67: Fractured plate. The tibial fracture was unstable. Plaster applied until 28.9.67 Started work 23.11.67.
Op. 15.8.67: Removal of plate.
Follow-up examination 3.5 years after the accident: Condition of leg good. (Slight valgus deformity).

12. B. H. 250416, bank accountant

Accident 29.12.67. Automobile collision (driver).
Open comminuted fracture of right tibia + right Monteggia fracture + concussion.
Op. 29.12.67: Open reduction + AO plate osteosynthesis. Relieving skin incision.
X-ray postoperatively: Position of fracture exact.



a b c d e f

CASE 12 A. A grade III open comminuted transverse fracture (a) treated with a compression plate. This resulted in a satisfactory fracture position (b). Five months after the accident roentgenograms revealed a broken screw (c), and some days later fracture of the plate (d). Intramedullary reaming and nailing were subsequently performed (e), and no further complications occurred.

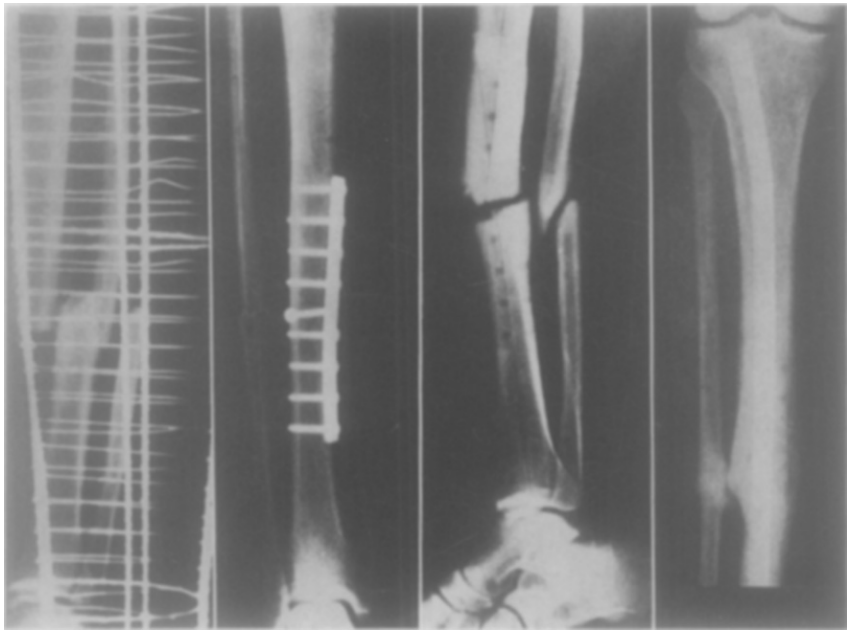
Op. 8.1.68: Skin graft.
Discharged after 1 month with PTB splint.
X-rays satisfactory. 28.3.68 slight weight-bearing. Started work April 68.
X-ray 30.5.68 showed loosened screw.
2.6.68, fracture of the plate and refracture of the tibia occurred while out walking.
Op. 12.6.68: Removal of osteosynthesis material + reaming of the medullary cavity and intramedullary nailing.
Fracture stable postoperatively. Started to bear weight on the leg after a few days.
X-ray 29.8.69: Fracture healed.
Op. 12.6.70: Removal of intramedullary nail.
Followed up 3 years after the accident: Condition execellent.

CASE 12 B. To prevent tension on the skin suture a relieving incision was made dorsally. There were no subsequent skin problems.

13. S. Z 470614, engineer

Accident 12.8.67. Collision during a football match.
Closed transverse facture through the right tibia and fibula.
Op. 12.8.67: Open reduction + AO osteosynthesis with plate and compression screws.
X-ray postoperatively: *Slight diastasis.*
Postoperative *marginal necrosis.* Treatment: elevation of the limb.
26.10.67: Slight weight-bearing.
23.11.67: Full weight-bearing. There was some pain on weight-bearing, however.
Sept. 68, fracture healed.
Op. as outpatient 19.9.68: Removal of plate and screws. Half a screw was left in owing to fracture of the screw during the operation.
Military service 21.10.68. The right foot stuck in a shoe-scraper 29.10.68.

The patient felt how the right leg fractured.
X-ray: Refracture. Sclerotic fracture ends.
Op. 4.11.68: Removal of screw remnant + reaming of the medullary cavity and intramedullary nailing.
Fracture stable postoperatively. Weight-bearing after a few days.
X-ray: Successful healing.
Follow-up examination 3 years after the accident: Condition excellent.



a b c d

CASE 13. Closed transverse fracture (a), treated with a compression plate (b). The osteosynthesis was satisfactory. One month after removal of the plate, refracture occurred during military service. The fracture line appeared to pass through the previous fracture zone (c), from which it seemed that the fracture had never healed completely. Treated with intramedullary reaming and nailing (d), after which healing took place with no complications.

14. R. G. 480116, factory worker

Accident 28.9.68. Motor-cycle accident.
Open comminuted transverse fracture of left tibia.
Op. 28.9.68: Revision, open reduction and AO plate osteosynthesis.
A small triangular wedge of bone was removed from the tibia. *The fracture cannot have been stable.*

X-ray postoperatively: Diastasis.
X-ray 31.10.68: Relatively wide fracture gap.
8.11.68. Sustained a slight blow on the left tibia from a door.
X-ray: Fractured plate and refracture of the tibia.
Op. 11.11.68: Removal of plate, reaming of the medullary cavity and intramedullary nailing, and bone graft.
X-ray postoperatively: Position of fracture good. Started full weight-bearing 28.3.69.
X-ray 23.1.70: Fracture healed.
Op. 18.9.70: Removal of intramedullary nail.
Followed up 2 years after the accident: Condition of leg good.

CASE 14. Open comminuted transverse fracture (a). The anterior wedge-shaped cortical fragment was removed at the plate osteosynthesis, resulting in a defect (b). There was diastasis of a few mm between the lateral cortical fragment surfaces. Six weeks after the operation the plate fractured (c). Intramedullary reaming and nailing were performed and the postoperative course was satisfactory (d).

15. H. P. 460408, craftsman

Accident 28.10.68. Autmobile collision (driver).
Bilateral open comminuted tibial fractures. *Extensive injuries to the skin and soft tissues of the right leg.* Fracture of femoral condyle in right knee. Injury to right posterior tibial artery. The *circulation was reduced in both feet.*
Op. 28.10.68: Left leg - Plaster splint + traction.
Right leg - Revision + *arterial suture* + AO plate osteosynthesis. A relatively large skin defect was left open. The fibular fracture was left.
Postoperatively, a right-sided peroneal paresis was also noted.
Op. 1.11.68: Right leg - Exploration of right common peroneal nerve + osteosynthesis with a Rush pin.
Left leg - Reduction and external fixation with a simple Hoffmann appliance.
Large necrotic areas in the muscle and skin developed in the right lower leg (see Fig.). The plate was completely uncovered.
Culture: Enterococci, proteus, coli, staph. albus.
Op. 15.11.68: Right leg - Removal of plate + fixation with a double Hoffmann appliance.
Op. 19.11.68: Reduction of fracture of right femoral condyle + screw osteosynthesis. The condition of the right lower leg was worse, with extensive necrosis of the muscle. Both the medial and lateral surfaces of the tibia were exposed.
Op. 20.12.68: Right below-knee amputation.
The stump healed after a revisional operation.
Pseudarthrosis developed in the left tibia.
Op. 2.4.69: Decortication + bone graft + plaster fixation.
There was gradual healing of the left tibia and of the fracture of the right femoral condyle.
Followed up 1.5 years after the accident: Some problems with the amputation stump. Worked occasionally part-time.
Included in Table 24 (6).

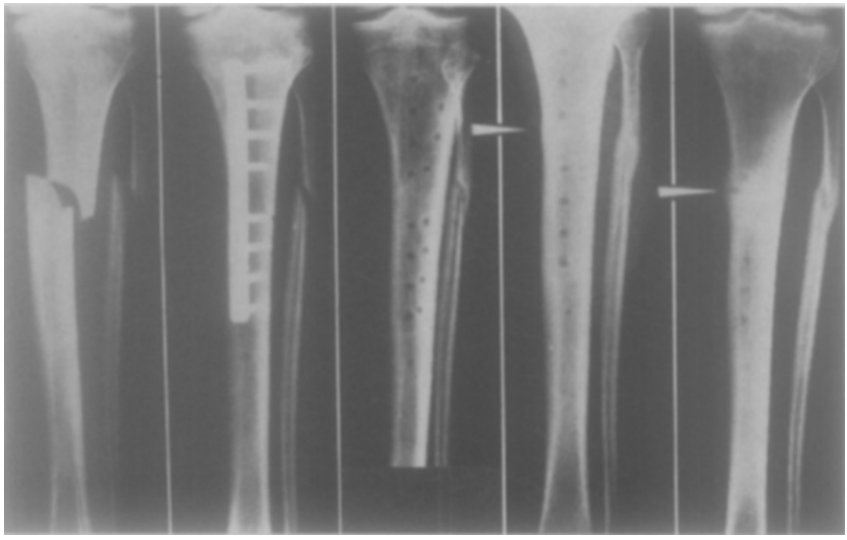
16. E. J. 121202, artist

Accident 27.12.67. Knocked down by a car when walking. Probably under the influence of alcohol.
Pelvic fracture + open *very dirty* comminuted tibial fracture on left side.
Op. 28.12.67: Open reduction + AO osteosynthesis with plate and compression screws.
Fracture in exact position postoperatively. Marginal necrosis after a few days. Gradually developed a large ulcerous cavity, and the plate was exposed. Culture: Alpha streptococci.
Treatment: Flush-drainage + Lincocin^{R} + plaster fixation.
X-ray 4.4 and 2.5.68. Poor callus. Screws loosened. Plaster continued.
X-ray 7.6.68: Angulation deformity.

The skin did not heal until Sept. 68. Hoffmann fixation planned, but the equipment was not available.
Op. 18.9.68: Removal of plate and screws + intramedullary nailing after reaming of the medullary cavity.
Gradual weight-bearing postoperatively. There was aching and pain on weight-bearing, however. Developed a fistula in May '70.
X-ray 9.9.70: The fracture was still visible.
Culture: Staph. albus.
Op. 3.11.70: Removal of intramedullary nail.
Fever peaks postoperatively. The secretion from the fistula continued for only a short time, and then stopped.
Follow-up examination 4 years after the accident: Condition acceptable. 5° varus deformity. Muscular atrophy. The skin was also healed. Subjectively very good. Some limitation of knee movements. No secretion the last year.

17. S. J. 070105, forestry worker

Accident 30.9.68. A tree fell over his left leg at work.
Closed proximal tibio-fibular fracture.
Op. 30.9.68: Reduction with AO plate osteosynthesis.
One screw passed through the fracture gap.



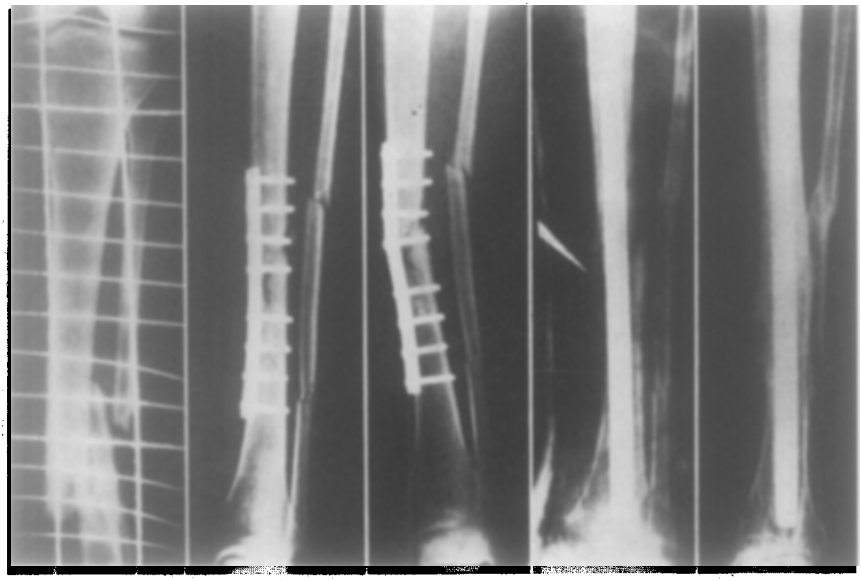
a b c d e

CASE 17. A closed proximal tibial fracture (a). Compression osteosynthesis was performed (b). Good healing. The osteosynthesis material was removed 18 months after the accident (c). Further trauma occurred 3 months later, causing a small fissure (d). Treated with plaster. After a further few months there was bridging callus corresponding to the fissure (e).

No complications postoperatively. Started weight-bearing Jan '69.
Full weight-bearing March 69.
X-ray 13.9.69: Fractures healed.
Op. 13.3.70: Removal of plate and screws.
Moderate trauma 9.6.70: Refracture. Plaster applied for 4 months.
Followed up 4 years after the accident.
Condition acceptable. Fracture healed. Full ankle mobility. Tendency to swelling.

18. B. J. 430705, caretaker

Accident 20.8.66. Alcohol intxication. Knocked down by a car when walking. Open comminuted tibial fracture on right side, closed comminuted tibial fracture on left side.

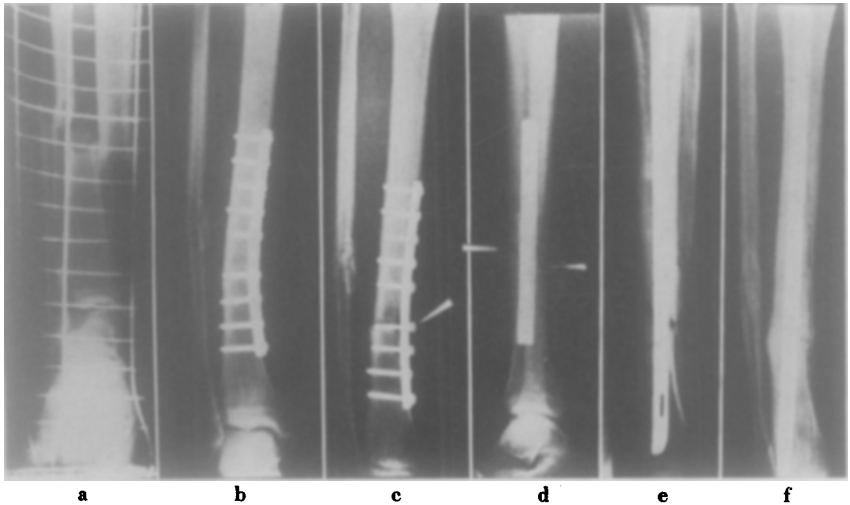


CASE 18. A closed comminuted transverse fracture of the left tibia (a). An open comminuted fracture of the right tibia was treated with a neutralization plate complemented with cancellous bone grafting and healed without complications. On the left side the positions of the osteosynthesis material and fracture after treatment with a compression plate were apparently satisfactory (b). Three months after the accident fracture of the plate and refracture of the tibia occurred. After a period of plaster fixation intramedullary reaming and nailing, together with a bone graft, were performed (the arrow at d shows the bone graft). Plaster was applied for 3 months because of uncertainty of the rotational stability. There was mature bone reconstruction after a further 12 months (e).

Op. 20.8.66: Reduction + AO plate osteosynthesis bilaterally, and bone graft in addition on the right side.
X-ray postoperatively: Right side 4 mm diastasis. Exact position on the left side. Discharged 17.10.66 (2 months). Walked with sticks.
X-ray 10.11.66: satisfactory.
18.11.66 his left leg gave way when he got out of bed.
X-ray: *Fractured plate* + refracture of tibia. Plaster splint.
X-ray 22.12.66: Right leg satisfactory. Left tibia - open angulation posteriorly, some periosteal callus.
X-ray right leg 25.2.67: Fracture healed.
Op. 27.2.67: Removal of plate from left tibia + intramedullary nailing after reaming of medullary cavity + bone graft. The fracture was not stable, however, as the nail had perforated the anterior surface of the tibia. Plaster was therefore applied, and kept on until 25.5.67. Full weight-bearing 10.8.67. Started work 12.2.68.
O. 8.5.68: Removal of plate and screws from right tibia.
Follow-up examination 4 years after the accident: Excellent condition bilaterally. Intramedullary nail still in situ.

19. U. W.470121, crane operator

Accident 28.4.68. Kicked during a football match.
Closed transverse tibio-fibular fracture on right side.



a b c d e f

CASE 19. A closed transverse tibial fracture (a), treated with a compression plate, which was curved slightly too much. Most probably for this reason there was poor bone contact on the lateral side. The instability was manifested in time in a moveable plate and resorption zones around the screws (c). Resorption was also seen in the fracture gap itself (d). Intramedullary nailing was therefore undertaken (e), and the subsequent course was free from complications (f).

Op. 28.4.68: AO osteosynthesis with plate and screws. *A few small fragments were removed. A screw was placed in the fracture gap.*
X-ray postoperatively: Slight diastasis.
Discharged after 2 weeks, with a PTB splint. Started weight-bearing 50% 26.7.68 (3 months).
X-ray 31.5.68: Slight medial angulation.
X-ray 26.7.68: Poor callus formation, resorption zone.
X-ray 6.9-68: Periosteal callus. Resorption around the screw.
18.10.68, the plate was moveable.
Op. 12.11.68: Removal of plate and screws + intramedullary nailing after reaming of medullary cavity. The fracture was then stable. Bore weight on the leg after a few days.
Started work 16.6.69.
X-rays: gradual healing.
Op. 29.9.70: Removal of intramedullary nail.
Follow-up examinations 2.5 years after the accident: Condition of leg excellent.

20. B.B. 450325, male nurse

Accident 3.6.69. Collided with a car when riding a motor-cycle. Left femoral fracture + open transverse fracture of left tibia.
Op. 3.6.69: Open reduction + AO plate osteosynthesis of tibial fracture + tibial traction.
X-ray postoperatively: The fracture position was almost exact.
Op. 13.6.69: Intramedullary nailing of the femoral fracture after reaming of the medullary cavity.
Transferred to his local hospital 20.6.69. After a few days signs of infection were noted in the tibia and trochanteric region.
Culture: Staph. aureus. Treated with Micropenin®.
X-rays: Gradual healing. The infection subsided after a few months. Partial weight-bearing after 6 months. Full weight-bearing after 8.5 months. Started work after 18 months.
Followed up 2.5 years after the accident: Excellent condition. No signs of infection.

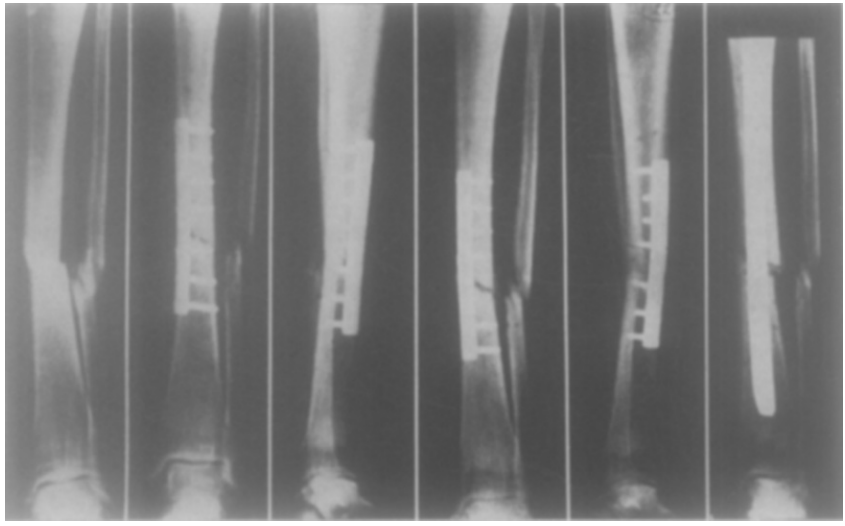
21. S.D. 491210

Accident 21.5.69. Alcohol intoxication. Knocked down by a car when walking. Open comminuted fracture of right tibia.
Op. 22.5.69: AO osteosynthesis with plate and compression screws.
X-ray postoperatively: Position of fracture exact. Discharged after 1 week. Did not come for check-up until 4.7.69. Poor mobility in ankle joint, and swelling. *Had probably started weight-bearing very early.*
While out walking an 18.10.69 he felt a « snap » in the lower leg.
X-ray: Refracture and fracture of the plate. Plaster applied.
X-ray 28.11.69: Angulation deformity. Plaster continued.
X-ray 26.2.70: Pseudarthrosis.
Op. 4.3.70: Removal of plate and screws + intramedullary nailing after reaming of the medullary cavity.

Postoperative course uneventful. Discharged 11.3.70. Did not come for further examinations.
Followed up 2.5 years after the accident. Condition excellent.

22. J. G. 891230, retired

Accident 5.9.69. Knocked down by a car while walking.
Dislocation of right shoulder + closed transverse fracture of left tibia and fibula.
Closed reduction of shoulder dislocation.
Op. 5.9.69: Osteosynthesis with AO plate.
X-ray postoperatively: Diastasis.
Transferred to Kungsgärdet Hospital, Uppsala, 26.9.69, with a PTB splint.
Full weight-bearing after 4 months.
9.1.70, pain in the leg.
X-ray: Refracture and *fracture of plate.*
Op. 15.1.70: Removal of plate and screws + intramedullary nailing after reaming of medullary cavity.
X-ray postoperatively: Fracture position good. Weight-bearing gradually increased.



a b c d e f

CASE 22. A closed transverse tibial fracture (a), treated with compression osteosynthesis. Roentgenograms showed some diastasis (b + c). After 4 months there was fracture of the plate and refracture of the tibia (d + e). Treated with intramedullary reaming and nailing (f)

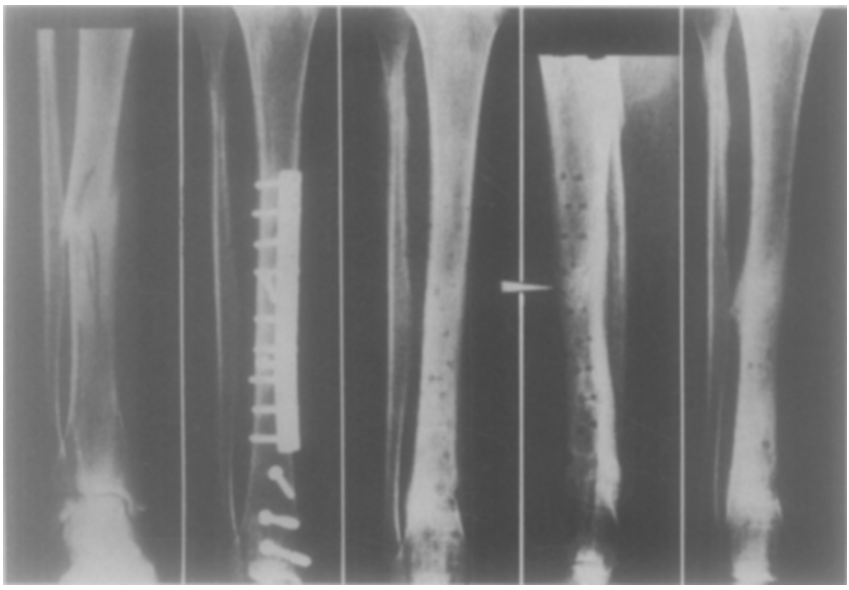
X-ray 24.10.70: Good callus formation.
Follow-up examination 1 year after the accident: Condition of leg acceptable (swelling, tendency to eczema). Fracture healed. Good mobility of the ankle joint. No subjective symptoms.

23. R. Ö. 531119, student

Accident 3.6.69. Kicked during a football match.
Closed transverse fracture of right tibia and fibula.
Treated in his local hospital with *closed reduction and plaster.*
Fracture position not satisfactory. To University Hospital, Uppsala in 19.6.69.
Op. 23.6.69: Osteosynthesis with plate and compression screws.
X-ray postoperatively: Position of fracture exact.
Used crutches, with no weight-bearing on the right leg, until Oct. 69.
Sustained a blow on the right tibia during an *ice-hockey match 5.3.70.*
A haematoma developed and subsequently *perforation of the skin.*
X-ray 12.5.70: Pseudarthrosis.
Op. 3.6.70: Removal of plate and screws + intramedullary nailing after reaming of medullary cavity.
The fracture was stable. Bore weight on the leg after a few days.
X-ray 15.12.70: Resorption around the nail. Pseudarthrosis.
Op. 9.2.71: The nail was replaced by a coarser one. The fracture was subsequently stable. Weight-bearing.
Follow-up examination 1.5 years after the accident: Condition of leg good (Relatively short time after the last operation).

24. M. P. 330413, housewife

Accident 2.7.69. Under the influence of alcohol she jumped out from a window on the 1st floor.
Longitudinal closed tibial fracture on the right side.
Op. 3.7.69: AO osteosynthesis with plate and screws.
X-ray postoperatively: Position of fracture exact.
Rapid mobilization, discharged after 1 week. Partial weight-bearing after 1.5 months.
Sept. 69 metallosis. Necrosis developed over the plate. Pain in fracture area.
X-ray: The fracture was healing.
Op. 21.11.69: Removal of plate and screws.
Postoperatively, PTB splint until Jan 70, after which she started to bear weight on the leg.
18.1.70, a « snap » was felt in the leg.
X-ray: Nothing abnormal. Treatment: no weight-bearing on leg.
X-ray 5.3.70: The fracture is visible, in a good position and with considerable callus. Full weight-bearing allowed. Follow-up examination 1.5 years after the accident: Condition of leg execellent.



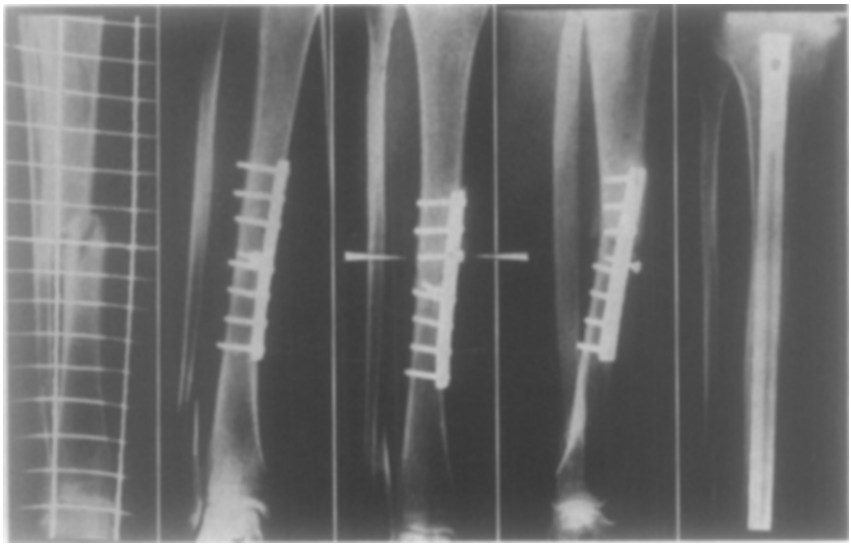
a b c d e

CASE 24. A longitudinal closed tibial fracture with involvement of the distal articular surface (a). Osteosynthesis with a neutralization plate and compression screws (b) was performed. Metallosis developed, with pain and some skin necrosis over the plate. This necessitated removal of the plate after only 4½ months. A PTB splint was applied for about 2 months postoperatively to prevent weight-bearing. Full weight was then borne on the leg and the patient had pain, but no fissure or fracture was observed (c). Only after a further 2 months was a fracture line (d) discovered which filled with considerable periosteal callus after 2 more months (e).

25. B. J. 290511, car paint sprayer, musician

Known *alcoholic*. 1961 fracture of humerus.
Accident 11.10.66. Knocked down by a car. *Intoxicated.*
Closed transverse fracture of right tibia.
Op. 12.10.66: Open reduction + AO plate osteosynthesis.
Small triangular wedge of bone absent. Otherwise a good position. One month later he sustained a further minor injury. Readmitted with haematoma. Probably *bore weight on the leg very early.*
X-ray 10.11 and 24.11.66: Position unchanged.
X-ray 9.1 and 9.2.67: Angulation deformity, periosteal callus.
Loosed screw: Instability.
Op. 22.2.67: Removal of plate and screws + intramedullary nailing after reaming of the medullary cavity.

The fracture was subsequently stable. Bore weight on the leg after a few days.
15.6.67: The fracture was healed both clinically and roentgenologically. Followed up 5 years after the accident: Condition of leg excellent. Intramedullary nail removed.



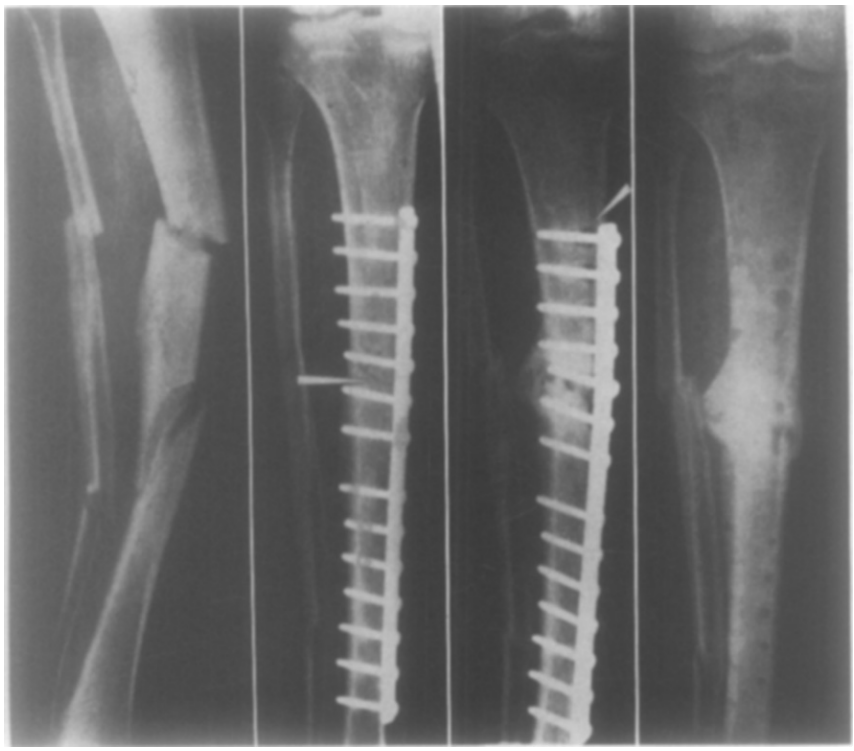
a b c d e

CASE 25. A closed transverse tibial fracture (a), treated with a compression plate and compression screws which resulted in a satisfactory position (b). After very early weight-bearing some screws loosened and irritation callus was observed (c). After some further time there was some angulation of the fracture (d). The plate was removed and intramedullary reaming and nailing were performed, which resulted in an exact fracture position (e) and a complication-free healing course.

26. D. A. 920205, retired

Accident 28.11.66. Knocked down by a car.
Closed right-sided double fracture with a dm-long intermediate fragment in the tibia (+ broken tooth).
Op. 28.11.66: AO osteosynthesis with compression plate and screws.
Outpatient examination 23.4.67: Instability of upper fracture. Plaster applied.
X-ray 27.4.67: Distal fracture healed. Periosteal callus had formed proximally. Some weight-bearing allowed.
X-ray 25.5.67: Resorption around the upper screws. Bending of the plate.
8.8.67: A fistula had developed. Fracture unstable. Culture: negative.

Op. 9.8.67: Removal of AO-plate and screws. Plaster applied.
X-ray 28.9.69: Bridging callus. Clinically healed. Thereafter no symptoms from the fracture. Developed carcinoma of the prostate and a chronic infection of the urinary tract.
At follow-up examination 4.5 years after the accident the patient was confined to bed. He had never borne full weight on the leg. No subjective symptoms from the fracture.
Included in Table 24 (3).



a b c d

CASE 26. A closed comminuted tibial fracture with a dm-long intermediate fragment. After compression osteosynthesis the screws and fracture were in a good position, although the upper fracture showed an apparently negligible diastasis (see arrow at b). Resorption gradually occurred around the uppermost screws and callus developed, especially laterally, signs indicating instability. After removal of the plate, plaster was applied for a time and bridging callus formed.

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