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Department of Orthopaedic Surgery M, Bispebjerg Hospital, and the Departments of Plastic and Maxillo-Facial Surgery, Rigshospitalet, Copenhagen, Denmark.

150 OPEN FRACTURES OF THE TIBIAL SHAFT—THE RELATION BETWEEN NECROSIS OF THE SKIN AND DELAYED UNION

P. A. TØNNESEN, J. HEERFORDT & M. PERS

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In this paper an attempt is made to assess the influence of soft-tissue trauma and treatment on the healing of open fractures of the tibia. The development of skin necrosis has been taken as evidence that the soft-tissue treatment has been inadequate.

MATERIAL AND METHODS

The material consists of 150 consecutive, open fractures of the tibial shaft treated at Department M, Bispebjerg Hospital, Copenhagen, during the years 1958–1970 inclusive. Only diaphyseal fractures are included, all fractures involving the knee or ankle joints having been ruled out. Multi-traumatized patients, and patients who for other reasons cannot be evaluated in this connection have likewise been excluded. There were 43 women and 107 men. The average age was 44 years (range 15–84 years).

Classification of trauma

The material has been divided into two groups according to the severity of trauma using the classification proposed by Bauer et al. (1962) and adopted by Edwards (1965) (Table 1).

Group 1: Direct, high-energy trauma to the lower leg. This group, which consists of 139 fractures, comprises all cases in which: a. motor vehicles were involved (74 motor cars, 35 motorcycles and 16 light motorcycles, totalling 125 fractures); b. the victim fell from a height of more than 3 meters (9 fractures); and c. the lower leg was hit by a direct blow from a heavy object (5 fractures).

Group 2: Indirect, low energy trauma caused by forces arising from the human body itself, for instance torsional trauma, or from other forces of comparable magnitude. This group consists of 11 fractures caused by: a. falls from table or chair (7 fractures); b. falls while playing football (2 fractures); and c. falls with a bicycle (2 fractures).

Table 1. Severity of trauma (according to Bauer et al. 1962).

	Low-energy	High-energy	Total
Bauer et al.:	10	82	92
Edwards:	4	114	118
Our material:	11	139	150

Classification of soft-tissue injury

We have adopted the following classification which has been used by several writers (Veliskakis 1959, Matter 1970, Hamza et al. 1971, Olerud & Karlström 1972) (Table 2).

Grade 1: Puncture wounds 'from within' or small lacerations up to about 2 cm in length with no loss of skin and minimal muscle damage (19 fractures).

Grade 2: Larger wounds over 2 cm in length with contusion of the adjacent skin and some muscle damage (75 fractures).

Grade 3: Severe crush injuries with extensive damage to the skin and muscles (56 fractures).

It must be noted that all the patients with low-energy trauma had Grade 1 lesions of the soft tissue, whereas nearly all of the patients subjected to high-energy trauma had lesions of Grades 2 or 3.

Classification of fracture type

The anatomical fracture *level* has been classified according to the method used by Olerud & Karlström (1972) as follows:

1) Proximal metaphysis	7 cases
2) Diaphysis	118 cases
3) Diaphysis + distal metaphysis	25 cases

The fracture *types* have been divided according to the classification proposed by Edwards (1965) as follows:

1) Transverse fractures. This group comprises:	
a) simple transverse fractures	66 cases
b) all comminuted fractures with one or more intermediate fragments, including 12 double fractures	74 cases
Totalling 140 transverse fractures.	
2) Longitudinal fractures: all other fractures, a total of	10 cases

Fracture healing

In this study we have arbitrarily defined union as having occurred when weight-bearing without plaster cast was possible.

Treatment

A total of 96 fractures, 64 per cent of the material, were given conservative treatment consisting of soft-tissue revision, fracture reduction, and the application

Table 2. Soft-tissue lesions (according to Veliskakis 1959).

	Number of patients	Per cent
Grade 1:	19	13
Grade 2:	75	70
Grade 3:	56	37
Total	150	100

Grade 1: Wounds less than 2 cm, no skin loss.
Grade 2: Wounds over 2 cm and contusion of skin/muscle.
Grade 3: Severe crushing, extensive contusion/loss of skin and muscle.

of a (split) plaster cast, in many instances supplemented by wire traction through the heel. The treatment has been somewhat more conservative than in Bauer et al.'s series (1962) in which only 45 per cent were treated conservatively or in Edwards' series (1965), in which 50 per cent were treated conservatively.

A further 54 patients were treated by operations of the following types: 25 plate osteosyntheses of the Lane type, 17 Rush-pin fixations, 6 screw-fixations and 1 fixation by cerclage wire. There were 5 fixations with Kirschner wires incorporated in plaster casts. These have been counted as operations, but they might as well have been included in the group of conservatively treated cases. Nine operations were carried out as secondary procedures from 5 to 36 days after the original trauma (average 18 days).

The incidence of operative treatment in relation to the degree of soft-tissue injury is seen in Figure 1.

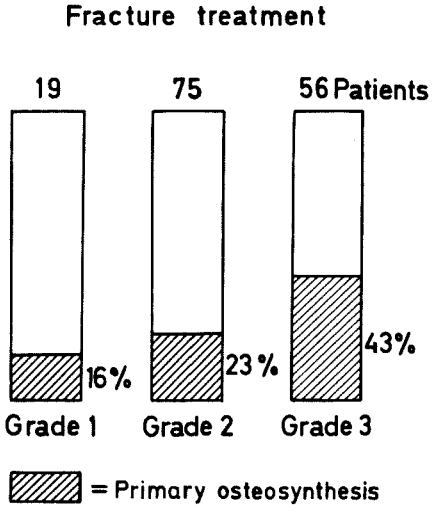

Figure 1. The distribution of conservative and operative treatment in the material.

Table 3. Soft-tissue treatment.

	Number of patients	Secondary skin necrosis
No suture	23	0
Simple suture	92	32
Free graft	9	2
Relaxing incision + free graft	22	6
Pedicle flap + free graft	4	1
	150	41

Smaller wounds were left open for healing by secondary intention, whereas larger wounds were closed. Relaxing incisions and skin-grafting on primary and secondary defects were used to a certain extent (Table 3).

The primary treatment was carried out by senior registrars, about 20 in number, over the 12 years covered by this paper. They all had several years of training in general surgical and orthopaedic departments, but none of them had had any regular plastic surgical training.

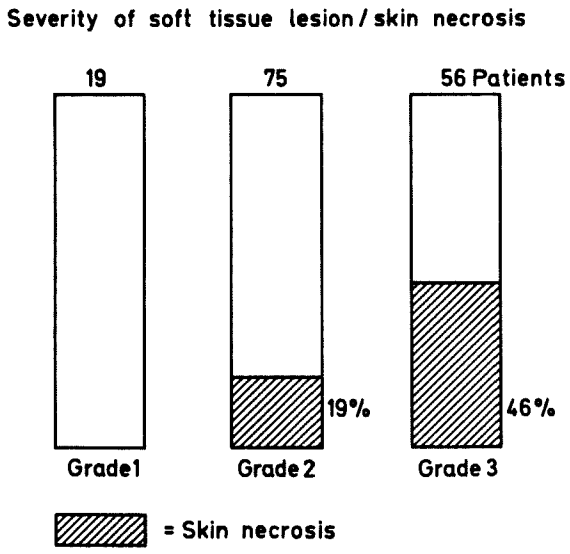

Figure 2. The incidence of skin necrosis in relation to the degree of soft-tissue injury (Grades 1, 2 & 3).

RESULTS

Among 23 patients in whom the wounds were allowed to heal by secondary intention there were no cases of skin necrosis, and this was also the case in 41 of the remaining patients irrespective of the method of soft-tissue closure (Table 3). It must be pointed out that none of the instances of skin necrosis mentioned in Table 3 indicated failure of skin grafting but rather were due to a too optimistic assessment of the viability of the traumatized and oedematous skin at the time of primary treatment.

Delayed primary suture was undertaken in seven cases which all healed uneventfully.

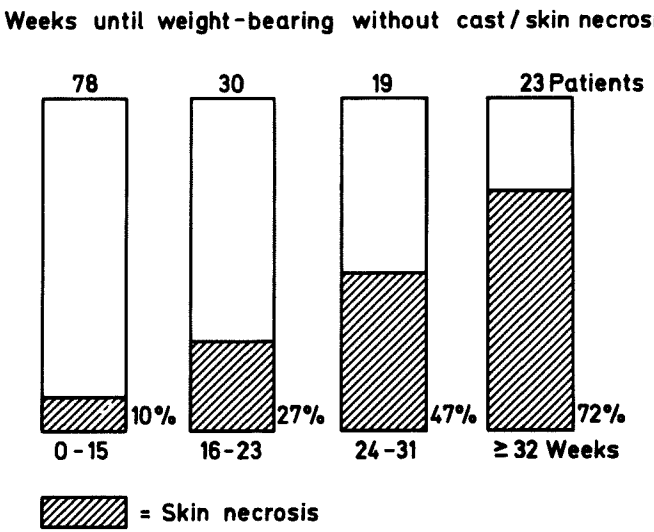

Figure 3. The relation between the incidence of skin necrosis and the time for fracture healing, defined as weightbearing without a plastercast.

Table 4. Fracture type/treatment/skin necrosis.

Transverse fractures	Primary osteosynthesis		No primary osteosynthesis	
	Total No.	Skin necrosis, per cent	Total No.	Skin necrosis, per cent
Simple	21	43	45	22
Comminuted	21	33	53	25
Total	42	38	98	23

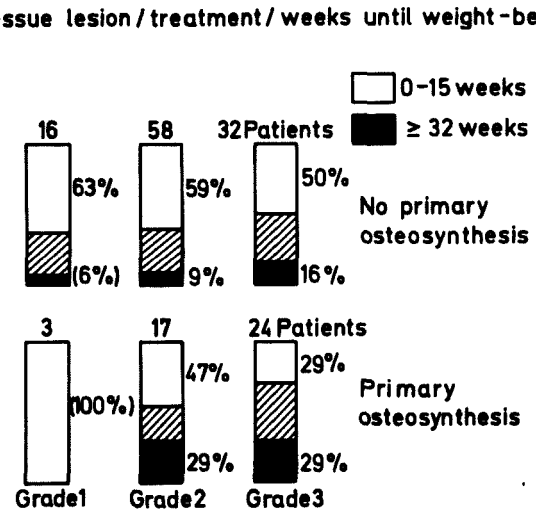

Figure 4. The relation between the extent of soft-tissue injury (Grades 1, 2 & 3) and fracture healing (weeks until weightbearing) in conservatively and operatively treated patients.

The frequency of skin necrosis, totalling 41 cases (27 per cent of the material) increased with the severity of soft-tissue lesion (Figure 2), and the presence of skin necrosis was closely correlated to the occurrence of delayed union (Figure 3).

Skin necrosis occurred in 18 of the 44 cases treated by primary osteosynthesis (41 per cent), whereas only 23 patients out of the remaining 106 cases (22 per cent) developed skin necrosis. (Transverse fractures are listed in Table 4).

A comparison of the results of conservative and operative treatment is seen in Figure 4.

There were no amputations.

DISCUSSION

When discussing the treatment of open tibial fractures the main point of contention has been the question of conservative treatment versus operative treatment using metallic implants. Most British writers, notably Charnley (1961), Watson-Jones (1962), Nicoll (1964) and Saad (1970) have warned against the use of metallic implants because of the increased risk of infection and non-union, and they have attached greater importance to soft-tissue treatment than to rigid

fracture fixation. The alternative principle has been adoped by the representatives of the Swiss A.S.I.F. group (Willenegger 1967 & 1972, Matter 1970, Allgöwer 1971) and by others, notably McNeur (1970), Hicks (1971), Ketenjian & Shelton (1972), Olerud & Karlström (1972) and Solheim (1973), who tend to maintain that even deep infections will subside if an absolutely rigid fixation can be provided.

Infanger et al. (1971) reported excellent results in 95 per cent of 230 (predominantly closed) fractures of the lower leg treated according to the A.S.I.F. principles. 91 per cent of the fractures were caused by indirect, low-energy violence (skiing). It is interesting to note that only 11 out of 150 fractures in the present material were caused by low-energy violence. They are, however, too few to form a basis for any conclusions, and they will be left out of the following discussion.

Nicoll (1964) concluded that five factors: "comminution, wound, displacement, infection and loss of bone" are fundamental when comparing methods of treatment. Edwards (1965) demonstrated the intimate connection between skin necrosis, infection and fracture prognosis. These combined findings demonstrate how misleading any discussion of tibial fractures will be if the severity of trauma is not taken into account.

In this material the results in the more serious lesions (Grades 2 and 3) are rather unsatisfactory, regardless of the type of treatment employed. Out of the 96 fractures that were treated conservatively, 32 per cent had not healed after 20 weeks. In his analysis of 674 conservatively treated patients, Nicoll (1964) similarly found that 33 per cent had failed to heal after 20 weeks in the groups that—on the basis of soft-tissue lesions and fracture type—were comparable to our Grades 2 and 3 lesions.

The relation between fracture type and healing time in cases with

Table 5. Healing time in transverse fractures with and without skin necrosis.

Transverse fractures	No skin necrosis					Skin necrosis				
	Weeks:	0–15	16–23	24–31	≧32	Weeks:	0–15	16–23	24–31	≧32
	No.	Per cent				No.	Per cent			
Simple	40	70	15	10	5	19	11	26	26	37
Comminuted	49	59	25	8	8	20	20	15	20	45
Total	89	64	20	9	7	39	15	21	23	41

and without necrosis of the skin is seen in Table 5. Delayed union correlated with necrosis of the skin and not with fracture type.

As can be seen in Figure 4, 29 per cent of the fractures treated by primary osteosynthesis, in Grade 2 and 3 lesions respectively, had not united by the 32nd week, while among the conservatively treated cases only 9 and 16 per cent, respectively, had failed to unite.

Increasing severity of soft-tissue damage coincided with increased operative activity (Table 1). Increasing severity of fracture type, however, did not. 21 simple and 21 comminuted transverse fractures were operated upon, while 45 simple transverse fractures and 53 comminuted ones were treated conservatively. In all of the cases treated by primary osteosynthesis some kind of supplementary plaster cast was applied, effectively preventing day-to-day checking of soft-tissue viability.

The striking relation between necrosis and delayed union seen in Figure 3—which is also found in Edwards' study (1965)—certainly seems to be more than a coincidence. It is reasonable to assume that the unsatisfactory results in many cases can be ascribed to: 1) faulty judgement of soft-tissue viability, 2) further reduction of vascularity by operative intervention, and 3) plaster bandages obscuring the region of interest and making secondary plastic surgical procedures difficult.

In A.S.I.F. osteosynthesis, plaster casts are not required, but meagre results in severe cases are nevertheless also found in series with compression plates, as shown by Olerud & Karlström (1972) who reported 34 per cent 'severe healing disturbances' defined as 'deep, virulent infection, bending and fracture of the plate, refractures, skin necrosis and delayed healing' in the group of transverse, open

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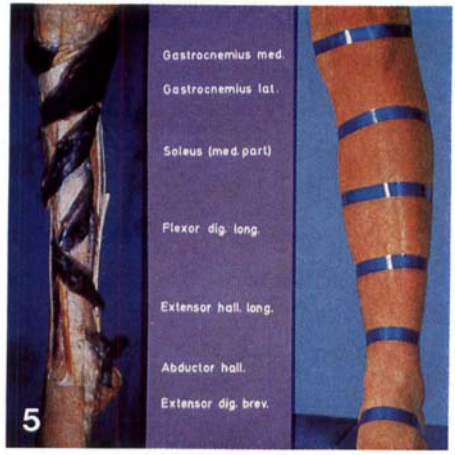
Figure 5. On the right side the lower leg divided into 5 areas. On the left the muscles that can be used for myoplasties in these areas; dissected out in a cadaver and stained blue.

Figure 6. Direct, high-energy trauma resulting in a transverse fracture with extensive damage to the skin. The fracture is reduced and immobilized by a Hoffmann apparatus. Devitalized skin has been excised. Medial part of the soleus muscle has been prepared for myoplasty.

Figure 7. Primary cover by split-skin grafting.

Figure 8. Appearance after 12 days. The grafts have taken.

Figure 9. Appearance after 10 weeks. The Hoffmann apparatus has been removed. The fracture has united and the area is covered by muscle and skin.


Gastrocnemius med.
Gastrocnemius lat.
Soleus (med. part)
Flexor dig. long.
Extensor hall. long.
Abductor hall.
Extensor dig. brev.
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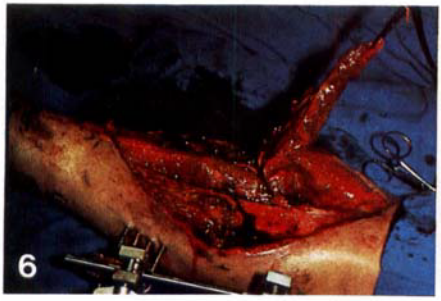
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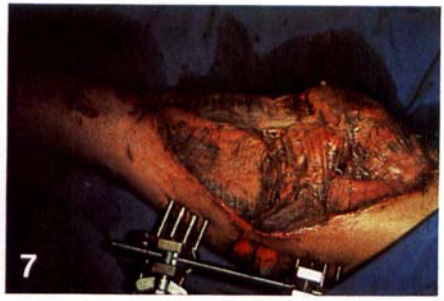
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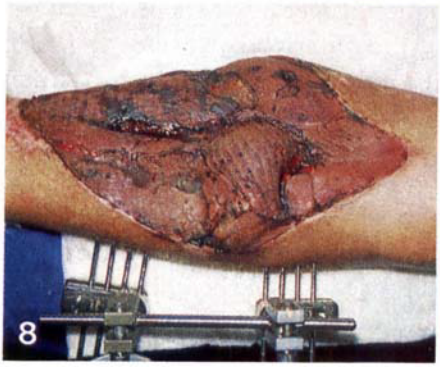
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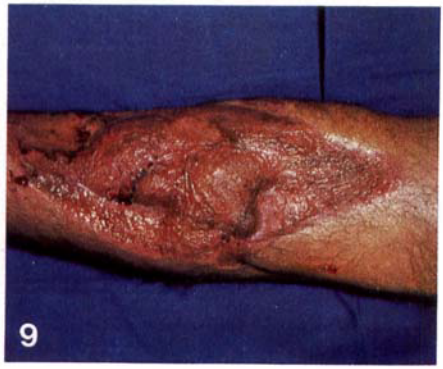
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diaphyseal fractures. The results published by Olerud & Karlström (1972) have been so discouraging that Bauer & Hulth (1973) have proposed that the A.S.I.F. compression plates be altogether abolished in tibial fractures. In this material intramedullary nailing has not been used; nor did Olerud & Karlström (1972) recommend it as a *primary* fixation.

For lesions of Grades 2 and 3 in which internal fixation is undesirable on account of the additional operative trauma and the risk of infection, and in which plaster casts hamper plastic surgical procedures, primary transfixation according to the method of Hoffmann (1954) seems to be the logical solution. This method has been materially improved in later years, and the complications are negligible compared to the obvious advantages offered by the method in cases with severe soft-tissue lesions (Vidal et al. 1970, survey by Olerud 1973).

Even though the risk of incurring additional soft-tissue damage through the treatment itself can thus be minimized, the difficult problem of covering a denuded fracture line with vascularized tissue remains. Direct suture, even in connection with relaxing incisions, often leads to necrosis (Table 3). Local rotational flaps are notoriously risky on the lower leg, especially in traumatized tissue. Cross-leg flaps, using Hoffmann's apparatus on both legs, can sometimes be used, but can be technically difficult, are uncomfortable for the patient, and are not to be recommended for patients over 50 years of age.

One promising method of covering the anterior surface of the tibia with well vascularized tissue is the technique of muscle transposition introduced by Ger (1966). Several of the muscles in the lower leg are able to take over each other's function, making it possible to transpose one of them across the defect, thus covering the fracture with viable, innervated muscle providing ample vascularity around the fracture site (Andersen & Helmig 1970, Barfod & Pers 1970, Barfred & Reumert 1973, Pers & Medgyesi 1973). The transposed muscle belly is then, in its turn, covered with split skin grafts that take without any difficulty, as muscles can be regarded as ideal recipient sites.

Only the muscles in Figure 5 can be employed without functional impairment, and the neuro-vascular bundles to the muscles must be carefully protected both during the dissection and after-treatment.

It should be emphasized that the detrimental effects of an unsuccessful myoplasty are so serious that these procedures should be reserved for experts, preferably plastic surgeons.

There is, however, no easy short-cut to success in the treatment of the most severe cases. Correct estimation of soft tissue viability in the acute stage is admittedly difficult. For this and other reasons it has been suggested that all patients with extensive soft-tissue injury and/or bone loss be referred to a 'superspecialist' immediately after the accident (Bauer & Hulth 1973).

The aim of this paper has been to emphasize the importance of adequate soft-tissue coverage in primary fracture treatment, and it is suggested that training in plastic surgical techniques should be an integral part of the training of orthopaedic surgeons.

CONCLUSIONS

1. The incidence of skin necrosis rises with the severity of trauma.
2. The incidence of delayed union rises with the incidence of skin necrosis.
3. The incidence of delayed union is high in conservatively treated cases, but even higher in cases treated by primary osteosynthesis.
4. As an alternative treatment of open tibial fractures with skin lesions of Grades 2 and 3, a treatment combining Hoffmann's transfixation and Ger's myoplastic procedures is suggested.
5. Close cooperation of orthopaedic and plastic surgeons is recommended.

SUMMARY

In 150 open fractures of the tibial shaft a close relationship between the presence of skin necrosis and delayed union was found. The incidence of skin necrosis rose with the severity of trauma. It was high (22 per cent) among the fractures that were treated conservatively, but even higher (41 per cent) among those treated with primary osteosynthesis.

Neither conventional conservative treatment nor osteosynthesis seems to be satisfactory as a primary treatment of the most severe cases. It is instead suggested that external fixation by the Hoffmann-Vidal technique should be combined with transposition of viable muscle tissue across denuded fractured bone areas according to the method of Ger.

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REFERENCES

Allgöwer, M. (1971) Weichteilprobleme und Infektionsrisiko der Osteosynthese. *Langenbecks Arch. klin. Chir.* **329**, 1127–1136.

Andersen, J. B. & Helmig, O. (1970) Myoplastik ved behandlingen af inficerede crusfracturer med bløddels defekt over tibia. *Ugeskr. Læg.* **132**, 1048–1050.

Barfod, B. & Pers, M. (1970) Gastrocnemius-plasty for primary closure of compound injuries of the knee. *J. Bone Jt Surg.* **52**-B, 124–127.

Barfred, T. & Reumert, T. (1973) Myoplasty for covering exposed bone or joint on the lower leg. *Acta orthop. scand.* **44**, 532–538.

Bauer, G. C. H., Edwards, P. & Widmark, P. H. (1962) Shaft fractures of the tibia. *Acta chir. scand.* **124**, 386–395.

Bauer, G. & Hulth, A. (1973) Kompressionsosteosyntes enligt AO vid underbenets diafysfrakturer bör överges. *Svenska Läk.-Tidn.* **70**, 4752–4753.

Charnley, J. (1961) *The closed treatment of common fractures.* 3rd ed. E. & S. Livingstone Ltd., Edinburgh, 1961.

Edwards, P. (1965) Fracture of the shaft of the tibia: 492 consecutive cases in adults. *Acta orthop. scand.* Suppl. 76.

Ger, R. (1966) The operative treatment of the advanced stasis ulcer: A preliminary communication. *Amer. J. Surg.* **111**, 659–663.

Hamza, K. N., Dunkerley, G. E. & Murray, C. M. M. (1971) Fractures of the tibia. *J. Bone Jt Surg.* **53**-B, 696–700.

Hicks, J. H. (1971) High rigidity in fractures of the tibia. *Injury* **3**, 121–132.

Hoffmann, R. (1954) Ostéosynthèse externe par fiches et rotules. *Acta chir. scand.* **107**, 72–88.

Infanger, K., Fenner, A., Cadalbert, M. & Schamaun, M. (1971) Ergebnisse der operativen Behandlung der Unterschenkelschaftfrakturen anhand von 230 Fällen. *Helv. chir. Acta* **38**, 311–316.

Ketenjian, A. Y. & Shelton, M. L. (1972) Primary internal fixation of open fractures: A retrospective study of the use of metallic internal fixation in fresh open fractures. *J. Trauma* **12**, 756–763.

Matter, P. (1970) Grundsätzliche Indikationsfehler bei offenen Frakturen. *Langenbecks Arch. klin. Chir.* **327**, 858–860.

McNeur, J. C. (1970) The management of open skeletal trauma with particular reference to internal fixation. *J. Bone Jt Surg.* **52**-B, 54–60.

Nicoll, E. A. (1964) Fractures of the tibial shaft. A survey of 705 cases. *J. Bone Jt Surg.* **46**-B, 373–387.

Olerud, S. & Karlström, G. (1972) Tibial fractures treated by AO compression osteosynthesis. *Acta orthop. scand.*, Suppl. 140.

Olerud, S. (1973) Treatment of fractures by the Vidal-Adrey method. *Acta orthop. scand.* **44**, 516–531.

Pers, M. & Medgyesi, S. (1973) Pedicle muscle flaps and their applications in the surgery of repair. *Brit. J. plast. Surg.* **26**, 313–321.

Saad, M. N. (1970) The problems of traumatic skin loss of the lower limbs, especially when associated with skeletal injury. *Brit. J. Surg.* **57**, 601–615.

Solheim, K. (1973) Tibial fractures treated according to the AO-method. *Injury* **4**, 213–220.

Veliskakis, K. P. (1959) Primary internal fixation in open fractures of the tibial shaft. *J. Bone Jt Surg.* **41**-B, 342–354.

Vidal, J., Rabischong, P., Bonnel, F. & Adrey, J. (1970) Etude biomécanique du fixateur externe d'Hoffmann dans les fractures de jambe. *Montpellier chir.* **16**, 43–52.

Watson-Jones, R. (1962) *Fractures and joint injuries.* II, 4th. ed. E. & S. Livingstone Ltd., London.

Willenegger, H. (1967) Versorgung von offenen Frakturen. *Chirurg* **38**, 341–347.

Willenegger, H. (1972) Licht und Schatten über der Indikation zur Knochenbruchbehandlung. *Mschr. Unfall-heilk.* **75**, 455–468.

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Correspondence to:

Dr. P. A. Tønnesen
Jens Juels Gade 48
DK–2100 Copenhagen
Denmark

Translator: P. A. Tønnesen, MD