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TIBIAL SHAFT FRACTURES CAUSED BY INDIRECT VIOLENCE

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A series of 182 fractures of the adult tibial shaft caused by indirect violence, i.e. torsion, axial compression or bending without direct impact, and located at the junction of the middle and distal thirds of the tibia is reported. Fall at ground level was the mode of injury in 59 per cent. The initial lateral displacement was marked or severe in 38 per cent. The treatment was conservative in 114 patients. Internal fixation was undertaken only if acceptable position of the fracture could not be attained and maintained by conservative means. Screw fixation was mainly used for longitudinal fractures, plate osteosynthesis for fractures with a butterfly fragment, and intramedullary nailing for short oblique fractures. Healing time, anatomical restoration and functional recovery were assessed.

The following factors were associated with prolonged healing time: marked or severe initial lateral displacement ($P < 0.01$), butterfly fragment ($P < 0.02$), repeated closed reduction ($P < 0.02$) and high-energy trauma ($P < 0.05$). Delayed union occurred in 13.7 per cent. The overall infection rate was 5.5 per cent, infection being involved in 36 per cent of the cases with delayed union. Intramedullary nailing, the infra-isthmal location of the fracture in addition often necessitating a supplementary plaster cast, showed the lowest complication rate. With conservative treatment marked or severe initial lateral displacement predisposed ($P < 0.01$) to angular deformity and shortening. Refractures were seen in 7 per cent after conservative treatment.

Key words: fracture fixation; pseudarthrosis; tibial shaft fracture

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Tibial shaft fractures caused by indirect low-energy violence have traditionally enjoyed a benign reputation (Bauer et al. 1962, Edwards 1965). Indeed the skin damage of these injuries is insignificant but the degree of initial displacement and instability of these fractures vary from minor to severe. Operative management is justified if acceptable position cannot be guaranteed by conservative treatment (Slätis & Rokkanen 1967, Nicoll 1974). The weakest region of the tibia and thus the site of fracture, when caused by indirect violence, is the junction of the middle and distal thirds (Martens et al. 1981). Unfortunately no ideal operative method for fractures distal to the isthmus of the tibial intramedullary cavity seems to exist. The operative methods can be divided into adaptive and rigid. An adaptive fixation like Goetze's cerclage wiring (Böhler 1974) and interfragmentary compression screwing requires supplementary immobilization with plaster cast. Rigid internal fixation can be achieved by AO plate osteosynthesis (Müller et al. 1977) and a nearly rigid fixation by the Kaessmann intramedullary compression rod (Hutter et al. 1977). Conventional intramedullary nailing (Küntscher 1962) seldom is rigid in infra-isthmal tibial shaft fractures but can, as well as flexible medullary wires (Hasenhuttl 1981), be practised as an adaptive method.

The present retrospective clinical series con-

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centrates solely on tibial shaft fractures caused by indirect violence in adults. The aims of the study were to characterize these fractures, to consider the indications for internal fixation and to compare the results of alternative operative methods.

PATIENTS AND METHODS

During 1974–78 a total of 611 tibial shaft fractures in patients over 15 years of age were treated at the Department of Orthopaedics and Traumatology, Helsinki University Central Hospital. The studied series consists of 182 consecutive fractures at the junction of the middle and distal thirds of the tibia caused by indirect, namely torsional, bending without direct impact or axial compressive violence (Alms 1961). The trauma was considered indirect, besides the evidence of the patient's history and absence of skin contusion, on the following morphological grounds: an angle of more than 30 degrees between the fracture plane and a horizontal line perpendicular to the tibial shaft cortex and no serrated spiking of the bone ends. Fractures with a solitary butterfly fragment and fulfilling the criteria above were included.

The mean age of the patients was 36 years, 33 years for men and 41 for women. The male:female ratio was 2.4:1. The violence causing the fracture was classified as moderate or severe according to Edwards (1965): moderate violence was considered to result from falls at ground level (107 fractures) or from heights less than 2 m (10 fractures) and from sports injuries (25 fractures); severe violence from accidents in which a motor vehicle was involved (31 fractures) and from falls from a height of more than 3 m (nine fractures) (Table 1). The fracture was regarded as longitudinal if its length exceeded the double diaphyseal diameter. The initial lateral displacement was graded as slight if the contact between the fragments was at least one half of the diaphyseal diameter in both anteroposterior and lateral radiograms. The displacement was moderate if the contact was less in either view and severe if less in both views or if there was no contact between the bone ends in either view. The fracture was closed in 84 per cent. Puncture wounds occurred in 21 patients and small lacerations in eight patients. The fibula was intact in 14 per cent.

The management was conservative whenever acceptable position of the fracture was attained by closed reduction and a long-leg plaster cast. The fracture position was accepted if lateral displacement both in anteroposterior and lateral views was less than one half of the diaphyseal diameter, angulation in both views was under 5 degrees and shortening less than 1 cm. When the fracture was stable a few weeks before anticipated union the long cast was replaced by a patellar-tendon-bearing cast and full weight-bearing was allowed.

In 62 patients the initial fracture position was acceptable as such and no actual closed reduction under anaesthesia was needed. In 33 patients marked or severe initial lateral displacement, shortening and instability of the fracture were considered indications for emergency internal fixation. In the other 87 patients a total of 128 closed reductions and 19 axial wedgings were performed. A delayed internal fixation was undertaken in 35 of these patients on the average 13 days after the accident because of recurrent malposition after one or several attempts to closed reduction. The distribution of the 68 internal fixations is shown in Table 2. The fixations with screws and plates were performed according to the AO principles (Müller et al. 1977); 14 intramedullary nailings were done with a Küntscher-nail after closed reaming of the marrow cavity, one with the Kaessmann compression rod (Fig.

Table 1. Type of fracture and nature of violence

Type of fracture	Nature of violence		Significance	Total
	Moderate (low energy trauma)	Severe (high energy trauma)		
Fracture line configuration				
Simple longitudinal	64 (90)	7 (10)		71
Simple short oblique	48 (77)	14 (23)		62
Fractures with a butterfly fragment	30 (61)	19 (39)	$P<0.01$	49
Initial lateral displacement				
Slight	89 (79)	23 (21)		112
Marked	43 (80)	11 (20)		54
Severe	10 (63)	6 (37)	N.S.	16
Total	142 (78)	40 (22)		182

( ) per cent.

Table 2. Type of fracture and method of treatment

Type of fracture	Method of treatment				Total
	Conservative	Screw fixation	Plate fixation	Intramedullary nailing	
Fracture line					
Simple longitudinal	39 (55)	24	7	1	71
Simple short oblique	45 (73)	3	6	8	62
Fractures with a butterfly fragment	30 (61)	–	12	7	49
Initial displacement					
Slight	94 (84)	11	5	2	112
Marked or severe	20 (29)	16	20	14	70
Nature of causative violence					
Moderate (low energy trauma)	93 (65)	22	17	10	142
Severe (high energy trauma)	21 (53)	5	8	6	40
Total	114 (63)	27	25	16	182

( ) per cent.

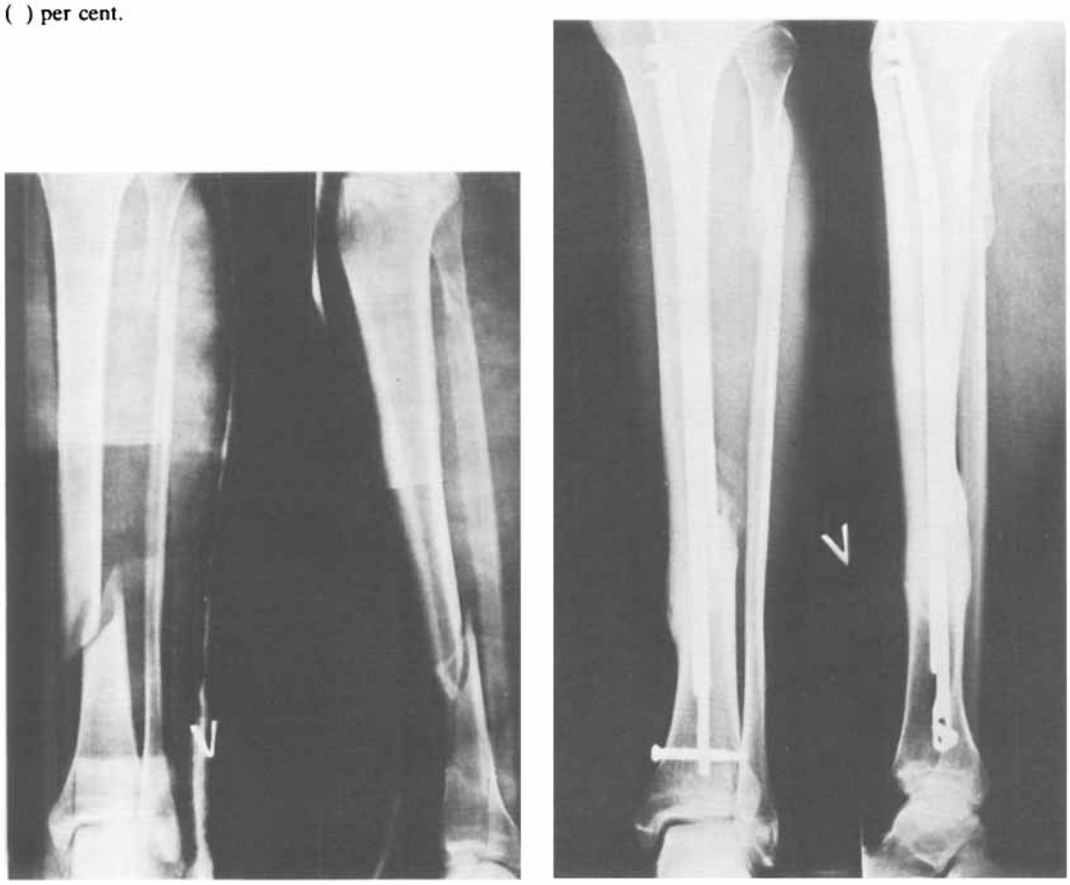

Figure 1. A longitudinal fracture with marked initial lateral displacement and shortening in plaster cast after unsuccessful attempt to closed reduction (a). Internal fixation was performed with the Kaessmann compression rod and solid union is seen 14 weeks later (b).

1) and one with the Ender nail. Plaster cast was used in all screw fixed fractures and after 12 intramedullary nailings. The operations were done by senior registrars.

Clinical union was considered completed when the fracture was absolutely stable, local tenderness absent and the patient was able to commence weight-bearing on the unsupported limb. Union was regarded as delayed if uncompleted 24 weeks after the accident (Sakellarides et al. 1964). If union could not be expected without secondary measures the condition was considered non-union. The observation period was on the average 19 months. All complicated cases were followed until the ultimate result was clear. Three aspects were noted when assessing the result: duration of healing, anatomical restoration and functional recovery. Complete data could be obtained of all patients for the first two variables but for functional recovery the notes were inadequate in 4 per cent.

For union time median was used because of a skew distribution. For statistical analysis of the results Student's t-test and the chi-square test were used.

RESULTS

Etiology

Fractures with a butterfly fragment were significantly more frequent in high-energy injuries than in those caused by moderate violence. This was valid also for open fractures but not for fractures with marked or severe initial displacement (Table 1).

Union time

The median union time of the whole series was 15.1 weeks. Marked or severe initial lateral displacement was the most important single factor predisposing to prolonged union time (Table 3, Fig. 2). Puncture wounds did not influence the union time. The difference between young adults and older age groups was insignificant. Repeated closed reductions, axial wedgings not included,

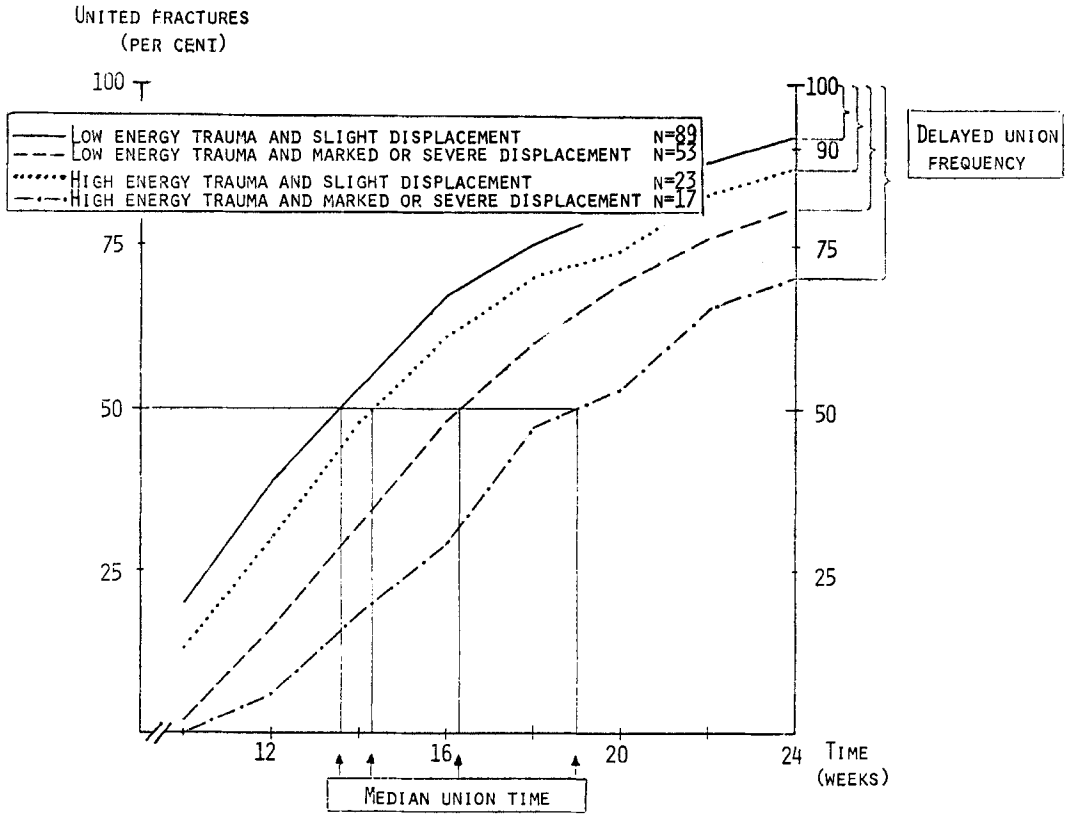

Figure 2. Cumulative percentage of united fractures.

Table 3. Union time

	Median union time (weeks)	Significance	Delayed union frequency (per cent)	Significance
Fracture line				
Simple	14.4		12.0	
Butterfly	16.8	$P<0.02$	18.4	N.S.
Initial displacement				
Slight	13.7		8.9	
Marked or severe	17.4	$P<0.01$	21.4	$P<0.05$
Nature of causative violence				
Moderate	14.7		12.0	
Severe	16.3	$P<0.05$	20.0	N.S.
Treatment				
Conservative (total)	15.3		14.0	
with repeated closed reductions	19.2	$P<0.02$	25.0	N.S.
Operative (total)	14.7		13.2	
with complicated course	24.5	$P<0.01$	53.3	$P<0.01$

prolonged the union time by 3.9 weeks on an average while the average time of final apposition in these cases was 11 days after the injury.

Complications

The overall infection rate was 2.0 per cent for closed fractures with conservative treatment, 15 per cent for open fractures with conservative treatment, 7.7 for closed fractures with operative treatment and 13 per cent for the open ones with operative treatment. The infections after closed fractures with conservative treatment were superficial ones in consequence of plaster sores. Fractures originating from high-energy traumata had a higher infection rate ($P < 0.01$) than those from low-energy injuries. Deep infection with fistula formation ensued in one conservatively treated open fracture and in three closed fractures after plate fixation (Table 4).

The internal fixation failed in four screwed fractures, on the average 5 weeks after the operation as a result of trivial stumbling or slipping. All these fractures had a marked or severe initial lateral displacement (Fig. 3). They all united without secondary measures, but in two patients the union was delayed and all four showed residual angular deformity of more than 5 degrees. In addition one plate loosened after postoperative infection.

Delayed union, including non-union, complicated 13.7 per cent of the fractures (Table 3).

Table 4. Complications

Complication	Treatment of fracture Conservative	Operative
Local		
Superficial infection	3	3
Osteitis	1	3
Failed osteosynthesis	–	5
Delayed union		
Simple delay	13	7
Non-union	3	2
Refracture	8	2
General		
Deep venous thrombosis	1	2
Pulmonary embolism	–	1
Fat embolism	–	1
Total no. of complications	29	26
Total no. of patients with complications	21 (18)	15 (22)

( ) per cent.

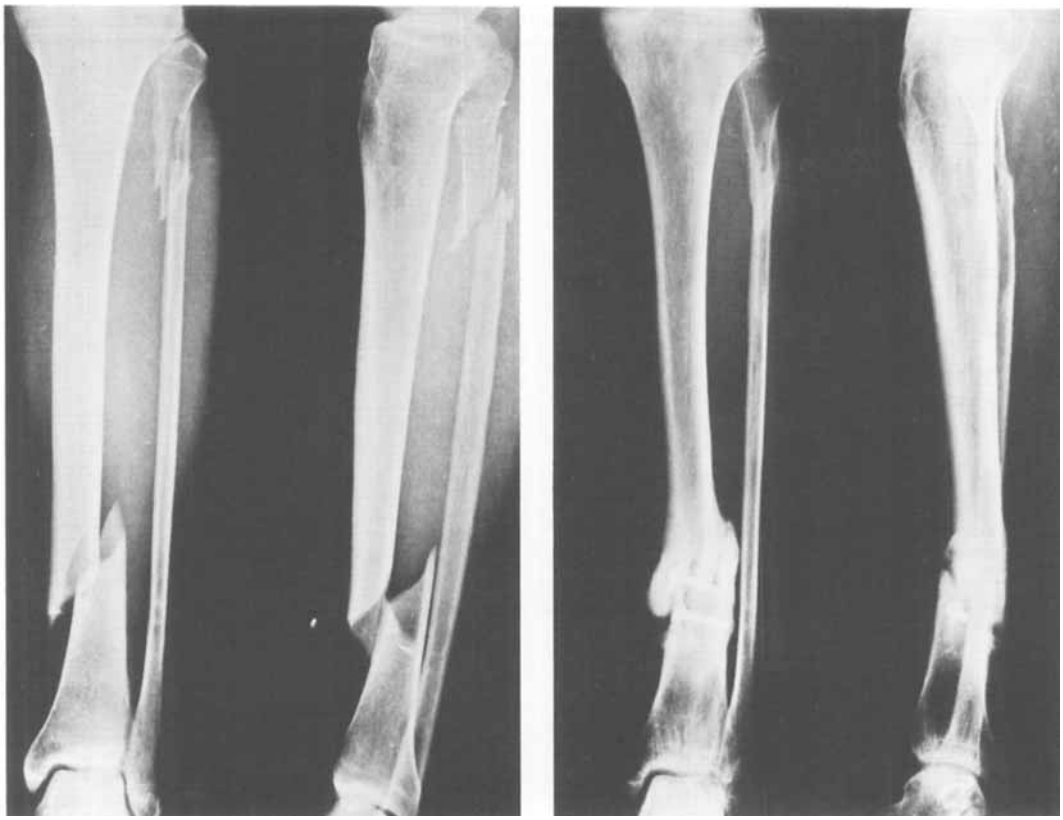

Figure 3. A longitudinal fracture with severe initial displacement (a) was fixed by interfragmentary compression screwing and immobilized by a long-leg plaster cast. The fixation failed a few weeks later as a result of trivial stumbling. Delayed union in a two-plane angular deformity followed (b).

Superficial or deep infection was involved in 36 per cent of these. Of the 25 fractures with delayed union, 20 united eventually without secondary operative intervention with a median union time of 29 weeks. Five fractures developed nonunion and were subjected to secondary measures, subcortical cancellous bone grafting (Phemister-Charnley operation) in four patients and intramedullary nailing alone once, on the average 23 weeks after the initial trauma.

Refracture, failed internal fixations not included, was noted in 10 patients (5.5 per cent) within 12 months of the primary accident. The management of the initial fracture had been conservative in eight patients and screw fixation in two. The mean interval between the primary fracture and the refracture was 22 weeks and between completed clinical union and the occurrence of the refracture 7 weeks. They all united with conservative treatment within 20 weeks.

The general complications (Table 4) included three cases of deep venous thrombosis in the injured extremity, two of which occurred in patients with an intramedullary nailed fracture and a supplementary long-leg plaster cast.

The overall complication rate, severe residual deformities included, was 18 per cent for conservative treatment, 22 per cent for screw fixation, 28 per cent for plate fixation and for intramedullary nailings 12 per cent. There was no difference in the complication rate between the immediate and delayed internal fixations.

Table 5. Residual deformity and symptoms

Residual deformity	Symptoms			Treatment		
	Ankle dorsiflexion loss and/or painful swelling	Symptomfree	Data inadequate	Total	Conservative	Operative
Severe						
Angulation >15°	4	–	–	4	3	1
Rotatory mal-union >15°	1	–	–	1	1	–
Shortening >20 mm	5	–	–	5	4	1
Minor						
Varus or valgus 5–15°	6	6	–	12	10	2
Anterior or posterior bowing 5–15°	4	6	–	10	9	1
Angulation in two planes 5–15°	4	3	1	8	6	2
Shortening 10–20 mm	6	8	1	15	13	2
Total severe or minor deformities	30 (70)	23 (17)	2	55 (30)	46 (40)	9 (13)
Insignificant or no deformity	13 (30)	109 (83)	5	127 (70)	68 (60)	59 (87)
	43	132	7	182	114	68

( ) per cent.

Residual deformity

Severe residual deformity was seen in 5.5 per cent and minor deformity in 25 per cent (Table 5). Marked or severe initial lateral displacement significantly ($P < 0.01$) increased the risk of angular deformity or shortening with conservative treatment. All patients with severe residual deformity expressed subjective complaints. Complaints and/or ankle dorsiflexion loss were recorded in 47 per cent of the patients with minor residual deformity and in 11 per cent when the deformity was insignificant. The difference is statistically significant ($P < 0.01$). Tibiofibular spontaneous synostosis was seen in four patients, all symptomfree.

Social and economic aspects

The hospital stay lasted with conservative treatment on an average 12 days. With emergency operation it lasted 16 and with delayed internal fixation 33 days. Superficial infection alone prolonged the hospital stay by 2 weeks. For patients with deep infection and/or non-union the mean duration of the hospitalization was 73 days. The average duration of the sick-leave in the whole series was 184 days. Six patients had to change to lighter work and three were pensioned.

DISCUSSION

Two-thirds of the patients with the studied fracture type posed no obvious management problems. They had fractures with only slight initial displacement and were successfully treated by conservative means. In one third there was an instability in the fracture that, with conservative treatment, resulted in reduction problems and a compromised healing potential. Like direct trauma, indirect violence and subsequent energy absorbed by the tissues show a continuous scale from mild to severe. As the majority of tibial

shaft fractures in urban areas are caused by direct violence, the distribution of the mode of injury in this series differed, as expected, considerably from unselected tibial shaft fracture series (Thunold et al. 1975, Önnerfält 1978). Indirect violence is, however, by no means non-existent in motor vehicle accidents. The severity of the initial displacement did not seem to depend on the nature of the causative forces and indeed most of the fractures with marked or severe initial displacement of this series were caused by falls at ground level.

The concept of union, both clinical and especially radiological, is always arbitrary both as to definition and for the individual patient (Austin 1977, Nicholls et al. 1979). This fact renders comparisons with previous reports unrewarding. The site of tibial fracture has no influence on the speed of union (Ellis 1958). An additional butterfly fragment prolonged the union time but still more significant was the degree of the initial lateral displacement. By definition of the nature of the violence severe skin injuries were not seen but in agreement with Tønnesen et al. (1975) puncture wounds did not seem to affect the union time. The relatively long average union time in this series could certainly have been shortened by allowing earlier weight-bearing particularly for the stable fractures with only slight displacement.

The problems of delayed union and infection often are interlaced. The overall infection rate of a clinical series is dependent on the definition of superficial infection and on how strictly these are recorded (Karaharju et al. 1975). Comparisons are thus usually informative only for deep infections. The frequency of osteitis here was close to previous reports for fractures with minimal skin injury (Aho & Hakkarainen 1974, Jensen et al. 1977). Infection and initial severe displacement, not surprisingly, dominated the problematics of delayed union. But the observed disadvantageous effect of repeated closed reduction on union time might deserve attention. The detrimental influence of a long interval between the trauma and the final apposition on healing has been previously pointed out by Hedenberg & Pompeius (1959). The majority of cases with delayed union in this series fortunately turned out to be fractures with a simply prolonged union time rather than heralding non-union as they eventually united without additional measures. However a few patients would indisputably have benefitted from a more active bone grafting policy, advocated by Rokkanen & Slätis (1972).

The frequency of refractures was higher than reported by Chrisman & Snook (1968). The risk of recurrent indirect violence against the tibia obviously is ubiquitous as compared to the more specific direct violence. The tome for most of the refractures coincided with the maximum post-traumatic bone mineral loss about 20 weeks after the injury (Andersson & Nilsson 1979). The total complication rate of the operatively treated patients was close to the 19 per cent reported by Kristensen (1979) for longitudinal fractures of the tibial shaft. When examining these figures it should be remembered that minor healing disturbances, even if the loss of time may be considerable, do not necessarily exclude acceptable or even excellent ultimate functional result (Olerud & Karlström 1972). Residual deformity impends when displaced unstable fractures of the tibial shaft are managed conservatively. Still higher malalignment rates than observed in this series are reported for distal tibial shaft fractures by van der Linden & Larsson (1979).

The healing time of fractures with marked or severe initial lateral displacement was shortest and the residual deformity frequency lowest after successful internal fixation. Immediate internal fixation did not, in contrast with Smith (1974), increase the complication rate but delayed operation prolonged the hospital stay significantly. Longitudinal and short oblique fractures with marked displacement often redislocate in the plaster when the swelling subsides. The high number of delayed internal fixations here reflects this fact. Operative treatment of these fractures as an emergency procedure should thus be considered unless the risks inherent in it exceed the risk of a poor functional result with conservative treatment.

Interfragmentary compression screwing gave good results in simple longitudinal fractures with only moderate initial lateral displacement. But the number of failed fixations seems to be high in fractures with severe displacement. Also high-energy fractures with possible occult additional

fissures are less suited for screwing. Loosening of screws has also been reported by Önnerfält (1978) but with considerably slighter subsequent healing disturbances than in this series. Plate fixation providing rigid fixation and allowing immediate joint mobilization offers important advantages but the consequences of an infected plate osteosynthesis are disastrous. The few deep infections of this series did not occur as a result of unpremeditated incisions in devitalized skin. The infection risk associated with a wide exposure and a heavy metallic implant on the tibia seems unavoidable (Bauer & Hulth 1973).

Conventional intramedullary nailing proved to be a reliable method although rigid fixation was achieved only in a few short oblique fractures. The minor disadvantages of a supplementary plaster cast (Solheim & Bø 1973) did not disturb the acceptable results of intramedullary nailing even in high-energy fractures with a displaced butterfly fragment. The Kaessmann intramedullary compression rod adds rotational stability to intramedullary nailing. Extensive clinical experience of this method is looked forward to.

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