ACTA ORTHOPAEDICA SCANDINAVICA
SUPPLEMENTUM NO. 76

From the Orthopaedic Research Laboratories (Head: Göran C. H. Bauer, M. D.)
of the Orthopaedic Department (Head: Sophus von Rosen, M. D.)
University of Lund, Malmö General Hospital, Malmö, Sweden

Fracture of the Shaft of the Tibia: 492 Consecutive Cases in Adults

IMPORTANCE OF SOFT TISSUE INJURY

BY PER EDWARDS

MUNKSGAARD COPENHAGEN 1965

PRINTED IN SWEDEN BY
BERLINGSKA BOKTRYCKERIET
LUND 1965

CONTENTS

FIGURES

TABLES

I. Introduction

During the period 1841 through 1861, 150 patients with open fractures of the lower leg were treated at Guy's Hospital in London. Forty-nine of these patients died from infection (Bruns, p. 399). These results were typical for the era preceding the introduction of antiseptic and aseptic management of open wounds. In 1882 Bruns (p. 398) reported on a series of 126 open fractures of the lower leg with a mortality rate of 7 per cent due to infection. These results from the 19th century indicate the trend over the last one hundred years in the management of fractures of the shaft of the tibia: increased efficiency due to prevention and treatment of infection.

Today the results of treatment of this fracture are recorded in terms of morbidity rather than mortality. Expressed in such terms present-day techniques for treatment of fracture of the shaft of the tibia are still far from satisfactory. In a series of 3544 such fractures collected from the last decades, gun shot fractures excluded, the rate of osteomyelitis was 8 % (Table 24).

In an earlier investigation of fracture of the shaft of the tibia from this institution (Bauer, Edwards and Widmark, 1962) it was found that the incidence of infection and poor end results was directly related to the etiology of the fractures: the results were uniformly good in fractures caused by moderate, indirect violence and were relatively poor in fractures caused by severe direct violence. These results were interpreted to suggest that the prognosis in fractures of the shaft of the tibia was related more to the severity of soft tissue damage than to the bone injury.

This hypothesis was tested in a series of experimental fractures of the shaft of the tibia in dogs (Edwards, 1965). It was found that the rate of healing was delayed in those fractures which had a crush injury of the skin over the fracture.

Therefore in a series of fractures of the shaft of the tibia special attention was given to the management of the skin injury. Additional damage to potentially injured skin was avoided, and primary closure of open fractures was done, with skin grafts when necessary. In the investigation reported

here the findings in this *Prospective Series* of fractures are compared with the findings in an earlier consecutive *Control Series*. The results of this comparison are described in three etiologically different types of fracture.

II. Material and Methods

The material comprised 492 fractures of the shaft of the tibia in 483 adult patients treated in the Orthopaedic Department of the University of Lund at the General Hospital in Malmö (Malmö Allmänna Sjukhus) during the years 1949 through 1963. During the period of this investigation all fracture cases requiring hospital admission in the 225,000 population of Malmö were referred for treatment to the Orthopaedic Department. The records of the Orthopaedic Department thus reveal all fractures of the shaft of the tibia diagnosed in Malmö during this period. The reader is referred to Alffram (1964) for further definition of the population at risk in this community. Some of the cases in this material were studied with isotope techniques by Wendeberg (1961) and by radiometric bone density techniques by Nilsson (1965). All of the 173 fractures described by Bauer, Edwards and Widmark (1962) are included in this material. *All data pertinent to this investigation are presented in code form in Section IX, A.*

A. DEFINITION OF PROBANDS

The purpose of this investigation was to assess the value of methods of treatment of fractures of the shaft of the tibia in adults by comparison of associated complications, Healing Time and Final Status in a *Prospective* Series with those in a *Control* Series. The lower age limit for this study was set at 16 years, as done by Ellis (1956) and Bergentz and Thureborn (1957). The limit of the tibial shaft was set proximally at the *tibial tuberosity* and distally at a point *three centimeters above the ankle joint line.*

Six groups of patients failed to qualify as probands because they received (a) primary, or (b) final treatment elsewhere, (c) had serious concomitant disease, (d) had multiple injuries of such severity that significant data could not be obtained, (e and f) had fractures through obviously pathological bone, or (g) died before completion of treatment (Table 1). For epidemiologic reasons all available data concerning those of the above who were residents of Malmö are shown in Section IX, B.

TABLE 1 Patients with fractures of the shaft of the tibia who did not qualify as Probands

	Control Series	Prospective Series
a Fractures which received primary treatment at another hospital	38	11
b Fractures which received end or final treatment at another hospital	19	2
c Fractures in patients with serious disease or deformities	10	2
d Fractures in patients with such serious other injury that significant data concerning the tibial fracture could not be obtained.	2	0
e Fractures through bone grafts or refractures	4	0
f Fractures in Paget's disease	0	1
g Fractures in patients who died a short time after the accident.	8	2

Ten patients treated for fracture of the shaft of the tibia in Malmö during the period of this investigation (1949 through 1963) died before completion of treatment. Five of them had severe *multiple injuries* and died from: *fat embolism* within three days of injury (3 patients), *brain injury* (1 patient), and *myocardial infarction* (1 patient). Five patients without multiple injuries died from verified *myocardial infarction* (1 patient), *suicide* (1 patient), and *pulmonary embolism* 3-4 weeks after injury (3 patients). For reasons stated above none of these patients qualified as probands.

The age-and-sex distribution of the probands is shown in Tables 3 and 4.

1. *Control Series*

The Control Series contained 305 probands, residents of the city of Malmö, with 311 fractures sustained during the period 1949 through 1960.

2. *Prospective Series*

The Prospective Series contained 178 probands from the Southern region of Sweden, with 181 fractures sustained during the period 1961 through 1963. Forty-six of these probands with 47 fractures were not residents of Malmö.

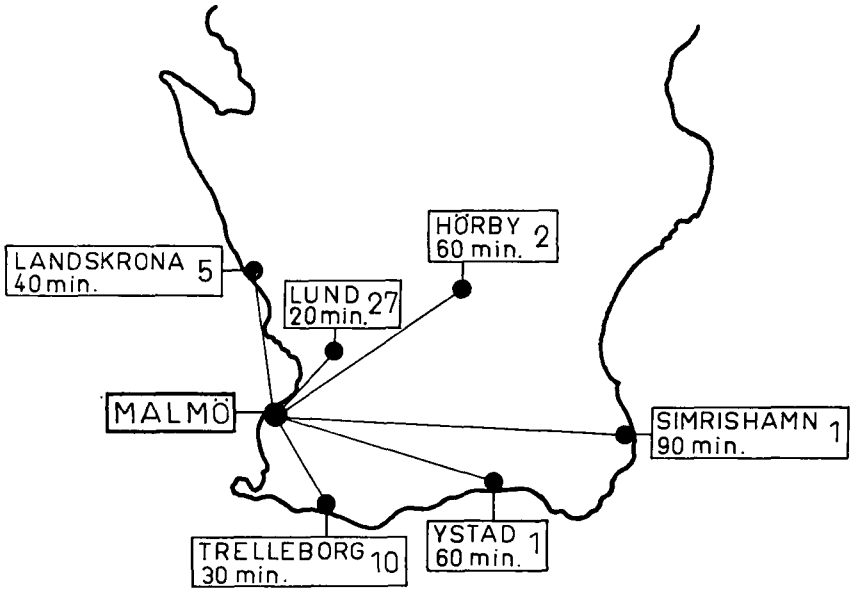


FIGURE 1 Map of Southern region of Sweden showing driving time and number of probands referred to Malmö from other hospitals.

3. *Comparison Between Control and Prospective Series*

There was no appreciable difference in the age and sex distribution of probands in the two series. The two series differed in one respect: by agreement with the chiefs of surgery at five hospitals in the Southern region of Sweden (Fig. 1) patients with fracture of the shaft of the tibia were immediately conveyed to the Malmö Orthopaedic Department for treatment regardless of whether or not they were residents of Malmö. This agreement was reached for two reasons: (a) to increase the number of probands and (b) to test the practical consequences of declaring a specific type of fracture an emergency requiring centralized treatment in the same manner that is accepted for burn injuries.

B. STATISTICAL METHODS

Standard statistical methods have been used. Comparisons subjected to statistical analysis have been indicated in the text as follows:

***	$P<0.001$
**	$0.001<P<0.01$
*	$0.01<P<0.05$
—	$P>0.05$

Percentage values shown in the text or in tables are always based on numbers greater than 100.

C. CLASSIFICATION OF FRACTURES

The material was classified according to (1) anatomic and (2) etiologic parameters.

1. *Anatomic Parameters*

The anatomic classification was made in regard to (a) bone injury and (b) soft tissue injury, to distinguish factors which might influence the choice of method of treatment of fractures of the shaft of the tibia.

a. Bone Injury

Classification of the bone injury was made on the basis of initial radiographs read by the author. Fractures were classified according to (i) *location,* (ii) *pattern,* and (iii) *displacement.*

(i) The *location of fracture* was defined conventionally as being the *upper, mid* or *lower* third of the tibia.

(ii) The *pattern of fracture* was defined to distinguish between transverse and longitudinal fractures. Within the former a distinction was then made between comminuted and not comminuted fractures.

α. Transverse fractures: all fractures in which the fracture line formed an angle of 45 to 90 degrees with the long axis of the shaft and all comminuted fractures, i.e., those with one or more intermediate fragments involving at least half of the bone diameter. By definition double fractures were thus included in this group.

β. Longitudinal fractures: all other fractures, i.e., fractures which have been called long spiral fractures or long oblique fractures.

(iii) *Displacement of fracture* was defined in essential agreement with the criteria of Jackson and McNab (1959) and Adler et al. (1962).

No displacement: fractures without displacement except for angulation in relation to the long axis of the tibia of less than 15 degrees.

Moderate displacement: fractures with transverse displacement where, regardless of angular displacement, the contact between the major fragments was at least ⅓ of the diameter of the shaft or where the shortening was 1 cm or less.

Marked displacement: all other fractures.

b. Soft Tissue Injury

The conventional distinction made between *closed* and *open* fracture has been amplified by consideration of the *size of the wound* in essential agreement with the recommendations of Freeman and Jarves (1958) (Table 2). In the Control Series these measurements were invariably found in the case records, and in the Prospective Series these measurements were made by the author. The size of the wound was defined as:

insignificant — (about one centimeter or less),
small — (about 2 to 5 centimeters),
large — (about 6 to 10 centimeters),
major — (more than 10 centimeters or gross defect).

The insignificant and small wounds would roughly correspond to Ellis' (1956) minor compound injuries, and the large and major wounds to his major compound injuries.

No attempt was made to classify injury to muscle or other subcutaneous soft tissues, except nerve or major arterial lesions. Such lesions were found in only one case.

c. Contamination of Fracture

The presence or absence of gross contamination in transverse fractures was expressed with relation to the size of the wound, and the exposure of the fracture in the wound (Table 2). Primary cultures of micro-organisms were not made.

In the entire material the incidence of exposure of the fracture in the wound was higher *** among fractures with wounds larger than 6 cm (37 of 47) than among fractures with wounds less than 6 cm (14 of 71).

There was no difference between the Control and the Prospective Series as regards incidence of exposure of the fractures in the wound or of gross contamination of the open fractures.

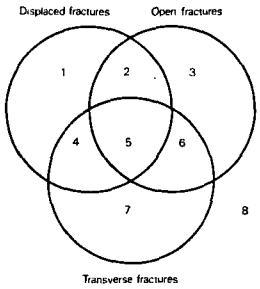


FIGURE 2 Diagrammatic representation of fractures of the tibial shaft classified according to skin injury, displacement and type of bone injury.

TABLE 2 Relation between the size of wound, exposure of fracture, and gross contamination in transverse fractures

Control Series					Fracture exposed in wound	Prospective Series				
	The size of wound (cm)					The size of wound (cm)				
Total	< 1	2—5	6—10	> 10		< 1	2—5	6—10	> 10	Total
27(5)	2	8	10(2)	7(3)	+	—	4(1)	9	11(3)	24(4)
44(1)	20	19(1)	4	1	—	8	10	5	—	23
71(6)	22	27(1)	14(2)	8(3)	Total	8	14(1)	14	11(3)	47(4)

Figures in brackets represent number of fractures grossly contaminated with foreign material.

TABLE 3 Anatomic classification of fractures of the shaft of the tibia

Anatomic Classification	Venn Diagram Area	Numbers of Fractures		
		Control	Prosp.	Total
Displaced Longitudinal Closed	1	118(51)	47(20)	165(71)
Displaced Longitudinal Open	2	7(3)	5(2)	12(5)
Undisplaced Longitudinal Open	3	—	—	—
Displaced Transverse Closed	4	94(23)	62(9)	156(32)
Displaced Transverse Open	5	71(11)	47(9)	118(20)
Undisplaced Transverse Open	6	4(1)	—	4(1)
Undisplaced Transverse Closed	7	17(1)	11(—)	28(1)
Undisplaced Longitudinal Closed	8	—	9(4)	9(4)
Total		311(90)	181(44)	492(134)

Figures in brackets represent fractures in females.

d. Correlation of Anatomic Parameters

The correlation between pattern of fracture, degree of displacement, and soft tissue injury was defined through the use of a Venn diagram (Fig. 2). It was found that 439 of 492 fractures (89 %) were distributed between three of the eight possible types. All fractures which belonged to these three types were displaced. One of the three types contained *165 closed, longitudinal* fractures, and the other two types contained all displaced transverse fractures, divided between *156 closed, transverse* and *118 open transverse* fractures. About one half of the 53 fractures which did not belong to the three main types were undisplaced, closed, transverse fractures (Table 3).

This method of correlating anatomic parameters is similar in principle to the one shown as Table V by Nicoll (1964). However, Nicoll excluded fractures that later became infected, and distinguished between comminuted and not comminuted fractures rather than between transverse and longitudinal fractures as done here. A formal analysis of the significance of a Venn diagram (Feinstein, 1963) as regards diagnosis, etiology, treatment and prognosis of fractures of the shaft of the tibia will be published by Bauer and Edwards (1966).

2. *Etiologic Parameters*

A fracture occurs when the forces applied to the bone exceed the strength of the bone. The etiology of fracture may thus be related to two factors: (a) bone strength, and (b) the nature of the forces applied.

a. Bone Strength

Bone strength, unfortunately, cannot be measured directly in vivo. However, by removal from this investigation of cases with obviously diminished bone strength caused by localized lesions such as Paget's disease, some uniformity has been assured. More important, bone strength tends to decrease with increasing age, particularly in women (Bauer, 1960; Alffram, 1964); identification of the probands in terms of age and sex, therefore, provided a rough estimate of this factor.

b. Nature of Forces

The nature of the forces causing a fracture cannot be measured exactly in individual cases. However, rough estimates of the *direction* and *magnitude* of these forces can be made. It is well known (Adams, 1964) that

the direction of the forces operating can be deduced from the shape of the fracture: angular or *direct* forces cause transverse fractures, and torsional or *indirect* forces cause longitudinal fractures (Bruns, 1882). A rough estimate of the magnitude of the forces was provided in this investigation by adoption of definitions used in an earlier study (Bauer, Edwards and Widmark, 1962). The guiding principle was to distinguish between (i) trauma, resulting from high energy forces, and (ii) trauma, resulting from low energy forces. Forces originating from the human body or the equivalent of such forces have been judged as low in energy. On this basis the following definitions emerged:

(i) Severe violence (283 fractures) resulting from:

α. All accidents in which a *motor vehicle* was involved (216 fractures),

β. *Falls from a height* of more than three meters (12 fractures),

γ. *Blows from very heavy objects* (55 fractures). This group included fractures caused by *crush* injuries.

(ii) Moderate violence (209 fractures) resulting from all other types of accidents:

α. *Falls at ground level* or from *low heights* such as chairs or tables (141 fractures),

β. *Sports injuries including soccer football* (34 fractures) and *skating* (7 fractures). There were no ski injuries.

γ. *Bicycle accidents* (27 fractures) in which a motor vehicle was not involved.

3. *Correlation of Anatomic and Etiologic Parameters*

The *degree of violence* was determined in the three main anatomic types of fracture defined above, that is, closed longitudinal, closed transverse, and open transverse types (Table 4). Severe violence caused 84 % of the transverse type fractures and 14 % of the longitudinal type fractures. Out of the former, 97 % of the open and 74 % of the closed fractures were caused by severe violence. The higher incidence of severe violence in the transverse fractures agreed with the *incidence of comminution*: it was 44 % in open fractures, 31 % in closed fractures caused by severe violence, and 18 % in closed fractures caused by moderate violence.

Cases with *multiple injuries* were similarly distributed between the main anatomic types: 70 of the 81 cases were found among those caused by severe violence; the incidence of multiple injuries was 31 % in open transverse fractures, 20 % in closed transverse fractures and 9 % in longitudinal fractures. In the closed transverse fractures the incidence of multiple in-

TABLE 4 Correlation of anatomic and etiologic classification of displaced fractures of the shaft of the tibia

Fracture Type	Violence		Total	Mean age ± SD
	Severe	Moderate		
Closed Longitudinal	23(5)	142(9)	165(14)	46.5 ± 15.0
Closed Transverse	116(29)	40(2)	156(31)	42.8 ± 20.3
Open Transverse	114(36)	4(—)	118(36)	44.1 ± 18.8

Figures in brackets indicate multiple injuries.

juries was five times higher in those caused by severe violence than in those caused by moderate violence (Table 4).

Among the transverse fractures the *degree of displacement* was marked rather than moderate in 76 % of the closed and 88 % of the open fractures. Also, among the closed transverse fractures the degree of displacement correlated with the degree of violence. Essentially the same correlation was found in the minor anatomic types. For example, whereas 18 of the 28 undisplaced, closed, transverse fractures were caused by *severe violence,* only 2 of these were comminuted, and the 10 fractures of this type which were caused by *moderate violence* were all soccer football injuries.

As noted above the age and sex composition of the population at risk is of etiologic importance in fractures of the shaft of the tibia. The correlation between this etiologic factor and the anatomic classification is shown in Table 4. Only 19 % of the transverse fractures occurred in females as compared to 43 % of the longitudinal fractures (Table 3).

It was pointed out above that the pattern of the fracture is generally determined by the direction of the forces which caused the fracture. It has been shown in this section that the type of fracture, based on the correlation between anatomic parameters, is closely correlated with the magnitude of the forces which caused the fracture. This correlation between anatomic and etiologic parameters indicates that the anatomic clasification provides a detailed etiologic classification: closed, longitudinal fractures were caused predominantly by moderate violence, whereas transverse fractures were caused by severe violence. This pattern became even more apparent by separation of the transverse types in closed and open fractures; the incidence of fractures caused by severe violence was greater *** in the latter type.

The anatomic appearance of fracture of the shaft of the tibia thus provides a record of the etiologic factors involved. Therefore, the anatomic

TABLE 5 Interval between accident and osteosynthesis

Control Series				Prospective Series		
< 24 hours	1—6 days	> 1 week	Type of Fracture	< 24 hours	1—6 days	> 1 week
66	19	9	Longitudinal	31	1	—
40	7	9	Transverse closed	31	1	—
24	1	12	Transverse open	30	—	1
130	27	30	Total	92	2	1

classification will be used below in the description of treatment, complications and Final Status of the fractures.

4. *Comparison Between Control and Prospective Series*

In residents of Malmö there was no significant difference between the two series with regard to the distribution of fractures between the main anatomic types, and within these types the distribution of the degree of violence was similar. The incidence of displaced transverse fractures was 53 % in the Control and 60 % in the Prospective Series, and in these groups the incidence of open fractures was identical. In both series the open transverse fractures were almost solely the result of severe violence. In the Control Series the incidence of closed transverse fractures caused by severe violence was slightly higher than in the Prospective Series (74 of 94 as compared to 42 of 62 fractures) but this difference was not significant. The incidence of multiple injury was 17 % in the Control Series and 21 % in the Prospective Series.

The two series did not differ as regards sex and age distribution of probands in the main types of fractures.

The two series were thus drawn from the same universe as regards etiology of the fractures.

D. TREATMENT OF FRACTURES

1. *Primary Treatment*

The general policy at this hospital has been to institute immediate definitive treatment of fractures of the shaft of the tibia. Plaster from toes to groin was used in all 492 fractures, preceded by a period of traction in only 18 cases, all in the Control Series. Internal fixation was used in 290 of 425

TABLE 6 Primary treatment of displaced longitudinal fractures

Initial Displacement	Closed or no Reduction		Closed Reduction and Blind Nailing		Open Reduction and Internal fixation		Open Reduction Without Internal Fixation	
	Control	Prospective	Control	Prospective	Control	Prospective	Control	Prospective
Moderate	9	8	—	—	4	—	1	—
Marked	14(2)	7	—	1	90	31	—	—

Figures in brackets represent fractures treated with traction.

fractures (68 % of total) which were reduced, usually within 24 hours of injury (Table 5). The management of the three major types of fractures is described below. Section IX, A contains information on the treatment in the individual cases.

a. Longitudinal Fractures (Table 6)

Throughout the period of this investigation the principles of the treatment of longitudinal fractures remained unchanged: a high frequency of open reduction and *internal fixation plus long leg plaster* in displaced fractures and *long leg plaster* alone in undisplaced fractures. The frequency of open reduction and internal fixation, usually with screws, was 85 % in markedly displaced longitudinal fractures. The 12 open longitudinal fractures were treated in the same way after the wound had been sutured.

The two series differed in two respects: (1) in the *Control Series* the skin incision was always placed over the antero-medial surface of the tibia and the internal fixation material was placed subcutaneously. In the *Prospective Series* the incision was made so as to avoid the antero-medial surface of the tibia, and the internal fixation material was placed under the muscles on the lateral surface of the tibia. (2) In the *Prospective Series* osteosynthesis was performed earlier than in the control series (Table 5).

b. Closed Transverse Fractures

In the closed, transverse fractures the frequency of internal fixation was equal in the two series (56 of 94 in the Control Series and 32 of 62 in the Prospective Series) while the frequency of open reduction (Table 7) was higher*** in the Control (55/94) than in the Prospective Series (9/62) and the methods of internal fixation were different (Table 8). In the *Control Series* the most common type of fixation was a plate which was always placed on the antero-medial surface of the tibia with the incision in the same area. In the *Prospective Series* closed reduction and blind nailing was done in 23 of 28 nailed, and when open reduction was deemed necessary, the incision was placed so as to avoid the antero-medial surface of the leg. The plate was not used in the Prospective Series. In the Prospective Series osteosynthesis was performed earlier than in the Control Series (Table 5).

c. Open Transverse Fractures

(i) *Skin injury.* In the open transverse fractures in the *Control Series* the skin was always closed primarily. A relaxing incision was done three times and skin grafting was never used.

TABLE 7 Primary treatment of displaced closed transverse fractures

Initial Displacement	(a)		(b)		(c)		(d)		Total	
	Control	Prosp.	Control	Prosp.	Control	Prosp.	Control	Prosp.	Control	Prosp.
Moderate	15(1)	16	—	—	5	—	1	—	21(1)	16
Marked	22(1)	14	1	23	50	9	—	—	73(1)	46

(a) Closed reduction or no reduction
(b) Closed reduction and blind nailing
(c) Open reduction and internal fixation
(d) Open reduction without internal fixation
Figures in brackets represent fractures treated with traction

TABLE 8 Methods of internal fixation of closed transverse fractures

Comminution of Fracture	(a)		(b)		(c)		(d)		(e)		Total	
	Control	Prosp.	Control	Prosp.	Control	Prosp.	Control	Prosp.	Control	Prosp.	Control	Prosp.
—	38	1	—	24(21)	—	—	—	—	4	—	42	25(21)
+	10	3	2(1)	2(2)	1	2	1	—	—	—	14(1)	7(2)

(a) Plate and/or screws with or without encircling wire
(b) Intramedullary nail alone (figures in brackets represent blind nailings)
(c) Intramedullary nail combined with encircling wire
(d) Encircling wire
(e) Other methods

TABLE 9 Initial treatment of wound in open transverse fractures in Prospective Series

Size of Wound	(a)	(b)	(c)	(d)	(e)	(f)	(g)	Total
Insignificant	8	—	—	—	—	—	—	8
Small	14	—	—	—	—	—	—	14
Large	11	1	—	1	—	1	—	14
Major	3	1	1	—	4	1	1	11
	36	2	1	1	4	2	1	47

(a) Suture
(b) Bipedicle skin flap and split thickness graft
(c) Unipedicle skin flap and split thickness graft
(d) Split thickness graft
(e) Muscle graft and split thickness graft
(f) Muscle graft and skin closure
(g) Muscle graft and bipedicle skin flap and split thickness graft

By contrast the guiding principle of treatment in the *Prospective Series* was primary closure of the skin with care to avoid tension. Drainage was not used. Immediate skin transplantation, always combined with internal fixation, was performed in 8 of 11 wounds over 10 cm in length, in 3 of 14 wounds between 6 and 10 cm in length; it was not done in wounds less than 6 cm long. Methods used in the treatment of the wound are shown in Table 9 and will be described in detail by Edwards (1965). Special emphasis was placed on providing a muscle bed for the skin graft.

(ii) *Bone injury.* In the *Prospective Series* the choice of treatment of the bone injury as well was guided by the necessity to avoid additional damage to the skin (Table 10). In the Control Series 13 fractures were treated by skeletal traction. This method was never used in the *Prospective Series.* There was no significant difference in the frequency of internal fixation in the two series (37 of 71 in the Control Series and 31 of 47 in the Prospective Series). In the *Control Series* the Lane plate and/or screw were chosen for internal fixation in 30 of 37 fractures (Table 11). In the *Prospective Series* these methods were replaced by intramedullary nailing with the Rush pin (28/31). In 22 of these fractures the nail was used alone, blind in 14 and open in 8. In 6 fractures a nail was used in combination with encircling wire. Four of these were double fractures.

TABLE 10 Primary treatment of open transverse fractures

Initial Displacement	(a)		(b)		(c)		(d)		Total	
	Control	Prosp.	Control	Prosp.	Control	Prosp.	Control	Prosp.	Control	Prosp.
Moderate	8(3)	3	—	—	3	—	—	—	11(3)	3
Marked	22(10)	12	1	14	33	17	4	1	60(10)	44

(a) Closed reduction or no reduction
(b) Closed reduction and internal fixation
(c) Open reduction and internal fixation
(d) Open reduction without internal fixation
Figures in brackets represent fractures treated with traction

TABLE 11 Methods of internal fixation of open transverse fractures

Comminution of Fracture	(a)		(b)		(c)		(d)		(e)		Total	
	Control	Prosp.	Control	Prosp.	Control	Prosp.	Control	Prosp.	Control	Prosp.	Control	Prosp.
—	15	1	1(1)	17(12)	—	—	1	—	4	—	21(1)	18(12)
+	15	1	—	5(2)	—	6	—	1	1	—	16	13(2)

(a) Plate and/or screws with or without encircling wire
(b) Intramedullary nail alone (figures in brackets represent blind nailings)
(c) Intramedullary nail combined with encircling wire
(d) Encircling wire
(e) Other methods

d. Primary Complications

Complications considered in this investigation were *necrosis of the skin,* and *osteomyelitis.* Data on these complications were derived from the case records (Control Series) or by direct observation (Prospective Series).

(i) *Necrosis of the skin.* In this investigation necrosis of the skin was defined as that necrosis of the skin located over the antero-medial surface of the tibia *and* over the fracture region. A distinction was made between *superficial* necrosis of the skin (no exposure of bone) and *deep* necrosis of the skin (with exposure of bone). The incidence of necrosis of the skin is shown in Table 12.

(ii) *Osteomyelitis.* Osteomyelitis was defined as *obvious infection with fistula formation.* This definition made it unlikely that such a complication could have escaped being recorded in the Control Series. Osteomyelitis was graded according to the time required for healing and cessation of drainage: *mild* when less than one year, *severe* when more than one year. The incidence of osteomyelitis is shown in Table 12.

In agreement with Adams (1961) no distinction has been made between osteitis (inflammation of bone) and osteomyelitis (inflammation of bone and bone marrow). In accordance with the British and American usage the term osteomyelitis has been preferred even though the term osteitis is commonly used in Sweden.

Comments: The incidence of fractures with primary complications was greater *** among open (29/118) than among closed fractures (6/156). There was no difference in the incidence of fractures with primary complications in reduced open fractures treated with as compared without internal fixation (Table 13).

The incidence of primary complications in the Control Series in fractures with wounds more than 6 cm in length was greater ** (12/22) than in those with wounds less than 6 cm in length (9/49). (Table 13.)

2. *Secondary Treatment*

Secondary treatment of the *skin injury* was defined as those surgical procedures undertaken *24 hours* or more after injury. Secondary treatment of the *bone injury* was defined as those surgical procedures undertaken *3 months* or more after injury. The indications for secondary treatment are shown in Table 14 and will be described below. Five fractures, all in the Control Series, developed complications following secondary treatment (necrosis of the skin and/or osteomyelitis). In four of these fractures the primary treatment had also been associated with complications.

TABLE 12 Incidence of primary complications in displayed transverse fractures

	No. of Fractures		Severe Osteomyelitis		Slight Osteomyelitis		Deep Necrosis of the Skin		Superficial Necrosis of the Skin	
	Control	Prosp.	Control	Prosp.	Control	Prosp.	Control	Prosp.	Control	Prosp.
Closed	94	62	5	—	1	—	2	—	1	—
Open	71	47	10	1	3	—	9	3	9	5
% of Total			9.1 %	0.9 %	2.4 %	0 %	6.7 %	2.8 %	6.1 %	4.6 %

TABLE 13 Primary complications in reduced open transverse fractures

Fractures treated with internal fixation							Fractures treated without internal fixation					
Total		Wound < 6 cm.		Wound > 6 cm.			Wound < 6 cm.		Wound > 6 cm.		Total	
no. of fract.	no. of fract. compl.	no. of fract.	no. of fract. compl.	no. of fract.	no. of fract. compl.	Material	no. of fract.	no. of fract. compl.	no. of fract.	no. of fract. compl.	no. of fract.	no. of fract. compl.
37	12(8)	28	6(5)	9	6(3)	Control	21	3(2)	13	6(3)	34	9(5)
31	6(—)	13	—	18	6(—)	Prospective	8	1(—)	6	1(1)	14	2(1)
68	18(8)	41	6(5)	27	12(3)	Total	29	4(2)	19	7(4)	48	11(6)

Figures in brackets represent fractures with osteomyelitis

a. Indications

(i) *Skin injury.* Ten fractures in the Control Series and 8 fractures in the Prospective Series were treated because of necrosis of the skin. In the *Control Series* 18 operations were performed 2—48 months after injury. In most cases transplantation with a cross leg flap or split thickness grafts was used. Split thickness grafts were the final treatment in all but 2 fractures. In the *Prospective Series* 10 operations were performed 2-10 weeks after injury; in all but one, transplantation with split thickness skin grafts was performed. Four operations in 2 fractures were done as completion of immediate skin grafting.

(ii) *Slow union.* Twelve transverse fractures in the Control Series and 18 in the Prospective Series were treated secondarily because of slow union. In both series the majority were treated with *bone grafts* alone, or in combination with an *intramedullary nail.* Healing was obtained in all but two cases treated with this indication, both in the Control Series.

(iii) *Osteomyelitis.* Thirteen transverse fractures in the Control Series and one in the Prospective Series were operated secondarily because of osteomyelitis. The procedures were *sequestrectomy* and/or *saucerization.* The infectious process as well as the fracture healed in all but 5 cases. These 5 cases occurred in the Control Series, and 3 of these were later treated by *amputation* 1, 2 and 6 years after the initial injury.

(iiii) *Ankle joint stiffness.* In 2 transverse fractures in the Control Series *Achilles tendon lengthening and posterior capsulotomy* of the ankle were done to correct ankle joint contracture.

(v) *Malalignment.* Tibial *osteotomy* because of malalignment was done in 2 transverse and 1 longitudinal fracture in the Control Series and in 1 transverse fracture in the Prospective Series.

b. Osteomyelitis in Relation to Necrosis of the Skin in Transverse Fractures (Table 15)

The incidence of osteomyelitis was higher *** in fractures with necrosis of the skin (16 of 30) than in those without necrosis of the skin (6 of 244).

The incidence of osteomyelitis was higher ** in fractures with deep necrosis of the skin (13 of 16) than in those with superficial necrosis of the skin (3 of 14).

The incidence of severe osteomyelitis was higher *** in fractures with deep necrosis of the skin (12 of 16) than in those with superficial necrosis of the skin (1 of 14).

TABLE 14 Secondary treatment of displaced fractures of the shaft of the tibia

Type of Fractures	Number of Fractures		Indication for Secondary Treatment							
			Malalignment		Ankle Joint Stiffness		Osteomyelitis		Slow Healing	
	Control	Prosp.	Control	Prosp.	Control	Prosp.	Control	Prosp.	Control	Prosp.
Longitudinal	118	47	1	—	—	—	—	—	—	—
Closed Transverse	94	62	—	—	—	—	5	—	5	5
Open Transverse	71	47	2	1	2	—	8	1	7	13

TABLE 15 Osteomyelitis in relation to necrosis of the skin in transverse fractures

Necrosis of the skin	Osteomyelitis			
	None	Slight	Severe	Total
None	238	1	5	244
Superficial	11	2	1	14
Deep	3	1	12	16
Total	252	4	18	274

E. HEALING TIME

1. *Collection of Data*

Healing Time was defined here as the period of time from the accident until full clinical stability of the fracture had been reached. Stability was checked each time the plaster was changed. Due to the closer personal attention to the fractures in the Prospective Series over-estimation of the Healing Time probably occurred to a lesser degree in that series than in the Control Series.

2. *Analysis of Data*

For the purpose of comparing the Prospective with the Control Series with regard to Healing Time in the three main fracture types two parameters were defined: (a) time for healing of 50 % of the fractures, and (b) time for healing of 95 % of the fractures. The former parameter was analyzed because of general convention. However, it is insensitive to the occurrence in a group of fractures of a subgroup with extremely long Healing Times. Here the 95 % Healing Time is superior; it is sensitive to both of two important modalities in a family of data, average and distribution. In studies of fracture healing this latter modality is of supreme importance because the distribution of Healing Times is always skewed; no fracture heals instantaneously and some may never heal. The methods used in this analysis of Healing Time are based on graphic probit analysis, and the results of this analysis have been published by Edwards and Nilsson (1965).

3. *Presentation of Data*

Individual Healing Times are shown in Section IX. A. The 50 % and 95 % Healing Times are shown in Tables 20 and 22.

F. FINAL STATUS OF FRACTURES

One year or longer after the injury the probands were evaluated to determine the Final Status of the fracture of the shaft of the tibia (Table 16).

1. *Follow-up of Probands*

The Final Status could be evaluated in 95 % of the 483 probands of this investigation. All probands who had had complications in the form of

TABLE 16 Probands evaluated for Final Status of fractures

Control Series			Prospective Series	
Probands	Fractures		Probands	Fractures
305	311	*Primarily Treated*	178	181
		Follow-up		
14	14	Dead	1	1
9	9	Not available	—	—
282	288	Available for evaluation	177	180
		Final Status		
9	10	Excluded because of other injuries or disabilities	6	7
273	278	Available for classification of final status	171	173

necrosis of the skin, osteomyelitis or pseudarthrosis were available for evalution of Final Status.

a. Control Series

At the time of follow-up 1960-1961 14 probands were dead, 9 probands could not be traced, and 282 probands with 288 fractures were available for evaluation (Table 16). All probands received and answered a questionnaire concerning shortening of the fractured leg, restriction of motion of ankle or knee joints, pain, swelling, skin ulcers, disability pension, and ability to return to previous occupation. On the basis of these questionnaires and the case histories 180 fractures were examined by a team of three orthopaedic surgeons; 59 of these fractures were examined by the author. These 180 fractures included (1) all probands who had answered that they had residual symptoms from the injured extremity, (2) all probands whose case histories revealed that when last seen at the hospital they were not completely free from complaint or physical evidence of defective function or malalignment, and (3) all patients whose case records suggested that complications had occurred.

The case records in the 23 probands who were unavailable for follow-up were analyzed for incidence of complications and all other factors except Final Status. None of those probands had had necrosis of the skin, osteomyelitis, or pseudarthrosis.

b. Prospective Series

All but 4 of the 178 probands of the Prospective Series were followed continuously by the author. One of these 4 died before completion of treatment from chronic heart disease, 2 were treated at an institution for alcoholics, and 1 had moved to another region. The last case was evaluated by another orthopaedic surgeon according to a detailed scheme, and the other 2 were evaluated by the author. Thus 177 of the 178 probands of the Prospective Series were available for evaluation.

2. *Classification of Final Status of Fractures*

The Final Status of fractures was classified as *good, fair* or *poor* according to criteria shown in Table 17. The fractures were classified according to the lowest rating obtained in any one of the 8 categories studied.

3. *Probands with Multiple Injury*

In the classification of Final Status of fractures consideration was given to the following.

a. Other Injury to the Same Limb Sustained Simultaneously

In the entire material 37 fractures of the shaft of the tibia were associated with fractures of the ankle (20), foot (3), knee (7), femur (5), femoral neck (2) and fracture of vertebrae with paresis of the legs (1).

Nine fractures in the Control Series, and 5 fractures in the Prospective Series were excluded from classification of Final Status because persisting symptoms and signs were such that it was probable they were not related to the fracture of the shaft of the tibia. All 14 had symptoms and impaired function related directly to the associated fractures. When persisting symptoms or impaired function did not relate directly to the associated fracture, the probands were included in the classification of the Final Status.

All of the excluded fractures healed without evidence of persisting osteomyelitis. Two of these had had complications; 1 osteomyelitis in the Control Series and 1 necrosis of the skin in the Prospective Series.

TABLE 17 Classification of Final Status of Probands

	Good	Fair	Poor
1. Pain	Little or none	Slight	Severe
2. Work Capacity	Normal	Difficulty or inability to do heavy work	Markedly decreased; light seated work only
3. Limp	None	Slight with or after severe exercise	Constant
4. Sports Activity	Normal	Decreased ability	Short walks only
5. Knee Motion	Stable; full extension; loss of flexion less than 20°	Stable; full extension; flexion to at least 90°	Lack of full extension; flexion to less than 90°
6. Ankle Motion	Less than 10° loss of dorsiflexion; less than 20° loss of plantarflexion	Dorsiflexion over 90°; less than 30° loss of plantarflexion	Dorsiflexion less than 90°; more than 30° loss of plantarflexion
7. Foot Motion	Less than 25 % decrease of pro- and supination	Moderately decreased	Severely decreased
8. Swelling of Lower Leg	Slight, only after exercise	Slight	Constant

Poor results also include:
1. amputation
2. osteomyelitis with recurrent drainage
3. pseudarthrosis

b. Disability or Injury to the Same Limb Occurring Before Evaluation of Final Status

Two probands with fracture of the tibial plateau (1 in each series), and 1 proband (Prospective Series) with diabetic gangrene, were excluded because the Final Status could not be evaluated.

c. Status Prior to the Injury

If records showed that there had been prior disability of the affected limb, such disability was considered in the classification of Final Status.

In the Control Series 273 probands with 278 fractures, and in the Prospective Series 171 probands with 173 fractures, were available for evaluation of Final Status.

III. Results

The results of this investigation are expressed in terms of (A) comparison of the Prospective with the Control Series as regards incidence of complications, Healing Time and Final Status in the three main fracture types, and (B) correlation of the incidence of osteomyelitis with Healing Time and Final Status.

A. COMPARISON OF PROSPECTIVE SERIES WITH CONTROL SERIES

1. *Longitudinal Fractures*

The Final Status in the 149 longitudinal fractures was 83 % good and 17 % fair with little difference between the Control and the Prospective Series (Table 18). None of the fractures of this type had a poor Final Status. Only one complication was observed: a fracture with superficial skin necrosis in the Control Series.

The Healing Times for both 50 % and 95 % of the fractures were somewhat shorter in the Prospective as compared to the Control Series (Table 19).

2. *Closed Transverse Fractures*

A marked difference between the Control and the Prospective Series was observed as regards incidence of osteomyelitis (Table 12) and Final Status (Table 20) in the closed transverse type of fracture.

In the *Control* Series 7 of 94 fractures developed osteomyelitis (6 primary and 1 secondary). In the *Prospective* Series none of 62 fractures developed osteomyelitis.

In the entire material the Final Status was good in 75 %, fair in 20 % and poor in 5 %. None of the 7 fractures with poor Final Status occurred in the Prospective Series.

There was no difference between the two Series as regards Healing Time

TABLE 18 Final Status in longitudinal fractures

	Good	Fair	Poor	Total
Control Series	82	22	—	104
Prospective Series	41	4	—	45
Total	123	26	0	149

TABLE 19 Fracture healing time

	Healing time for 50 % of the group (months)		Healing time for 95 % of the group (months)	
Type of Fracture	Control	Prospective	Control	Prospective
Displaced, closed longitudinal	2.9	2.2	5.0	3.5
Displaced, closed transverse	3.5	3.1	12	9.0
Displaced, open transverse	4.8	4.5	20	14

TABLE 20 Final Status in closed transverse fractures

	Good	Fair	Poor	Total
Control	58	22	7	87
Prospective	54	8	—	62
Total	112	30	7	149

(Table 19) for 50 % of the fractures. The Healing Time for 95 % of the fractures was shorter in the Prospective as compared to the Control Series.

3. *Open Transverse Fractures*

A marked difference between the Control and the Prospective Series was observed as regards incidence of osteomyelitis (Table 12) and Final Status (Table 21) in the open transverse type of fracture.

In the *Control* Series 14 of 71 fractures developed osteomyelitis (13 primary and 1 secondary). In the *Prospective* Series 1 of 47 fractures developed osteomyelitis.

TABLE 21 Final Status in open transverse fractures

	Good	Fair	Poor	Total
Control Series	31	19	14	64
Prospective Series	32	9	1	42
Total	63	28	15	106

TABLE 22 Effect of osteomyelitis on healing time

Type of Fracture	Healing time for 95 % of the group (months)	
	Including Osteomyelitis	Excluding Osteomyelitis
Closed, transverse fractures (control+prospective series)	10	9
Open, transverse fractures (control+prospective series)	19	14
Open, transverse fractures (control series)	20	14
Open, transverse fractures (Prospective series)	14	14
Fractures complicated by osteomyelitis (control+prospective series)	34	

In the entire material the end results were good in 59 %, fair in 26 % and poor in 15 %. Only 1 of the 15 fractures with poor Final Status occurred in the Prospective Series.

There was no difference between the two Series as regards Healing Time for 50 % of the fractures (Table 19). The Healing Time for 95 % of the fractures was markedly shorter in the Prospective as compared to the Control Series.

4. *Other Fractures*

There were no complications in the 47 fractures which did not belong to the three main fracture types. The Final Status was good in 46 cases and fair in 1 case. No comparison between the Control and Prospective Series was made in this small group of heterogenous fractures.

TABLE 23 Correlation of osteomyelitis and Final Status in transverse fractures

	Osteomyelitis	
Final Status	Control	Prospective
Good	3	—
Fair	4	—
Poor	13	1

B. CORRELATION OF OSTEOMYELITIS WITH HEALING TIME AND FINAL STATUS IN TRANSVERSE FRACTURES

1. *Healing Time*

Table 22 shows the time for healing of 95 % of the transverse fractures with a distinction between those complicated and those not complicated by osteomyelitis. The difference between the two Series in Healing Time for 95 % of the fractures was found to be due entirely to the higher incidence of osteomyelitis in the Control Series.

2. *Final Status*

All of the 22 fractures with poor Final Status in this investigation occurred in displaced transverse fractures, either open or closed, treated with open reduction and internal fixation.

a. Fractures Complicated by Osteomyelitis (Table 23)

The Final Status was classed as poor because of (a) *amputation:* 3 fractures (all in the Control Series) were amputated because of chronic osteomyelitis. In 2 of these the fracture had not healed; (b) *chronic osteomyelitis:* 4 fractures (all in the Control Series) had chronic osteomyelitis with drainage continuing over 4 to 10 years. In 3 of these the Final Status was poor also because of marked ankle joint stiffness; (c) *other criteria:* 7 fractures (6 in the Control Series) were classed as poor according to criteria shown in Table 17. All had severe stiffness of the ankle or foot with severe objective as well as subjective disability. In no case was there severe limitation of knee motion; in 5 of the 7 cases knee motion was normal.

b. Fractures Uncomplicated by Osteomyelitis

The Final Status was classed as poor because of (a) *pseudarthrosis:* 2 fractures in the Control Series did not heal; (b) *other criteria:* 6 fractures (all in the Control Series) were classed as poor, 2 because of markedly impaired walking capacity combined with pain, and 4 because of marked stiffness of the ankle joint with both subjective and objective disability.

COMMENTS:

No fracture was found to have poor Final Status because of decreased knee motion. Of 13 fractures which were classed as poor by criteria other than amputation, chronic osteomyelitis or pseudarthrosis, 8 had normal knee motion and 5 had only moderate decrease of knee motion. Limitation of ankle and/or foot motion, particularly dorsiflexion, was the criterion in these cases.

IV. Discussion

In this investigation two consecutive series of fractures of the shaft of the tibia received treatment which differed in that in the second or Prospective Series particular attention was paid to associated skin lesions with the object of preventing bone infection. A comparison of Final Status in the Control and Prospective Series showed that this object was achieved, and that the incidence of fractures with osteomyelitis, pseudarthrosis and poor function fell to nearly zero. This finding will be discussed below in relation to proposed causes of poor results of treatment of fractures of the shaft of the tibia.

A. CAUSES OF POOR RESULTS IN FRACTURES OF THE SHAFT OF THE TIBIA

Three factors tend to interfere with healing of bone, (1) deficient blood supply, (2) poor apposition of fracture fragments, and (3) infection.

1. *Deficient Blood Supply*

a. Effect of Fracture Upon Nutrient Artery

Slow or non-union of fractures of the shaft of the tibia have been attributed to deficient blood supply through the nutrient artery: in Watson-Jones' textbook (1957, Fig. 29, p. 16), for example, fractures at the junction of the lower and middle thirds of the shaft of the tibia are depicted as jeopardizing the blood supply to the lower of the fragments in the same way as fractures of the femoral neck or of the carpal scaphoid bone. The evidence for this mechanism is largely circumstantial: in the past pseudarthrosis of fractures in this area was particularly frequent. However, this observation can be just as easily explained by the fact that most open, comminuted fractures of the shaft of the tibia occur in this region. In this investigation for example, open comminuted fractures affected the lower two-thirds of the shaft 34 times out of 38. Furthermore, the incidence of delayed union and non-union seems to be evenly distributed over the tibial shaft (Ellis, 1956; Nicoll, 1964). Finally, in cases of non-union of the shaft of the

tibia studied with tracer techniques, no evidence of deficient blood supply has been found (Wendeberg, 1961). In the investigation reported here the improved results following frequent use of intramedullary nailing cannot be related to blood supply as an important factor.

b. Loss of Blood Supply to Intermediate Fragments

Poor results in comminuted and double fractures have often been explained as due to poor blood supply of the intermediate bone fragments, especially after "periosteal stripping" (Compere, 1949) during open reduction. Little evidence is available to support this view. It is more impressive, perhaps, that non-union is often successfully treated with the aid of grafts completely devoid of blood supply. This investigation does not prove or disprove the hypothesis discussed here. The results suggest, however, that it is of limited value as an explanation for *poor* results of fractures of the shaft of the tibia.

2. *Poor Apposition of Fracture Fragments*

Whereas fractures may unite even under extremely unfavourable conditions of apposition of the fracture surfaces, there is unanimous agreement that good apposition and stability of any fracture are desirable.

Treatment by traction of fracture of the shaft of the tibia may result in slow or non-union, not necessarily related to distraction (Watson-Jones and Coltart, 1944). Nicoll (1964) found that there was a high incidence of delayed union among fractures treated by continuous traction, related less to the traction treatment and more to the greater incidence of higher risk fracture types among fractures so treated. This suggests that such mechanical factors as the degree of stability at the fracture site may be relatively unimportant as regards the etiology of poor results in the treatment of fracture of the shaft of the tibia.

The Lane plate has been felt to maintain separation of fracture fragments caused by resorption of bone in the process of healing. The slotted plate was introduced to permit compression of the fracture ends. However, experimental attempts to exert pressure on the fracture ends have been unsuccessful in shortening Healing Time (Reynhold and Key, 1953, 1954) and there are no clinical reports that slotted plates have given better results than the Lane plate (Cave, 1965).

In this investigation the plate was used in the Control Series with good results in fractures caused by moderate violence and the results became increasingly poor in proportion to the severity of violence that caused the fracture. In tibial osteotomies the Lane or slotted plates have been used

without untoward effect. One may conclude, therefore, that poor results following use of the plate are related to the type of fracture rather than to the plate itself.

3. *Infection*

The role of infection as a cause of poor results in treatment of fractures in general and of fractures of the shaft of the tibia in particular is well documented. Before Lister the mortality rate in open fractures of the shaft of the tibia was about 40 %; immediate amputation was the method of lowering this rate. Recognition of bacteria as the cause of infection, and institution of appropriate antiseptic or aseptic precautions reduced the mortality rate to about 5 % (Bruns, 1882). In more recent literature the results of treatment of open fractures of the shaft of the tibia under peacetime conditions are measured in terms of morbidity rather than mortality, but infection still rates high as a cause of poor results. For example, Campbell (1960) found 15 cases of non-union in 100 open fractures of the shaft of the tibia; 10 of those associated with infections. Nicoll (1964) reported on 22 infected wounds in 144 open fractures with delayed or non-union in 13 of these infected cases. Hicks (1964) showed that two-thirds of amputations for fracture of the shaft of the tibia performed at the Birmingham Accident Hospital were due to infection. He pointed out that necrosis of the skin was feared as starting a chain of events that lead to amputation.

The correlation between necrosis of the skin and osteomyelitis was particularly striking in the investigation reported here; 12 of 18 fractures with severe osteomyelitis had deep necrosis of the skin. Three cases were amputated; all had infection and 2 had established pseudarthrosis of the fracture.

In their clinical analysis of Healing Times for fracture of the shaft of the tibia Urist et al. (1954) had difficulties in establishing realistic values for fractures complicated by osteomyelitis because of a high frequency of amputations. In this investigation amputation was rarely performed.

The disastrous effect of osteomyelitis on healing of fractures of the shaft of the tibia was clearly shown by comparison of the time for healing of 95 % of the fractures: it was 14 months in open transverse fractures without osteomyelitis and 34 months in fractures with osteomyelitis (Table 22).

4. *Conclusion*

One may conclude that osteomyelitis still looms large as the leading cause of poor results following treatment of fracture of the shaft of the tibia.

B. PREVENTION OF INFECTION IN MANAGEMENT OF FRACTURES OF THE SHAFT OF THE TIBIA

1. *Longitudinal Fractures*

The results of this investigation emphasize the well-known fact that longitudinal fractures are very rarely open, and if so, the wounds are of little consequence. The reason is that these fractures are caused by indirect, moderate violence which probably only rarely results in a crush injury of the skin. Therefore, the management of these fractures carries little or no risk of necrosis of the skin or subsequent infection. In this series of 165 such fractures, 76 % of which were treated with internal fixation, usually with screws or occasionally with a plate, the results were uniformly good with regard to infection. Only 1 fracture with superficial necrosis of the skin was encountered, and this complication did not affect the Final Status of the fracture. The uniformly favorable results of internal fixation of this type of fracture noted in this investigation do not necessarily mean that operation is the method of choice. The results do show, however, that open reduction and internal fixation does not materially increase the risk of infection over that associated with other types of elective surgery.

In the Control Series the operative approach to the fracture was always directly through the skin over the antero-medial surface of the tibia. In the Prospective Series an approach was chosen which avoided the subcutaneous surface of the tibia; the osteosynthesis material was always placed under muscle. This difference in approach failed to influence the incidence of complications: it was close to zero even in the Control Series. By comparison with transverse fractures, usually caused by direct, severe violence, one may conclude that the skin over longitudinal fractures has not been crushed, and that it can therefore tolerate operative incisions.

2. *Closed Transverse Fractures*

The literature contains abundant evidence that conservative treatment of this fracture is hardly ever associated with infection (Böhler, 1957) and that open reduction and internal fixation of this fracture are associated with a high incidence of infection (Table 24). Indeed, with reference to the discussion above it seems probable that the reason the Lane plate has come into disrepute is because mechanically it has been the method of choice in this type of fracture. The data from the literature receive support from the findings in this investigation: there were no infections among the 67 closed, transverse fractures in the combined series which were treated conserva-

tively, while 6 out of 55 fractures in the Control Series treated with open reduction and internal fixation, were primarily complicated by osteomyelitis. The association of necrosis of the skin and osteomyelitis in 3 cases who had an operative incision through traumatized skin suggested the treatment adopted in the Prospective Series. Here closed reduction was done and fixation was accomplished either by blind nailing or transfixation and plaster according to the type and location of fracture. The results demonstrated the value of this treatment: no case of infection was encountered in the Prospective Series.

This investigation has shown that avoidance of incision through potentially damaged skin prevents infection and subsequent poor results in closed, transverse fractures of the shaft of the tibia. However, some of these fractures could probably have been treated equally well by closed reduction without internal fixation.

3. *Open Transverse Fractures*

Considerable confusion exists in the literature concerning the etiology of infection in open fractures of the shaft of the tibia. Four possibilities seem to be important in this respect:

(a) that every open fracture by definition must be regarded as contaminated,
(b) that an open wound left open is a potential portal of entry for pathogenic bacteria,
(c) that the mechanism of fracture is such that the soft tissues (skin, fascia, muscle) have been severely crushed and may be partly devitalized,
(d) that any foreign object, for example a device for internal fixation, may enhance the risk of infection or when infection is already present, may increase the severity of the infection.

The first two of these contentions were discussed by Essex-Lopresti (1950) in his eloquent plea for early closure of the open wound in trauma. He advanced evidence that contamination should not be equated with infection: all bacteria are not pathogenic, and the tissues are equipped for handling bacterial invasion. Essex-Lopresti also showed that the risk of secondary contamination with pathogenic bacteria increases with the period of time a wound is left open. Apparently the idea that excision of damaged soft tissue had priority over closure of the wound in open fractures gained acceptance during the First World War and received further emphasis from

Trueta's (1939) report from the Spanish Civil War. A search of the literature has failed to reveal any evidence that closure of the wound in open fractures under peacetime conditions should be done other than at the earliest possible opportunity.

On the other hand there is ample evidence of the correlation between the size of the wound and the incidence of infection. In a series of 175 open fractures of the long bones, the majority of which were fractures of the shaft of the tibia, Moberg (1942) observed osteitis or gas gangrene in 30 out of 53 cases who had severe soft tissue damage, in 11 out of 66 cases who had only moderately severe soft tissue damage, and in 1 out of 56 cases with small, indirect type wounds. In the Control Series reported here 12 out of 22 fractures with wounds larger than 6 cm developed necrosis of the skin and/or osteomyelitis. Such complications were observed in only 9 out of 49 fractures with smaller wounds. This difference was significant**.

The material presented here was too small to permit a valid analysis of the association between gross contamination of the fracture with foreign material, and osteomyelitis.

A thorough search of the literature has failed to reveal any detailed reports on results of immediate skin closure performed, if necessary, with the aid of free or pedicled skin grafts. Several authors advocate this principle, however, and plastic surgeons have expressed surprise that it is not followed in open fractures of the tibia when it is firmly established in the treatment of open hand injures (Connelly, 1956).

Table 24 which contains 3544 cases from the literature shows that internal fixation of open fractures of the tibial shaft with plates has been associated with a high incidence of infection. It seems likely that observation of such cases has led to the belief that the foreign body as such creates an adverse situation (Campell, 1960). However, many authors use internal fixation in selected cases of open fractures of the shaft of the tibia. Some of them (Johansson, 1953; Veliskakis, 1959) have pointed out, that if internal fixation is indicated on mechanical grounds, the nature of the soft tissue injury should be the deciding factor in the choice of the method of treatment. Carpenter, Dobbie and Siewers (1952) stress that the more extensive the wound, the greater is the indication for internal fixation.

In view of the findings in this investigation it seems likely that incision through damaged skin, and/or inadequate closure of the skin may cause necrosis of the skin and subsequent osteomyelitis. The choice of treatment of the bone injuries in the Prospective Series was guided by the necessity to avoid additional damage to the skin. Even though the frequency of

TABLE 24 Incidence of osteomyelitis in published series of fractures of the shaft of the tibia

Treatment	Closed Fractures			Open Fractures		
	No. of Cases	Osteomyel.	%	No. of Cases	Osteomyel.	%
Closed reduction—plaster or traction (1, 3, 4, 6, 7, 12, 13, 16, 17)	1558	3	0.2	723	107	15
Closed reduction—intramedullary nail (2, 3, 10, 11, 12)	195	1	0.5	144	24	17
Open reduction—intramedullary nail (1, 11, 14)	39	2				
Open reduction—plate (1, 3, 5, 7, 8, 12, 17)	276	41	15	191	49	26
Open reduction—internal fixation—miscellaneus methods (1, 3, 6, 7)	35	1		46	9	
Open reduction with or without internal fixation (4, 7)	98	10		20	4	
Miscellaneus methods (open or closed) (9, 15)	—	—		219	21	10
	2201	58	3	1343	214	16

1) Adler et al. (1962)
2) Alms (1962)
3) Andersen et al. (1961)
4) Bergentz and Thureborn (1957)
5) Blockey (1956)
6) Böhler (1957)
7) Carpenter et al. (1956)
8) Dahl-Iversen (1928)
9) Freeman and Garnes (1958)
10) Krösl (1957)
11) Lauritzen (1949)
12) Lottes et al. (1952)
13) Mauck (1943)
14) Palmer (1950)
15) Solheim (1960)
16) Tucker et al. (1961)
17) Veliskakis (1959)

internal fixation was high (37 of 47 fractures) the wound was enlarged in only 1 case. Blind nailing was often used. Only in 4 fractures, all double fractures, was the bone exposed in an area other than the wound. All cases in which transplantation of skin was done as a primary procedure were treated with internal fixation. None of those developed osteomyelitis.

In this investigation it was thus not possible to demonstrate any relationship between the introduction of a metallic device for internal fixation and an increased hazard of complications (Table 13) even though such devices were used in cases with extensive soft tissue injuries.

The results of this investigation are interpreted as follows. *Presently available methods of skin transplantation make it possible to close most wounds in open fractures encountered in civilian practice.* Also, the mechanical means for securing adequate, not necessarily firm, fixation of the fracture are readily available. Perhaps internal fixation is more important in open than in closed fractures: damaged skin or a skin graft needs a quiet bed to avoid undue pressure and permit early secondary transplantation of skin when needed.

The skin and occasionally the skin graft showed signs of necrosis in 8 cases in the Prospective Series. In view of the above it seemed reasonable to repair such areas with additional skin grafts in all cases. The outcome of such procedures is interpreted as indicating the necessity for an active approach to the skin problem.

In view of the higher risk for necrosis of the skin and osteomyelitis over age 45 (Bauer and Edwards, 1965), special attention should be given to elderly individuals.

C. CORRELATION OF ANATOMY, ETIOLOGY AND THERAPY IN FRACTURES OF THE SHAFT OF THE TIBIA

In general definition of etiologic factors is a prerequisite for effective therapy and prevention of disease. It was shown above that the anatomic classification used here corresponds to an etiologic classification of fractures of the shaft of the tibia. Therefore, an attempt was made (Bauer and Edwards, 1966) to define the boundaries of choice of treatment of fractures of the shaft of the tibia on the basis of the anatomic classification. It is seen (Fig. 3) that one and the same Venn diagram may symbolize definition of etiology, anatomy and therapy in fractures of the shaft of the tibia. It should perhaps be stressed that the guidelines for treatment presented here define *restrictions* on choice of treatment rather than the *optimal* treatment. For

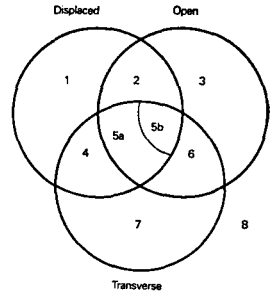


FIGURE 3 Restrictions imposed by attention to skin problem on choice of treatment of fracture of the shaft of the tibia.

Venn Diagram Area	Type of Fracture	Skin Problem
1	Displaced, closed, longitudinal	Skin does not restrict choice of treatment.
2	Displaced, open, longitudinal	Wound must not be left open (grafts need never be used); otherwise skin does not restrict choice of treatment.
4	Displaced, closed, transverse	Incision of skin over the fracture should be avoided.
5 a	Displaced, open, transverse (wound $<$ 6 cm)	Wound must not be left open. Grafts need hardly ever be used primarily but wound must be watched for signs of necrosis. If necrosis develops secondary transplantation of skin may be needed. Enlargement of wound should be avoided.
5 b	Displaced, open, transverse (wound $>$ 6 cm)	Wound must not be left open. These large wounds often need primary transplantation of skin, followed by secondary transplantation if areas of necrosis appear. Graft bed probably improved by muscle graft and osteosynthesis.

example, nothing in this investigation supports use of internal fixation of fractures of the shaft of the tibia. However, the investigation does show that it can be used, and how it can be used.

D. CENTRALIZED TREATMENT OF FRACTURES OF THE SHAFT OF THE TIBIA

Only because of rigid adherence for three years to the policy that one staff member was responsible for treatment of all fractures of the shaft of the tibia and immediate referral from other hospitals of fractures of the shaft of the tibia, was it possible to accumulate the material presented as the Prospective Series here.

This policy appears to have resulted in immediate benefit to individual patients in terms of fewer complications, and the patients apparently did not find it too inconvenient to pass by their local hospital to receive continued treatment. An important reason for this is explained by Fig. 1, which shows the distance to Malmö from the hospitals involved, expressed as driving time.

Perhaps centralized treatment of certain types of fractures will become as much an accepted policy as is already the case for severe burns, anuria, certain types of birth defects, and in certain areas, pseudarthrosis of the tibia. The results of this investigation indicate that the definition of cases of fracture of the shaft of the tibia which should be centralized may exclude longitudinal fractures. Further refinement of definitions will lessen the pressure on the center, and minimize the competition between central and peripheral hospital units.

As regards the necessity to provide all physicians in training with equal opportunities for learning management of fractures, centralization will promote rather than prevent such opportunities: the presence of a relatively high concentration of severe open fractures of the shaft of the tibia has had a stimulating effect upon all concerned in the management of such cases even though only one individual has been primarily responsible for all of these cases.

V. Conclusions

1. Infection is the most important causative factor in poor results of fractures of the shaft of the tibia.
2. Infection is directly related to secondary contamination through devitalized areas of the skin.
3. *Longitudinal fractures,* generally caused by indirect, moderate violence, are bound to give good results; treatment with internal fixation does not carry more risk of osteomyelitis than other elective procedures.
4. *Transverse fractures* are generally caused by direct, severe violence which may cause skin damage, obvious in open fractures but severe also in closed fractures. Choice of treatment of the fracture is limited by restrictions imposed by attention to the skin injury. Closed methods, with or without blind intramedullary nailing, are preferred. Skin incisions should not be made through potentially damaged skin, especially not over the subcutaneous antero-medial surface of the tibia.
5. In *open transverse fractures* the wound should be closed without delay, avoiding tension and using pedicle or free skin grafts when necessary as a primary procedure. Necrosis of skin or grafts should be aggressively treated by additional grafting procedures.

VI. Summary

A. PURPOSE

The purpose of this investigation was to test the hypothesis that prognosis and optimal choice of treatment of fractures of the shaft of the tibia are related more to the extent of skin injury than to the extent of bone injury.

B. MATERIAL

The probands of this investigation were 483 adult patients with 492 traumatic fractures of the shaft of the tibia treated during a fifteen-year period, 1949-1963 at the Orthopaedic Department of an urban community. Fractures which involved the knee or ankle regions were not included in this material.

Anatomically fractures with displacement belonged in three main groups, (a) closed longitudinal fractures, (b) closed, transverse fractures, and (c) open, transverse fractures. The transverse fractures included short oblique, comminuted, and double fractures, and were caused predominantly by severe violence such as motor vehicle accidents, whereas the longitudinal fractures were caused predominantly by moderate violence such as falls at ground level or from low heights, or bicycle accidents.

The anatomic classification used here was thus closely correlated with the etiology of the fractures.

The material was divided into two series (a) a *Control Series* of 311 fractures treated during the period 1949-1960, and (b) a *Prospective Series* of 181 fractures treated during the period 1961-1963.

C. TREATMENT

The general policy throughout the period of this investigation was to institute early definitive treatment, usually within 24 hours of injury. Plaster from toes to groin was used in all fractures, and internal fixation was used in 290 of 425 fractures which were reduced.

The difference in treatment between the two Series depended on the main type of fracture.

1. *Displaced, Closed, Longitudinal Fractures*

Throughout the period of this investigation the treatment of longitudinal fractures remained unchanged: the frequency of internal fixation, usually with screws, was 85 % in markedly displaced fractures.

2. *Displaced, Closed, Transverse Fractures*

In the closed, transverse fractures the frequency of internal fixation was equal in the two Series (56 of 94 in the *Control* and 32 of 62 in the *Prospective Series*) while the frequency of open reduction was higher *** in the *Control* (55/94) than in the *Prospective* Series (9/62) and the methods of internal fixation were different. In the *Control Series* the most common type of internal fixation was a plate. In the *Prospective Series* intramedullary nailing was preferred. In the *Control Series* the plate was always placed on the antero-medial surface of the tibia with the incision in same area. In the *Prospective Series* closed reduction and blind nailing was done in 23 of 28 nailed, and when open reduction was deemed necessary, the incision was placed so as to avoid the antero-medial surface of the leg.

3. *Displaced, Open, Transverse Fractures*

a. Skin Injury

In the open transverse fractures in the *Control Series* the skin was always closed primarily. A relaxing incision was done three times and skin grafts were never used.

By contrast the guiding principle of treatment in the *Prospective Series* was primary closure of the skin with care to avoid tension. Drainage was not used. Immediate transplantation of the skin as pedicle or free grafts, always combined with internal fixation, was performed in 8 of 11 wounds over 10 cm in length and in 3 of 14 wounds between 6 and 10 cm in length; transplantation of skin was not done in 22 wounds less than 6 cm in length.

b. Bone Injury

In the *Prospective Series* the choice of treatment of the bone injury as well, was guided by the necessity to avoid additional damage to the skin. In the *Control Series* 13 fractures were treated in traction. This method was never used in the *Prospective Series.* There was no significant difference in the frequency of internal fixation in the two series (37 of 71 in the *Control*

Series and 31 of 47 in the *Prospective Series*). In the *Control Series* internal fixation by means of a plate and/or screws was used in 30 of 37 fractures. In the *Prospective Series* these methods were replaced with intramedullary nailing with a Rush pin (28/31). In 22 of these fractures the nail was used alone. In 6 fractures additional fixation was provided by encircling wire. Four of these were double fractures.

D. COMPLICATIONS

Complications considered in this investigation were necrosis of the skin and osteomyelitis.

Thirty fractures had necrosis of the skin, 16 *deep* (with exposure of bone) and 14 *superficial* (no exposure of bone).

Twenty-two fractures developed osteomyelitis, 18 *severe* with drainage more than one year, and 4 *mild.*

E. FINAL STATUS

Follow-up one year or longer was made in 95 % of the probands. All probands who had had necrosis of the skin and/or osteomyelitis were available for evaluation. Fourteen probands with other injury to the same limb were excluded from evaluation of Final Status. The fracture of the shaft of the tibia healed in those excluded.

Evaluation of Final Status was made with regard to subjective and objective signs of impaired function, and the fractures were classified as *good, fair* or *poor.* Good implied complete resumption of normal activities, and poor implied poor functional status, severe complaints, osteomyelitis with recurrent drainage, pseudarthrosis and amputation.

F. RESULTS

The results of this investigation were expressed in terms of (1) comparison of the Prospective and Control Series as regards complications, Healing Time and Final Status in the three main fracture types, and (2) correlation of the incidence of osteomyelitis with Healing Time and Final Status.

1. *Comparison of Prospective Series with Control Series*

a. Closed, Displaced, Longitudinal Fractures

The Final Status in the 149 longitudinal fractures was 83 % good and 17 % fair with little difference between the Control and the Prospective Series. None of the fractures of this type had poor Final Status. One com-

plication only was observed: a fracture in the Control Series with superficial necrosis of the skin. The Healing Time for 95 % of the fractures was somewhat shorter in the Prospective as compared to the Control Series.

b. Closed, Displaced, Transverse Fractures

A marked difference between the Control and the Prospective Series was observed as regards incidence of osteomyelitis and Final Status in the closed transverse fractures.

In the *Control Series* 7 out of 94 fractures developed osteomyelitis, 6 primary and 1 secondary. In the *Prospective Series* none of 62 fractures developed osteomyelitis.

In the entire material the Final Status was good in 75 %, fair in 20 % and poor in 5 %. None of the 7 fractures which were classified poor as regards Final Status occurred in the Prospective Series. The Healing Time for 95 % of the fractures was shorter in the Prospective as compared to the Control Series.

c. Open, Displaced, Transverse Fractures

A marked difference between the Control and the Prospective Series was observed as regards incidence of osteomyelitis and Final Status in the open transverse fractures.

In the *Control Series* 14 of 71 fractures developed osteomyelitis, 13 primary and 1 secondary. In the *Prospective Series* 1 of 47 fractures developed osteomyelitis.

In the entire material the Final Status was good in 59 %, fair in 26 % and poor in 15 %. Only 1 of the 15 fractures which were classified poor as regards Final Status occurred in the Prospective Series. The Healing Time for 95 % of the fractures was markedly shorter in the Prospective as compared to the Control Series.

d. Other Fractures

The Final Status in the 47 fractures which did not belong to the three main fracture types was good in 46 and fair in 1 case. The number of cases was too small to permit any comparison between the two Series.

2. *Correlation of Osteomyelitis with Healing Time and Final Status in Transverse Fractures*

All of the 22 fractures with poor Final Status in this investigation occurred in displaced transverse fractures, either open, or closed, treated with open

reduction and internal fixation. Fourteen of these 22 occurred in fractures complicated by osteomyelitis.

a. Fractures Complicated by Osteomyelitis

The difference between Control and Prospective Series in Healing Time was found to be due entirely to the higher incidence of osteomyelitis in the Control Series.

The Final Status was classed as poor because of (i) *amputation:* 3 fractures (all in the Control Series) were amputated because of chronic osteomyelitis. In 2 of these the fracture had not healed; (ii) *chronic osteomyelitis:* 4 fractures (all in the Control Series) had chronic osteomyelitis with drainage continuing over 4 to 10 years. In 3 of these the Final Status was poor also because of marked ankle joint stiffness; (iii) *other criteria:* 7 fractures (6 in the Control Series) were classed as poor because of severe stiffness of the ankle or foot with severe objective as well as subjective disability. In no case was there severe limitation of knee motion.

The incidence of osteomyelitis was higher*** in fractures with necrosis of the skin (16 of 30) than in those without necrosis of the skin (6 of 244). The incidence of osteomyelitis was higher** in fractures with deep necrosis of the skin (13 of 16) than in those with superficial necrosis (3 of 14). The incidence of severe osteomyelitis was higher*** in fractures with deep necrosis of the skin (12 of 16) than in fractures with superficial necrosis of the skin (1 of 14).

b. Fractures Uncomplicated by Osteomyelitis

The final Status was classed as poor because of (i) *pseudarthrosis* 2 fractures in the Control Series did not heal; (ii) *other criteria:* 6 fractures (all in the Control Series) were classed as poor; 2 fractures because of marked inability to walk, combined with pain; 4 fractures because of marked stiffness of the ankle joint with both subjective and objective disability.

G. CONCLUSIONS

1. Infection is the most important causative factor in poor results of fractures of the shaft of the tibia.
2. Infection is directly related to secondary contamination through devitalized areas of the skin.

3. *Longitudinal fractures,* generally caused by indirect moderate violence, are bound to give good results; treatment with internal fixation does not carry more risk of osteomyelitis than other elective procedures.
4. *Transverse fractures* are generally caused by direct, severe violence which may cause skin damage, obvious in open fractures, but severe also in closed fractures. Choice of treatment of the fracture is limited by restrictions imposed by attention to the skin injury. Closed methods, with or without blind intramedullary nailing are preferred. Skin incisions should not be made through potentially damaged skin, especially not over the subcutaneous antero-medial surface of the tibia.
5. In *open transverse fractures* the wound should be closed without delay, avoiding tension and using pedicle or free skin grafts when necessary as a primary procedure. Necrosis of skin or grafts should be aggressively treated by additional grafting procedures.

VII. Acknowledgments

Financial support was obtained from research grants awarded to Professor Göran C. H. Bauer from the U.S. Public Health Service (N. I. D. R. Grant No. DE-1452, and General Support Branch, Grant No. 1 SO1 FR-05495) and from the Swedish Medical Research Council, and to the author from Herman Järnhardt's Stiftelse, Malmö, Fylgias 80-års fond, Stockholm, and the Faculty of Medicine, the University of Lund.

VIII. Bibliography

Adams, J. C. (1961): Outline of orthopaedics. 4th edition, E. S. Livingstone, Ltd., p. 61, London.

Adams, J. C. (1964): Outline of fractures including joint injuries. 4th edition, E. S. Livingstone Ltd., p. 6, London.

Adler, J. B., Shaftan, G. W., Rabinowitz, J. G. and Herbsman, H. (1962): Treatment of tibial fractures. J. Trauma, *2*: 59.

Alffram, P. A. (1964): An epidemiologic study of cervical and trochanteric fractures of the femur in an urban population. Acta orthop. scand. Suppl. 65.

Alms, M. (1962): Medullary nailing for fracture of the shaft of the tibia. J. Bone Jt Surg. *44-B*: 328.

Andersen, M. N., McDonald, K. and Stephens, J. G. (1961): A study of the effect of open and closed treatment on rate of healing and complications in fractures of the tibial shaft. J. Trauma, *1*: 290.

Bauer, G. C. H. (1960): Epidemiology of fracture in aged persons. A preliminary investigation in fracture etiology. Clin. Orthop. *17*: 219.

Bauer, G. C. H., Edwards, P. and Widmark, P. H. (1962): Shaft fractures of the tibia. Etiology of poor results in a consecutive series of 173 fractures. Acta chir. scand. *124*: 386.

Bauer, G. C. H. and Edwards, P. (1965): Age dependent factors in the etiology of poor results of fractures of the shaft of the tibia. To be published in Acta orthop. scand.

Bauer, G. C. H. and Edwards, P. (1966): Etiology, incidence and therapy of fractures of the shaft of the tibia expressed in terms of symbolic logic. To be published.

Bergentz, S. E. and Thureborn, E. (1957): Shaft fractures of the lower leg: Open versus closed reduction. Acta chir. scand. *114*: 235.

Blockey, N. J. (1956): The value of rigid fixation in the treatment of fractures of the adult tibial shaft. J. Bone Jt Surg. *38-B*: 518.

Bruns, P. (1882): Die allgemeine Lehre von den Knochenbrüchen. Deutsche Chirurgie, *27*: part 1, Ferd. Enke, Stuttgart.

Böhler, L. (1957): Die Technik der Knochenbruchbehandlung. Verlag f. Medizinische Wissenschaften, Wilhelm Maudrich, Wien, Band II, 2 Teil, p. 1852; 1892.

Campbell, R. D. Jr. (1960): Treatment of tibial shaft fractures. In "Surgical Treatment of Trauma", P. A. Wade (ed.) Grune and Stratton, New York.

Carpenter, E. B., Dobbie, J. J. and Siewers, C. F. (1952): Fractures of the shaft of the tibia and fibula. Comparative end-results from various types of treatment in a teaching hospital. Arch. Surg. *64*: 443.

Cave, E. F. (1965): Orthopedic surgery (Ed.) Surg. Gynec. Obstet. *120*: 282.

Compere, E. L. (1949): Avascular necrosis of large segmental fracture fragments of the long bones. J. Bone Jt Surg. *31-A*: 47.

Connelly, J. R. (1956): Plastic surgery in bone problems. Plast. reconstr. Surg. *17*: 129.

Dahl-Iversen, E. (1928) : On the frequency and the duration of osteitis after osteosynthesis, illustrated by 274 cases on re-examination of 66 cases of operatively treated fractures. Acta chir. scand. *63* : 41.

Edwards, P. (1965 a) : The effect of crush injury to the skin on healing of fracture of the shaft of the tibia in dogs. Acta orthop. scand. Vol. 36. In press.

Edwards, P. (1965 b) : Management of wound in open fractures of the shaft of the tibia. To be published.

Edwards, P. and Nilsson, B. (1965) : Graphic representation of healing time in fractures of the shaft of the tibia. Acta orthop. scand. Vol. 36. In press.

Ellis, H. (1956) : A study of some factors affecting prognosis following tibial shaft fractures. Thesis, Bodleian Library, Oxford.

Essex-Lopresti, P. (1950) : The open wound in trauma. Lancet, *1* : 745.

Feinstein, A. R. (1963) : Boolean algebra and clinical taxonomy. I. Analytic synthesis of the general spectrum of a human disease. New Engl. J. Med. *269* : 929.

Freeman, W. A. and Garnes, A. L. (1958) : Open tibial shaft fractures. — Immediate soft tissue closure. Amer. J. Surg. *95* : 415.

Hedenberg, I. and Pompeius, R. (1959—60) : Shaft fractures of the lower leg. Comparing the early results of open and closed treatment in 120 cases. Acta chir. scand. *118* : 339.

Hicks, J. H. (1964) : Amputation in fractures of the tibia. J. Bone Jt Surg. *46-B* :

Jackson, R. W. and Macnab, I. (1959) : Fractures of the shaft of the tibia. A clinical and experimental study. Amer. J. Surg. *97* : 543.

Johansson, O. (1953) : Viewpoints on primary osteosynthesis in compound fracutres. Acta chir. scand. *105* : 473.

Key, J. A. and Reynolds, F. C. (1953) : Contact splints (eggers) VS. standard bone plates in the fixation of experimental fractures. Ann. Surg. *137* : 911.

Krösl, W. (1957) : Ergebnisse der Marknagelung bei 65 geschlossenen und 45 offenen Brüchen des Unterschenkels. 54 Heft zur Unfallheilk. p. 181.

Lauritzen, G. (1949) : Medullary nailing. A clinical and critical study. Acta chir. scand. Suppl. 147.

Lottes, J. O., Hill, L. J. and Key, J. A. (1952) : Closed reduction, plate fixation, and medullary nailing of fractures of both bones of the leg. A comparative end-result study. J. Bone Jt Surg. *34-A* : 861.

Mauck, H. P. (1943) : Treatment of fractures of both bones of leg by conservative methods. Sth. med. J. *36* : 609.

Moberg, E. (1942) : Zur Frage der Wundheilung bei komplizierten Frakturen der langen Röhrenknochen. Acta chir. scand. *86* : 43.

Nicoll, E. A. (1964) : Fractures of the tibial shaft. A survey of 705 cases. J. Bone Jt Surg. *46-B* : 373.

Nilsson, B. (1965) : Bone densitometry. Acta orthop. scand. To be published.

Palmer, I. (1950) : Review of the complications and technical problems of intramedullary nailing. J. Bone Jt Surg. *32-B* : 721.

Palmer, I. (1954) : A dualistic method of treating pseudarthrosis. Acta chir. scand. *107* : 261.

Reynolds, R. D. and Key, J. A. (1954) : Fracture healing after fixation with standard plates contact splints, and medullary nails. J. Bone Jt Surg. *36-A* : 577.

Solheim, K. (1960) : Fractures of lower leg. Acta chir. scand. *119* : 268.

Trueta, J. (1939) : Treatment of war wounds and fractures with special reference to the closed method as used in the war in Spain. Forew. by E. W. Hey Groves, Pp. 156, H. Hamilton, London.

Tucker, J. T., Watkins, F. P. and Carpenter, E. B. (1961) : Conservative treatment of fractures of the shaft of the tibia. J. Amer. med. Ass. *178* : 802.

Urist, M. R., Mazet, R. Jr. and McLean, F. C. (1954) : The pathogenesis and treatment of delayed union and non-union. J. Bone Jt Surg. *36-A* : 931.

Watson-Jones, R. and Coltart, W. D. (1943) : Slow union of fractures with a study of 804 fractures of the shafts of the tibia and femur. Brit. J. Surg. *30* : 260.

Watson-Jones, R. (1957) : Fractures and joint injuries. Vol. I. 4th edition, E. S. Livingstone Ltd, London.

Veliskakis, K. P. (1959) : Primary internal fixation in open fractures of the tibial shaft. J. Bone Jt Surg. *41-B* : 342.

Wendeberg, B. (1961) : Mineral metabolism of fractures of the tibia in man studied with external counting of Sr^{85}. Acta orthop. scand. Suppl. 52.

IX. Coded Data

A. PROBANDS

CONTROL SERIES

A	B	C	D	E	F	G	H	I	K	L	M	N	O	P	R	S	T	U	V
1	1	27	F	11	—	3	++	+	—	7^{0}	—	—	—	4	—	—	1	7	a
	2	27	F	11	—	3	++	+	—	7^{0}	—	—	—	3	—	—	1	8	b
	3	30	F	11	—	2	+	—	—	7^{0}	—	—	—	3	—	—	1	5	a
	4	31	F	11	—	3	++	+	—	7^{4}	—	—	—	3	—	—	6	14(3)	a
	5	31	F	11	—	3	++	+	—	7^{3}	—	—	—	4	—	—	2	15	b
	6	31	F	11	—	3	++	+	—	8^{0}	—	—	—	2	—	—	1	6	a
	7	32	F	11	—	3	++	+	—	7^{0}	—	—	—	3	—	—	1	7	a
	8	32	F	10	—	2	++	+	—	7^{0}	—	—	—	3	—	—	2	6	a
	9	34	F	11	—	3	++	+	—	7^{30}	—	—	—	5	—	—	4	9	a
	10	34	F	11	—	3	++	+	—	7^{33}	—	—	—	6	—	—	2	17	b
	11	35	F	11	—	3	++	+	—	10^{0}	—	—	—	3	—	—	2	5	a
	12	37	F	11	—	2	++	+	—	8^{0}	—	—	—	3	—	—	x	x	a
	13	38	F	11	—	3	++	+	—	8^{0}	—	—	—	3	—	—	1	6	a
	14	42	F	11	—	2	++	+	—	7^{0}	—	—	—	3	—	6 S	2	5	x[3]
	15	43	F	11	—	3	++	+	—	8^{0}	—	—	—	4	—	—	2	8	a
	16	43	F	11	—	3	++	+	—	7^{2}	—	—	—	1	—	—	1	7	a
	17	45	F	11	—	3	++	+	—	7^{0}	—	—	—	4	—	—	1	5	a
	18	45	F	10	—	3	++	+	—	10^{0}	—	—	—	2	—	—	3	7	a
	19	45	F	10	—	3	++	+	—	7^{0}	—	—	—	4	—	—	2	8	b
	20	47	F	11	—	3	++	+	—	8^{0}	—	—	—	3	—	—	2	12	b
	21	47	F	11	—	3	++	+	—	7^{0}	—	—	—	3	—	6 S	10	11	a
	22	47	F	11	—	3	++	+	—	7^{0}	—	—	—	3	—	—	3	5	b
	23	47	F	11	—	3	++	+	—	7^{0}	—	—	—	4	—	—	2	8	a
	24	49	F	11	—	3	++	+	—	7^{0}	—	—	—	5	—	6 S	2	9	b
	25	51	F	11	—	3	++	+	—	8^{0}	—	—	—	3	—	6 S	5	x	x[2]
	26	52	F	11	—	3	++	+	—	7^{0}	—	—	—	3	—	—	2	8	a
	27	52	F	10	—	3	+	—	—	7^{14}	—	—	—	3	—	—	11	9	a
	28	54	F	11	—	3	++	+	—	8^{9}	—	—	—	3	—	—	8	10	a
	29	55	F	11	—	2	++	+	—	7^{0}	—	—	—	4	—	—	5	13	a
	30	59	F	11	—	3	++	+	—	7^{5}	—	—	—	4	—	—	17	8	a
	31	59	F	10	—	3	++	+	—	7^{0}	—	—	—	4	—	9	8	8	a

32	64	F	11	—	2	++	+	—	8^2	—	—	—	4	—	6 S	11	9	a
33	64	F	11	—	3	++	+	—	7^2	—	—	—	2	—	—	8	8	x^+
34	64	F	11	—	3	++	+	—	$7^0, 10^0$	—	—	—	4	—	—	6	7	a
35	73	F	11	—	3	++	+	—	$8^0, 10^0$	—	—	—	4	—	—	x	x	a
36	74	F	11	—	3	++	+	—	7^0	—	—	—	2	—	—	1	4	a
37	78	F	11	—	2	++	+	—	7^0	—	—	—	2	—	—	2	11	x^+
38	80	F	11	—	3	++	+	—	8^2	—	—	—	2	(N)	—	14	5	a
39	39	F	11	—	3	++	+	—	1	—	—	—	7	—	—	1	27	b
40	40	F	11	—	3	++	+	—	1	—	—	—	3	—	—	x	x	a
41	41	F	11	—	3	++	+	—	2	—	—	—	5	—	9	8	8	a
42	45	F	11	—	3	+	+	—	1	—	—	—	2	—	—	1	4	b
43	47	F	11	—	3	++	+	—	1	—	—	—	3	—	—	1	4	a
44	49	F	11	—	3	+	+	—	0	—	—	—	2	—	4 S	2	4	x^3
45	50	F	11	—	3	+	+	—	0	—	—	—	2	—	—	1	6(2)	a
46	58	F	11	—	3	++	+	—	0	—	—	—	3	—	—	16	5	a
47	63	F	11	—	2	++	+	—	1	8^3	—	—	6	—	—	27	10	b
48	69	F	11	—	3	+	+	—	0	—	—	—	3	—	—	1	4	a
49	72	F	1	—	3	+	+	—	14	—	—	—	5	—	—	4	15	b
50	78	F	11	—	1	++	+	—	1	—	—	—	3	—	—	12	4	x^+
51	78	F	11	—	3	++	+	—	1	—	—	—	3	—	—	x	x	x^+
52	21	M	11	—	3	++	+	—	7^4	—	—	—	4	—	—	12	5	a
53	22	M	8	—	3	++	+	—	7^2	—	—	—	3	—	—	14	5	a
54	25	M	11	—	3	++	+	—	7^3	—	—	—	4	—	—	1	10	x^1
55	26	M	11	—	2	++	+	—	7^0	—	—	—	4	—	—	2	5	x^+
56	26	M	10	—	3	++	+	—	7^0	—	—	—	4	—	—	1	6(1)	x^1
57	28	M	11	—	3	++	+	—	7^0	—	—	—	3	—	—	10	4	a
58	28	M	1	—	3	++	+	—	7^0	—	—	—	2	—	—	6	5	a
59	30	M	10	—	3	++	+	—	7^0	—	—	—	3	—	—	4	6	a
60	33	M	11	—	3	++	+	—	7^0	—	—	—	3	—	—	9	9	b
61	33	M	11	—	2	++	+	—	7^{12}	—	—	—	2	—	—	2	7(1)	a
62	34	M	11	—	3	+	—	—	7^0	—	—	—	3	—	—	1	6	x^1
63	34	M	7	—	3	++	+	—	7^0	—	—	—	2	—	—	1	5	a
64	35	M	11	—	3	++	+	—	10^0	—	—	—	6	—	—	1	12	b
65	36	M	7	—	3	++	+	—	$8^0, 10^0$	—	—	—	5	—	—	2	6	a
66	37	M	11	—	3	++	+	—	7^2	—	—	—	2	—	—	14	10	a
67	38	M	11	—	3	++	+	—	7^3	—	—	—	4	—	—	1	8	b

A	B	C	D	E	F	G	H	I	K	L	M	N	O	P	R	S	T	U	V
	68	38	M	11	—	3	++	+	—	7^{0}	—	—	—	4	—	—	5	14	b
	69	39	M	10	—	3	++	+	—	7^{0}	—	—	—	4(7)	—	—	5	11	x^{1}
	70	40	M	11	—	3	++	+	—	7^{0}	—	—	—	4	—	—	1	7	a
	71	40	M	11	—	3	++	+	—	7^{0}	—	—	—	3	—	—	1	10(1)	b
	72	43	M	10	—	3	++	+	—	10^{0}	—	—	—	5	—	—	1	7	x^{+}
	73	43	M	11	—	3	++	+	—	7^{2}	—	—	—	2	—	—	1	5	a
	74	43	M	11	—	3	++	+	—	7^{0}	—	—	—	2	—	—	2	6	b
	75	45	M	11	—	3	++	+	—	7^{0}	—	—	—	4	—	—	2	8	a
	76	45	M	3	—	3	++	+	—	7^{0}	—	—	—	3	—	—	3	6	a
	77	46	M	10	—	3	++	+	—	$7^{0}, 10^{0}$	—	—	—	5	—	—	2	11	a
	78	46	M	7	—	3	++	+	—	7^{0}	—	—	—	4	—	—	4	10	b
	79	46	M	10	—	3	++	+	—	7^{46}	—	—	—	4	—	—	18	7	a
	80	47	M	11	—	3	+	+	—	7^{6}	—	—	—	3	—	—	1	5(2)	a
	81	47	M	1	—	3	++	+	—	10^{0}	—	—	—	3	—	—	2	7	a
	82	49	M	10	—	2	++	+	—	7^{11}	—	—	—	4	—	—	6	x	a
	83	49	M	10	—	3	++	+	—	7^{6}	—	—	—	3	—	—	1	4	a
	84	50	M	10	—	3	++	+	—	8^{0}	—	—	—	3	—	—	4	10	a
	85	50	M	11	—	3	++	+	—	$7^{0}, 10^{0}$	—	—	—	6	—	—	2	14	a
	86	50	M	11	—	3	++	+	—	7^{0}	—	—	—	3	—	—	2	9	a
	87	51	M	11	—	3	++	+	—	7^{0}	—	—	—	3	—	—	1	7	x^{+}
	88	52	M	11	—	3	++	+	—	7^{10}	—	—	—	4	—	—	3	10	a
	89	52	M	7	—	3	++	+	—	7^{0}	—	—	—	4	—	—	3	9	a
	90	53	M	11	—	3	++	+	—	7^{2}	—	—	—	4	—	—	16	10	b
	91	55	M	11	—	3	++	+	—	7^{0}	—	—	—	5	—	—	4	12	a
	92	56	M	10	—	3	++	+	—	7^{0}	—	—	—	5	—	—	4	18	a
	93	56	M	11	—	3	++	+	—	7^{0}	—	—	—	4	—	—	4	9	a
	94	57	M	11	—	3	++	+	—	$7^{0}, 8^{0}$	—	—	—	5	—	—	8	14	a
	95	58	M	11	—	3	++	+	—	7^{0}	—	—	—	5	—	—	3	11	a
	96	58	M	11	—	3	++	+	—	7^{2}	—	—	—	3	—	—	1	7	a
	97	59	M	11	—	3	++	+	—	7^{0}	—	—	—	4	—	—	15	x	a
	98	60	M	11	—	2	++	+	—	8^{6}	—	—	—	5	—	—	3	9	a
	99	61	M	11	—	2	++	+	—	8^{0}	—	—	—	3	—	—	2	8	a

	100	62	M	3	—	3	++	+	—	7^{0}	—	—	—	4	—	—	3	9	a
	101	64	M	11	—	3	++	+	—	7^{3}	—	—	—	3	—	—	6	12	b
	102	64	M	11	—	3	++	+	—	7^{0}	—	—	—	3	—	—	12	6	a
	103	69	M	10	—	2	++	+	—	7^{0}	—	—	—	5	—	—	26	x	a
	104	73	M	11	—	3	++	+	—	7^{0}	—	—	—	4	—	—	4	10	a
	105	75	M	2	—	3	++	+	—	7^{12}	—	—	—	4	—	—	5	10	a
	106	77	M	7	—	3	++	+	—	7^{0}	—	—	—	2	—	2	24	x	a
	107	78	M	11	—	3	++	+	—	7^{0}	—	—	—	4	—	—	3	6	a
	108	16	M	11	—	2	++	+	—	1	—	—	—	5	—	—	1	7	a
	109	16	M	11	—	2	+	—	—	1	—	—	—	3	—	—	3	6	a
	110	18	M	3	—	3	++	—	—	1	—	—	—	4	—	—	4	6	a
	111	22	M	8	—	2	++	+	—	1	—	—	—	5	—	—	1	6	a
	112	36	M	11	—	3	+	+	—	1	—	—	—	3	—	—	1	4	a
	113	38	M	7	—	1	+	—	—	0	—	—	—	2	—	—	20	x	a
	(273)																		
	114	41	M	11	—	2	+	+	—	0	—	—	—	4	—	—	10	13	a
	115	45	M	11	—	2	+	+	—	0	—	—	—	4	—	—	1	7(2)	a
	116	49	M	10	—	3	++	+	—	1	—	—	—	5	—	—	12	9	b
	117	51	M	1	—	1	++	+	—	1	—	—	—	12	—	—	6	x	b
	118	63	M	10	—	2	++	+	—	2	—	—	—	3	—	—	11	5	a
2	119	28	F	11	—	3	++	+	be	7^{0}	—	—	—	4	—	—	2	7	a
	120	51	F	11	—	2	++	+	a	8^{0}	—	—	—	2	—	—	2	12	a
	121	74	F	1	—	1	++	+	b	1	—	—	—	3	—	—	24	9	a
	(147)																		
	122	28	M	7	—	2	++	+	ce	7^{0}	—	—	—	3	—	—	11	5	a
	123	42	M	1	—	3	++	+	be	7^{0}	—	—	—	5	—	—	3	16	b
	124	52	M	11	—	3	++	+	ae	7^{0}	—	—	—	3	—	—	3	5	a
	125	69	M	1	—	3	++	+	b	2	—	—	—	3	—	6 S	8	10(2)	x^{+}
4	126	21	F	1	—	3	++	+	—	8^{0}	—	—	—	4	—	—	5	x	a
	127	23	F	1	—	2	++	+	—	8^{21}	—	—	—	4	—	—	4	13	b
	128	34	F	1	—	2	++	+	—	7^{0}	—	—	—	4	—	—	2	6	a
	129	40	F	3	—	3	++	+	—	9^{3}	—	—	—	11	—	—	20	15	a
	130	47	F	4	+	d	++/++	+	—	6^{0}	—	—	—	10(11)	—	—	13	21(13)	a
	131	56	F	1	—	1	++	+	—	8^{0}	—	—	—	5	—	—	5	31	a

CONTROL SERIES (cont.)

A	B	C	D	E	F	G	H	I	K	L	M	N	O	P	R	S	T	U	V
4	132	57	F	4	—	1	++	+	—	8^{2}	$1^{6,13}$	—	—	20	—	—	11	36	b
	133	58	F	10	+	3	++	+	—	8^{55}	—	—	—	4	—	—	27	10	a
	134	59	F	1	—	2	++	+	—	$7^{0}, 13^{0}$	—	—	—	5	—	9	28	x	b
	135	72	F	1	—	1	++	+	—	8^{14}	—	—	—	3	—	—	16	12	a
	136	72	F	1	+	2	++	+	—	5^{0}	—	—	—	3	—	1	5	11	a
	137	74	F	1	+	3	++	+	—	7^{0}	—	—	—	3	—	9	25	16	b
	138	74	F	1	+	1	++	+	—	$6^{0}, 10^{0}$	—	—	—	3(8)	—	5 S	21	12	x[2]
	139	29	F	2	+	3	++	+	—	2	—	—	—	4	—	—	9	11	b
	140	44	F	1	—	2	+	+	—	3	—	—	—	6	—	—	2	13(1)	a
	141	55	F	1	—	3	++	+	—	4	—	—	—	6	—	8	20	x	b
	142	60	F	1	—	1	+	+	—	14	—	—	—	5	—	—	17	11	b
	143	60	F	11	+	3	++	+	—	1	—	—	—	3	—	—	20	8	b
	144	65	F	11	+	3	+	+	—	1	—	—	—	3	—	—	14	8	a
	145	72	F	11	—	3	+	+	—	1	—	—	—	4	—	—	19	6	a
	146	72	F	11	—	1	+	+	—	0	—	—	—	5	—	—	3	5	b
	147 (121)	74	F	1	—	1	++	+	—	3	—	—	—	5(7)	—	9	24	9	a
	148	81	F	1	—	1	++	+	—	1	—	—	—	5	—	9	25	13	a
	149	16	M	7	—	2	++	+	—	8^{0}	—	—	—	3	—	—	2	5	a
	150	16	M	8	—	2	++	+	—	7^{0}	—	—	—	3	—	—	2	7	a
	151	17	M	3	—	3	++	+	—	8^{0}	—	—	—	3	—	—	2	4	a
	152	18	M	3	—	2	+	—	—	8^{5}	—	—	—	3	—	6 S	12	9	x[2]
	153	18	M	2	—	2	++	+	—	8^{0}	—	—	4^{5}	3(9)	(NO)	—	6	11	a
	154	19	M	11	—	2	++	+	—	8^{9}	—	—	—	3	—	—	3	8	a
	155	19	M	1	—	2	++	+	—	8^{0}	—	—	—	5(7)	—	—	1	10	a
	156	20	M	2	—	2	++	+	—	9^{0}	—	—	—	4	—	—	4	5	a
	157	21	M	2	—	3	++	+	—	7^{3}	—	—	—	5	—	—	6	7	a
	158	21	M	1	—	2	++	+	—	8^{0}	—	—	—	6	—	—	4	9	a
	159	21	M	3	—	2	++	+	—	8^{0}	—	—	—	3	—	4 S	8	7	a
	160	22	M	2	—	3	++	+	—	8^{0}	—	—	—	4	—	—	1	9	a
	161	23	M	2	—	3	++	+	—	8^{0}	—	—	—	2	—	—	1	7	a
	162	25	M	2	—	2	++	—	—	8^{0}	—	—	—	4	—	—	1	8	a

163	**26**	**M**	**2**	—	**3**	++	+	—	8^{0}	$7^{8,\ 10,\ 11,\ 17}$	—	—	16	O	—	6	31	b
164	27	M	8	—	3	++	+	—	9^{2}	—	—	—	4	—	—	2	5	a
165	27	M	2	—	3	++	+	—	8^{17}	—	—	—	3	—	6 S	10	4	a
166	28	M	10	—	2	++	+	—	8^{0}	—	—	—	4	—	—	6	11	x^{1}
167	28	M	2	—	2	++	+	—	8^{2}	—	—	—	3	—	—	6	7	a
168	28	M	7	—	3	+	+	—	8^{0}	—	—	—	4	—	—	2	9	a
169	31	M	2	—	1	+	—	—	8^{0}	—	—	—	3	—	—	4	7	a
170	31	M	8	—	3	++	+	—	8^{0}	—	—	—	3	—	—	2	6	a
171	35	M	1	—	1	++	+	—	8^{0}	—	—	—	7	—	—	1	10	a
172	37	M	6	+	2	++	+	—	8^{0}	—	—	—	2	—	—	4	12(6)	a
173	38	M	2	—	3	++	+	—	7^{0}	—	—	—	8(10)	—	—	16	15	a
174	41	M	7	+	d	++/++	+	—	7^{0}, 8^{0}, 10^{0}	—	—	—	3	—	—	4	11	b
175	43	M	7	+	d	0/++	+	—	8^{0}	—	—	—	4	—	—	2	11	b
176	46	M	3	—	3	++	+	—	8^{8}	—	—	—	4	—	—	3	8	a
177	46	M	11	—	3	++	+	—	8^{0}	—	—	—	2	—	6 S	4	8	a
178	47	M	11	—	3	++	+	—	8^{10}	—	—	—	4	—	—	3	7	a
179	49	M	1	—	3	++	+	—	8^{0}	—	—	—	5	—	—	1	8	a
180	50	M	1	—	2	++	+	—	9^{30}	—	—	—	4	—	3 S	18	15	x^{2}
181	52	M	11	—	1	++	+	—	8^{0}	—	—	—	3	—	—	2	4	a
182	53	M	7	—	1	++	—	—	8^{0}	—	—	—	4	—	—	7	9	a
183	57	M	7	+	3	+	+	—	10^{20}	$7^{11,\ 13,\ 15,\ 22}$	—	—	9	O	—	7	P	c (O)
184	60	M	1	—	2	++	+	—	8^{0}	—	—	—	5(7)	—	6	20	24 P	c
185	63	M	2	+	2	++	+	—	8^{0}	—	—	—	4	—	—	2	13	a
186	65	M	7	+	3	++	+	—	8^{0}	$1^{8,\ 30,\ 48}$ $7^{44,\ 60,\ 70}$	—	—	33(54)	NO	S** —	80	P	c (amp)
187	65	M	1	—	2	+	+	—	8^{0}	$7^{5,\ 10}$	—	—	7(12)	NO	—	50	40 P	c
188	66	M	10	+	3	++	+	—	7^{0}, 10^{0}	7^{6}	—	4^{3}	8	NO	—	36	12	b
189	71	M	1	—	3	++	+	—	7^{0}	—	—	—	4	—	—	18	13	a
190	76	M	1	+	1	++	+	—	8^{0}	1^{5}	—	—	13	—	—	49	P	c (ps)
191	84	M	1	+	d	+/++	+	—	8^{3}	—	—	—	3(7)	O	8	11	P	c (O)
192	16	M	2	—	3	+	+	—	0	—	—	—	2	—	—	1	4	b
193	16	M	3	+	3	++	+	—	3	—	—	—	5	—	—	2	6	a
194	17	M	3	—	2	+	—	—	1	—	—	—	3	—	—	1	4	a
195	18	M	8	—	2	++	+	—	3	—	—	—	4	—	—	1	6	a
196	18	M	8	—	2	+	+	—	1	—	—	—	3	—	—	1	4	a

** primary complications —

CONTROL SERIES (cont.)

A	B	C	D	E	F	G	H	I	K	L	M	N	O	P	R	S	T	U	V
4	197	21	M	2	+	3	+	+	—	1	—	—	—	3	—	—	2	7	a
	198	22	M	4	—	2	++	+	—	3	—	—	—	5	—	8	5	10 P	b
	199	23	M	3	+	2	+	+	—	2	—	—	—	3	—	—	9	5	a
	200	25	M	8	—	2	++	+	—	4	—	—	—	5	—	—	7	10	b
	201	29	M	8	—	3	++	+	—	3	—	—	—	5	—	—	2	12	b
	202	31	M	1	—	3	++	+	—	1	—	—	—	4	—	6	4	8	a
	203	39	M	7	—	2	++	+	—	3	—	—	—	7	—	—	10	15(1) P	b
	204	41	M	1	+	2	+	+	—	1	—	—	—	3	—	—	1	8	x^1
	205	42	M	2	—	3	+	+	—	1	—	—	—	6	—	—	1	11	a
	206	43	M	1	+	d	0/+	+	—	1	—	—	—	3	—	—	2	8	x^+
	207	43	M	4	+	d	++/0	+	—	3	—	—	—	7	—	6 S	2	10	a
	208	44	M	3	+	2	++	+	—	3	—	—	—	4	—	—	2	6	a
	209	44	M	7	—	2	++	+	—	3	—	—	—	6	—	6	2	12	a
	210	47	M	2	—	2	++	+	—	1	5^4	—	—	9	—	8	4	17	a
	211	52	M	1	—	3	++	+	—	3	—	—	—	5	—	—	9	12	b
	212	52	M	1	—	3	++	+	—	4	—	—	—	4	—	8	12	11(5)	b
	213	55	M	7	—	3	++	+	—	1	6^5	—	—	13	—	—	4	19	a
	214	55	M	7	—	1	+	—	—	0	—	—	—	3	—	—	3	7	a
	215	55	M	7	+	2	+	+	—	1	—	—	—	3	—	—	15	10	b
	216	56	M	11	+	3	++	+	—	3	—	—	—	4	—	—	1	9	a
	217	66	M	1	+	1	++	+	—	1	—	—	—	5	—	—	16	14 P	b
	218 (290)	79	M	1	—	1	++	+	—	4	—	—	—	8(11)	—	—	44	P	c
	219	84	M	11	—	1	+	+	—	1	—	—	—	2	—	—	1	x	x^+
5	220	29	F	1	—	2	++	+	a	5^0	—	—	—	3	—	—	3	5	a
	221	30	F	1	—	2	++	+	b	8^0	—	—	—	3	—	1	6	11	b
	222	41	F	1	—	3	++	+	bf	9^{20}	—	—	—	5	—	—	8	11	a
	223	45	F	1	+	d	0/+	+	a	8^{15}	—	—	—	3	—	—	5	18(8)	b
	224	72	F	1	—	2	++	+	ce	10^0, 13^0	—	1	—	6	—	—	17	8	a
	225	17	F	1	—	2	++	+	ce	3	9^{27}	1	—	6	(N)	—	10	17	b
	226	25	F	6	—	3	++	+	be	1	—	—	—	4	—	—	4	6	a

227	48	F	11	—	2	++	+	cef	11	—	—	—	8	—	—	4	16	a
228	70	F	1	—	3	++	+	ce	1	—	—	—	4	—	—	20	11 P	c
229	72	F	1	—	2	++	+	b	13	—	—	—	7(9)	—	—	32	19	b
230	86	F	1	—	2	+	+	d	3	—	—	—	4	—	9	10	6	a
231	17	M	2	—	3	++	+	b	8^{0}	—	—	—	2	—	8	2	7(4)	a
232	18	M	3	+	2	++	+	a	8^{0}	—	—	—	7(12)	—	—	1	14	a
233	19	M	1	+	2	++	—	be	7^{0}	7^{2}, 9^{26}	—	—	6	(NO)	9	14	16	b
234	20	M	2	—	3	++	+	b	8^{29}	—	—	—	6	—	—	21	8	x^{1}
235	22	M	2	—	2	++	+	c	8^{0}	1^{8}	—	—	10(12)	(N)	—	10	14	a
236	28	M	7	—	3	++	+	b	8^{30}, 9^{30}	—	—	—	3	N	—	9	19	a
237	29	M	2	—	2	++	+	a	9^{21}	—	—	—	3	—	2S, 4S	20	7	a
238	32	M	2	—	2	++	+	a	8^{0}	—	—	—	2	—	—	1	7	b
239	35	M	2	+	3	++	+	b	9^{7}	—	—	—	4	—	—	3	8	a
240	37	M	7	—	2	+	—	a	8^{30}	—	—	—	6	—	—	13	10	b
241	39	M	6	—	2	++	+	ae	8^{35}	—	—	—	6	—	9	2	8	b
242	42	M	7	—	3	++	+	a	8^{0}	—	—	—	3	—	—	2	8	a
243	42	M	1	+	d	++/++	+	a	8^{0}, 8^{0}	—	—	—	7	—	—	6	14	a
244	43	M	2	—	2	++	+	a	7^{0}	—	—	—	3	—	8, 3 S	36	24	x^{2}
245	44	M	2	+	3	++	+	ae	8^{0}	—	—	—	2	—	—	4	8	a
246	46	M	3	+	3	++	+	be	7^{0}	—	—	—	3	—	—	11	5	a
247	46	M	7	+	d	0/++	+	a	7^{15}	—	—	—	4	—	—	6	11	a
248	47	M	7	+	3	+	+	c	8^{0}	$7^{7, 8, 36}$	—	8^{21}	35(40)	NO	—	60	43 P	c
249	48	M	2	+	d	++/++	+	def	7^{6}	$7^{5, 13}$	1	—	7	NO	9	28	19	c
250	48	M	3	—	3	++	+	b	8^{0}	8^{36}	—	8^{46}, 4^{48}	3	N(O)	6S, 7S	37	41	x^{3}
251	51	M	2	—	2	++	+	b	9^{10}	—	—	—	8	(O)	—	17	15	b
252	54	M	2	—	2	++	+	de	7^{0}	6^{22}	—	8^{4}, $4^{5, 6, 22}$ 3^{10}	25(29)	NO	8	64	40 P	c (O)
253	54	M	2	+	2	++	+	a	8^{0}	1^{4}, $7^{6, 10}$ 3^{15}, 2^{20}, 10^{27}	—	8^{4}	26	NO	—	55	36 P	c (amp)
254	54	M	5	+	2	++	+	def	8^{0}	$1^{3, 12, 15}$ 7^{9}, 3^{12}	—	—	39	NO*S	—	153	P	c
255	56	M	2	+	3	++	+	ce	7^{0}	—	—	4^{4}	14	(N)	—	20	31 P	c (ps)
256	57	M	1	—	2	++	+	de	7^{0}	—	—	—	6	—	—	6	24 P	b
257	58	M	1	—	2	++	+	a	8^{30}	7^{39}	—	—	5(12)	O	—	56	30 P	c (O)

(259)

* primary complications (N)

A	B	C	D	E	F	G	H	I	K	L	M	N	O	P	R	S	T	U	V
5	258	58	M	11	—	3	++	+	ce	7^{0}	—	—	—	4	—	—	2	7	a
	259	58	M	1	+	2	++	+	a	8^{21}	—	—	—	6	—	—	56	30 P	c
	(257)																		
	260	64	M	7	+	2	++	+	b	8^{0}	—	—	—	4	—	—	8	11	a
	261	69	M	1	—	3	++	+	b	8^{0}	—	—	—	7	—	—	8	9	x^{+}
	262	74	M	1	+	d	+/++	+	be	$7^{0}, 8^{0}$	—	—	—	3	—	—	7	15	a
	263	16	M	10	—	2	+	—	b	1	—	—	—	4	—	—	2	8	a
	264	16	M	3	+	3	+	—	ce	2	$1^{5}, 8^{14, 38}$	—	—	6	—	—	13	36	b
	265	19	M	2	—	3	++	+	a	1	—	—	—	3	—	8, 9	6	7	a
	266	22	M	2	—	2	+	+	b	1	—	—	—	4	—	8	18	7	a
	267	24	M	2	+	2	++	+	c	2	—	—	—	9	—	—	6	18 P	b
	268	25	M	7	+	3	++	+	b	2	1^{6}	—	—	14	—	—	—	23	b
	269	25	M	6	+	1	++	+	b	3	—	—	—	6	—	9	3	10	b
	270	26	M	2	—	2	+	+	cef	2	—	—	—	3	—	1, 9	4	5	a
	271	30	M	2	—	3	+	+	b	1	—	—	—	5	—	—	2	6	a
	272	31	M	2	+	d	++/++	+	be	2	—	—	—	6(10)	—	6 S	30	17 P	x^{2}
	273	38	M	7	+	d	+/++	+	be	1	1^{23}	—	—	16(25)	—	4 S	20	34 P	b
	(113)																		
	274	38	M	3	—	2	++	+	de	3	—	—	—	14	(N)	—	16	17 P	b
	275	41	M	7	—	3	++	+	be	1	—	—	—	3	—	—	9	9(2)	a
	276	41	M	7	+	2	+	—	a	1	—	—	—	3	—	—	4	6	x^{+}
	277	44	M	1	+	1	++	+	b	2	7^{5}	—	—	10	NO	—	33	15	a
	278	44	M	1	+	2	++	+	a	2	—	—	—	6	—	—	9	10	b
	279	44	M	1	—	2	++	+	a	1	—	—	—	4	—	—	8	7	a
	280	45	M	2	—	2	++	+	c	2	—	—	4^{13}	6	(N)O	4 S 9	25	10 P	c
	(281)																		
	281	45	M	2	+	1	++	+	b	2	—	—	—	3	—	—	25	10	b
	(280)																		
	282	47	M	7	+	3	++	—	de	2	$7^{3}, 10^{9}$	—	$4^{2, 4}$	9	NO	—	44	P	c (amp)
	283	51	M	6	+	3	++	+	ce	1	—	—	—	4	(N)	9	30	x	a
	284	56	M	7	—	3	++	+	def	2	—	—	$4^{2, 3, 3}$	17	NO	—	39	36 P	c
	285	58	M	6	—	2	++	+	a	11	—	—	—	5	—	8	6	9	a

	286	58	M	1	+	2	+	+	b	2	—	—	—	7	O	—	29	20	a
	287	64	M	1	+	3	++	+	be	3	—	—	—	14	(N)	—	13	23(5)	b
	288	67	M	7	+	d	0/++	+	a	2	—	—	—	10	—	—	52	30 P	c
	289	76	M	1	—	3	++	+	ce	14	—	—	—	8(11)	—	—	21	x	x^+
	290	79	M	1	—	1	++	+	a	4	—	—	—	8(11)	—	—	44	P	c
	(218)																		
6	291	39	F	1	—	2	0	+	b	0	—	—	—	3	—	—	1	6	a
	292	31	M	4	—	2	0	—	a	0	—	—	—	4	—	—	11	15	a
	(293)																		
	293	31	M	4	+	3	0	—	a	0	—	—	—	4	—	7 S	11	15	x^2
	(292)																		
	294	43	M	1	—	2	0	+	a	0	—	—	—	2	—	—	5	9	a
7	295	47	F	1	—	2	0	—	—	3	—	—	—	5	—	—	4	10(1)	a
	296	16	M	3	—	3	0	—	—	0	—	—	—	3	—	—	3	4	a
	297	16	M	2	—	1	0	—	—	1	—	—	—	2	—	—	1	3	x^1
	298	17	M	1	—	1	0	+	—	0	—	—	—	3	—	—	1	5	a
	299	18	M	2	—	2	0	—	—	0	—	—	—	4	—	—	1	8	a
	300	18	M	7	—	2	0	—	—	0	—	—	—	2	—	—	7	3	a
	301	18	M	2	—	3	0	—	—	0	—	—	—	2	—	—	4	3	a
	302	21	M	2	+	2	0	—	—	1	—	—	—	5	—	—	18	8	a
	303	22	M	4	—	3	0	—	—	0	—	—	—	7	—	—	7	12	a
	304	24	M	8	—	2	0	—	—	0	—	—	—	2	—	—	7	6	x^1
	305	25	M	8	—	2	0	—	—	0	—	—	—	3	—	—	1	4	a
	306	26	M	8	—	2	0	—	—	0	—	—	—	2	—	—	10	5	a
	307	26	M	8	—	3	0	—	—	0	—	—	—	5	—	—	2	6	a
	308	27	M	8	—	2	0	—	—	0	—	—	—	2	—	—	—	3	a
	309	29	M	8	—	2	0	+	—	1	—	—	—	2	—	—	2	3	a
	310	41	M	8	—	2	0	—	—	0	—	—	—	3	—	—	2	5	a
	311	43	M	1	—	2	0	—	—	0	—	—	—	3	—	8	3	6(1)	x^+

PROSPECTIVE SERIES

A	B	C	D	E	F	G	H	I	K	L	M	N	O	P	R	S	T	U	V
1	1	16	F	9	—	3	++	+	—	7^0	—	—	—	2	—	—	1	3	a
	2	42	F	9	—	3	++	+	—	7^0	—	—	—	3	—	—	5	6	b
	*3	44	F	11	—	3	++	+	—	7^0	—	—	—	4	—	—	1	8	a
	4	45	F	11	—	3	++	+	—	7^0	—	—	—	3	—	—	1	6	b
	5	46	F	9	—	3	++	+	—	7^0	—	—	—	2	—	—	2	4	a
	6	49	F	11	—	3	++	+	—	7^0	—	—	—	3	—	—	2	11	a
	7	49	F	11	—	3	++	+	—	7^0	—	—	—	4	—	—	20	7	a
	8	52	F	11	—	3	++	+	—	7^0	—	—	—	3	—	—	1	5	a
	9	53	F	11	—	3	++	+	—	7^0	—	—	—	2	—	—	6	5	a
	10	55	F	11	—	3	++	+	—	5^0	—	—	—	3	—	6S	2	6	a
	11	60	F	11	—	3	++	+	—	10^0	—	—	—	2	—	—	3	10	a
	12	70	F	11	—	3	++	+	—	$7^0, 10^0$	—	—	—	3	—	—	x	x	x[3]
	13	23	F	9	—	3	+	—	—	0	—	—	—	2	—	—	0	6	a
	14	29	F	11	—	3	+	—	—	0	—	—	—	3	—	—	0	5	a
	15	37	F	11	—	3	+	+	—	0	—	—	—	3	—	—	0	5	a
	16	43	F	11	—	3	+	+	—	0	—	—	—	2	—	—	0	4	a
	17	56	F	1	—	3	+	+	—	0	—	—	—	2	—	9	11	4	a
	18	56	F	11	—	3	++	+	—	3	—	—	—	5	—	—	3	11	a
	19	70	F	1	—	3	++	+	—	3	—	—	—	3	—	—	22	12	b
	(123)																		
	20	88	F	11	—	3	+	—	—	0	—	—	—	3	—	—	0	x	a
	21	22	M	11	—	3	++	+	—	7^0	—	—	—	4	—	—	2	5	a
	22	24	M	9	—	3	++	+	—	7^0	—	—	—	4	—	—	2	8	a
	23	34	M	11	—	3	++	+	—	7^6	—	—	—	4	—	—	4	x	a
	24	36	M	11	—	2	++	+	—	7^0	—	—	—	3	—	—	2	4	a
	*25	38	M	10	—	3	++	+	—	7^0	—	—	—	3	—	—	1	5	a
	26	39	M	6	—	3	++	+	—	7^0	—	—	—	2	—	7 S, 9	24	x	x[3]
	27	41	M	11	—	3	++	+	—	10^0	—	—	—	4	—	—	1	9	a
	*28	42	M	6	—	3	++	+	—	7^0	—	—	—	2	—	—	1	9	a
	29	42	M	11	—	3	++	+	—	7^0	—	—	—	3	—	—	1	x	a
	*30	43	M	7	—	3	++	+	—	7^0	—	—	—	2	—	—	1	5	b

1	31	43	M	11	—	3	++	+	—	7^0	—	—	—	3	—	—	2	5	a
	32	45	M	11	—	3	++	+	—	7^0	—	—	—	2	—	—	2	5	a
	33	46	M	11	—	3	++	+	—	7^0	—	—	—	2	—	—	1	5	a
	*34	51	M	11	—	2	++	+	—	7^0	—	—	—	2	—	—	1	7	a
	35	53	M	3	—	2	++	+	—	10^0	—	—	—	3	—	6S	5	6	a
	36	58	M	11	—	2	++	+	—	7^0	—	—	—	2	—	—	1	6	a
	*37	59	M	6	—	3	++	+	—	7^0	—	—	—	3	—	6S	1	8	a
	38	59	M	11	—	3	++	+	—	7^0	—	—	—	2	—	—	1	6	a
	39	60	M	10	—	3	++	+	—	10^0	—	—	—	3	—	—	2	7	a
	40	63	M	11	—	3	++	+	—	10^0	—	—	—	2	—	—	3	7	a
	41	16	M	2	—	1	++	—	—	3	—	—	—	3	—	—	3	5	a
	42	17	M	9	—	2	+	—	—	0	—	—	—	2	—	—	1	3	a
	43	18	M	9	—	3	+	+	—	0	—	—	—	2	—	—	0	4	a
	44	46	M	11	—	3	++	+	—	1	—	—	—	3	—	—	1	5	a
	45	46	M	11	—	3	++	+	—	3	—	—	—	4	—	—	1	8	a
	46	47	M	11	—	3	++	+	—	3	—	—	—	3	—	—	3	8	a
	47	54	M	3	—	3	++	+	—	3	—	—	—	3	—	—	4	9	a
2	48	27	F	11	—	2	++	+	a	5^0	—	—	—	2	—	—	2	5	a
	*49	74	F	11	—	3	++	+	a	7^0	—	—	—	2	—	6S	6	x	x^+
	50	52	M	10	—	3	++	+	b	7^0	—	—	—	3	—	9	3	5	a
	*51	21	M	3	—	1	+	+	b	1	—	—	—	7	—	—	6	10	a
	52	89	M	5	—	3	+	—	b	0	—	—	—	3	—	—	4	5	a
4	*53	19	F	4	—	2	++	+	—	5^0	—	—	—	4	—	1, 9	6	7	a
	54	41	F	4	+	d	++/++	+	—	$6^0, 10^0$	6^8	—	—	10	—	1, 9	7	23(5)	b
	55	62	F	1	—	2	++	+	—	5^0	—	—	—	3	—	—	3	6	a
	56	72	F	1	—	2	++	+	—	5^0	—	—	—	3	—	—	3	7	a
	57	77	F	1	—	2	++	+	—	5^0	6^7	—	—	8(10)	—	—	11	11	a
	*58	60	F	11	—	3	+	+	—	3	—	—	—	3	—	—	3	12	b
	59	73	F	1	—	1	++	—	—	1	—	—	—	3	—	9	14	8	a
	60	74	F	11	—	1	+	+	—	0	—	—	—	4	—	—	4	7	a
	61	82	F	11	—	3	+	+	—	0	—	—	—	3	—	—	x	x	a
	*62	16	M	7	—	2	++	+	—	5^0	—	—	—	3	—	—	2	5	a
	63	16	M	8	—	3	++	+	—	5^0	—	—	—	2	—	—	1	4	a

A	B	C	D	E	F	G	H	I	K	L	M	N	O	P	R	S	T	U	V
4	64	17	M	8	—	2	++	+	—	6^0	—	—	—	4	—	—	1	8	a
	65	18	M	7	—	3	++	+	—	6^0	—	—	—	5	—	—	1	8	a
	*66	20	M	2	—	2	++	+	—	5^0	—	—	—	5	—	—	2	13	a
	67	22	M	8	—	2	++	+	—	5^0	—	—	—	4	—	—	1	5	a
	68	22	M	8	—	3	++	+	—	5^0	—	—	—	2	—	—	1	5	a
	69	23	M	8	—	2	++	+	—	5^0	—	—	—	5	—	—	1	6	a
	*70	24	M	8	—	2	++	+	—	5^0	—	—	—	2	—	—	1	4	a
	71	24	M	4	+	2	++	+	—	7^0	—	—	—	2	—	—	2	6	a
	*72	25	M	1	—	3	++	+	—	5^0	—	—	—	3	—	—	1	6	a
	73	28	M	8	—	2	++	+	—	5^0	6^8	—	—	11	—	—	2	8	b
	74	29	M	8	—	2	++	+	—	5^0	—	—	—	3	—	—	2	6	a
	75	30	M	1	—	2	++	+	—	5^0	—	—	—	5	—	9	12	6	a
	76	41	M	11	—	2	++	+	—	5^5	—	—	—	3	—	—	3	6	a
	*77	50	M	7	—	2	++	+	—	5^0	—	—	—	3	—	—	1	7	a
	*78	51	M	7	—	2	++	+	—	5^0	—	—	—	7	—	—	2	12	a
	79	51	M	11	—	3	++	+	—	5^0	—	—	—	3	—	9	3	8	a
	*80	52	M	7	+	d	0/++	+	—	5^0	—	—	—	3	—	—	2	7	a
	81	53	M	2	—	2	++	+	—	6^0	—	—	—	3	—	—	2	14	a
	*82	55	M	4	+	d	++/++	+	—	6^0, 10^0	—	—	—	5	—	—	2	10	a
	*83	57	M	1	+	d	0/++	+	—	7^0	—	—	—	1	—	—	2	10	a
	*84	57	M	1	—	2	++	+	—	5^0	—	—	—	5	—	8	2	11	a
	85	60	M	1	+	2	++	+	—	5^0	—	—	—	4	—	9	9	8	a
	86	61	M	1	+	2	++	+	—	7^0	—	—	—	2	—	—	8	13	b
	87	63	M	2	—	2	++	+	—	5^0	—	—	—	4	—	—	2	7	a
	88	79	M	1	—	3	++	+	—	7^0	—	—	—	8	—	—	1	10	a
	*89	16	M	2	—	3	++	+	—	1	—	—	—	3	—	—	1	5	a
	*90	17	M	2	—	1	+	—	—	1	—	—	—	3	—	—	0	7	a
	91	17	M	2	—	3	++	+	—	1	—	—	—	3	—	—	2	5	a
	92	17	M	2	—	3	++	+	—	3	—	—	—	3	—	—	2	6	a
	93	17	M	3	+	3	+	—	—	0	—	—	—	2	—	—	0	3	a
	94	19	M	4	+	2	++	+	—	3	—	—	—	4	—	5	14	8	a
	95	21	M	2	+	d	++/++	+	—	3	6^6	—	—	10	—	—	5	20	b

4	*96	21	M	8	—	3	+	—	—	1	—	—	—	5	—	—	1	6	a
	97	25	M	2	—	3	+	—	—	0	—	—	—	4	—	—	0	7	a
	98	28	M	8	—	2	+	+	—	1	—	—	—	2	—	—	2	5	a
	*99	29	M	2	—	2	+	—	—	1	—	—	—	4	—	5S	3	10	a
	100	30	M	8	—	2	+	—	—	0	—	—	—	5	—	—	2	10	a
	*101	31	M	1	—	2	++	+	—	3	—	—	—	3	—	—	3	6	a
	*102	32	M	7	—	3	++	+	—	3	—	—	—	4	—	—	2	8	a
	103	34	M	8	—	2	+	—	—	0	—	—	—	2	—	—	0	5	a
	*104	34	M	1	+	d	0/++	+	—	3	—	—	—	4	—	—	1	7	a
	105	37	M	8	—	2	+	+	—	1	—	—	—	6	—	—	1	11	a
	106	39	M	7	—	2	+	—	—	0	—	—	—	3	—	—	0	6	a
	*107	54	M	10	+	3	++	+	—	3	—	—	—	4	—	—	4	9	b
	108	61	M	1	—	3	++	+	—	1	—	—	—	3	—	—	1	9	b
	109	63	M	1	—	3	+	—	—	0	—	—	—	2	—	—	0	5	a
	110	64	M	10	+	1	+	+	—	1	—	—	—	3	—	—	16	8	a
	111	69	M	1	+	1	+	+	—	0	—	—	—	4	—	9	2	12	a
	112	72	M	1	+	2	++	+	—	3	—	—	—	11	—	—	52	16	b
	113	73	M	1	+	2	++	+	—	3	—	—	—	4	—	2S	38	16	a
	114	77	M	1	—	3	++	+	—	3	1^4	—	—	7	—	—	6	11	a
5	115	16	F	2	—	2	++	+	b	5^0	—	—	—	3	—	—	2	4	a
	116	35	F	1	+	d	++/++	+	def	$6^0, 10^0$	—	2	—	4	—	—	6	10	a
	117	64	F	1	+	2	++	+	de	$6^0, 10^0$	6^7	—	—	10	—	—	10	15	b
	118	65	F	1	+	2	++	+	def	$10^0, 12^0$	1^6	—	—	9	—	5	34	13	b
	119	80	F	1	+	3	++	+	de	6^0	—	6	—	4	—	—	5	6	a
	120	37	F	4	—	3	+	+	a	3	—	—	—	2	—	5, 6 S, 7, 9	x	x	a
	121	56	F	11	—	3	+	—	ce	0	—	—	—	4	—	—	2	8	a
	*122	62	F	1	—	3	++	+	ce	3	—	—	—	4	—	—	2	9	a
	123 (19)	70	F	1	—	3	++	+	be	3	—	—	—	4	—	—	22	12	b
	124	16	M	2	—	2	++	+	b	5^0	—	—	—	3	—	—	1	6	a
	125	22	M	5	—	2	++	+	ce	5^0	—	—	4 ½	3	(N)	—	4	6	a
	126	24	M	2	—	1	++	+	be	5^0	—	—	—	3	—	6S	2	10	a
	*127	26	M	2	—	2	++	+	a	6^0	6^{22}	—	—	8(25)	—	—	3	15(6)	a
	128 (130)	30	M	7	—	2	++	+	c	5^0	—	—	—	3	—	9	x	x	a

A	B	C	D	E	F	G	H	I	K	L	M	N	O	P	R	S	T	U	V
5	129	30	M	7	—	2	++	+	c	5^0	—	6	—	4	—	—	2	9	a
	130	30	M	7	+	2	++	+	de	6^0, 10^0	4^3	5	$4^{1,3}$, 3^2	9	N	3S	x	x	x^2
	(128)																		
	131	31	M	7	—	2	++	+	bef	5^0	—	—	—	5	—	3 S, 5 S, 6	11	16	x^2
	132	34	M	1	+	d	++/++	+	a	6^0, 10^0	—	—	—	5	—	5 S, 6 S, 8	10	x	x^2
	*133	35	M	4	—	2	++	+	c	6^0	—	2	—	3	—	—	3	5	a
	134	35	M	7	—	2	++	+	a	5^0	—	—	—	3	—	—	2	6	a
	*135	37	M	1	—	2	++	+	ce	5^0	—	—	4^1	6	N	—	7	14	a
	*136	41	M	6	+	3	++	+	a	5^0	—	—	—	4	—	—	2	8	a
	137	51	M	1	—	3	++	+	b	7^{10}	1^{11}	—	—	14	—	—	3	17	a
	138	55	M	6	+	2	++	+	a	5^0	6^6	—	—	8	—	—	6	16	a
	139	56	M	1	+	2	++	+	de	6^0	6^4	3	4^1	12	(N)	—	6	22	b
	140	58	M	1	+	3	++	+	de	7^0, 12^0	1^9	7	—	13	—	9	14	18	b
	141	64	M	7	—	2	++	+	ce	5^0	—	—	4 ½	7	(N)	6S	4	16	a
	*142	65	M	3	—	1	++	+	a	5^0	—	—	—	4	—	—	2	9	a
	143	69	M	2	+	2	++	+	ce	6^0	—	—	4^1	7	(N)	—	6	12	a
	*144	71	M	1	+	d	++/+	+	be	6^0, 10^0	—	—	—	7	—	9	6	12	b
	145	72	M	7	—	3	++	+	de	6^0	1^{14}	5	—	11(18)	—	—	4	20	a
	*146	75	M	2	+	d	++/++	+	c	6^0, 10^0	6^7	4	—	12	—	—	21	17	b
	*147	77	M	7	—	2	++	+	de	6^0	—	5	—	4	—	—	11	12	a
	(148)																		
	*148	77	M	7	—	2	++	+	de	6^0	—	5	—	8	—	—	11	12	a
	(147)																		
	*149	78	M	7	—	2	++	+	b	5^0	—	—	—	3	—	—	1	8	a
	150	16	M	2	—	3	++	+	ce	1	—	—	—	3	—	—	1	4	a
	151	16	M	2	+	2	++	+	b	3	—	—	—	3	—	—	2	5	a
	152	19	M	2	—	3	++	+	c	3	6^5	—	—	9	—	—	5	14	b
	*153	20	M	2	—	3	++	+	b	3	—	—	4^1	4	(N)	1	6	14	a
	154	20	M	2	+	3	++	+	ce	3	6^5	—	—	12	—	3S	34	x	x^2
	*155	21	M	2	+	1	++	+	def	14	7^8, 1^7, 8^{33}	—	3^2	27	N, O	9S	30	38 P	c
	156	21	M	4	—	2	+	—	b	0	—	—	—	3	—	3	9	8	a
	*157	25	M	7	—	3	++	+	b	1	—	—	—	4	—	—	1	7	a

	*158	29	M	6	—	2	++	+	a	3	—	—	—	5	—	7, 9S	x	x	x[a]
	*159	41	M	1	+	3	++	+	ce	3	1[7]	—	—	12	—	2	10	16	b
	160	55	M	2	+	3	++	+	b	3	—	—	—	5	—	8	3	13	a
	*161	59	M	7	—	3	++	+	b	3	—	—	—	3	—	—	3	6	a
7	*162	16	M	2	—	2	0	+	—	0	—	—	—	4	—	—	1	7	a
	163	16	M	2	—	3	0	+	—	0	—	—	—	2	—	9	2	3	a
	164	16	M	7	—	3	0	—	—	0	—	—	—	2	—	—	0	2	a
	165	17	M	3	—	2	0	—	—	0	—	—	—	1	—	—	1	3	a
	166	17	M	3	+	2	0	—	—	0	—	—	—	2	—	—	4	3	a
	*167	18	M	8	—	2	0	+	—	0	—	—	—	3	—	—	1	7	a
	168	18	M	8	—	3	0	—	—	0	—	—	—	2	—	—	0	3	a
	169	37	M	8	—	2	0	—	—	0	—	—	—	2	—	—	0	4	a
	170	37	M	7	+	1	0	—	—	0	—	—	—	3	—	—	0	7	a
	171	55	M	1	—	1	0	—	—	0	—	—	—	3	—	—	0	4	a
	172	66	M	3	—	1	0	—	—	0	—	—	—	3	—	—	1	4	a
8	173	21	F	11	—	2	0	+	—	0	—	—	—	2	—	—	1	3	a
	174	53	F	11	—	3	0	+	—	0	—	—	—	2	—	—	8	6	a
	175	59	F	11	—	3	0	—	—	0	—	—	—	3	—	—	0	4	a
	176	74	F	1	—	2	0	—	—	0	—	—	—	2	—	—	3	4	a
	177	17	M	8	—	2	0	—	—	0	—	—	—	2	—	—	0	3	a
	178	17	M	8	—	2	0	—	—	0	—	—	—	2	—	—	2	3	a
	179	17	M	11	—	3	0	—	—	0	—	—	—	2	—	—	0	3	a
	180	27	M	11	—	3	0	—	—	0	—	—	—	3	—	—	0	6	a
	181	44	M	3	—	3	0	—	—	0	—	—	—	2	—	—	0	3	a

B. NON-PROBANDS WHO WERE RESIDENTS OF MALMÖ

CONTROL SERIES

A	B	C	D	E	F	G	H	I	K	L	M	N	O	P	R	S	T	U	V
1	1a	30	F	6	—	3	++	+	—	10	—	—	—	?	—	3 S, 8, 9	?	?	?
	2c	76	F	11	—	3	++	+	—	8	—	—	—	2	—	—	14	4	?
	3c	57	F	11	—	1	+	+	—	0	—	—	—	3	—	—	17	?	?
	4c	74	F	11	—	3	++	+	—	2	—	—	—	3	—	—	8	?	?
	5c	78	F	11	—	3	++	+	—	1	—	—	—	4	—	—	1	?	?
	6a	28	M	4	—	2	++	+	—	10	—	—	—	4	—	3 S, 9	?	?	?
	7a	29	M	11	—	3	++	+	—	10	—	—	—	?	?	?	?	?	?
	8a	30	M	11	—	3	++	+	—	7	—	—	—	2	—	—	1	4	?
	9a	30	M	9	—	2	++	—	—	7	—	—	—	3	—	—	2	6	?
	10a	42	M	2	—	3	++	+	—	10	—	—	—	3	—	4 S, 5 S	2	10	?
	11g	46	M	11	—	3	++	+	—	7	—	—	—	—	—	—	2	—	—
	12a	46	M	?	—	3	++	?	—	10	—	—	—	?	?	?	?	?	?
	13c	75	M	11	—	2	++	+	—	7	—	—	—	6	—	—	—	3	c (ps)
	14g	77	M	1	—	3	++	+	—	7	—	—	—	—	—	—	—	6	—
	15a	21	M	10	—	3	+	?	—	1	—	—	—	3	—	—	1	10	?
	16a	27	M	11	—	3	+	+	—	1	—	—	—	3	—	—	1	6	?
	17d	31	M	6	—	1	+	+	—	0	—	—	—	?	—	3 S, 8, 9	?	?	?
	18e	33	M	11	—	2	+	—	—	1	—	—	—	3	—	—	2	9	?
	19c	40	M	11	—	3	+	?	—	2	—	—	—	2	—	—	6	?	?
2	20c	45	F	11	—	3	++	+	b	10	—	—	—	3	—	—	20	7	a
	21a	48	F	4	—	3	++	+	c	2	—	—	—	5	—	8	8	?	?
	22a	40	M	3	—	2	++	+	?	10	—	—	—	4	?	—	?	?	?
4	23g (48)	75	F	1	—	2	++	+	—	8	—	—	—	—	—	1, 8, 9	< 1	—	—
	24a	26	F	4	+	2	+	—	—	0	—	—	—	3	—	1, 9	14	9	?
	25e	36	F	11	—	2	+	—	—	1	—	—	—	2	—	—	6	4	a
	26a	45	F	4	+	2	+	+	—	1	—	—	—	7	—	—	2	10	a
	27c	51	F	11	—	3	+	+	—	1	—	—	—	2	—	—	22	11	?
	28a	17	M	4	—	2	++	+	—	6	—	—	—	2	—	3, 8, 9	10	?	?
	29a	25	M	8	—	2	++	+	—	8	—	—	—	4	—	—	1	6	a

4	30a	40	M	?	+	3	++	?	—	6, 10	7	—	—	10	N?O	—	12	?	?
	31a	51	M	10	+	d	0/++	+	—	9	—	—	—	5	—	—	13	?	?
	32a	16	M	1	—	2	++	+	—	1	—	—	—	4	—	—	3	7	?
	33a	19	M	8	—	2	+	+	—	1	—	—	—	3	—	—	3	5	a
	34a	19	M	3	—	3	+	+	—	0	—	—	—	3	—	—	6	5	a
	35e	21	M	11	—	3	++	+	—	3	—	—	—	6	—	—	3	9	?
	36a	24	M	8	—	2	+	+	—	1	—	—	—	4	—	—	4	9	?
	37a	28	M	7	+	1	+	+	—	1	—	—	—	3	—	—	3	5	?
	38g	34	M	4	—	1	+	?	—	0	—	—	—	—	—	8, 9	< 1	—	—
	39a	34	M	4	—	3	+	?	—	1	—	—	—	4	—	—	1	6	?
	40a	36	M	6	—	3	++	+	—	1	—	—	—	4?	—	7S	11	?	?
	41a	40	M	2	+	1	+	+	—	1	—	—	—	3	—	—	14	5	a
	42a	41	M	2	—	3	++	+	—	2	—	—	—	7	—	—	3	?	?
	43c	42	M	11	+	1	+	+	—	0	—	—	—	3	—	—	3	7	?
	44a	60	M	10	+	3	+	+	—	0	—	—	—	3	—	—	2	9	?
	45a	61	M	1	+	3	++	+	—	2	—	—	—	4	—	8, 9	?	48	?
	46a	62	M	7	—	3	++	+	—	1	—	—	—	9	—	9	44	?	?
	47d	69	M	11	—	1	+	?	—	?	—	—	—	?	?	3 S	?	?	?
5	48g (23)	75	F	1	+	2	++	+	b	—	—	—	—	—	—	8, 9	< 1	—	—
	49a	21	M	2	—	2	++	+	?	8	—	—	—	3	—	—	14	9	?
	50a	22	M	2	—	3	++	+	a	8	—	—	—	9	—	6S	4	16	a
	51e	36	M	2	—	3	++	+	a	7	—	—	—	3	—	—	6	6	?
	52a	44	M	2	—	2	++	+	?	6	—	—	—	3	—	—	?	11	?
	53a	46	M	9	+	3	++	+	?	10	—	—	—	5	—	—	10	15	?
	54g	67	M	2	—	3	++	+	b	8	—	—	—	—	—	1	< 1	—	—
	55a	18	M	3	+	2	+	+	?	1	—	—	—	3	—	8	?	5	?
	56a	19	M	1	+	2	++	+	?	1	7	—	?	?	NO	8	?	?	?
	57a	21	M	1	+	3	++	+	b	2	—	—	—	5	—	—	14	?	?
	58a	24	M	3	+	3	++	+	?	2	1,8	—	4	11	NO	—	38	?	c
	59a	31	M	4	+	2	++	+	?	2	—	—	—	9	—	—	12	11	?
	60g	45	M	1	—	3	++	+	b	3	—	—	—	—	—	—	3	—	—
	61g	69	M	1	+	3	++	+	?	1	—	—	—	—	—	1, 9	—	—	—
	62g	83	M	1	+	3	++	+	b	3	—	—	—	—	—	8, 9	< 1	—	—
8	63c	32	M	11	—	3	0	—	—	0	—	—	—	1	—	—	?	7	?

Letters under B referred to table 1

PROSPECTIVE SERIES

A	B	C	D	E	F	G	H	I	K	L	M	N	O	P	R	S	T	U	V
1	1a	46	F	11	—	2	+	+	—	0	—	—	—	3	—	—	1	?	?
	2a	30	M	11	—	3	++	+	—	7	—	—	—	2	—	—	?	5	a
	3a	50	M	1	—	3	++	+	—	7[17]	—	—	—	3	—	4 S, 8	?	?	?
	4a	42	M	11	—	3	+	—	—	1	—	—	—	4	—	—	?	?	?
	5c	44	M	11	—	1	0	—	—	0	—	—	—	2	—	—	—	4	?
2	6g	75	F	6	—	3	++	+	—	3	—	—	—	—	—	—	3	—	—
4	7f	72	F	10	—	2	++	+	—	5	—	—	—	3	—	—	2	8	a
	8g	54	M	2	—	2	++	+	—	5	—	—	—	—	—	—	4	—	—
	9a	17	M	1	—	2	++	+	—	2	—	—	—	5	—	8	?	9	a
	10a	27	M	7	—	2	+	+	—	1	—	—	—	3	—	—	1	4	?
	11a	40	M	4	—	1	+	+	—	0	—	—	—	5(8)	—	6 S, 4	?	14	?
	12c	57	M	1	—	1	+	+	—	1	—	—	—	6	—	—	11	8	?
5	13a	29	F	4	—	2	+	+	b	1	—	—	4	5	N	—	3	12	a
	14a	17	M	4	+	2	++	+	d	3	—	—	8, 24	5	N	—	?	?	?
	15a	21	M	2	+	1	+	+	a	2	—	—	—	3	—	—	?	?	?
	16a	21	M	7	+	2	+	—	a	0	—	—	—	3	—	—	—	?	?

Letters under B referred to table 1

Key to Data

A *Anatomic Classification of Fractures*

1. displaced, longitudinal, closed fractures
2. displaced, longitudinal, open fractures
3. undisplaced, longitudinal, open fractures
4. displaced, transverse, closed fractures
5. displaced, transverse, open fractures
6. undisplaced, transverse, open fractures
7. undisplaced, transverse, closed fractures
8. undisplaced, longitudinal, closed fractures

B *Case*

Figures in brackets represent patients with bilateral fractures
• represent non residents of Malmö referred from other hospital

C *Age (years)*

D *Sex*

F = female M = male

E *Cause of Injury*

1. pedestrian or bicycle rider injured in collision with an automobile or a motorcycle
2. motorcycle rider injured in collision with an automobile or a motorcycle
3. motorcycle rider injured in single motorcycle accident
4. automobile driver or passengers injured in traffic accident
5. bicycle or motorcycle rider injured in collision with a train or tram in motion
6. fall from a height more than 3 meters
7. blow from a very heavy object, or a crush injury
8. soccer football injury
9. skating injury
10. single bicycle accident
11. fall at the ground level or from a low height

F *Comminution of Fracture*

\+ comminuted fracture
— not comminuted fracture

G *Location of Fracture*

1. proximal third of tibia
2. middle third of tibia
3. distal third of tibia
d. double fracture

H *Displacement*

0 no displacement
\+ moderate displacement
\+ + marked displacement
In double fractures the left sign indicates the proximal fracture

I *Fracture of Fibula*

\+ fracture of fibula
— no fracture of fibula

K *The Size of Wound, Exposure of Fracture and Contamination with Foreign Material*

a. 1 cm or less
b. 2—5 cm
c. 6—10 cm
d. more than 10 cm of skin defect
e. exposure of fracture
f. contamination with foreign material

L *Primary Treatment of Fracture (small figures represent days after the accident)*

0. no reduction and plaster fixation
1. closed reduction and plaster fixation
2. closed reduction and traction followed with plaster fixation
3. closed reduction and transfixation
4. closed reduction and compression treatment
5. closed reduction and internal fixation with a Rush pin
6. open reduction and internal fixation with a Rush pin or a Küntscher nail
7. open reduction and internal fixation with screws
8. open reduction and internal fixation with plates
9. open reduction and internal fixation with bone grafts
10. open reduction and internal fixation with encircling wires
11. open reduction and compression treatment
12. open reduction and bone shortening
13. open reduction and transfixation
14. open reduction without internal fixation

M *Secondary Treatment of Fracture (small figures represent months after the accident)*

1. bone graft
2. osteotomy of fibula
3. compression transfixation
4. compression transfixation and shortening of the bone
5. internal fixation with a Küntscher nail or a Rush pin
6. internal fixation with an intramedullary nail and bone grafts (Palmer, 1954)
7. sequestrectomy and/or saucerization
8. osteotomy of tibia
9. achilles tendon lengthening and posterior capsulotomy
10. amputation

N *Initial Treatment of Wound* O *Secondary Treatment of Wound (small figures represent months after the accident)*

1. relaxing incision
2. bipedicle skin flap and free split-thickness skin graft
3. unipedicle skin flap and free split-thickness skin graft
4. split-thickness skin graft
5. muscle graft and free split-thickness skin graft
6. muscle graft and skin closure
7. muscle graft and bipedicle skin flap and split-thickness skin graft
8. crossleg skin flap

P *External Fixation (months) (figures in brackets represent clinical union)*

R *Complications (S secondary complications)*

(N) necrosis of the skin (superficial)
N necrosis of the skin (deep)
(O) slight osteomyelitis
O severe osteomyelitis

S *Other Fractures or Injuries (S other fractures 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 patella
5. fracture of the tibial plateau
6. fracture of the ankle
7. fracture of the foot
8. injury of the head
9. other severe injuries

T *Hospitalization (weeks)*

x not available for evaluation

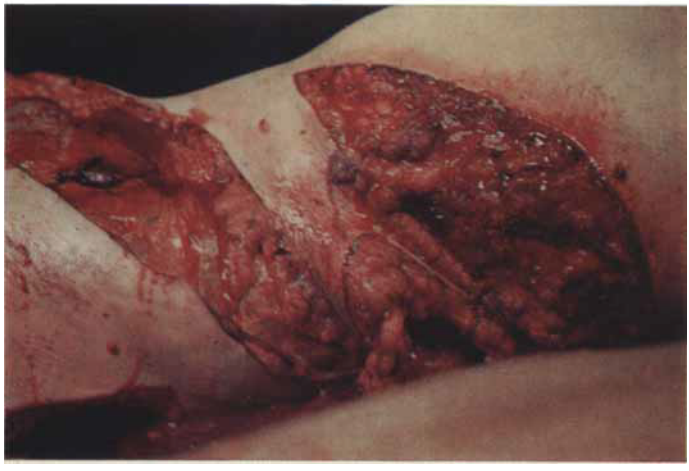
U *Disability (months)*

First figure: total disability
Figure in brackets: 50 % disability
x Not available for evaluation
P Pension

V *Final status*

a. good
b. fair
c. poor: amp. = amputation, o = chronic osteomyelitis with drainage, ps = pseudarthrosis
x not available for evaluation
x^1 untraceable
x+ dead
x^2 other fractures to the same limb
x^3 diabetic gangrene

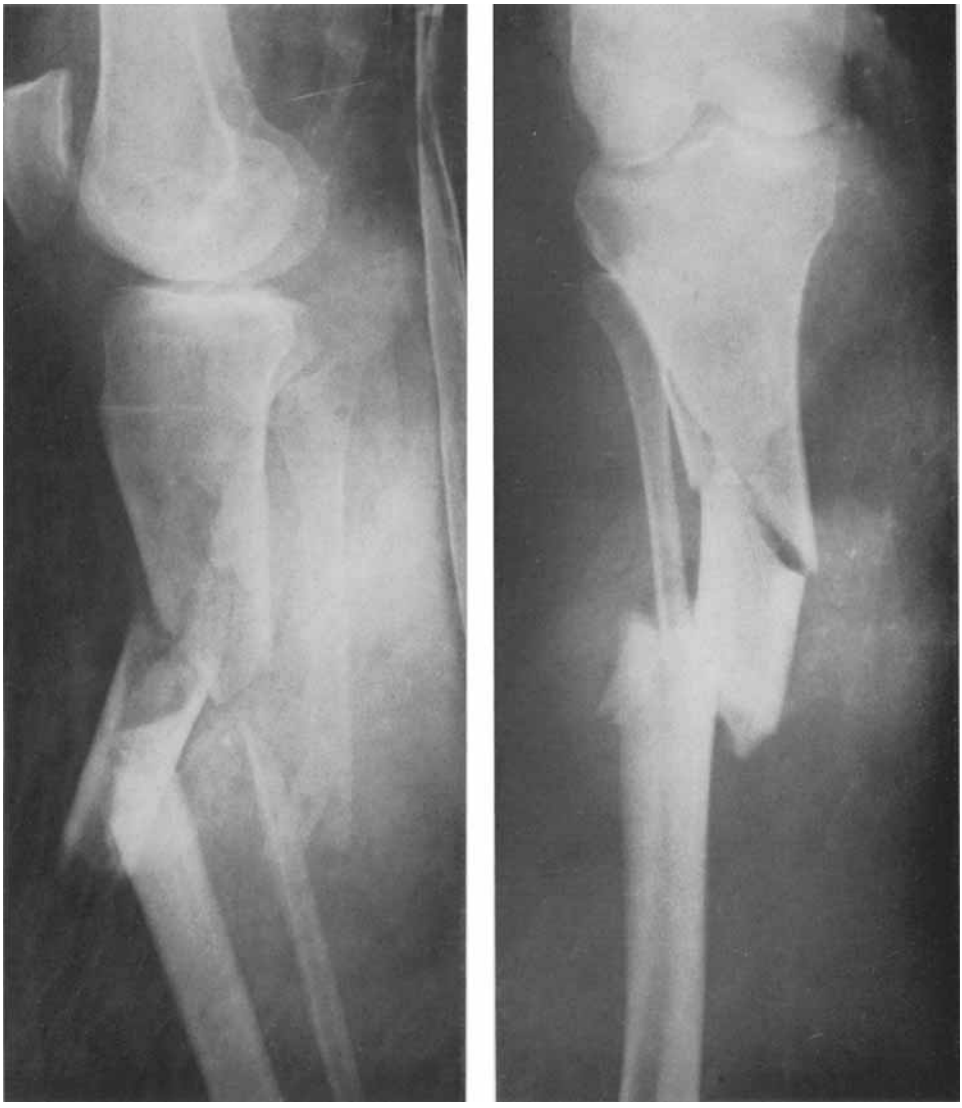
X. Reproductions of Colour Photographs and Radiographs



Photographs on admission immediately after accident.

CASE 116—PROSPECTIVE SERIES

A 35 year old woman was run over by a car. One of the wheels went across her right lower leg. There was a large laceration involving the medial and posterior part of the calf, and the popliteal fossa. Immediate operation with internal fixation and skin transplantation was performed.



X-rays on admission showed a markedly displaced double fracture.

3 weeks after the accident.

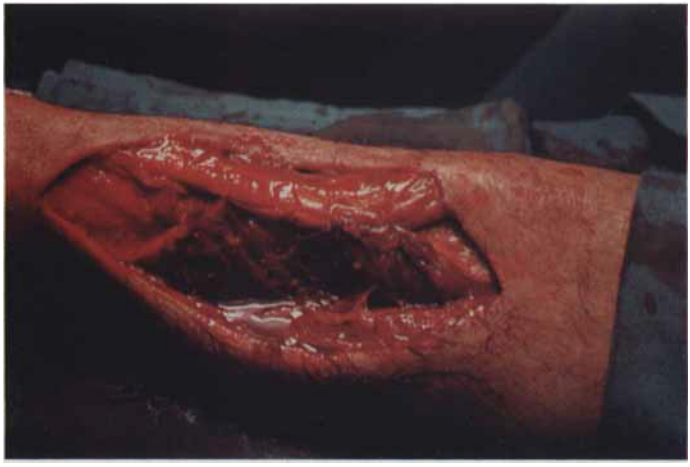
10 months after the accident.

Following excision of devitalized tissue there was a large defect. It was found possible to mobilize the skin from the lateral side of the leg over the front of the tibia so that the fracture region was covered with full thickness skin. The defect medially and posteriorly was covered with split thickness grafts.

5 months after the accident.

Internal fixation was done with a Rushpin and encircling wire. Immobilization in plaster was continued for 4 months; she returned to work after 10 months. The final status was good with a full range of motion of knee and ankle joints.

There was a large wound with wide exposure of a comminuted fracture.



After internal fixation, a muscle graft was sewn over the entire fracture region.

CASE 140—PROSPECTIVE SERIES

A 58 year old man run over by a car. One of the wheels crossed his left leg. Patient was admitted and operated immediately after the accident.

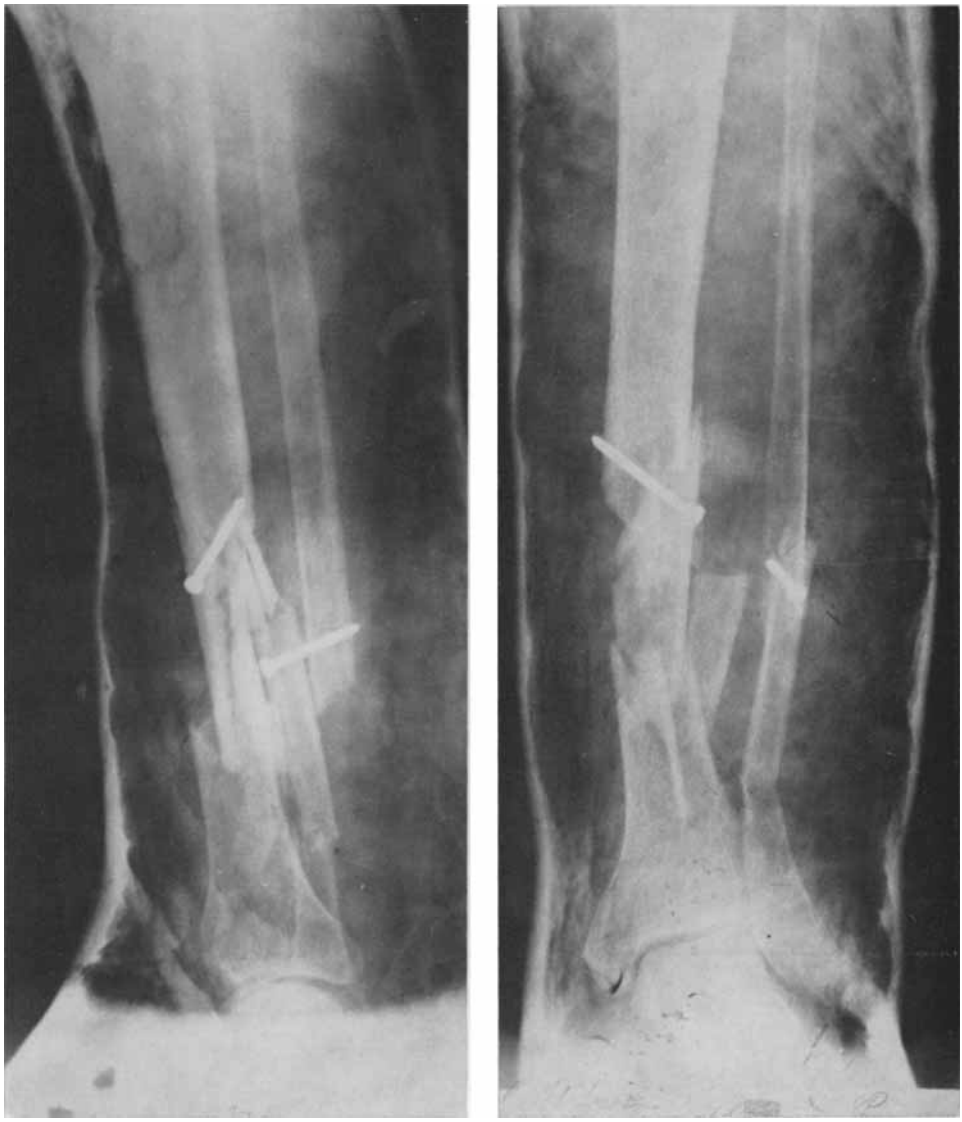
Comminuted fracture with partial loss of bone along 12 cm of the shaft of the tibia.

The wound has been sutured.

The defect created laterally has been covered with a free graft.

After a relaxing incision had been made laterally, and the flap had been undermined, the wound could be closed without tension. The defect created by the relaxing incision was covered with split thickness graft.

Photographs 10 days after the accident when the wounds were rebandaged for the first time.

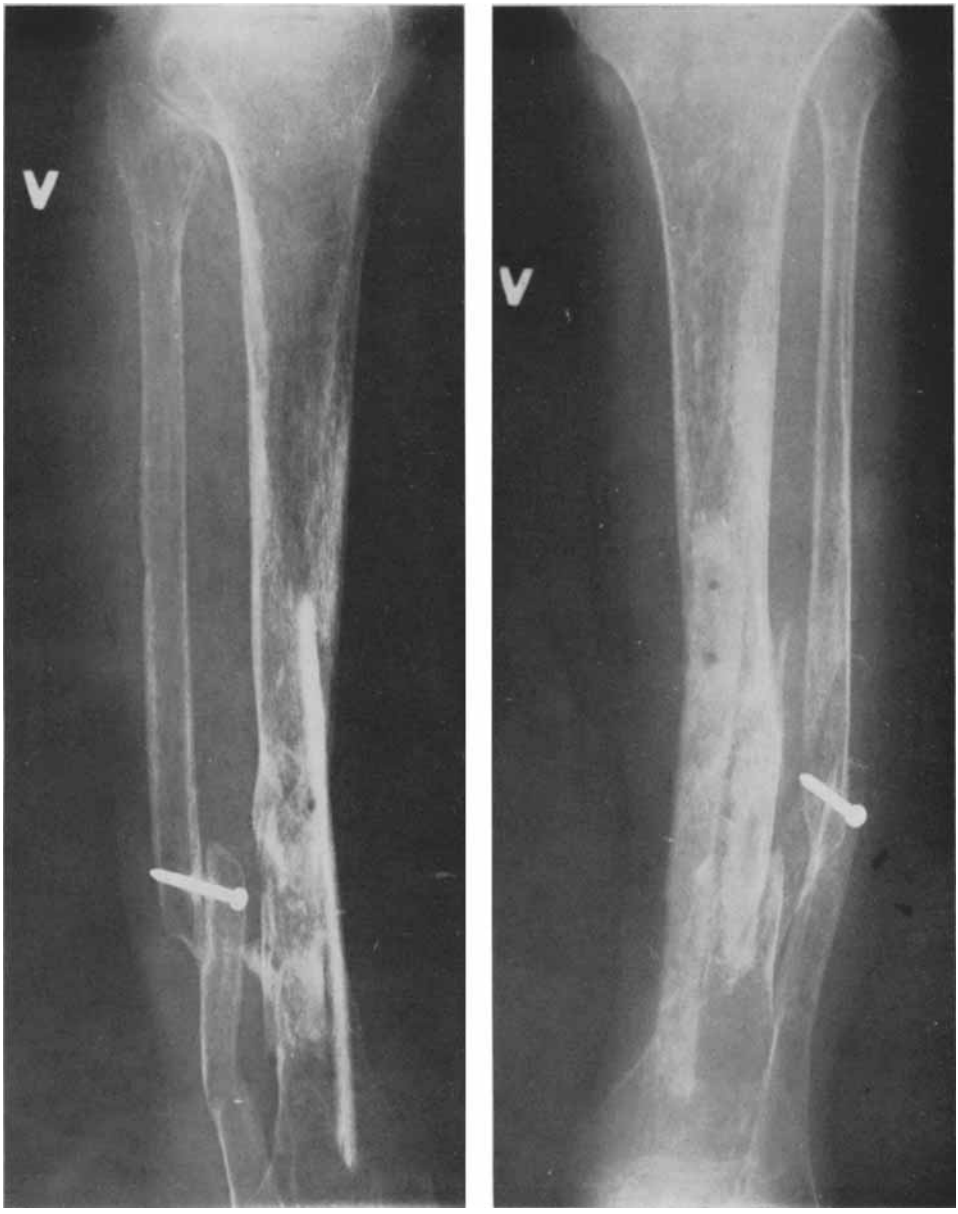


X-rays immediately after operation

Shortening was minimized by fixation of the largest of the intermediary fragments with a screw. A second screw was placed in the fibula in order to stabilize the fracture.

The wound 15 months after the accident.

The grafted relaxing incision 15 months after the accident.



X-rays 13 months after the accident.

9 months after the accident a bone graft was placed across the fracture.

The fracture was immobilized in plaster for 13 months. The patient resumed work after 18 months. The final status was fair with full range of motion of knee and ankle joints, but with a shortening of 1 ½ cm.