Bone debridement and limb lengthening in type III open tibial shaft fractures

No infection or nonunion in 9 patients

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ABSTRACT – We retrospectively reviewed a consecutive series of 9 patients with tibial shaft fractures and extensive soft tissue damage, who had completed treatment by means of bone resection and distraction. 4 patients had type IIIB fractures and 5 type IIIC. The median follow-up time after bone resection was 27 (12–43) months. All patients were treated with debridement of devitalized soft tissue and resection of dead bone at the fracture site. The median bone shortening was 4 (3–9) cm. Equal limb-length was restored by proximal corticotomy and lengthening. A free vascular flap in 5 patients and a local flap in 4 patients corrected the soft tissue loss. All soft tissue transfers were successful, except in 1 case, which healed after a new free flap was made. The median union time of the fracture was 8 (4.5–28) months from the injury and 7 (3–10) months from the time of bone resection. There were no deep infections or nonunions and no secondary amputations.

This series shows that bone debridement and limb lengthening, with a multidisciplinary approach, is often successful in salvaging limbs at high risk of amputation. ■

The decision whether to suggest salvage or amputation of a mangled lower extremity is challenging for the surgical team during the initial assessment. The presence of soft tissue contamination or devitalized soft tissue and/or bone fragments increases the risk of infection and nonunion. If a salvage procedure is chosen, fracture stabilization, wound irrigation, serial debridement, and soft tissue coverage will be essential in the early stage. Microvascular surgery has made soft tissue coverage possible, even in large defects (Hammer et al. 1992, Reigstad et al. 1992, Spiro et al. 1993). Although free muscle flaps appear to reduce the prevalence of infection (Mathes and Nahai 1980, Chang and Mathes 1982) and the time-to-union (Richards et al. 1986), osteomyelitis is the commonest complication in patients with attempted limb salvage with free flap coverage (Georgiadis et al. 1993). Inadequate debridement of devitalized bone may be the major cause of chronic infection (Damholt 1982, Swiontkowski 1989).

At our center, tibial shaft fractures complicated by infected nonunion have been treated by debridement of devitalized soft tissue and bone. Using a multidisciplinary approach, we have applied this technique also in the early stage of tibial shaft fractures with extensive soft tissue and avascular bone, to reduce the infection rate and union time. When necessary, a flap transfer can correct soft tissue loss and equal limb-length can be regained by distraction lengthening. We evaluated the outcome in 9 patients with tibial shaft fractures having extensive soft tissue damage, treated with resection of the devitalized bone at the fracture site and distraction lengthening.

Patients and methods

We retrospectively reviewed a consecutive series of 9 patients having tibial shaft fractures and extensive soft tissue damage, who had undergone treatment with bone resection and distraction osteogenesis between May 1994 and June 1997 at Sahlgrenska University Hospital (Table 1). The

Table 1. General table

A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	X
1	26	M	1	IIIB	C23	0	0	0	41	a	1	a	0	0	2	4.5	77	0	46	30	10	34
2	15	M	2	IIIC	C13	2,3	1	d	34	b	0	a	2	0	2	4	3	0	21	21	5	24
3	20	M	2	IIIC	A3	1	2	c	11	b	1	b	2,1	1	4	4	28	0	34	27	8	35
4	24	M	2	IIIB	C33	2,4	0	a	29	b	0	c	2,1	0	1	9	1	0	49	32	5	19
5	30	F	1	IIIB	B21	0	0	a,b	18	b	0	a	1	0	0	3	2	3	28	31	9	43
6	30	M	1	IIIB	B1	0	0	0	26	c	1	c	0	2	3	5.5	25	4	41	39	7	29
7	22	M	2	IIIC	C22	3	1	0	50	b	0	a	0	0	0	4	4	0	33	24	8	35
8	23	M	2	IIIC	C31	1	3	a,b	25	b	0	c	0	0	0	3.5	0	15	23	7	7	30
9	55	M	1	IIIB	A12	0	0	0	4	b	0	c	1	0	1	3	2	16	17	22	8	12

A Patient number
B Age
C Gender
D Type of trauma
- 1 fall
- 2 motorcycle acident

E Classification of soft tissue injury
F Classification of fractures (AO)
G Injured artery
- 0 none
- 1 popliteal
- 2 anterior tibial
- 3 posterior tibial
- 4 peroneal

H Type of vascular repair
- 0 none
- 1 venous graft to posterior tibial
- 2 venous graft to popliteal
- 3 suture

I Associated injury
- a head, unconscious
- b pelvis and lower extremities (other than limb studied), life -threatening
- c pelvis and lower extremities, (other than limb studied) not life-threatening
- d upper extremities

J Injury Severity Score (ISS)
K Primary treatment of fractures
- a intramedullary nail
- b external fixation frame
- c plate

L Complications after primary treatment
- 0 none
- 1 deep infection

M Type of flap
- a local fasciocutaneous flap
- b crossleg
- c free latissimus dorsi

N Complications related to bone resection and elongation
- 0 none
- 1 pin loosening
- 2 refracture

O Complications related to plastic surgery
- 0 none
- 1 partial flap necrosis
- 2 flap necrosis

P Secondary procedures
- 0 none
- 1 pin replacement
- 2 correction of external fixator
- 3 free latissimus dorsi flap
- 4 debridement of flap

Q Length of resection (cm)
R Time between trauma to resection/ weeks
S Time between bone resection and corticotomy/ weeks
T Time between corticotomy and healed lengthening/ weeks
U Time between resection and healed fracture /weeks
V Lengthening index (weeks/cm)
X Follow-up time (months)

median follow-up after bone resection was 27 (12–43) months. 5 patients had type III B tibial fractures and 4 type III C, according to the Gustilo et al. (1984) classification. The fracture type was classified using the AO system.

The median age of the patients was 23 (15–55) years and 8 were men. Motorcycle accidents had caused the injury in 5 patients and falls in 4. The median Injury Severity Score (ISS) was 26 (4–50). 2 patients had deep infections, 1 who had been initially treated with intramedullary nailing and multiple cancellous bone grafting (case 1), and 1 who had been primarily treated with plating and had a missed compartment syndrome (case 6). 1 patient had fallen from the fourth floor and also had an open pelvic fracture and a dislocated knee joint (case 5). 1 patient (case 8) had an associated open femoral fracture with an extensively mangled quadriceps tendon. After the femur was shortened 8 cm at the fracture site, sufficient soft tissue was available to cover the fracture. The equal length of the femur was later attained by proximal corticotomy and distraction osteogenesis over an intramedullary nail. He had also developed septic arthritis in the ankle joint, associated with wide draining cavities at the fracture site. In

Figure 1. Case 3 initially.

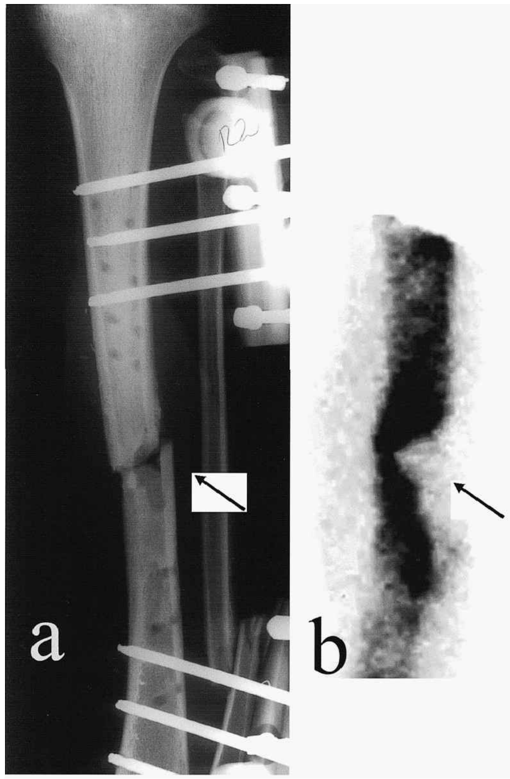

Figure 2. Shortly before bone resection, with sclerotic lateral cortex at the fracture site. Scintigram from the same patient shows the reduced activity in the same area (b).

3 patients, a scintigram was used preoperatively to verify the presence of devitalized bone (Figure 2).

At the last follow-up, the patients were examined by one of the authors and an unbiased observer. All patients assessed their pain intensity on a 100 mm visual analogue scale at rest and while walking. The degree of sensation was shown on a patient's drawing. The patients answered questions about their walking ability and employment. Patient satisfaction was measured on a 100 mm visual analogue scale, with the anchor points being "the worse result" (0 mm) and "the best result" (100 mm). Motion of the knee and ankle joint was measured with a goniometer.

The indication for tibial shortening was an excessive comminuted fracture or presence of devitalized bone at the fracture site. The indication for distraction osteogenesis was limb shortening of at least 3 cm. Deep infection or insufficient soft tissue coverage was a contraindication for corticotomy at the same time as the bone resection.

Treatment

The soft tissue defects were treated by a multidisciplinary team, including plastic and vascular surgeons, throughout the early treatment and late reconstructive surgery. All arterial injuries were treated by vascular surgeons, except in case 4 whose circulation recovered after acute shortening and fracture stabilization. Soft tissue coverage was achieved by a microvascular free latissimus dorsi transfer in 4 patients and a cross-leg flap in 1. In 4 patients (cases 1, 2, 5 and 7), major plastic surgery was avoided because bone resection reduced the size of the soft tissue defect so that a local fasciocutaneous flap with or without split-thickness skin grafting was adequate for wound coverage. We used the lengthening method described by DeBastiani et al. (1987). Avascular bone was removed until punctate bleeding was seen from the fracture ends. The fracture gap was then closed by immediate docking of the fracture ends (Figure 3). The fractures were stabilized by a

Figure 3. After resection of the devitalized bone (4 cm) and proximal corticotomy (a), 3 months later during the lengthening procedure (b) and 8 months (c) after corticotomy shortly following removal of the external fixation frame.

monolateral external fixation frame (Orthofix LRS, Bussolengo, Verona, Italy). In all patients, treatment was bifocal with a corticotomy in the proximal metaphysis. This method entailed division of the medullary bone and cortex, using a drill and osteotome. After 2 weeks, the bone segment was lengthened by 0.5 mm twice a day. After the completion of lengthening and maturation of the regenerated site, dynamization was performed to promote further corticalization. The fixator was removed when thorough corticalization of the corticotomy site and formation of callus on 3 of 4 cortices at the fracture site were seen (Figure 3).

Results

The median length of bone shortening was 4 (3–9) cm. The patient (case 1) who had a deep infection before bone resection was cured, with no recurrence at follow-up. All fractures healed without further procedures. The median time from the injury to the resection of the avascular bone was 4 (0–79) weeks. Corticotomy was performed at the same session as the resection of the dead bone in 5 patients and at a median of 9.5 (3–16) weeks after the bone resection in the other 4 patients. The median time-to-union of the fractures was 8 (4.5–28) months from the time of injury and 7 (3–10) months from the time of bone resection. Corticalization of the lengthening site was achieved at a median of 33 (17–49) weeks after bone resection. The median lengthening index (total treatment time per cm of lengthening) was 8 (5–10) weeks/cm. Equal lengths were achieved in all patients, except in a non-compliant patient (case 9), who had a residual discrepancy of 1 cm. This patient also developed a recurvatum deformity of 15° at the corticotomy site. No other malunion was seen. There was no clinical evidence of neurological compromise or compartment syndrome related to corticotomy, distraction or fixation.

All soft tissue transfers healed uneventfully, except in 1 patient (case 6). After a second free latissimus dorsi flap from the opposite side, the soft tissue also healed.

The median pain score was 15 (0–40) at rest and 48 (0–66) when walking. Abnormal sensation over the distribution of the superficial peroneal nerve was reported in 3 patients, suralis nerve in 2 patients and posterior tibial nerves in 1 patient. No changes were noted in neurological status after surgery. All could walk without an aid. 2 patients walked a distance of less than 1 km, 5 patients up to 3 km, and 2 patients more than 3 km. 4 patients returned to work, 3 were retired on a disability pension, and 2 were unemployed. The mean general satisfaction with the outcome was 82 (30–99). No patient preferred limb amputation to salvage. The range of motion in the knee and ankle joints

Table 2. Knee and ankle range of motion

	Knee joint				Ankle joint			
	Flexion		Extension		Dorsiflexion		Plantar flex.	
Case	left	right	left	right	left	right	left	right
1	120	120	0	0	10	10	60	45
2	120	120	0	0	0	10	50	50
3	120	120	0	0	–30	10	60	60
4	130	130	0	0	5	15	60	30
5	110	110	0	0	15	5	50	50
6	130	130	0	0	5	0	45	0
7	150	150	0	0	5	30	50	50
8	130	60	0	–10	15	0	60	0
9	70	120	0	0	0	10	10	45

on the injured side were compared to the uninjured side. Side-to-side differences were seen in knee flexion and both directions in the ankle joint (Table 2).

Pin-site infections occurred in all patients. They resolved satisfactorily with local incision and antibiotic treatment, except in 3 cases, who also had pin loosening. 1 required resiting of the pin on 1 occasion, while in the other 2 patients, pin loosening occurred near the time of corticalization of the lengthening site. These 2 patients used a protection for 4 weeks after frame removal. Arthrodesis of the ankle joint was needed in 2 patients. 1 patient (case 6) developed significant equinus deformity and stiffness of the ankle joint with severe pain. Before arthrodesis, lengthening of the Achilles tendon and posterior capsulotomy were performed unsuccessfully. The other patient (case 8) had an excessive comminuted tibial shaft fracture with extension to the ankle joint. He had septic arthritis, which was cured by antibiotics and draining before resection of the devitalized bone at the fracture site. Arthrodesis was performed at the same time as shortening.

3 patients had refractures, which were caused by adequate trauma. 1 was injured in a bicycle accident (case 3), 1 while playing football (case 2), and another in a fall from a rock while fishing (case 4). The refracture in case 2 was located at the corticotomy site and in the other 2 at the resection site. In case 4, the refracture was treated with intramedullary nailing, while in the other 2, functional bracing was used. All refractures united uneventfully.

Discussion

In this series of patients, there were no deep infections, nonunions, or secondary amputations. All fractures healed without bone grafting. The soft tissue transfers were successful, except in 1 case, which healed after a use of a new free flap.

Deep infection, neurovascular injury and amputation are common in open tibial fractures with severe soft tissue loss. Gustilo et al. (1984) reported infection rates of 4% in type IIIA tibial fractures, 52% in type IIIB, and 42% in type IIIC, while amputation rates were 0%, 16%, and 42%, respectively. Georgiadis et al. (1993) found a high rate of complications in 22 patients with IIIB open tibial fractures and 5 patients with type IIIC, who were treated with limb salvage. 12 patients had osteomyelitis, 9 had vascular problems needing reoperation and amputation was necessary in 4 patients. 2 of our patients developed active deep infection at the fracture site, before referral to us. 2 infections were cured after debridement of both devitalized soft tissue and dead bone. There were no cases of deep infection in the remaining 7 patients, who had been treated initially with this regime. Our efforts to detect devitalized bone at the fracture site may explain the differences in the rate of deep infection between the study by Georgiadis et al. (1993) and ours. Dead bone is a medium for bacterial colonization and must be debrided (Hierholzer and Hierholzer 1982). The numerous techniques for limb lengthening have removed this last objection to excision of all devitalized bone (Schrodt et al. 1971, Manning 1978, Wagner 1978, Hood and Riseborough 1981, Kempf et al. 1986, Paley et al. 1990). Conventional methods with massive cancellous grafts have proved to be inferior to callus distraction, as regards major complications (Cierny and Zorn 1994). In our patients, all fractures healed, thanks probably to the presence of viable bone at the fracture site, covered by soft tissue with adequate circulation.

The rate of complications with limb-lengthening surgery is related to the surgeon's amount of experience and it has a substantial learning curve. Gustilo grade IIIB and IIIC tibial fractures with a large segmental defect have been managed by distraction osteogenesis through fractures or corticotomy (Atkins et al. 1998, Carrington et al. 2000).

Song et al. (1998) reviewed the results after tibial bone defects treated with internal bone transport, using the Ilizarov method in 14 patients with open fractures and 13 with infected nonunions. Two thirds of the patients had complications, including malunion, residual tibial shortening and refracture. Pin tract infection was the commonest complication. There was only 1 case of recurrent osteomyelitis. One third of our patients had pin tract infections and refractures. The latter were the results of new trauma among active young people and might have been avoided by longer treatment in a brace. However, major complications are commoner during distraction osteogenesis using Ilizarov's method, than with DeBastiani's method (Price and Mann 1991, Dahl et al. 1994).

After bone resection, limb lengthening can be achieved by one of 2 methods: segment transport or immediate docking of the fracture ends. The disadvantages of bone transport are docking site problems, such as malalignment, and the need for supplemental bone grafting of the docking site to facilitate healing. Immediate docking at the fracture site results in excess soft tissue around the shortened area, with some risk of occlusion of the artery. However, in these injuries the excess soft tissue is needed to minimize the risk of joint contractures.

Our patients had no distraction-related neurovascular compromises and no premature or delayed corticalization. In general, limb lengthening in patients with posttraumatic shortening is a question of restoring bone and otherwise intact soft tissue to their initially normal lengths. Thus, lower complications rates can be expected with limb lengthening after posttraumatic shortening than that with congenital shortening or deformity (Paterson 1990, Garcia-Cimbrelo et al. 1992, Johnson 1994). Although, pin-site infections occurred in all patients, we did not perceive this as a major problem, since all of them were resolved by using debridement and antibiotic therapy. A high prevalence of pin-site infection should be expected during treatment with external fixation for a longer period of time. Usually, immobilization results in osteoporosis which, in combination with a pin-site infection, can lead to a loss in pin anchorage.

In conclusion, patients with grade III open tibial fractures should be initially treated with irrigation, serial debridement, antibiotic therapy, adequate fixation and given sufficient viable soft tissue coverage. Resection of the devitalized bone, simultaneous compression of the fracture gap and, if required, limb lengthening, are treatments which result in low rates of infection and nonunion. Consequently, this treatment regime is often successful in salvaging limbs which otherwise would have been at high risk for amputation.

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