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From the Department of Orthopaedic Surgery, Lund University Hospital in Lund, Sweden.

Fracture of the Tibial Shaft Treated by Primary Operation and Early Weight-Bearing

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CONTENTS

FIGURES

We have still a long way to go before the best method of treating a fracture of the shaft of the tibia can be stated with finality. I feel sure that a closed method will eventually prevail, but we need mechanical aids to improve our control of the bone fragments. It is possible time will show that an intramedullary rod, introduced through the tibial tubercle, without exposing the fracture site, will be enough to enhance alignment as an adjuvant to closed methods. Used in this simple way the intramedullary rod will not be responsible for immobilisation; it will merely control alignment and prevent slipping of the reduced fracture.

John Charnley 1961.

We regard immediate open reduction with internal fixation as the best method of avoiding further soft-tissue damage, reducing the infection rate and healing the fracture in a correct anatomical position.

Henning Höjer, Jan Gillquist and Sten-Otto Liljedahl, 1977.

1. INTRODUCTION

The treatment of fractures of the shaft of the tibia has remained a subject of vigorous debate for several decades. Hardly any other important fracture has inspired such a broad spectrum of opinion as regards optimal treatment; the extreme belief in open surgery and rigid fixation promoted by the AO-group has fueled a reaction from Dehne et al. (1961), Sarmiento (1967, 1970, 1974) and their followers who have demonstrated that closed treatment, only, can prevent serious complications. Between these extremes a more eclectic approach has emerged. Bauer et al. (1962) have shown that the incidence of deep infection and poor results are directly correlated to the cause of the fracture. They proposed that the extent of soft tissue rather than bone injury should guide the choice of treatment; open surgery and internal fixation would be well tolerated in low energy fractures but quite hazardous in high energy fractures. This hypothesis was confirmed by Edwards (1965) in a controlled prospective series of 161 displaced fractures with but one case of deep infection.

The fact that deep infection in fractures of the tibia can be virtually avoided does not mean that treatment routines cannot be improved and simplified. Edwards usually kept his fractures in a full leg-length plaster without weight-bearing until the fracture healed; in open transverse fractures this treatment could last a year or more. By contrast, Dehne et al. (1961), Brown and Urban (1969) and Sarmiento (1967, 1970, 1974) have shown that the tibial fracture tolerates early weight-bearing but they seem to have accepted rather serious shortening and malalignment.

The basis for the present investigation was to combine the principles of Edwards and Sarmiento. The fractures were thus subjected to active primary treatment with open surgery and internal fixation in displaced longitudinal fractures and closed intramedullary nailing of displaced transverse fractures and they were then allowed early weight-bearing with free knee motion in a below-the-knee cast. Already from the start the investigation was planned to permit a close comparison not only with Edwards's series but also with Olerud and Karlström's (1972a) review of tibial fractures treated by the AO compression plate. In order to simplify this comparison the definitions and terminology used by Edwards (1965) and/or Olerud and Karlström (1972a) have been used.

II. MATERIAL

This prospective investigation was started August 1, 1973 and ended June 30, 1976. The source material comprised all patients 15 years and older with a fracture of the tibia between the tibial tuberosity and 3 cm proximal to the ankle joint in whom primary treatment was started at the Department of Orthopaedics in Lund during the period of investigation and who did not receive secondary treatment elsewhere. The following groups were excluded from the source material.

(1) 17 patients who received primary treatment elsewhere;
(2) 11 patients who received secondary treatment elsewhere;
(3) 10 patients with 11 fractures who had other injury or disease which prevented early mobilisation with weight-bearing (Table 1).
(4) 3 patients who were never subjected to early weight-bearing because the surgeons in charge had misunderstood the agreed treatment schedule.
(5) 3 patients with 4 fractures in which local skin- or other soft tissue problems were thought to prevent the treatment schedule. One of these patients had such extreme obesity that the PTB-plaster was judged not to give sufficient stability to her rather proximal fracture. One patient was an 87-year old man with such fragile skin that it was deemed unwise to apply a non-padded plaster early. One patient with bilateral tibial fractures had a crush injury of the left popliteal artery and very slow healing of the soft tissues.

Table 1.
Fractures not subjected to early weight-bearing

Multiple injury or disease		11
Skull injury	2	
Thoracic and abdominal injury	1	
Pelvic and/or femoral fracture	6	
Senility	2	
By mistake		3
Soft tissue problems		4
Total		18

In none of the 13 patients in groups 3 and 4 above did the fracture itself prevent early weight-bearing.

After exclusion of the above patients, the base material of the investigation comprised 105 patients. Two of these had bilateral fractures and three sustained re-fracture after the initial fracture had healed. In all three the re-fracture was caused by adequate trauma; in two of these the fracture occurred distant to the initial fracture. Therefore these three re-fractures were regarded as fresh fractures. The base material thus comprised 110 fractures of the tibia (Figure 1).

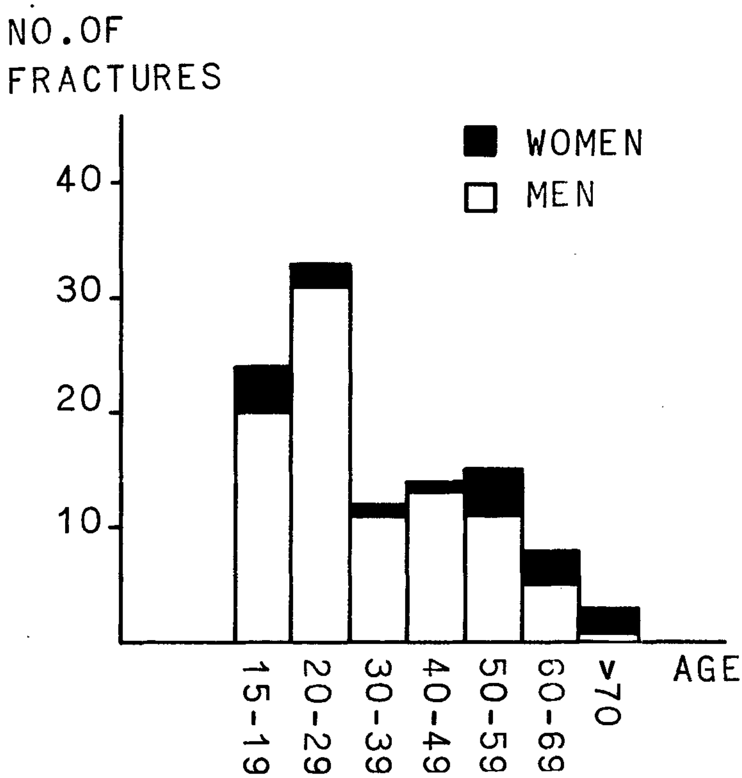

Fig. 1
Age and sex distribution

Classification of the fractures (Table II)

The fractures were classified according to Edwards (1965) with but minor modifications.

(1). Longitudinal vs transverse fractures. Longitudinal fractures were defined as such fractures in which the fracture line formed an angle of less than 45° with the long axis of the diaphysis. All other fractures were classified as transverse. An additional classification was introduced by distinction between simple transverse fractures with an angle close to 90° and short oblique fractures with an angle less than 90°.

(2) Displaced fractures. Fractures with minimal displacement were classified as non-displaced. Contrary to Edwards (1965) no attempt was made to sub-classify the displaced fractures; before X-ray examination all grossly displaced fractures were reduced and in six fractures traction was applied to the calcaneus. In the displaced fractures the fibula was not fractured in two longitudinal fractures, six closed transverse fractures and six open transverse fractures.

(3) Comminution (Table III). Fractures with an intermediary fragment larger than half the diameter of the diaphysis were classified as comminuted. Comminuted fractures with additional intermediary fragments were classified as grossly comminuted. When the diaphysis had fractured at two separate levels the fracture was classified as a double fracture.

(4) Closed vs open fractures. The size of the wound is shown in Table IV. In all the open longitudinal fractures the wounds were obviously caused by simple piercing of the skin from within.

(5) Fracture level (Table V). Edwards (1965) had recognized three fracture levels, proximal midshaft and distal. As it now seems well established that the healing conditions of truly diaphyseal fractures is the same regardless of level (Ellis 1958b, Nicoll 1964, Edwards 1965, Hoaglund and States 1967) it seemed more relevant to distinguish between diaphyseal and metaphyseal fractures.

Table II.
Classification of tibial shaft fractures (Edwards 1965).

	Present series Number	%	Uppsala series Number	%	Malmö series Number	%
1. Displaced longitudinal closed	24	22	44	33	47	26
2. Displaced longitudinal open	5	4	6	4	5	3
3. Non-displaced longitudinal open	-	-	-	-	-	-
4. Displaced transverse closed	37	34	46	34	62	34
5. Displaced transverse open	27	24	38	28	47	26
6. Non-displaced transverse open	-	-	-	-	-	-
7. Non-displaced transverse closed	16	15	1	1	11	6
8. Non-displaced longitudinal closed	1	1	-	-	9	5
Total	110	100	135	100	181	100

The Uppsala series refers to Olerud and Karlström 1972a.
The Malmö series refers to Edwards's prospective series (1965).

Table III.

Further classification of displaced transverse fractures of the tibial shaft

	Closed	Open	Total
Simple transverse fractures	13	5	18
Short oblique fractures	11	8	19
Comminuted fractures	8	10	18
Severely comminuted fractures	1	1	2
Double fractures	4	3	7
Total	37	27	64

Table IV.

The size of the wound associated with the tibial fractures

	≤1 cm	2-5 cm	6-10 cm	>10 cm	Total
Longitudinal fractures	5				5
Simple transverse fractures	1	4			5
Short oblique fractures	5	1	1	1	8
Comminuted fractures	1	8		1	10
Severely comminuted fractures	1				1
Double fractures	2	1			3
Total	15	14	1	2	32

Table V.

Fracture level

Proximal metaphysis	1
Diaphysis	96
Distal metaphysis	13
Total	110

Cause of the fractures (Table VI)

Traffic injury accounted for 40 % of the fractures; half of those occurred in patients riding mopeds or motor cycles. All sport fractures were soccer injuries; the lack of ski injuries is explained by the almost total absence of snow in southern Sweden during the investigation period. As regards the fractures caused by a fall, a height of 3 metres distinguished between low and high energy fractures.

Associated injury (Table VII)

Eleven fractures occurred in patients with multiple injuries. Nine of these were victims of traffic accidents, one fell from a height of 4 metres and one was involved in the collapse of a building scaffold.

Table VI.
Cause of tibial fracture

	No.
Severe violence	
Pedestrian	13
Moped- or motorcyclist	21
Cyclist in collision with a car	2
Car driver or passenger	8
Fall from a height of more than 3 metres	3
Blow from a heavy object or a crush injury	8
Total	55
Moderate violence	
Soccer injury	29
Single bicycle accident	1
Fall at ground level or from a low height	25
Total	55

Table VII.
Associated injuries

Head injury	3
Vertebral fracture	1
Pelvic fracture	2
Femoral fracture	1
Clavicular fracture	1
Scapular fracture	4
Humeral fracture	2
Radial fracture	1
Foot fracture	2
Spleen rupture	1
Brachial plexus injury	1
Total	19

These 19 injuries occurred in 11 patients.

III. METHODS

The aim of this investigation was (1) to provide primary definitive treatment as soon as possible, (2) to institute early weight-bearing in a PTB-plaster and (3) to do a follow-up not less than 6 months after the fracture.

Primary treatment (Table IX).

All treatment before the application of the PTB-plaster was defined as primary treatment. Operations were planned to be performed as early as possible; this meant that the operations were carried out by the surgeon on duty and therefore the number of surgeons involved at this stage was quite large, some 15. In 60 fractures the operation was performed within 24 hours, usually less than 12 hours, and in 10 fractures the operation was delayed 24 hours or more (Table VIII). The reason for this delay was concomitant injury or disease in six fractures (two head injuries, one ruptured spleen, one vertebral fracture, one intoxication, one poor skin), unacceptable initial reduction in two fractures, delays in transportation from site of injury to the hospital in one fracture, and unknown reasons in one fracture.

Table VIII.
Hours between injury and definitive operative treatment

	1-6	7-12	13-24	>24
Longitudinal fractures	5	8	8	3
Transverse closed fractures	7	13	1	5
Transverse open fractures	9	6	3	2
Total	21	27	12	10

In accordance with Edwards (1965) the cause of the fractures and thus the extent of skin damage decided the choice of primary treatment. A distinction was therefore made between longitudinal and transverse fractures.

(1) Longitudinal fractures. Open reduction and osteosynthesis was carried out whenever displacement was deemed more than acceptable. One, usually two or occasionally more screws were chosen rather than encircling wires which provide less stability (Lindahl 1964) and may cause osteonecrosis (Norberg 1977). In 18 of 29 displaced fractures osteosynthesis with screw(s) was thus performed. In one fracture an encircling wire was used because the fixation with screws did not succeed. In five fractures closed reduction and

Table IX.

Primary treatment in tibial fractures

Type of fracture	Plaster only	Closed reduction	Rush-pin	Screw(s)	Encircling wire	Transfixation	Total
Displaced longitudinal closed	3	2	4	14	1		24
Displaced longitudinal open			1	4			5
Displaced transverse closed	4	6	25			2	37
Displaced transverse open	4	4	18	1			27
Non-displaced transverse closed	16						16
Non-displaced longitudinal closed	1						1
Total	28	12	48	19	1	2	110

Plaster was used in all cases and all fractures subjected to osteosynthesis or transfixation were reduced.

osteosynthesis with a Rush-pin was preferred because of either marked swelling or osteopenia. In the remaining five fractures an acceptable position was obtained without need for an open operation. In the five open fractures the wound was closed with primary suture after excision of the wound margins.

(2) Transverse fractures. Non-displaced fractures were treated with a long-leg cast only. Displaced fractures which could be stably reduced by closed methods, likewise had a long-leg cast only. If stable reduction could not be obtained, blind nailing with a Rush-pin was performed. In comminuted fractures where the Rush-pin did not give sufficient stability, transfixation in plaster was preferred. The Rush-pin was introduced from behind the tibial tuberosity after length-wise splitting of the patellar ligament, so as to cause as little irritation as possible from the unpadded PTB-cast. The Rush-pin was chosen because it had been used successfully by Edwards (1965) and had been used for a long time in this department. Three-point fixation (Rush 1955) was not aimed at; the only purpose of the pin was to prevent shortening of the fracture by sliding of the fragments. In all 27 open transverse fractures the wounds were sutured primarily with a relaxing incision in only one fracture. In 18 fractures the displacement was reduced to a stable position without use of osteosynthesis. In 43 fractures fixation was obtained with a Rush-pin. One open, short oblique fracture in the distal metaphysis was stabilized with a screw. Transfixation was used in two comminuted fractures.

(3) Antibiotic treatment. All open fractures received antibiotics immediately on admission (Bowers et al. 1973, Patzakis et al, 1974, Gustilo and Anderson 1976, Lidgren and Sandegård 1977). As a principle fractures with small wounds were treated with penicillin and fractures with large wounds with a combination of penicillin and ampicillin. In cases where there was judged to be a risk of infection with Staphylococcus aureus resistent to penicillin, the latter was substituted by cloxacillin. In order to simplify this schedule all open fractures were treated with cephalothin/cephalexin during the last six months of the investigation.

(4) Primary plaster fixation. All fractures were initially stabilized with a long-leg plaster and the patients were mobilized with crutches without weight-bearing as soon as possible, usually within the first couple of days.

(5) Additional primary treatment (Table X). 19 fractures required a total of eight cast removals for re-reduction under anaesthesia and 14 wedgings. In one of the re-reductions the Rush-pin was partly extracted and re-inserted in a better position. All wedgings were made on the long-leg cast. If the fracture angulated after the long-leg

cast had been changed to a PTB-cast, a new PTB-cast was applied as recommended by Sarmiento (1974); no attempts were made to wedge the PTB-cast.

In one fracture a fasciotomy was performed because of threatening compartment syndrome; after a few days a split skin graft was applied.

Table X.
Additional primary treatment

Re-reduction	8
Wedging	14
Fasciotomy	1
Secondary skin closure	1
Total	24

Early weight-bearing

After 2-3 weeks the long-leg plaster was removed and a PTB-cast (Sarmiento 1967) was applied if wound healing and swelling permitted (Table XII) The patients were encouraged to bear full weight in the PTB-cast as soon as it was dry and most of the patients could do this without discomfort. The patients returned for X-ray control three weeks later and if they were still comfortable the original PTB-cast was retained for another six weeks. At twelve weeks the plaster was removed and the fracture was examined clinically for stability and by X-ray for evidence of callus formation. The decision as to whether further plaster fixation could be dispensed with was based on these examinations and on the nature of the fracture. In the majority no further plaster was deemed necessary and in a few cases the plaster was removed before 12 weeks, for example in non-displaced fractures and in some where already the six-week X-ray examination showed evidence of callus formation. The general schedule shown here was followed in 80% of the fractures in as much as they required only two PTB-casts (Table XI).

Table XI.
Number of PTB-casts

Type of fracture	1	2	3	> 3	Total
Displaced longitudinal	17	8	4		29
Displaced transverse closed	13	16	3	5	37
Displaced transverse open	10	9	5	3	27
Non-displaced	15	2			17
Total	55	35	12	8	110

Table XII.

Days between injury and first PTB-cast

Type of fracture	1-7	8-14	15-21	22-28	29-35	36-42	43-49	50-56	$m \pm$ s.e.m.	median
Displaced longitudinal		2	6	12	5		2	2	27 ± 2	23
Displaced transverse closed		3	11	12	4	4	2	1	26 ± 2	25
Displaced transverse open			7	12	4	2	1	1	27 ± 2	25
Non-displaced	2	6	6	3					15 ± 2	17
Total	2	11	30	39	13	6	5	4		

Secondary treatment (Table XIII)

Because of delayed healing six fractures were treated with fibulotomy, reaming of the medullary cavity and Küntscher-nailing (Christensen 1973) and three fractures were treated with subcortical cancellous bone-grafting (Phemister 1947, Charnley 1961). One of the graft procedures was performed after it had been found that a planned Küntscher-nailing could not be carried through. The Küntscher-nailed fractures were allowed full weight-bearing without plaster immediately after the operation. The graft operated fractures were stabilized in a PTB-cast with full weight-bearing for three months in two cases and 6.5 months in one case.

Table XIII.
Secondary treatment for delayed union

Küntscher-nailing	6
Bone grafts	3
Total	9

In planning the treatment of the series of fractures described here it was decided that any secondary operation should be performed as early as possible in order to avoid unnecessary delays. However, no definite time limit was set for these interventions. Some of these secondary operations were performed rather late (Table XIV) because some fractures, believed to be stable, later developed pain on weight-bearing; the indication for the secondary operation was pain in the fracture region and/or radiographic evidence of threatening pseudarthrosis.

Table XIV.
Weeks between initial injury and secondary treatment for delayed union

Type of fracture	20-29	30-39	40-49	50-59	Total
Transverse displaced closed	2	1	1	1	5
Transverse displaced open	1	1	1	1	4
Total	3	2	2	2	9

Healing times

Healing was judged to have occurred when the fracture was clinically stable and did not elicit pain on palpation or manual stress; the final plaster was thus often removed before radiographic evidence of complete healing was observed. However, osteosynthesis with screws in longitudinal fractures often is quite stable and hence it was difficult to evaluate the degree of healing in such cases clinically and by X-ray because visible callus formation was minimal. In these fractures, therefore, plaster fixation was usually carried through the full twelve weeks. The healing times were analyzed with graphic probit analysis (Edwards and Nilsson 1965). The healing time for fractures subjected to secondary Küntscher-nailing could not be determined because these fractures were stabilized at operation. These fractures were not included in the analysis of healing times.

Delayed union was defined as healing time longer than 20 weeks (Nicoll 1964).

Removal of osteosynthesis material

As the patients recovered from the fracture episode, the proximal end of the Rush-pin usually caused some pain during activities like running, crouching and kneeling. In most cases the pin was therefore removed after about one year; it was left in eight patients who were relatively old and inactive and did not experience any discomfort. The screws were removed in only two cases and then because of aching pain in the fracture region.

Follow-up

The patients were re-examined between 6 months and 3 1/2 years after the initial injury. In the base material 106 out of the 110 fractures were re-examined, i.e. 96 %. Two patients with non-displaced transverse fractures had moved far away from this region, one patient with a comminuted transverse fracture which had healed without complications refused to appear for re-examination and one patient with a displaced longitudinal fracture had died from reasons unrelated to the fracture episode.

The 18 fractures which for various reasons had been excluded from the source material (Groups 3-5, page 8) were subjected to re-examination. However, one of these patients, a mentally retarded man, was not examined because he had been moved to a remote long-term care unit.

The parameters examined at the re-examination (Table XV) were chosen from Edwards (1965) and Olerud and Karlström (1972a) to permit comparison with their series. In the final classification of the results observed at re-examination, sports activities were disregarded; most patients had never participated in sport activities. Furthermore, shortening, angulation or malrotation were disregarded unless they were symptomatic in terms of the other parameters examined. In agreement with Olerud and Karlström (1972a) those fractures were classified as excellent with symptoms only in Group I, good those with one or more symptoms in Group II, acceptable those with one symptom in Group III but without any untoward subjective problems, and poor those with symptom(s) in Group III with poor function.

Re-examination of the radiographic material

The radiographic material was re-examined with regard to malalignment. Displaced fractures were re-examined to ascertain whether the osteosynthesis had diminished the initial shortening. As regards angulation the true angle was determined according to Norman (1965), see Fig. 2. For those fractures where the final angulation was more than 5° the X-ray material before and after weight-bearing in the PTB-cast was examined to evaluate whether the angulation was due to early weight-bearing.

Statistical methods

For calculation of statistical significance the Z-test, chi-square test, Fischer's exact test, Student's t-test and F-test were used.

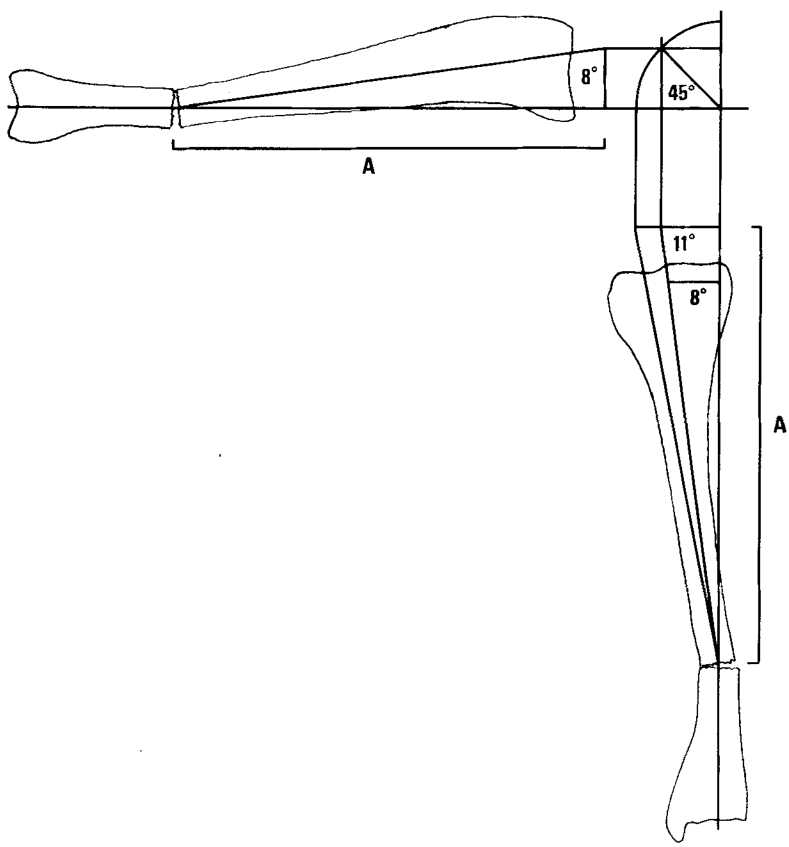

Fig. 2. Determination of the true fracture angle according to Norman (1965).
A fracture with 8° of angulation in the frontal and lateral projections. The true angle is 11° directed 45° anteriomedially.

Table XV.

Definition of parameters at the follow-up examination

	I	II	III
Subjective symptoms			
1. Work capacity	Unchanged	Difficulty in doing heavy work	Seated work only
2. Sports activity	Unchanged	Finished with some sport because of injury	Finished with all sports because of injury
3. Difficulty in walking	None	Slight limp after severe exercise	Constant limp
4. Pain at fracture area	None or neglibile	Moderate symptoms	Severe symptoms, pain at rest
5. Ankle joint symptoms	None or neglibile	Moderate symptoms	Severe symptoms
6. Knee joint symptoms	None or neglibile	Moderate symptoms	Severe symptoms
Objective signs			
7. Knee motion	Normal	0-110^o	Lack of full extension, flexion to less than 90^o
8. Ankle motion	Less than 10^o loss of dorsiflexion; less than 20^o loss of plantar flexion	Dorsiflexion over 90^o; less than 30^o loss of plantar flexion	Dorsiflexion less than 90^o; more than 30^o loss of plantar flexion
9. Foot motion	Less than 25% decrease of pro- and supination	Moderately decreased	Severely decreased
10. Foot contracture	None	Moderate	Severe cavus deformity
11. Calf atrophy	Less than 1 cm	1-2 cm	More than 2 cm
12. Malleolar swelling	Less than 1 cm	1-2 cm	More than 2 cm
13. Shortening	Less than 1 cm	1-2 cm	More than 2 cm
14. Angulation deformity	5^o or less	6-10^o	More than 10^o
15. Rotational deformity	10^o or less	11-20^o	More than 20^o

IV. RESULTS

Complications (Table XVI)

(1) Wound infection was defined as a wound with clinical evidence of infection, thus disregarding the results of bacterial culture. Deep infection was not observed in this series. In six fractures a superficial wound infection was observed; none of these required more than antibiotics. In two of these the infection occurred in the initial wound and in four in the operative wound (in one after open reduction of a longitudinal fracture, in one after extraction of the Rush-pin, in one after a graft operation, and in one after Küntscher-nailing).

(2) Skin necrosis. Insignificant necrosis of the wound margins was not recognized as necrosis. In six fractures superficial necrosis of the skin was observed; none required skin transplantation. One of these occurred over the fracture as a result of the initial trauma and in five because of pressure from the plaster. Three of these occurred in the long-leg cast with two appearing at the heel and in one because of pressure after wedging. Two skin necroses occurred in the PTB-cast, in one probably because of an attempt to correct an angulation during application of the PTB-cast and in the other because of pressure over the fibular head; this case also developed a partial peroneal palsy. The largest necrosis caused by the PTB-plaster is shown in Fig. 10.

(3) Peroneal palsy. One patient developed a partial peroneal palsy which had recovered completely at follow-up. This patient had a long period of lowered consciousness due to a hypercalcemic crisis following an overdose of dihydrotachysterol and calcium-therapy for phenytoin induced osteopenia: the absence of an adequate alarm response probably contributed to prolonged hyperpressure with peroneal injury and skin necrosis. At the follow-up she also had a cavus deformity of the foot.

(4) Thrombo-embolism. Clinical evidence of venous thrombosis, verified by phlebography occurred in four patients; in one of these the thrombosis involved the uninjured leg. Two of these four patients had pulmonary embolism and an additional two patients had pulmonary embolism without previous certain diagnosis of thrombosis. One of the patients with thrombosis was subjected to ligation of the inferior vena cava, thrombectomy and institution of an arterial venous shunt. In one of the patients with pulmonary embolism the diagnosis was made on the basis of his verbal account during the re-examination; he never sought medical advice during his thrombo-embolic episode.

Table XVI.

Complications in tibial shaft fractures

	Superficial wound infection	Skin necrosis due to		Peroneal palsy	Thrombosis	Embolism	Delayed union	Loose screws	Total
		Initial contusion	Pressure from the plaster						
Displaced longitudinal closed	1		1	1		2		3	8
Displaced longitudinal open		1			1				2
Displaced transverse closed	4		1		1		6		12
Displaced transverse open	1		3				7		11
Non-displaced transverse closed						2			2
Total	6	1	5	1	2	4	13	3	35

(5) Delayed union, i.e. healing time longer than 20 weeks, was observed in seven open and six closed transverse fractures. Delayed union was not observed in longitudinal fractures among whom the longest healing time was 18 weeks.

(6) Loosening of screws. In three longitudinal fractures the screws loosened and the fractures re-displaced somewhat, but never to the full preoperative position. The fracture with maximal displacement is shown in Fig. 11.

Hospitalization periods (Table XVII).

The mean hospitalization time was 13 days for transverse closed fractures and 14 days for longitudinal and transverse open fractures including hospitalization for secondary procedures. However, a few patients were hospitalized for a very long time because of concomitant injury or disease, for example two patients with head injury, two pelvic fractures, one severe asthma, one severe open fracture of the elbow, one vertebral fracture, one femoral fracture, two scapular fractures of which one had a plexus injury, one alcoholism, one with a hypercalcemic crisis. If these patients are excluded the mean hospitalization was 7 days for longitudinal fractures and 11 days for transverse fractures. It is thus better to show the median values: half of the patients stayed in hospital six days for longitudinal and closed transverse fractures and seven days for open transverse fractures.

Table XVII.
Days of hospitalization including secondary treatment

	A		B	
Type of fracture	$m \pm$ s.e m.	median	$m \pm$ s.e.m.	median
Displaced longitudinal	14 ± 4	6	7 ± 1	6
Displaced transverse closed	13 ± 2	6	11 ± 2	6
Displaced transverse open	14 ± 3	7	11 ± 3	7

A: All fractures
B: After exclusion of patients with other injury or disease

Healing times (Table XVIII)

The 50 % healing time was 2.8 months for longitudinal fractures, 3.1 months for closed transverse fractures and 3.4 months for open transverse fractures. The difference between different types of fracture was larger in terms of 95 % healing: 4.3 months for longitudinal fractures, and 4.8 and 5.9 months for closed and open transverse fractures, respectively.

Table XVIII.
Fracture healing times, this series (months)

Type of fracture	50 % of the group	95 % of the group
Displaced longitudinal	2.8	4.3
Displaced transverse closed	3.1	4.8
Displaced transverse open	3.4	5.9
Non-displaced	1.9	2.5

Disability periods (Fig. 3)

The cumulative disability period was determined for those patients who were eligible to sick-pay. Excluded from these calculations were thus students, pensioners and one woman who was pregnant After six months 2/5 of the patients with displaced longitudinal and closed transverse fractures and 1/3 of open transverse fractures had returned to their occupations. After twelve months these figures were 9/10 and 4/5 respectively. Two patients could not return to their previous occupations; one 58-year old man will probably have a disability pension and a 19-year old man was being retrained. A 68-year old man was working only half-time in his previous occupation.

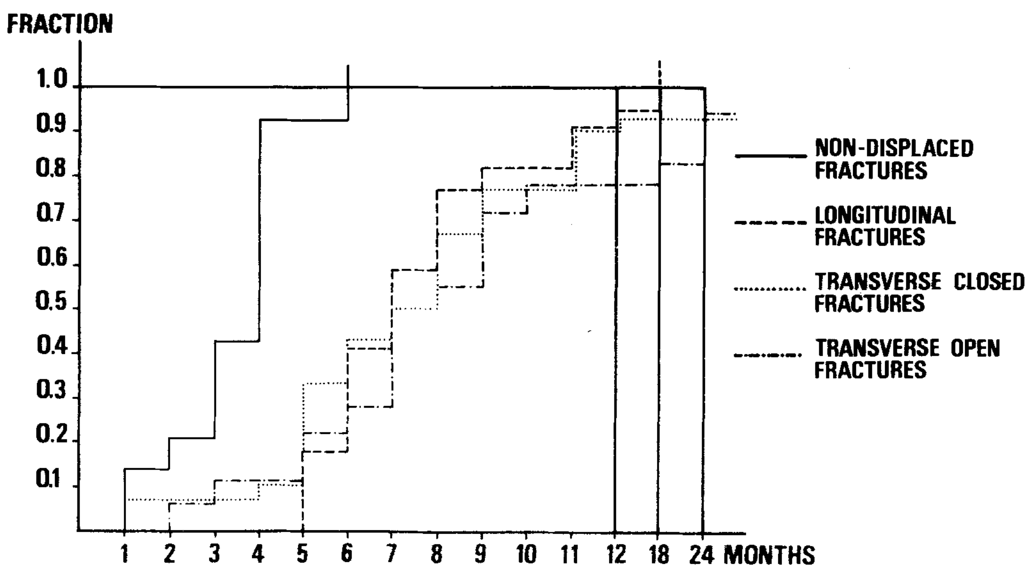

Fig. 3. Disability following tibial shaft fracture.
The figure shows fraction returned to work.

Results at follow-up (Tables XIX-XXI).

The final result could not be evaluated in one patient with a non-displaced longitudinal fracture because he had previously had a double fracture and the final result was due to his initial fracture.

(1) Working capacity. All but two patients could return to their previous jobs. However, as a result of the tibial fracture six patients had some problems when engaged in heavy work.

(2) Sports activities. Two patients had discontinued sport activities because of the fracture; one had continuous pain in the fracture region and one had limited function because of shortening, muscle atrophy and poor ankle motion. An additional four patients had diminished their sports activities. Two of them did sprinting for exercise but did not play as much soccer as they had previously done, one had already previously had a tibial fracture through soccer and did not want to subject himself to the risk of having a third fracture, and one patient with a double fracture after he had been hit by a car had some problems which did not allow full sports activity.

(3) Walking capacity. Two patients had a continuous limp, i.e. those who had been unable to return to their previous occupations.

(4) Pain. Two patients had rest-pain in the fracture region. One of those had a longitudinal fracture; the rest-pain was not aggravated by weight-bearing, he had full working and walking capacity and examination did not reveal the cause. One patient had very poor function after a severely comminuted distal fracture of the tibia.

(5) Ankle and foot motion. Four patients had objective and/or subjective symptoms of poor ankle and foot motion. Two patients had severe complaints. One of those had a severely displaced open distal fracture with severe soft tissue injury after he had been caught in a machine; he had only slightly decreased ankle motion. The other patient had a severely comminuted fracture in a traffic accident; he had contracture of the foot as described by Karlström et al. (1975) with minimal ankle and foot motion. One patient had been bone-grafted and treated in plaster for altogether 19 months; he had severely limited ankle and foot motion with contracture of the flexor hallucis longus but he had no subjective complaints, possibly because of limited activities. The fourth patient had a contracted foot following a longitudinal fracture but had no subjective complaints, also in this case probably because of decreased activity; the patient was 64-years old and was in very poor general condition.

Table XIX.

Subjective symptoms at follow-up of tibial shaft fractures

Type of fracture	Working cap.			Sports act.			Walking cap.			Pain			Ankle function			Knee function		
	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III
Displaced longitudinal closed	21	2		22		1	19	4		17	5	1	20	3		22	1	
Displaced longitudinal open	4	1		5			4	1		4	1		5			5		
Displaced transverse closed	34	1	1	32	4		35		1	34	1	1	33	2	1	36		
Displaced transverse open	24	3		26		1	22	4	1	24	3		23	3	1	27		
Non-displaced transverse closed	14			14			14			14			14			14		
Total	97	7	1	99	4	2	94	9	2	93	10	2	95	8	2	104	1	

Table XX.

Objective signs at follow-up of tibial shaft fractures

Type of fracture	Knee motion			Ankle motion			Foot motion			Foot contracture			Atrophy		
	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III
Displaced longitudinal closed	23			22	1		18	5		22		1	20	3	
Displaced longitudinal open	5			5			4	1		5			4	1	
Displaced transverse closed	36			35	1		30	5	1	35		1	31	5	
Displaced transverse open	27			26	1		21	5	1	26	1		21	5	1
Non-displaced transverse closed	14			14			14			14			13	1	
Total	105			102	3		87	16	2	102	1	2	89	15	1

Type of fracture	Swelling			Shortening			Angulation[x]			Rotational deformity		
	I	II	III	I	II	III	I	II	III	I	II	III
Displaced longitudinal closed	17	4	2	19	4		20	3	1	20	2	1
Displaced longitudinal open	2	3		5			4	1		5		
Displaced transverse closed	33	3		28	6	2	25	8	4	36		
Displaced transverse open	24	1	2	22	4	1	15	10	2	26	1	
Non-displaced transverse closed	14			14			16			14		
Total	90	11	4	88	14	3	80	22	7	101	3	1

x) Including the four patients who were not subjected to follow-up examination.

(6) Knee motion. All patients had normal knee motion. Only one had complaints from the knee, probably unrelated to the fracture. This case was a 60-year old man with a longitudinal fracture who after the fracture had healed was operated on for a meniscus lesion and who had clinical evidence of femoro-patellar arthrosis at the re-examination.

(7) Additional complaints. Five patients complained of pain or discomfort elicited from the scar above the tibial tuberosity at kneeling. None of these patients felt that these sensations constituted any major problem. One patient had a muscle hernia which felt uncomfortable after excessive walking; he refused surgery of the hernia.

(8) Muscle atrophy. The circumference of the fractured leg was compared with that of the normal leg. On the basis of this comparison 89 legs had a muscle atrophy of less than 1 cm, 15 between 1 and 2 cm and only one more than 2 cm. This latter case was an open double fracture with a large soft tissue injury but without any subjective complaints.

(9) Swelling. Swelling was evaluated by comparison of the circumference just proximal to the ankle joint of both legs. 90 legs had swelling of less than 1 cm, 11 between 1 and 2 cm and four more than 2 cm. The largest swelling was 4 cm in a patient who had had a longitudinal fracture. This patient had marked varicosities bilaterally and had been operated on for this reason on the non-fractured side. Of the 11 patients with moderate swelling one had had thrombosis of the contralateral leg. None of the other three patients with phlebographic evidence of thrombosis had any swelling on re-examination.

(10) Shortening. 88 legs had shortening of less than 1 cm, 14 had shortening of 1-2 cm and three had shortening of more than 2 cm. Of the 14 legs with moderate shortening, six occurred after longitudinal or short oblique fractures (four without osteosynthesis and two with Rush-pins), eight occurred in transverse fractures which had either delayed healing, were comminuted or double (six of these had a Rush-pin, one was transfixed and one was treated without osteosynthesis). In two of these cases the fibula was not fractured but they had healed in varus and the leg length was measured between the medial joint line of the knee and the tip of the medial malleolus. Of the three legs with shortening of more than 2 cm, two had double fractures with 2.5 cm shortening and one with 3.5 cm of shortening had a severe comminuted fracture which healed only after grafting; the primary treatment in all these three fractures was by Rush-pinning.

(11) Angulation. 80 fractures had no angulation; the fracture angle was 5° or less. 22 fractures had an angulation of $6-10^{\circ}$ and seven of more than 10°. In 16 of these 29 cases the fracture angle had increased by $5.9 \pm 1.3^{\circ}$ during weight-bearing, i.e. during the period between the X-ray examination immediately after the first PTB-cast had been applied and the final examination. The largest angulation was 31°; it had increased 20° during weight-bearing. This patient was 60-years old and refused to have the angle corrected. The second largest angulation was 15°, shown in Fig. 12. - In five fractures the angle was open anteriorly, in eight medially (varus) and in 11 antero-medially. In three fractures the angle was open posteriorly, in one posterior-medially and in one posterior-laterally. - Five of the fractures with angulation of more than 5° were longitudinal (one with encircling wire, two Rush-pins, one screwed, and one without osteosynthesis and with a non-fractured fibula), and 24 were transverse (19 with Rush-pins and five without osteosynthesis of which three had a non-fractured fibula).

(12) Rotational deformity. Malrotation was observed in four fractures but did not seem to cause any complaints. The largest malrotation was 30° in a 73-year old man and the next largest 20° in a 70-year old woman, permanently confined to a long-term institution.

(13) Over-all classifications of the final results (Table XXI). The over-all results in this series of 105 fractures evaluated were 67 % excellent, 24 % good, 6 % acceptable and 3 % poor. However, as expected, the over-all results in the non-displaced fractures were uniformly excellent. The results in the 91 displaced fractures were 57 excellent, 24 good, 7 acceptable and 3 poor. - The results at re-examination of the 17 fractures which had not been subjected to early weight-bearing are shown in the list of coded data. The functional result in this group was sometimes impossible to evaluate because of other disease and injury. Of the three fractures which by "mistake" were not subjected to early weight-bearing two would had been classified as excellent and one as good.

Table XXI.
Over-all results at follow-up of tibial shaft fractures

Type of fracture	Excellent	Good	Acceptable	Poor	Total
Displaced longitudinal closed	12	7	3	1	23
Displaced longitudinal open	2	3			5
Displaced transverse closed	26	9		1	36
Displaced transverse open	17	5	4	1	27
Non-displaced transverse closed	13	1			14
Total %	70 (67%)	25 (24%)	7 (6%)	3 (3%)	105

V. DISCUSSION

A useful program for treatment of tibial fractures should be applicable to the majority of these fractures but it need not include fractures with severe soft tissue problems due to arterial injury, nerve injury, extensive skin damage, etc and it need not include patients with multiple injuries. Based on the morbidity observed here, the program tested in this investigation was applicable to some 90 % of all cases of fracture of the tibia in adults. Furthermore, the program for treatment of tibial shaft fracture should be sufficiently simple not to require specialized experience, because the everyday run of tibial shaft fractures are treated in peripheral hospitals; complications following treatment with the AO-compression methods have been explained as due to insufficient expertise (Thunold et al. 1975). The program should ensure a low incidence of complications, especially serious complications, it should require as few active interventions as possible, short hospitalization and minimal convalescence, and the end result should compare with more complicated methods.

The results of this investigation will be compared here with Edwards´s (1965) prospective series (the Malmö series), and Olerud and Karlström´s (1972a) five year material of tibial shaft fractures treated with the AO-compression plate (the Uppsala series). I have chosen these materials for comparison because they are recent, and they are based on similar demographic and epidemiologic environments. In fact, the composition of the three series is almost identical with a dominance of high energy fractures caused by traffic accidents. However, in the Malmö series there was an overrepresentation of extensive soft tissue injury, referred from a wide area. The Uppsala series did not contain a similar proportion of severe soft tissue injury, perhaps because Olerud and Karlström (Olerud 1973, Karlström and Olerud 1975) preferred to use transfixation with the Vidal-Adrey method in such cases. However, the classification of soft tissue injury in the Uppsala series differs from that used in the Malmö series and in this investigation; a close comparison with the Uppsala series is therefore not feasible.

In principle the primary treatment in the Malmö series was the same as here; a comparison between these materials should show whether early weight-bearing in the PTB-cast had an influence on the end result. The therapeutic principles applied to the Uppsala series, on the other hand, were entirely different; a comparison should permit an analysis not only of the end results but also of the entire healing course. It would have been desirable to compare these series with a series of tibial shaft fractures not subjected to open treatment but only to early weight-bearing. However, the series of cases published by Dehne et al.(1961), Brown and Urban (1969), Sarmiento (1967, 1970, 1974).

Broström and Eriksson (1970), Lambding (1973), Balkfors (1974), Burkhalter and Protzman (1975), King (1975), Wiedmer and Bianchini (1975), Rosentahl et al. (1977), Suman (1977) were either selected or subjected to incomplete follow-up; they have not been described in sufficient detail to permit more than isolated comparisons.

Complications

In this series the majority of the complications were moderate; they did not require secondary interventions and they did not prolong the periods of hospitalization or treatment. Serious complications, to be discussed here, are thrombosis, embolism, deep infection with osteomyelitis, and delayed union requiring secondary operations. The incidence of serious complications in this material was 14 % with 6/37 in closed transverse fractures and 4/27 in open transverse fractures. By comparison with the Uppsala series, the total absence of osteomyelitis in this series was significant ($p < 0.05$) and this was true also of the total number of complications ($p < 0.05$) even though the definition of delayed union used here probably was somewhat stricter than the one used in Uppsala; in the Uppsala material about 1/4 of the patients were not allowed full weight-bearing until after 20 weeks.

(1) Thrombosis and embolism. Thrombosis was not recorded in the Malmö, Uppsala and Sarmiento (1974) series of 482 fractures. However, several authors (Hjelmstedt and Bergvall 1968, Nylander and Semb 1972, Vogl et al. 1972) have shown by phlebography that the incidence of deep thrombosis is high indeed in tibial fractures. Hjelmstedt and Bergvall (1968) found an incidence of 54 % in patients over 25 years with a significantly higher incidence in patients treated with internal fixation and a plaster cast as compared to those treated with a cast only. Vogl et al. (1972) found a lower incidence of deep thrombosis; like Olerud and Karlström (1972a) they treated the fractures with vacuum drainage and early motion. Possible the drainage and early motion in the Uppsala series explains the virtual absence of thrombo-embolism recorded there, whereas in this series the incidence was 5 % ($p < 0.01$). However, there was no difference between the Uppsala series and this series as regards the incidence of ankle or lower-leg oedema; in the Malmö series this sequel to deep thrombosis was not recorded separately and Sarmiento (1974) has not published any follow-up of his patients.

In this series the patients did not receive any prophylactic treatment against thrombosis. Because of the high incidence of thrombo-embolism in fractures of the hsaft of the tibia and because of the common complaint of a chronic swelling following these fractures, routine treatment with Macrodex[R] (Bergentz 1975) should perhaps be recommended in patients over 20 years of age. The severity of the fracture does not necessarily indicate the need for such prophylactic treatment; two of the thrombo-embolism cases in this series were non-displaced transverse fractures in patients aged 24 and 44 years.

(2) Osteomyelitis. In this series osteomyelitis did not occur and in the Malmö series only one case occurred in 109 displaced transverse fractures. By contrast, in the Uppsala series the over-all incidence of osteomyelitis was 5 % and of "metallosis" 10 %. The majority of the osteomyelitis cases occurred in the transverse fractures and in particular among the 38 open transverse fractures, 6 of which had this complication. The marked difference in incidence of osteomyelitis between this series and the Malmö series on one hand and the Uppsala series on the other is probably related to soft tissue and skin injury; after the skin has been exposed to high energy trauma it does not tolerate the additional injury associated with the exposure for plate osteosynthesis (Edwards 1965, Bauer and Hulth 1973).

The conservative attitude toward the handling of skin and soft tissues basic to this investigation has been applied in earlier materials, e.g. Zucman and Maurer (1969, 1970), Merle d'Aubigné et al. (1974), Lottes (1974), Harvey et al. (1975). These materials also had a low incidence of osteomyelitis. With the reservation that the distinction between wound infection and osteomyelitis was not always clearly defined, the incidence of wound infection in open fractures seemed to be somewhat higher than in this and in the Malmö series.

(3) Delayed union. The concept "delayed union" is hard to define; the time limit of 20 weeks (Nicoll 1964) represents more a conventional than a biologically meaningfull parameter. The time limit 20 weeks may still be useful, first to permit a comparison with other materials, and second, e.g. in this investigation, as an indication when unnecessarily prolonged treatment may be avoided by institution of secondary procedures.

The proponents of early weight-bearing in the treatment of fractures of the tibia have always argued that the healing course is promoted by such more physiological treatment (Borelius 1894, Gurd 1940, Dehne 1974, Sarmiento 1974). However, the analysis or presentation of fracture materials treated by early weight-bearing does not seem to permit this conclusion. Sarmiento (1967, 1970, 1974) has published values for the mean healing time in different types of tibial fractures but not the incidence of delayed healing. In his 1974 publication he had only two cases of pseudarthrosis in 482 fractures. In the series of open fractures of the tibial shaft treated with early weight-bearing, published by Brown and Urban 1969, the time in plaster was longer than 20 weeks in 23 of 63 cases. Rosentahl et al. (1977) treated 60 open tibial fractures with early weight-bearing; a pseudarthrosis operation was performed in ten of these cases, six of whom, however, were infected. Nicoll (1964) has carefully studied the incidence of delayed healing in a series of tibial fractures treated with closed methods without weight-bearing; he found an incidence of delayed union of 21 % in non-infected displaced fractures, ranging from 9 % in simple fractures to 39 % in severe fractures. In this series the incidence of non-union was 14 %, i.e. significantly ($p < 0.05$) lower than in the Nicoll (1964) series.

Edwards and Nilsson (1965) analysed the course of healing in the Malmö series by graphic probit analysis; the regression line for the course of healing obtained with this method does not suffer from undue influence of isolated extreme values. The healing times in this series were compared to those in the Malmö and Brown and Urban (1969) series. (Table XXII). In longitudinal fractures the healing times were significantly ($p < 0.01$) shorter in the Malmö series than in this series. The explanation for this may be that the proportion of fractures subjected to stable osteosynthesis with screws was higher in this series; following stable osteosynthesis the clinical evaluation of the fracture healing is difficult, little visible callus is formed, and therefore the period of plaster cast fixation was rarely shorter than 12 weeks.

As regards healing time in the displaced transverse fractures there was no difference between the Malmö and this series in terms of 50 % healing, but a difference in 95 % healing. This difference was largest in the open fractures where the 95 % healing time in this series was only half of that of the Malmö series. This difference may be due to the higher proportion of large skin wounds in the Malmö series. The data were corrected for this difference by exclusion from the Malmö series of all fractures with wounds larger than 10 cm; the 50 % and 95 % healing times in the Malmö series were now calculated to be 4.2 and 9.9 months, still longer than the 3.4 and 5.9 months values recorded in this series. When the Brown and Urban (1969) series of open fractures was subjected to the same probit analysis a similar pattern was observed; the 95 % healing time was shorter than in the Malmö series in spite of the fact that the Brown and Urban cases were war injuries with probably more comminution and more extensive soft tissue injury than in the Malmö series of civilian fractures. This comparison of the Brown and Urban (1969) and this series with the Malmö series would indicate that early weight-bearing does indeed shorten the healing time. However, in a series of 97 tibial fractures treated with closed methods and early weight-bearing in a PTB-plaster, Balkfors (1974) did not find any difference in healing times as compared to the Malmö series. This observation need not be valid because the treatment with PTB-cast was handled by a large number of surgeons and the patients were evaluated at six week intervals (Balkfors 1977).

Analysis of the variance of healing times for displaced transverse fractures revaled a significant ($p < 0.05$) difference between this series and the Malmö series for open as well as closed fractures. However, if the eleven cases with major soft tissue wounds in the Malmö series are discounted, the difference between the two series for open transverse fractures has only borderline significance.

Table XXII.
Fracture healing times (months)

Type of fracture	This series 50%	95%	Malmö series 50%	95%	Brown, Urban (1969) 50%	95%
Displaced longitudinal	2.8	4.3	2.2	3.5		
Displaced transverse closed	3.1	4.8	3.1	9.0		
Displaced transverse open	3.4	5.9	4.5	14.0	4.2	8.2

The Malmö series refers to the prospective series published by Edwards (1965).

In my opinion the weight of evidence suggests that early weight-bearing may have a favourable effect on the healing of fracture of the shaft of the tibia. However, early weight-bearing certainly does not guarantee healing.

Secondary operations

The incidence of secondary operations in this series (11 %) was significantly ($p < 0.01$) lower than in the Uppsala series (22 %) but the same as in the Malmö series (13 %). The relatively high incidence of secondary operations in the Uppsala series correlates with the incidence of complications common in fractures treated with the compression plate, notably osteomyelitis, broken plates and refractures.

Hospitalization periods (Table XXIII)

The periods of hospitalization in this series were shorter ($p < 0.05$ for longitudinal and transverse open fractures, $p < 0.01$ for transverse closed fractures) than in the Uppsala series, notably in the transverse closed fractures in which the median period of hospitalization in the Uppsala series was three times as long as in this series; this difference is explained by the relatively high incidence of secondary operations in the Uppsala series. However, the hospitalization periods were short in this series also when compared to the Malmö prospective series even though both series had a low incidence of complications. At least in part, the difference between this series and the Malmö series may be due to the general trend toward shorter periods of hospitalization during the 15 years which have elapsed between the two series.

The philosophy basic to this series included the aim of providing definitive treatment as early as possible; preoperative traction was rarely used. The majority of cases subjected to internal fixation were operated on within 24 hours (Table IX). As regards utilization of hospital beds the program for treatment used in this series would thus be preferable to the one published by Olerud and Karlström (1972b) which requires first open reduction and osteosynthesis with a compression plate, and then, as a secondary operation removal of the plate and medullary nailing. Other examples of seemingly unnecessary prolongation of the hospitalization period are the recommendations to perform delayed internal fixation (Solheim 1973, Smith 1974, Allgöwer 1975, Langård and Bø 1976, Jensen et al. 1977), apparently in an attempt to avoid the high incidence of complications following early primary osteosynthesis with the compression plate in high energy fractures.

Table XXIII.
Days of hospitalization for tibial shaft fractures, median values

Type of fracture	This series	Uppsala series	Malmö series
Displaced longitudinal	6	12	14
Displaced transverse closed	6	20	14
Displaced transverse open	7	18	35

The Malmö series refers to the prospective series published by Edwards (1965).
The Uppsala series refers to Olerud and Karlström (1972a).
The periods of hospitalization shown here include secondary treatment.

Disability periods

The period of disability is an uncertain and poor measure of the results of treatment of fractures of the tibia; even comparisons in the same community and during the same period of time may be invalid because of undefinable circumstances. As compared to this series, the Uppsala series had a somewhat higher number of patients back to work within six months but somewhat fewer at 12 months. There was not much difference in this respect between this series and the Malmö series except in open transverse fractures; at 12 months 2/3 of the patients here had returned to work and only about one half in Malmö; this difference was significant ($p < 0.05$) but may be due to the higher incidence of extensive soft tissue injury in the Malmö series.

With due regard to the difficulties in comparing disability periods the data discussed here may indicate that rehabilitation in non-complicated cases of compression plate treated tibial fractures is somewhat more rapid than in those treated in a plaster cast. However, the higher incidence of complications following compression plate fixation results in an increased number of patients with very long periods of disability.

Results of follow-up

Final evaluation of the treatment of fracture of the tibia must take into account both functional and anatomic parameters; if the two are confused evaluation is invalidated. Moderate shortening and/or angulation usually does not cause any inconvenience or impaired function. In terms of function it would thus not be reasonable to avoid such anatomic imperfections at the risk of a higher incidence of serious complications. Osteosynthesis with a compression plate is advocated in order to achieve a better end result than that obtainable with closed reduction and plaster (Olerud and Karlström 1972a). Whether this can indeed be achieved will be discussed here on the basis of a comparison of this series with the Uppsala series.

(1) Joint stiffness. The proponents of compression plate osteosynthesis believe that primary plaster fixation causes joint stiffness, especially in the ankle (Müller et al. 1970, Olerud and Karlström 1972a, Karlström and Olerud 1974). However, the incidence of joint stiffness was nearly the same in the Uppsala series as in this series. On the other hand in this series the stiffness was usually located below the astragalus which was never observed in the Uppsala series. At any rate, some residual ankle joint stiffness seems to be common following tibial fracture, probably due to ischaemic muscle damage (Ellis 1958, Owen and Tsimboukis 1967, Karlström and Olerud 1974, Karlström et al. 1975) i.e. the compartment syndrome (vide infra) rather than an effect of plaster fixation on the joints per se. The residual cavus deformity of the foot, which severely impairs function, has been thoroughly analyzed by Karlström et al. (1975).

(2) Atrophy. There was no difference between this series and the Uppsala series as regards muscle atrophy. Possibly early weight-bearing stimulates muscle function to the same degree as does early motion.

(3) Shortening. The use of early weight-bearing has been criticized as a cause of shortening in fractures of the tibia. Sarmiento (1974) has demonstrated that early weight-bearing does not increase the initial shortening. When the initial shortening is not deemed acceptable he has recommended transfixation to restore the length. Brown (1974) was more conservative; he felt that shortening was a small price for obtaining uncomplicated healing. Dehne et al. (1961) examined the shortening in a 12 % sample of his tibial fractures; 2/5 of these fractures had a shortening of 1,3 - 1,9 cm.

The reason to perform an osteosynthesis in this series was to decrease the final shortening. Accepting Sarmiento's (1974) statement that without osteosynthesis the final shortening equals the initial shortening these variables were measured. In the longitudinal fractures treated with screws the mean gain was 9 mm and the maximal gain 20 mm. In the short oblique and comminuted transverse fractures treated with a Rush-pin the mean gain was 8 mm and the maximal gain 34 mm.

The reason why osteosynthesis with the Rush-pin did not always prevent shortening was that the pin did not fit the entire circumference of the marrow cavity; a slight dislocation to the side therefore occurred, sometimes associated with shortening in oblique and comminuted fractures (Fig. 6).

Moderate shortening is usually not much of a problem if the function is otherwise good. It therefore does not seem indicated to subject the patients to an increased risk of complications solely to avoid shortening. However, there seems to be no reason to accept shortening if it can be avoided at no or little risk as demonstrated in this series.

(4) Angulation. At follow-up a high incidence of angulation was recorded. This problem seems to have been minimized by the proponents of weight-bearing and was therefore not identified in this investigation until at the time of follow-up. Brown and Urban (1969) found an angulation up to 15° in 44 of 63 fractures. Dehne et al. (1961) measured the fracture angles in 27 consecutive fractures in a total of 221 fractures; twelve of the 27 fractures had angulation, but not more than 10°; the authors concluded that angulation does not constitute a problem but in their figure 2C the angulation measured is about 17°. Gamble et al. (1972) found angulations of more than 5° in 20 % of their cases. Sarmiento (1974) reported 9 % angulation over 5° with maximal angulation of 12°. In all of the above publications the angulation has been measured only in AP and lateral X-rays projections; the true angulation may thus have been underestimated.

The high incidence of final angulation in this series was not always due to early weight-bearing. In seven cases an angulation seen in the immediate postoperative X-ray was caused by undue bending of the Rush-pin before insertion. In 18 fractures the angulation increased after the primary treatment and in 16 of those the increased angulation occurred during weight-bearing (Table XXIV). In ten fractures the angle increased less than 4° but in eight fractures it increased more than 7° and up to 23°. In three of these latter fractures the angle increased gradually until it was observed only when the fracture had healed (Fig. 13), in three fractures the fibula was not fractured, one fracture had very slow healing and one fracture occurred in a patient who was a chronic alcoholic and left the hospital without waiting for correction of the angulation which occurred after the long-leg cast had been changed to a PTB-cast.

Table XXIV.
Progression of deformity in tibial shaft fractures

	$\leq 5^\circ$	$6-10^\circ$	$>10^\circ$
Postoperative	12	17	
After first PTB-cast	12	16	1
After 3 weeks of weight-bearing	4	21	4
After 9 weeks of weight-bearing	2	22	5
Final angulation		22	7

As regards the direction of angulation it appeared that early weight-bearing had a general tendency to cause a varus angle but other types of angulations were also observed. There did not seem to be any correlation between fracture level and risk or type of angulation.

It appears from this investigation that early weight-bearing is definitely accompanied by a risk for angulation which one should be prepared to prevent and treat actively. All angulations should be corrected as early as possible, even those which seem acceptable; after a period of weight-bearing the angle may increase and it may soon prove difficult to correct. It is simple to wedge the long-leg cast, especially when the true angle and its direction have been determined. There should be no reason to accept an initial angulation of 15° as proposed by Wyman and Barr (1974). In this way the incidence of angulation should decrease considerably. Only one of those which developed severe angulation started weight-bearing with a truly straight tibia; this was a proximal fracture with a non-fractured fibula. In another two short oblique fractures with non-fractured fibulas the varus angles were corrected by wedging but they recurred when the PTB-plaster was applied and they then increased during weight-bearing.

(5) Over-all results (Table XXV). The functional over-all results were similar and generally favourable in the three series compared here. It is true that the Uppsala series was somewhat better than the Malmö series but this was very probably due to the high incidence of open transverse fractures in the latter series; after exclusion of the cases with major soft tissue injury (wound size larger than 10 cm) the end results in the Malmö series were comparable to the other series. Indeed, if one can achieve a low incidence of complications the functional end results seem to correlate more with the initial injury than with the type of treatment. It is in fact remarkable that the high incidence of complications in the Uppsala series did not adversely influence the end result; these facts suggest that the infected fractures were treated with a high degree of expertise.

One may argue that the over-all evaluation should include also non-symptomatic anatomic imperfections such as angulations. In the displaced fractures the sum of all parameters gave 38 % excellent, 46 % good, 13 % acceptable and 3 % poor; the aggregate excellent-good thus was about the same as when function only was evaluated.

Few authors have attempted to compare the end results of closed and open treatment of fractures of the tibia in one and the same investigation. Karaharju et al. (1975) have compared two such groups and their conclusions agreed with the observations here; there was little difference in end result between the two groups but a significant difference in the incidence of complications.

Table XXV.
Classification of final status at follow-up of displaced tibial shaft fractures

Fracture type	Malmö series	Uppsala series	Present series
Longitudinal			
Excellent-good	41	42	24
Fair-poor	4	1	4
Transverse, closed			
Excellent-good	54	39	35
Fair-poor	8	3	1
Transverse, open			
Excellent-good	32	25	22
Fair-poor	10	6	5
Total			
Excellent-good	127 (85%)	106 (91%)	81 (89 %)
Fair-poor	22 (15%)	10 (9 %)	10 (11%)

The Uppsala series refers to Olerud and Karlström (1972a).
The Malmö series refers to prospective series of Edwards (1965).

The comparisons done here between this series and the Malmö series and the Uppsala series presuppose that the latter represents the AO-compression plate method. An analysis of other publications based on that method (Rittman et al. 1970, Ketenjian and Shelton 1972, Gallinaro et al. 1973, Solheim 1973, Thunold et al. 1975) confirms that the Uppsala series is indeed representative. However, it has been stressed that the AO-methods require a technical expertise and that the complications are due to technical failures (Thunold et al. 1975). The series of fractures from the University Hospital in Basel (Rüedi et al. 1975), where the AO-methods are very well known, had a high incidence of serious complications in open fractures. The fractures were classified only into open and closed fractures. 43 % of the cases were ski injuries; the good prognosis in this type of fractures is well known (Infanger et al. 1971, van der Linden et al. 1975). In the 95 open fractures 23 severe complications occurred, 11 of these osteomyelitis. Among the open fractures 39 were probably after indirect trauma as the wounds were caused by simple piercing of the skin from within; the majority of the complications probably occurred in the other 56 fractures. It therefore seems reasonable to agree with Olerud's and Karlström's statement that the compression plate method is not suitable as a routine method in tibial shaft fractures (Olerud and Karlström 1972a, Karlström 1976).

The compartment syndrome

In this series one patient with a compartment syndrome received adequate treatment by early fasciotomy; the functional end result was excellent. In three patients active treatment of a compartment syndrome was not instituted; all had poor end results. In addition a patient who was never treated with early weight-bearing and PTB-plaster had a comminuted proximal fracture of the tibia with arterial injury; in spite of fasciotomy and repair of the artery he had a Volkmann contracture resulting in a contracted foot, probably because the arterial injury was repaired too late.

The compartment syndrome and its serious effect on the end results in fractures of the tibia has been known for a long time and it has been well described in numerous publications (Volkmann 1881, Ellis 1958a, Seddon 1966, Willhoite and Moll 1970, Sundén and Wiberg 1971, Fowler and Willis 1975, Holden 1975, Karlström et al. 1975, Matsen and Clawson 1975, Rorabeck and MacNab 1976). The importance of treating the compartment syndrome has been well documented (Ernst and Kaufer 1971, Feagin and White 1973, Patman et al. 1973, Sheridan and Matsen 1976) and seemingly reliable diagnostic methods based on measurements of the intramuscular pressure have recently been published (Whitesides et al. 1975, Matsen et al. 1976, Mubarak et al. 1976). One may ask why the diagnosis of compartment syndrome is still often not made and even when it is the patients often do not receive adequate treatment. However, it is not easy to routinely measure the intramuscular pressure; it is not enough to measure it once but it should be measured repeatedly or continously and in all the four compartments. There is a great need for simple and routinely useful methods for early diagnosis and treatment of the compartment syndrome. This series has confirmed Edwards's (1965) demonstration that osteomyelitis is a virtually avoidable complication in fractures of the tibia. Olerud and Karlström (1972a) have demonstrated that osteomyelitis can be treated so successfully that it does not jeopardize a favourable end result. Intramedullary reaming and nailing has been repeatedly shown to be a reliable method in the treatment of non-union (Christensen 1973). The compartment syndrome remains as the last unsolved threat to uniformly good end results in tibial fractures.

Ipsilateral fractures of the femur and the tibia

In this series only four cases had an ipsilateral femoral fracture. Only one of these could bear weight early in a PTB-cast; the femoral fracture was treated by intramedullary reaming and nailing. Another femoral fracture was treated in the same way but the patient had a head injury and an unstable pertrochanteric femoral fracture of the contralateral side which delayed mobilization. One femoral fracture was treated with a compression plate and could therefore not bear full weight (Hansson et al. 1977) and one was treated in traction for six weeks and the patient was then mobilized with a cast brace.

Several authors feel that ipsilateral fracture of the femur constitutes an indication for compression plate osteosynthesis of a tibial fracture (Nicoll 1974, Höjer et al. 1977, Karlström and Olerud 1977); early mobilization and better end results would be worth the increased risk of complications. However, the PTB-cast allows early motion of the knee and if the femoral fracture permits reaming and intramedullary nailing the patient can be mobilized earlier with full weight-bearing than with a plate osteosynthesis which does not allow weight-bearing.

The discomfort to the patient

Few authors have compared different methods of treatment of fracture of the tibia in terms of comfort or rather discomfort to the patients. From the start, this investigation aimed at making Edwards's (1965) method more comfortable to the patient without jeopardizing the end result. The majority of the patients tolerated the PTB-cast well; it was unpadded but it was applied only after the initial swelling had disappeared. In fact, all patients were satisfied with the PTB-cast and a few returned to their occupations in the cast. The majority learned to walk with or without a cane. A movable knee permits the patient to sit in the back-seat of a car, in the cinema, theater etc. Under special circumstances the PTB-cast permits driving a car, and a movable knee makes sexual intercourse easier (Brown 1974).

Practical recommendations

1. In order to diminish the risk of shortening by displacement of the fracture a thick intramedullary pin should be chosen so that the medullary cavity is adequately filled.
2. Do not bend the pin so much that the fracture angulates forwards; it should be bent only so that it obtains the shape of a Küntscher nail. If it is necessary to bend the distal end of the Rush-pin in order to find the entrance to the medullary cavity in the distal fragment, it is sufficient to bend the last three cm only. A thin Küntscher nail can be used instead of a Rush-pin.
3. All postoperative angulations should be corrected by wedging the long-leg cast as soon as possible. Postoperative malrotation can be corrected by a transverse circumcision of the plaster and rotation of the distal fragment within the plaster.
4. After the patient has been bearing full weight in the PTB-cast the position of the fracture should be checked by X-ray not later than at two weeks; if the fracture does not have any tendency to angulate further checks can be postponed until every fourth or sixth week.
5. The exact angulation should be determined at each X-ray examination; it is not enough by eye measurement alone.
6. If the patient is comfortable in the PTB-cast, it need not be changed unless checking for clinical evidence of healing.

VI. CONCLUSIONS

On the strength of the material presented here and in the light of earlier publications the following may be concluded concerning the treatment of the vast majority of fractures of the leg in adults.

1. Reduction and osteosynthesis with screw(s) in longitudinal fractures or intramedullary nailing in transverse fractures reduce the risk of shortening of the tibial shaft fracture.

2. In longitudinal fractures open reduction and osteosynthesis with screw(s) is associated with but little risk for local complications. Screw fixation does not preclude early weight-bearing in the PTB-cast.

3. In transverse fractures closed reduction and intramedullary fixation with a Rush-pin does not increase the risk for necrosis of the skin and osteomyelitis. After intramedullary nailing transverse fractures are well suited for early weight-bearing in a PTB-cast.

4. Early weight-bearing in a PTB-cast is recommended as the routine method in the majority of tibial shaft fractures.

5. Early weight-bearing may increase the angulation; weight-bearing should not be permitted until angulation has been corrected.

6. Early weight-bearing probably favours healing of transverse fractures.

7. The functional end result following early weight-bearing in a PTB-cast compares well with other methods and is more comfortable to the patient.

8. The compartment syndrome remains an important practical problem in the treatment of fractures of the leg.

VII. SUMMARY

A. Purpose of this investigation

The purpose of this prospective investigation was to test whether the active primary treatment of tibial shaft fractures practised by Edwards (1965) could be combined with early weight-bearing in the PTB-cast practised by Sarmiento (1967).

B. Case Material

The material consisted of 105 patients with 110 fractures of the tibial shaft; 17 fractures were not displaced and 93 displaced. 29 of the displaced fractures were longitudinal of which five were open and 64 were transverse, of which 27 were open. 55 of the displaced fractures were caused by high energy trauma, mainly traffic accidents.

C. Treatment

Primary definitive treatment was provided as soon as possible. In 10 fractures the operation was delayed 24 hours or more, mainly because of concomitant injury or disease.

(1) Displaced longitudinal fractures. Open reduction and osteosynthesis were performed when the displacement was deemed unacceptable. In 18 fractures the osteosynthesis was carried out with screw(s) and in one fracture an encircling wire was used. Ten fractures were reduced by closed methods; in five of these blind intramedullary nailing with a Rush-pin was performed. In the five open fractures the wound was closed with primary suture.

(2) Transverse fractures. Non-displaced fractures and displaced fractures which could be reduced to a stable position were treated with a long-leg cast only. If stable fixation could not be obtained, blind nailing with a Rush-pin was performed. In comminuted fractures where the Rush-pin did not give sufficient stability, transfixation in plaster was made. - In 18 fractures the displacement was reduced to a stable position without osteosynthesis. In 43 fractures fixation was obtained with a Rush-pin. One short oblique fracture was stabilized with a screw. Transfixation was used in two comminuted fractures. - In all 27 open fractures the wounds were sutured primarily with a relaxing incision in only one fracture. Antibiotics were used in all open fractures.

(3) Plaster fixation. All fractures were initially stabilized with a long-leg plaster, and the patients were mobilized with crutches without weight-bearing as soon as possible.

After 2-3 weeks the plaster was changed to a PTB-cast, if wound healing and swelling permitted. The patients were encouraged to bear full weight in the PTB-cast.

D. Complications

There were 20 minor and 15 severe complications. The severe complications were 9 fractures with delayed healing requiring secondary operations and 6 thrombo-embolic non-fatal episodes. There was no case of osteomyelitis in the series.

E. Final Status

In 96 % of the fractures the final status was determined at 1/2 - 3 1/2 years following the accident. The radiographic material was re-examined with regard to malalignment.

(1) Function. The over-all results were 67 % excellent, 25 % good, 6 % acceptable and 3 % poor. The results in the 91 displaced fractures were 57 excellent, 24 good, 7 acceptable and 3 poor.

(2) Malalignment. The re-examination of the radiographic material revealed a high frequency of angulation. 22 fractures had an angulation of 6-10° and seven more than 10°. In 16 of these 29 cases the fracture angle had increased by 5,9 $\pm$ 1,3° during weight-bearing. - Shortening of more than one cm was found in 17 fractures.

F. Comparison with previous investigations

The results of this investigation were closely compared with Edwards's (1965) prospective series and Olerud and Karlström's (1972a)review of tibial fractures treated by AO-compression osteosynthesis. There were only small differencies between the three series regarding the final functional status. Compared with the AO-series there was a lower frequency of both minor and serious complications, fewer secondary operations and shorter hospitalization times. As in Edwards's series osteomyelitis had been prevented, but the transverse fractures seemed to heal more rapidly.

G. Conclusion

It was concluded that the methods of treatment used here give a final result comparable to any other method, but with less discomfort to the patient. However, any angulation should be corrected before weight-bearing is permitted. The compartment syndrome remains an important practical problem in the treatment of fractures of the leg.

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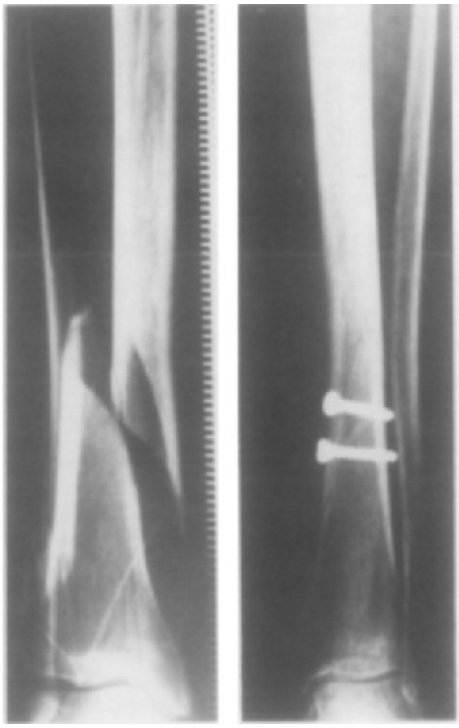
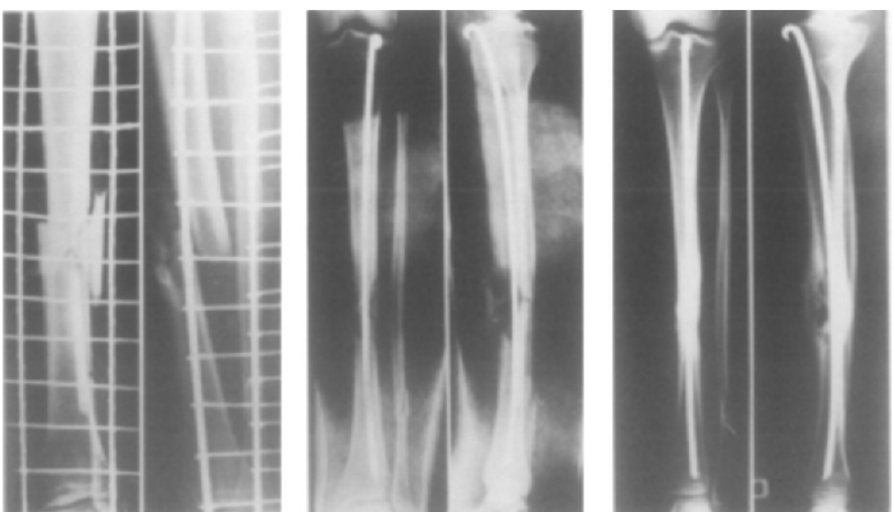


A B

Fig. 4. Longitudinal tibial shaft fracture treated with open reduction and osteosynthesis with screws.

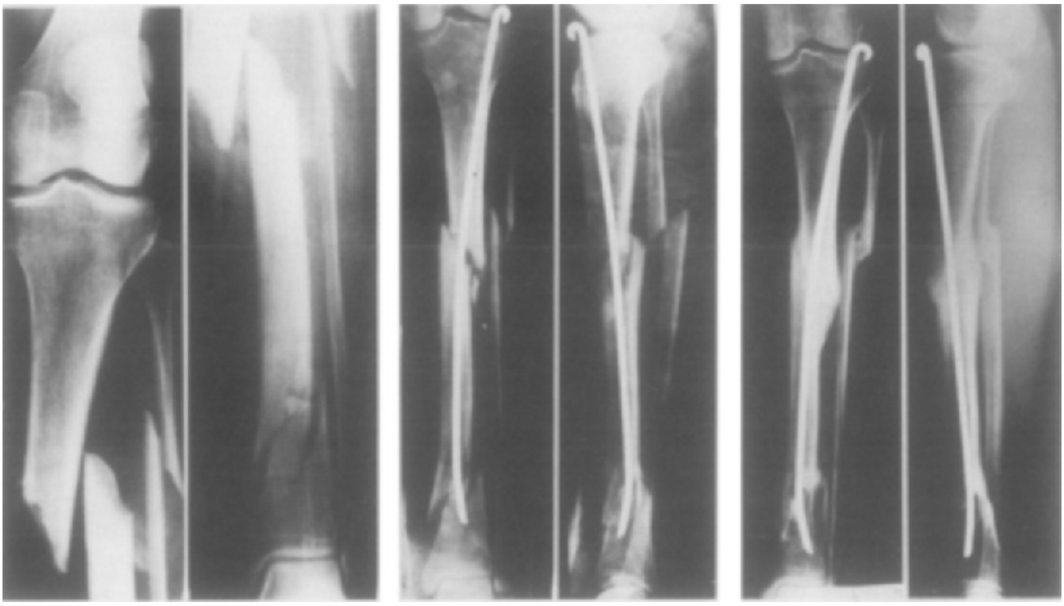
Case 26. A: Preoperative. B: Radiographic and clinical healing four months after the operation.



A B C

Fig. 5. Comminuted transverse fracture of the tibial shaft treated with closed reduction and fixation with a Rush-pin.

Case 82. A: On admission. B: In PTB-cast. C: Radiographic healing after 13 months.



A B C

Fig. 6. Double fracture of the tibial shaft treated with open reduction and fixation with a Rush-pin.

Case 93. A: On admission. B: After open reduction and fixation with a Rush-pin.
C: Radiographic and clinical healing after 6 months.

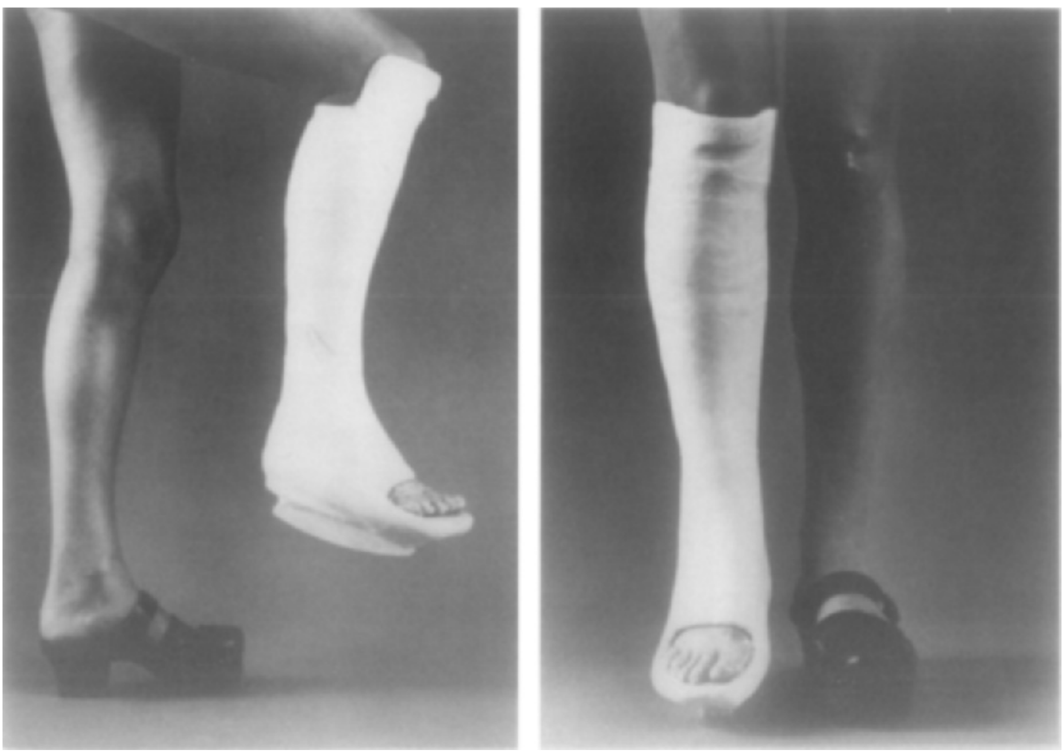
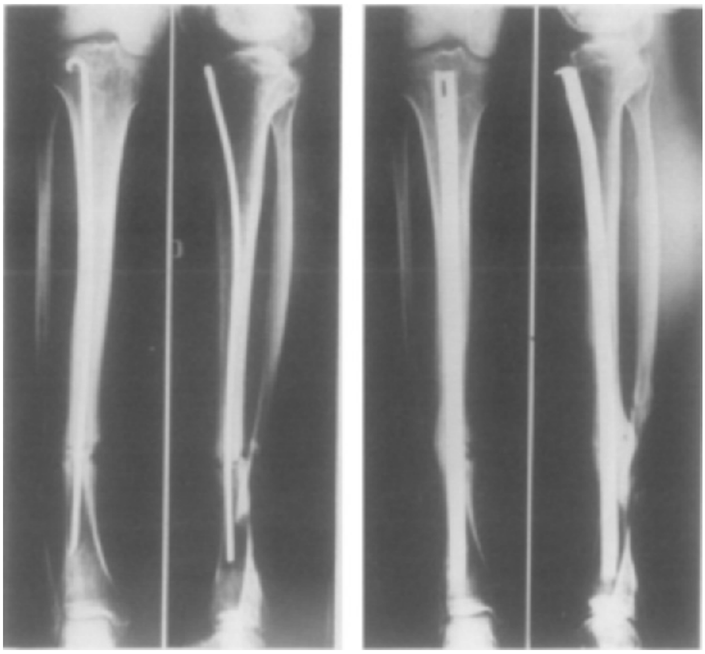


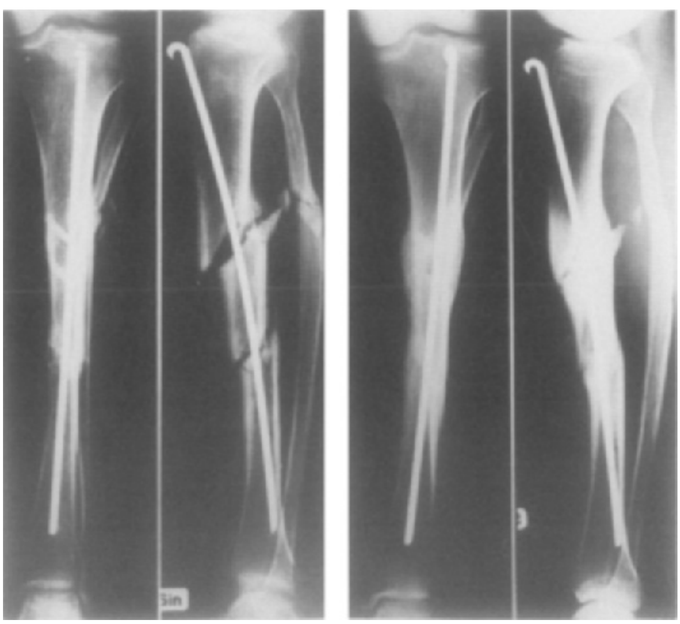
Fig. 7. PTB-cast.



A B

Fig. 8. Reaming and Küntscher-nailing for delayed union of tibial shaft fracture.

Case 49. A: Transverse fracture at 10 months with visible fracture-line, sclerosis of bone ends and pain on weight-bearing. B: Radiographic and clinical healing 11 months after the secondary operation.



A B

Fig. 9. Bone grafting for delayed union of tibial shaft fracture.

Case 64. A: Double fracture at five months with instability and no visible callus formation. B: Radiographic and clinical healing 9 months after the secondary operation.

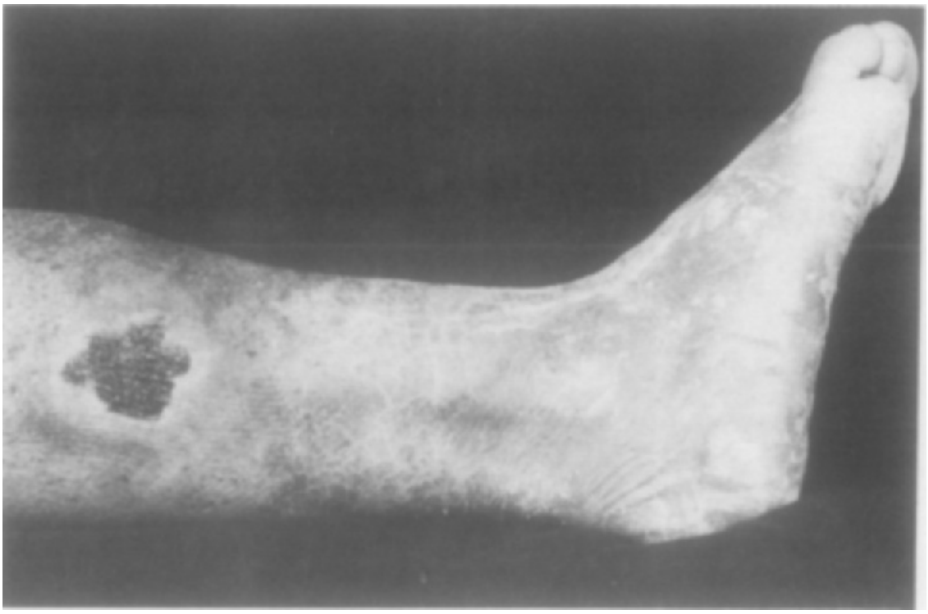


Fig. 10. Superficial skin necrosis caused by the PTB-cast.

Case 93. The necrosis was probably due to an attempt to correct the fracture angle during the application of the PTB-cast.

A B

Fig. 11. Loose screws in a longitudinal tibial shaft fracture after weight-bearing in PTB-cast.

Case 12. A: Immediately after the operation. B: After 3 weeks of weight-bearing in PTB-cast. Continued weight-bearing did not cause any further displacement; the fracture healed at 12 weeks.

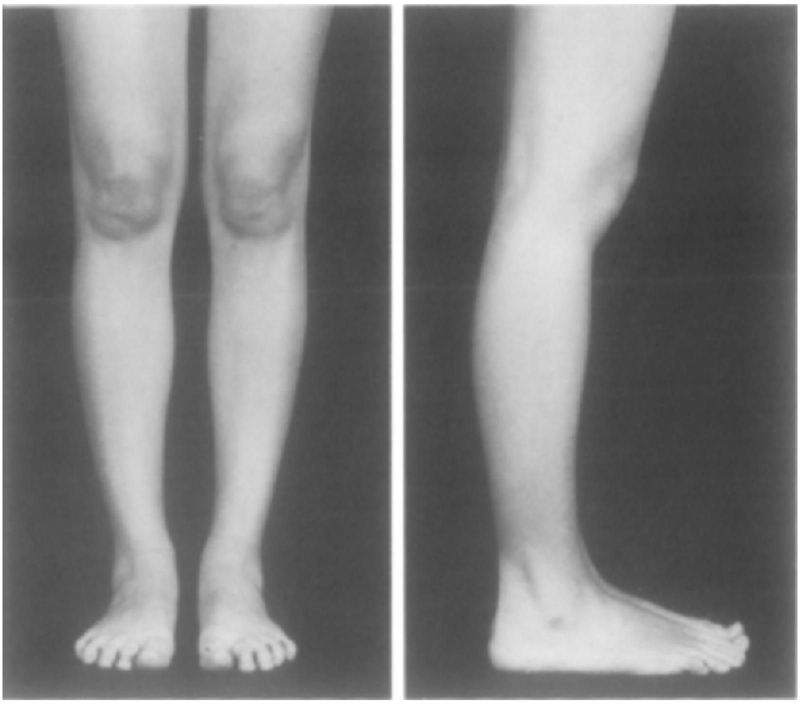


Fig. 12. Residual deformity after bilateral tibial shaft fractures.

Case 46, 47. The angulation was 13° and 15° on the left and right side, respectively.

A B

Fig. 13. Progression of angulation of tibial shaft fracture.

Case 42. A: After wedging of cast. B: After 9 weeks of weight-bearing. The difference in angulation was 12°.

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X. CODED DATA

A.The base material

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	2	72M	10		-	3	+				2						10	50	3	18	P	b
	3	62F	10		-	3	+				1				2,4	10	117	15	2	15	P	d
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	7	23M	2		-	3	+			23	6						4	21	1	12	5	c
	8	53M	10		-	2	+			13	6						3	22	1	11	11	b
	9	35M	10		-	2	+			7	6						4	32	1	11	5	a
	10	17M	10		-	2	-				2						1	22	1	8	S	a
	11	44M	10		-	2	+			28	6					4,9	32	29	1	9	10	a
	12	29M	10		-	2	+			48	6				8		6	23	1	12	4	a
	13	23M	10		-	2	+			13	6						4	18	3	18	10	a
	14	51F	10		-	3	+				1						8	28	1	11	5	b
	15	65M	10	+	-	3	+			288	7				3		16	47	1	13	P	c
	16	51M	7		-	2	+			4	4						4	21	2	13	7	c
	17	47M	10		-	2	+			20	6				8		5	24	3	18	8	a
	18	42M	6		-	2	+			5	6						3	22	2	14	5	a
	19	71F	10		-	2	-				1					10	34	27	1	13	P	a
	20	31F	10		-	3	+			11	6						3	14	2	14	0	b
	21	57F	10		-	2	+			18	6				8		4	27	1	18	6	a
	22	40M	10		-	2	+			10	6				6		16	31	1	12	7	a
	23	67F	10		-	2	+			6	4						8	22	1	10	P	a
	24	58M	10		-	2	+			6	6						6	29	2	14	6	b

A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	X
2	25	18M	3		-	3	+	a		4	6	1	1(a)				12	14	2	15	5	b
	26	59F	10	+	-	2	+	a		14	6		1(a)		5		15	35	1	13	6	a
	27	59M	9	+	-	2	+	a		9	4		1(e)				6	25	1	13	7	a
	28	62F	10		-	3	+	a		8	6		1(b)		1		13	21	3	11	8	b
	29	59M	10		-	2	+	a		7	6		1(a)				3	23	2	17	7	b
4	30	64M	2	+	-	2	+			7	10,4				3		6	33	2	15	5	a
	31	29M	8		-	2	+			6	4						4	17	1	11	5	b
	32	22M	8	+	-	2	+			4	4	1		1	7		11	26	4	-	12	a
	33 (90)	17M	7		-	2	+			10	4						54	30	2	16	R	a
	34	22M	5		-	2	-				2					10	7	20	2	14	0	a
	35	27M	8	+	-	2	+			10	4						2	25	2	12	4	a
	36	16M	6		-	3	+				2						3	46	1	11	4	a
	37	24M	2	+	-	2	+			5	4						2	22	2	10	5	a
	38	36M	8		-	2	+			22	4						4	21	2	17	7	b
	39	18M	2		-	2	-			8	5						4	22	2	11	8	a
	40	28M	8		-	2	+			6	4						4	26	1	12	4	a
	41	29F	4		-	2	+			8	4						6	29	2	14	6	a
	42	22M	2		-	3	+				2	2					3	38	3	20	8	b
	43	21M	8		-	2	+			6	4				3		4	21	4	17	12	b
	44	18M	2		-	2	+				1						3	19	1	12	4	a
	45	20F	1		-	2	+			11	4					1,4,5	23	17	1	13	S	a
	46	19F	1		-	2	-				1	2					35	26	2	13	8	a
	(47)	19F	1		-	2	-				1	2			2		35	26	2	13	8	a
	48	68M	1		-	2	+			7	4	1,2		1	3,5,7		36	31	5	-	P	b

A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	X
	49	26M	8		-	2	+			6	4			1	7		9	19	4	-	11	a
	50	30M	8		-	2	+				2						2	16	2	12	4	a
	51	18M	8		-	2	+			8	4						2	27	1	15	S	a
	52	22M	8		-	2	+				2						2	36	1	12	5	a
	53	20M	8		-	2	+				2						2	14	2	12	1	a
	54	22M	8		+	2	+			25	4	3,4					27	41	1	11	4	a
	55	66M	1		+	2	+			48	4	2				7,10	34	14	2	13	P	a
	56	46M	4		+	2	+			7	3						10	26	1	14	6	a
	57	32M	7		+	2	+			7	4,9	2		2	3,7		23	21	4	64	11	a
	58	31M	8		+	2	-			6	4						2	26	2	19	8	a
	59	17M	2		+	2	-				1					9	18	14	1	8	1	a
	60	31M	1		+	2	+			39	4						6	31	1	14	6	x
	61	28M	8		+	2	+			9	4						4	25	1	13	7	a
	62	56M	2		++	3	+			9	3	2			7		16	54	3	34	-	d
	63	39M	4	+	+++	2	+			8	4	1				4	14	39	1	15	5	b
	64	26M	1	+	+++	2	+			432	10,4			2	7		29	36	3	34	8	b
	65	40M	4		+++	2	+			8	4						6	19	2	16	17	b
	66	72F	1		+++	2	+			43	10,4					1,7,8,9	41	17	2	14	P	b
5	67	31M	7		-	2	-	a	+		1	2	1(c)				7	28	3	18	2	a
	68	52M	7	+	-	2	+	a		8	4		1(a)				6	25	1	14	8	a
	69	43F	7		-	2	+	a			1		1(c)		7		4	25	3	22	7	b
	70	41M	2		-	3	+	d		5	6		1,2(c)				9	37	1	8	7	b
	71	21M	3		-	2	+	a		19	10,4		1(a)				3	26	1	13	5	a
	72	53F	10		-	2	+	a		13	4		1(a)				7	19	2	15	6	a
	73	17M	2		-	1	-	ce			1		1(e)				7	28	2	16	S	b

A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	X
	74	18F	1	+	-	2	+	be		7	5	2	1(e)	1	7		9	24	3	-	16	b
	75	17M	2		-	2	-	b		4	4		1(d)				4	22	2	15	6	a
	76	48M	4		-	2	+	b		4	4		1(c)	1	2,7	5	64	46	2	-	24	c
	77	24M	8		-	2	+	a		6	4		1(a)				3	20	2	16	8	c
	78	59M	7	+	-	3	+	b		6	10,4		1(d)		7		7	21	4	34	19	c
	79	16M	2		-	2	-	b	+	408	4	1	1(d)			3S	30	19	2	15	S	a
	80	17M	2		+	2	-	b			1		1(c)				5	19	2	12	5	a
	81	26M	4	+	+	2	+	a		6	4	2	1(a)				5	33	1	13	2	a
	82	16F	2	+	+	2	+	b		48	10,4		1(a)			7	17	17	2	13	S	a
	83	16F	2		+	2	+	b		10	4	2	1(a)				5	24	1	11	S	a
	84	23M	1		+	2	+	be			2		1(a)				5	22	1	12	5	a
	85	15M	2		+	2	-	b	+		2		1(a)				3	34	1	10	S	a
	86	15M	2		+	2	+	b		5	4		1(a)				9	37	1	12	S	a
	87	18M	4	+	+	2	+	b		7	8		1(e)				6	26	1	10	8	a
	88	45M	6		+	2	-	d	+	7	5		1(c)		3	6	18	31	4	16	10	a
	89	55M	1	+	+	2	+	be		5	5	1,2	1(a)	3,1	7	10	38	54	3	-	P	a
	90 (33)	17M	7	+	++	2	+	a		10	4	2	1(e)	2	2,7		54	19	10	81	R	d
	91	65M	2	+	+++	2	+	a			2	1,2	1(a)		7		8	29	2	31	P	b
	92	41M	1		+++	2	+	a		24	4		1(d)			10	30	22	1	15	P	a
	93	52F	5	+	+++	2	+	b	+	5	5	1	1(e)		2		27	23	3	13	9	c
7	94	17M	8		-	2	-				1						0	1	1	6	2	a
	95	27M	8		-	2	-				1						0	22	1	10	3	a
	96	27M	4		-	2	-				1						0	12	1	8	3	a
	97	27M	8		-	2	-				1						0	10	1	7	6	x

A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	X
	98	44M	8		-	2	-				1				5,6		17	26	1	6	10	a
	99	25M	8		-	2	-				1						0	18	1	9	4	a
	100	24M	8		-	2	-				1						0	10	1	8	1	x
	101	34M	8		-	2	+				1						0	19	1	7	3	a
	102	32M	8		-	2	-				1						0	12	1	9	4	a
	103	16M	2		-	2	-				1						0	6	2	8	3	a
	104	29M	8		-	2	-				1						0	18	1	8	5	a
	105	33M	8		-	2	-				1						0	17	2	9	2	b
	106	19M	8		-	2	-				1						0	12	1	6	S	a
	107	28M	8		-	2	-				1						1	15	1	14	1	a
	108	24M	8		-	2	+				1				6		3	22	1	11	4	a
	109	25M	8		-	2	-				1						0	11	1	13	4	a
8	110	40M	10		-	2	-				1						1	18	1	6	-	xx

Fractures excluded from the source material (Groups 3-5, page 8).

A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	X
1	111	78F	10		-	2	+			24	4						-	-	-	35	P	xx
	112	53M	10		-	3	+			?	6						-	-	-	18	P	x
	113	31M	10		-	3	+			8	3			2	7		23	144	3	52	?	b
4	114 (125)	74M	2	+	-	2	+				2					7,9	146	-	-	10	P	b
	115	88M	1		-	2	+			?	10,4	2		1	7		23	69	3	-	P	c
	116	25M	2	+	-	2	+			24	4	1		1		1	63	88	2	?	?	b
	117	79M	5	+	-	2	+			72	10,4					2,3S,7	116	-	-	19	P	xx
	118	75K	10		-	1	+				1			3			79	-	-	12	P	a
	119	15M	2		-	2	-				1	1				3S	49	-	-	13	S	a
	120	27M	7		+	2	+			3	4					9	85	80	1	17	?	a
	(121)	27M	7		++	1	+			3	9,10	1,4,5			3,7		85	121	2	37	?	d
	122	58F	1	+	+++	2	+			?	10,4	1,1			2	1,8,9	120	88	7	42	?	c
5	123	18M	2		-	2	-	?		7	5	2	1(c)			1,8	31	46	2	17	?	a
	124	16M	2		+++	2	+	d		6	5		1(a)			3S,9	44	74	1	15	?	a
	125 (114)	74M	2	+	+++	2	+	b		2	4,9	4	1(e)		2	7	146	-	-	13	P	d
	126	18F	2		+	2	+	b			1	1	1(a)				18	67	1	19	S	a
	127	17M	4	+	+	2	-	b			10,1		1(d)			1,3,9	112	-	-	8	?	xx
	128	15M	2	+		3	+	b		4	2		1(a)				4	-	-	8	S	a

Case 124 has been published by Hansson et al. (1977).

XI. KEY TO DATA

A. Anatomic classification of fracture
1. Displaced longitudinal closed
2. Displaced longitudinal open
3. Non-displaced longitudinal open
4. Displaced transverse closed
5. Displaced transverse open
6. Non-displaced transverse open
7. Non-displaced transverse closed
8. Non-displaced longitudinal closed

B. Case
Figures in brackets represent patients with bilateral fractures

C. Age and sex
F = female
M = male

D. Cause of injury
1. Pedestrian hit by a car
2. Motorcyclist injured in collision with a car
3. Motorcyclist injured in single motorcycle accident
4. Car driver or passenger injured in traffic accident
5. Cyclist injured in collision with a car
6. Fall from a height more than 3 metres
7. Blow from a heavy object, or a crush injury
8. Soccer injury
9. Single bicycle accident
10. Fall at ground level or from a low height

E. Severe displacement on arrival

F. Comminution of fracture
- Non-comminuted fracture
+ Comminuted fracture
++ Severely comminuted fracture
+++ Double fracture

G. Location of fracture
1. Proximal metaphysis
2. Diaphysis
3. Distal metaphysis

H. Fracture of fibula

I. Size of wound
a. 1 cm or less
b. 2-5 cm
c. 6-10 cm
d. more than 10 cm
e. exposure of fracture

J. Contamination with foreign material

K. Hours from accident to operation

L. Primary treatment of fracture
1. No reduction and plaster fixation
2. Closed reduction and plaster fixation
3. Closed reduction and transfixation
4. Closed reduction and fixation with a Rush-pin
5. Open reduction and fixation with a Rush-pin
6. Open reduction and fixation with screws
7. Open reduction and fixation with cerclage
8. Open reduction and plaster fixation
9. Fasciotomy
10. Traction

M. Additional primary treatment of fracture
1. Re-reduction
2. Wedging of cast
3. Fasciotomy
4. Free split-thickness skin graft
5. Venous grafting of popliteal artery

N. Primary and secondary treatment of wound
(letter in brackets indicates the type of antibiotic(s) used.)
1. Excision and suture
2. Relaxing incision
3. Split-thickness skin graft
S. Secondary treatment
a. Penicillin
b. Ampicillin
c. Penicillin + ampicillin
d. Cloxacillin + ampicillin
e. Cephalothin/cephalexin

O. Secondary treatment of fracture
1. Fibulotomy, reaming and Küntscher-nailing
2. Bone-grafting
3. Küntscher distractor

P. Complications
1. Necrosis of contused skin
2. Necrosis from pressure of the plaster
3. Infection
4. Peroneal palsy
5. Thrombosis
6. Pulmonary embolism
7. Delayed union
8. Loose screws

Q. Other fractures or injuries
(S other fracture to the same limb)
1. Fracture of the pelvis
2. Fracture of the neck of the femur
3. Fracture of the shaft of the femur
4. Fracture of the scapula
5. Fracture of the humerus
6. Fracture of the foot
7. Head injury
8. Rupture of the spleen
9. Other injury
10. Other disease

R. Days of hospitalization

S. Days to PTB-cast

T. Number of PTB-casts

U. Weeks to clinical union

V. Months of disability
P = pension
O = not working for other reason
S = studying
R = occupational rehabilitation/retraining

X. Final status
a. Excellent
b. Good
c. Acceptable
d. Poor
x. Not available for evaluation
xx. Impossible to evaluate because of other injury or disease