Team approach to tibial fracture

37 consecutive Type III cases reviewed after 2–10 years

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During a 10-year period, we managed 35 patients with 37 cases of Type III open tibial fractures, 15 cases within 1 week and 22 as late referrals. In all cases, simultaneous assessment and management by a microvascular and an orthopedic surgeon were mandatory throughout the treatment period. 6 of the 15 acute cases had a primary amputation. Of the remaining 31 cases, limb salvage was possible in 27. 31 flaps, pedicle and microvascular free flaps were used. Major complications occurred in 6 cases, but in 27 cases infection-free solid union was obtained. At long-term follow-up, average 5 years, the function was good or acceptable in 23 cases. We conclude that: (1) patients with Type III tibial injuries should preferably be transferred within a week after injury to a hospital where major reconstructive procedures are commonly performed, (2) early soft tissue coverage is essential in the management of these injuries, (3) unilateral external fixation should be the preferred technique of stabilization, and, finally, (4) plastic surgery expertise is important in management of severe tibial fractures.

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The extensive loss of bone and soft tissue in Type III open tibial fractures represents some of the most defying reconstructive problems in trauma surgery (Gustilo et al. 1984). The introduction of a variety of local pedicle flaps and free tissue transfer by microsurgical techniques has added new possibilities in the reconstruction of bone and soft tissue defects (Jones and Chierny 1980, Shaw 1983). Even though very favorable success rates have been reported in series of Type III tibial fractures (Tönnesen et al. 1975, Byrd et al. 1985, Godina 1986, Yaremchuk 1986, Khouri and Shaw 1989, Melissinos and Parks 1989), others emphasize the importance of considering an amputation (Lange et al. 1985, Keblish 1986, Seiler and Richardson 1986, Hansen 1987, Herve et al. 1987, Howe et al. 1987, Bondurant et al. 1988, Seyfer and Lower 1989, Heatley 1988, Lange 1989).

We report our experiences based on 35 patients with 37 Type III tibial fractures treated during a 10-year period.

Patients and methods

Up to 1979, the responsibility for management of the severely injured limb at our hospital was divided between the plastic/microvascular and the orthopedic surgeons as follows. There was no strictly organized co-operation. Assessment and management were done at the respective departments, depending on whether the current problems were related to soft tissues or bone. These circumstances led to a situation where timing of different stages in the treatment was unnecessarily delayed. Furthermore, placement and selection of fracture fixation devices often interfered with soft tissue management or reduced the number of flap alternatives. Therefore, in 1980, a two-disciplinary approach was started where simultaneous assessment and management of these patients throughout the treatment program was mandatory. This included a close cooperation in long-term follow-up assessment and late reconstructive surgery.

During the period September 1980 through February 1990, 37 cases of Type III tibial fractures in 35 patients were seen. All cases were subtyped into 3 classes (Gustilo et al. 1984); there were 14 A, 10 B and 13 C cases (Table 1). 6 Type C cases and 1 Type B case were amputated primarily. The remaining 30 cases in 29 patients (7 women, 22 men), average age 33 (14–70) years, were considered appropriate for bone and soft tissue reconstruction. 8 of these cases were referred within a week after injury while 22 were late referrals with an average time from injury of 15 months (range 3 weeks to 9 years). Traffic accident was the most common cause of injury, and 15 patients had multiple injuries. 7 patients in the late-referral group had sequelae after war injuries sustained in the Middle East (5 patients) or in Latin America (2 patients).

Table 1. Observations in 35 patients with 37 Type III open tibial injuries

A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	R
1	M	17	1	2	1	2	9	7x14	–	16	2	1	4.0	4.0	0	7.3
2	W	15	1	1	3	1	5	8x10	–	8	2	2,1	4.4	4.5	1,2,2	4.1
3	W	60	1	1	1	1	3x4	6x10	–	56	2	3	3.0	6.0	0	6.1
4	M	14	1	2	1	1	7	7x11	–	32	2	3	3.0	5.5	0	9.2
5	M	39	2	1	1	1	3x6	6x8	–	6	1	4	5.0	6.5	0	10
6	M	32	1	2	6	2	11	10x25	1	<1	–	–	–	–	–	–
7	M	22	1	2	4	1	0	5x10	–	6	1	2	3.0	12	0	6.3
8	M	56	3	1	1	2	7	7x15	–	4	5	2,2	3.0	4.5	0	5.5
9	W	39	3	1	4	2	10	15x25	–	3	2,7	1	64	28	5	6.0
10	M	17	3	1	6	3	7	10x18	1	<1	–	–	–	–	–	–
11	M	17	3	1	1	1	3x5	7x10	–	104	2	1	3.5	6.0	0	3.6
12	W	69	1	2	3	1	0	10x20	–	5	2	2	4.0	4.5	0	6.5
13	M	31	4	1	1	2	5x10	4x10	–	56	2	2	4.0	5.0	0	3.9
14	W	14	1	2	2	2	7	20x35	–	<1	2	1	3.5	10	5	4.5
15	M	54	1	1	1	1	2x4	6x8	–	76	2	3	4.0	4.5	0	4.1
16	M	21	4	2	1	3	12	10x20	–	56	2	1	7.0	8.5	2	4.6
17	M	50	1	2	1	1	2x5	7x12	–	12	1	2	6.0	6.5	1	8.1
18	W	38	1	2	6	3	6x4	6x11	1	<1	–	–	–	–	–	–
19	M	44	3	1	4	2	5	6x11	–	40	2	3	4.5	10.0	0	7.5
20	M	70	2	1	1	1	6	8x15	–	8	2	2,1	8.0	N	1,2	2.0
21	M	37	5	2	2	2	6	4x8	–	12	2	2	6.0	6.0	0	2.5
22	M	21	5	1	1	3	6	6x10	2	<1	2	1	4.0	6.5	0	3.2
23	M	26	1	2	6	3	5x3	7x25	1	<1	–	–	–	–	–	–
24	M	26	4	1	3	3	10	7x15	–	55	2	1	–	–	1,6	–
25	M	27	4	1	1	2	10	8x12	–	144	2	1	3.5	12	7	4.2
26	W	17	1	2	2	3	7	10x15	2	<1	2	1	4.0	11	0	3.0
27	M	54	1	1	2	2	6	15x35	–	1	2	1	3.0	12	0	1.2
28	M	24	4	2	5	1	6x8	5x10	–	110	5		4.5	4.0	0	2.6
29	M	24	4	2	1	1	7x10	8x10	–	82	5	2	3.5	5.0	0	4.2
30	W	16	1	2	2	3	4x5	10x10	2	<1	2	2	3.5	3.5	N	3.9
31	M	28	4	2	1	1	4x6	6x10	–	468	5	2	8.0	7.5	0	2.6
32	M	24	1	2	1	3	3	5x7	3	<1	1	–	–	–	6	–
33	M	23	5	2	1	1	10	7x25	–	<1	1	0	4.5	8.5	0	6.0
34	M	23	5	2	1	3	5	6x15	2	<1	1	2	4.0	4.5	0	6.0
35	M	8	1	2	6	3	0	5x20	1	<1	–	–	–	–	–	–
36	W	6	3	2	6	3	0	20x40	1	<1	–	–	–	–	–	–
37	M	6	3	2	6	3	0	15x25	1	<1	–	–	–	–	–	–

A Case
(33/34 and 36/37 are bilateral injuries in 2 patients)
B Sex
C Age
D Etiology
1 traffic accident
2 fall
3 crush injury
4 war injury
5 miscellaneous
E 1 single injury
2 multiple injuries
F Primary stabilization
1 multiplane external fixation
2 unilateral external fixation
3 AO-plate
4 Ender nails
5 cast
6 vacuum splint
7 intramedullary nail
G Fracture classification
1 III A
2 III B
3 III C
H Bone defect (cm)
I Soft tissue defect (cm)
J Primary and/or secondary treatment
1 primary amputation
2 revascularization
3 replantation
K Weeks from injury to flap procedure
L Secondary fracture stabilization, see F
M Type of flap
1 free vascularized flap
2 pedicle muscular flap
3 fasciocutaneous flap
4 cross leg flap
N Weeks from reconstruction to stable soft tissue conditions
O Months to fracture union
N nonunion
P Complications
1 flap failure
2 anastomotic revision
5 deep infection
6 delayed amputation
7 refracture
N nonunion
R Years follow-up

Primary management in the 8 acute cases (Cases 14, 22, 26, 27, 30, 32, 33 and 34) consisted of a preoperative angiogram, fracture stabilization with an external frame (Hammer 1988) followed by a thorough debridement and vascular repair when required (Figure 1). Parenteral administration of combined antibiotics was started preoperatively and continued for 48–72 hours (Gustilo and Merkow 1990). When the primary debridement was completed, the wound was covered with moist dressings. At 2–3 days interval, the patients were returned to the operating room for re-evaluation and further debridements. We considered early soft-tissue coverage within 1–3 days indicated only when major neurovascular structures or joint surfaces were exposed (Mitchell and Shepard 1989). Otherwise, definitive wound coverage was completed within 4–7

days after injury. Skeletal reconstruction with bone grafts was usually performed up to 4–5 weeks after stable soft tissue conditions were achieved.

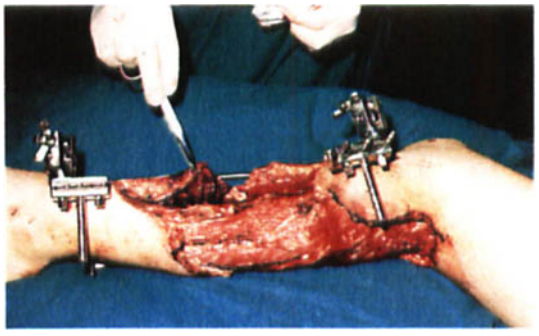
The 22 late referrals presented a more complex situation. 12 fractures were grossly unstable, whereas nonunion in 7 cases was diagnosed by shift comparison (Hammer et al. 1984). An average of 6 (2–13) unsuccessful surgical procedures had been done prior to referral. 14 cases had primarily been stabilized by bilateral or multiplane external fixation. In 10 cases, these frames were replaced by a unilateral system (Hammer 1988), either due to interference with soft tissue management, pin loosening, deep pin tract infection or gross instability in the antero-posterior plane. Preoperative evaluation included repeated bacteriologic cultures and routine laboratory tests to assess the general condition of the patients, including their metabolic status. 18 cases had an angiogram either prior to a microvascular free tissue transfer (MFTT) or postero-lateral bone transplantation (Harmon 1945). Extensive soft tissue fibrosis and clinically apparent infections confirmed by positive wound culture in all 22 cases required management in 2 stages: eradication of all infected tissue and soft tissue coverage followed by delayed bone reconstruction.

The bone defect was filled with gentamicin-containing beads (Klemm 1976; Septopal, Merck, Germany) and the wound was covered with a flap. To maximize the concentration of gentamicin, postoperative drains were avoided in all cases. At an average time of 7 (5–12) weeks after revision, the flap was raised and the gentamicin beads removed. The bone defect was grafted with a massive cancellous or a free vascularized bone graft.

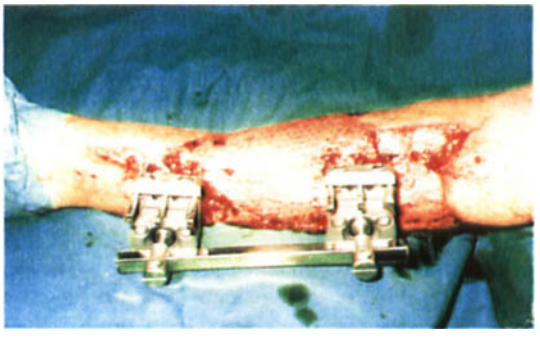
A MFTT was used in patients where a local pedicle muscular flap (PMF) was considered inadequate, due to local muscular injuries, the size and location of the wound, or if a vascularized bone transfer was scheduled. Fasciocutaneous flaps (FCF) were never used in the emergency situation, mainly due to difficulties in the assessment of the viability of the skin adjacent to the wound. However, in long-standing posttraumatic soft tissue and bone defects of reasonable size, and where wound conditions were stable, a FCF was considered reliable (Hallock 1989, Louton et al. 1989).

A total of 31 flaps were used (Table 2). Primary closure of the donor-site wound was always possible after a MFTT or a PMF. Otherwise, all exposed surfaces, including muscle-flap surfaces, were covered with meshed split skin grafts. Joint exercises were started in all patients as soon as soft-tissue conditions were stable. The stage and progress of fracture healing were followed by the technique described by Hammer et al. (1984) and Hammer (1985).

Figure 1. Case 14. Type III B injury in a 14-year-old girl.



The conditions at the first debridement 3 days after injury.



Due to gross instability in the AP-plane, the bilateral fixator was replaced by a unilateral device (the Hammer system) and the wound was covered with a free vascularized latissimus dorsi flap 14 days after injury.

The clinical appearance 3.5 years after injury. The patient rated her function as acceptable.

Table 2. The 31 flaps in 30 cases of Type III open tibial fractures

Type of flap	n	Vascularized bone
Microvascular free tissue transfer	12	4
Latissimus dorsi	8	1 (7th rib)
Iliac crest	3	3
Radial forearm	1	
Local pedicle muscular flap	13	
Soleus muscle	5	
Gastrocnemius muscle	8	
Lateral head	2	
Medial head	6	
Fasciocutaneous flap	5	
Cross leg flap	1	

Results

7 of the 15 acute cases had an early amputation. 6 of these had nonreconstructable injuries and were amputated within 24–48 hours (Cases 10, 18, 23, 35, 36, and 37). One patient (Case 6) had a technically salvageable limb but he had 7 additional compound injuries and was therefore not expected to benefit from a reconstruction. In addition, Case 32 had a complete traumatic amputation through the midshaft of the tibia with extensive soft tissue lacerations and arrived after approximately 9 hours of warm ischemia. Replantation was attempted but adequate revascularization was never achieved, and the amputation was completed 72 hours later.

In the other 7 cases, wound coverage was achieved at an average of 6 (1–14) days after primary debridement. In the 3 cases that underwent vascular repair after partial traumatic amputation, definitive soft tissue reconstruction was postponed until vascularization of the replanted limb was clinically stable.

There were no complications related to the flap procedures. Stable soft tissue conditions were achieved within an average time of 4 weeks and the bone defects were grafted 6–9 weeks later. 6 cases united without complications within 7 (3.5–12) months. Case 30 had a successful revascularization and an uncomplicated union of a tibio-calcanear arthrodesis 3 months after a composite MFTT from the iliac crest; an ipsilateral comminuted proximal tibial fracture did not unite until closed intramedullary nailing was performed 2.5 years after the injury. At follow-up (average 4 years), all 6 patients were able to walk with full weight bearing. Functional results were subjectively excellent in 2, good in 2 and acceptable in 3 injured limbs. All except 2 limbs had a substantial reduction in range of motion in the talocrural and subtalar joints. Nonetheless, all these 6 patients went back to gainful occupations or continued their educational program within an average time from injury of 1.5 years.

Among the late referrals, serious complications related to flap procedures were seen in 4 cases (Cases 2, 16, 20, and 24). In Cases 2 and 20 the PMF necrotized and was replaced by a free latissimus dorsi flap. Case 24 had a long-standing osteomyelitis, compromised soft tissue and a compound segmental fracture caused by a mine explosion; vascularization of the MFTT deteriorated rapidly, and with regard to the complexity of the injury, an amputation was performed after 4 days. Stable soft tissue conditions were achieved at a mean time of 2 (1–16) months after reconstruction. Besides 2 free vascularized bone grafts, an additional 17 autogenous cancellous bone grafts were required to achieve fracture healing. In 5 cases, anterior cancellous bone grafting was unsuccessful; 4 of these eventually healed after a posterolateral bone transplantation. Case 20 did not unite, but a custom-made brace permitted full weight bearing. Function after 4 (2–10) years rated good or acceptable in 16 of 21 late referrals; 20 of these patients were able to walk unaided.

Discussion

The advantages of cooperation between microvascular and orthopedic surgeons seem to be generally accepted (Meyer and Evans 1990, Ritchie et al. 1991). In spite of this, too many patients with compound tibial injuries are still managed with conventional orthopedic procedures with an increased risk of complications (Asko-Seljavaara et al. 1985, Byrd et al. 1985, Caudle and Stern 1986, Godina 1986), prolonged hospitalization and unsuccessful rehabilitation (Newington and Sykes 1991). However, in our experience, referral to a plastic or orthopedic surgeon depending on whether the problem is related to soft or hard tissues is not optimal. The management of either of these tissues cannot be properly performed without considering the complex relationship between these structures initiated by high energy trauma. In addition, the initial decision-making process is simplified if the whole spectrum of reconstructive problems and possibilities can be discussed on a multidisciplinary basis (Ruttle et al. 1984, Esterhai et al. 1990). Inadequate removal of devitalized and infected tissue, the use of split skin grafts on a poorly vascularized recipient bed combined with fear of creating an uncoverable defect and failed open cancellous bone grafting among patients referred late are probable explanations for failures. This emphasizes the importance of an early recognition of tibial injuries which may benefit from an early assessment by more than one specialist.

In a series of 532 patients who underwent microsurgical reconstruction following trauma, Godina (1984) compared 3 different groups. Group I underwent free flap transfer within 72 hours after injury, Group II between 72 hours and 3 months and Group III between 3 months and 13 years. The flap-failure rate was 1, 12 and 10 percent, respectively. However, a MFTT within 72 hours puts very high demands on the organization and the available resources—a 24-hour service involving a large number of surgeons with experience in microsurgical techniques. Furthermore, acute coverage may require more extensive debridement, which eventually will exclude the possibility of coverage with a relatively simple PMF. Coverage after 4–7 days, on the other hand, allows for a more accurate assessment of the extent of the injury. In addition, delayed coverage will give the surgical team more opportunities for a detailed and appropriate assessment of patient-related variables (Edwards et al. 1979). An important contributing factor for the poorer outcome after late management is that microsurgery is more difficult due to scar tissue and fibrosis that extend beyond the initial area of injury and involve the vessels (Weiland et al. 1984, Yaremchuk 1989). Godina (1986) found the predominant cause of flap failures in delayed and late reconstructions to be anastomotic complications. A similar experience was reported by Khouri and Shaw (1989) in a series of 304 consecutive cases managed with microvascular free flaps. A further contributing factor for the poorer outcome among late referrals is the need for more extensive resection of infected and necrotic bone (Christian et al. 1989). As a consequence, bone loss, that initially would have been suitable for a relatively simple cancellous bone graft, may be changed to a situation where a free vascularized graft must be considered (Weiland 1981). Even if free vascularized bone transfer may be successful (Newington and Sykes 1991), it is more costly and technically demanding, requires longer hospitalization time, and is not without serious complications (Weiland et al. 1984, Sowa and Weiland 1987).

We therefore agree with Lange (1989) that no patient with Type III tibial injuries should have an early amputation without prior consultation with an experienced center; the age of the patient seems to have no bearing on the success rate at limb salvage (Ritchie et al. 1991).

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