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Treatment of tibial bone defects with the Ilizarov circular external fixator in high-velocity gunshot wounds

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Summary. *One of the applications for circular external fixators is the treatment of large-bone defects which may be difficult to manage with conventional methods. Successful results have been reported with the use of circular external fixators, particularly in the treatment of infected tibial pseudoarthroses and those with bone loss. In this study, a total of 43 cases with tibial bone defects (18 infected) as a result of high-velocity gun-shot injuries were treated with circular external fixators between January 1, 1988 and December 31, 1995. The mean follow-up period was 50 months (range: 28–98 months) after the removal of the Ilizarov device. Satisfactory union was obtained in 40 cases without any major complication or additional surgical intervention, in spite of the large and in some cases infected defects. We conclude that this is a safe method for the treatment of infected or noninfected tibial bone defects.*

Résumé. *Une des applications des fixateurs externes circulaires (FEC) est le traitement des pertes de substance osseuse qu'on ne peut pas traiter facilement avec les méthodes classiques. Des auteurs rapportent les résultats de traitement dans des cas de pseudarthrose infectée du tibia. Ils rapportent les résultats de 48 perte de substance du tibia secondaire à des blessures par arme à feu. 18 d'entre-eux étaient infectés. Le délai d'observation moyen était de 50 mois (28–98 mois) après ablation de l'appareil d'Ilizarov. Dans 40 cas, il n'y as pas eu de complication majeure ni de nécessité d'intervention chirurgicale complémentaire. En conclusion, c'est une bonne méthode pour traiter les pertes de substance osseuse du tibia infecté ou non.*

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Introduction

The treatment of infected or noninfected tibial non-union, and particularly of grade-III open tibial fractures with segmental loss, is a challenge to orthopaedic surgeons. Sequestrectomy and debridement of infected bone and soft tissue with stable fixation are essential. The treatment usually takes years, with multiple surgical procedures, and the results may be poor. The resulting shortening, instability or bone loss may be difficulty to overcome with conventional grafting and stabilisation [2]. In the lower limb, and especially the tibia, the difference between the diameters of transplanted and host bone may produce potential stress concentration at the junction, which prolongs recovery time, eventually leading to refracture and pseudoarthrosis [2, 5].

The Ilizarov technique enables simultaneous correction of the deformity and formation of new osseous tissue without the use of bone graft, and allows weightbearing during the period of treatment [6, 10].

Other methods used in the treatment of tibial defects are autogenous, cancellous bone graft with or without an external fixator, the Papineau technique, a spacer with a prosthesis and massive allografts [2, 5, 7]. In gunshot wounds, since there is a high risk of infection due to contamination, none of these techniques are applicable. In this study, the results of management of infected and uninfected defects in the tibial bone with circular external fixators are assessed.

Patients and methods

Forty-three patients with tibial bone defects were treated with an Ilizarov circular external fixator (CEF) at the Orthopaedic and Traumatology Department of the Gülhane Military Medical Academy between January 1st, 1988 and December 31st, 1995 (Table 1). The injuries were due to high velocity gunshot wounds and 18 were infected. All the patients were male, with an average age of 24.7 years (range: 14–72) at the time of the index operation. The right side was affected in 19 cases and the left in 26. The length of the defect ranged from 2 to 15 cm with a mean of 9.7 cm. Bone loss was due to the initial injury in 30 cases, because of resection of infected or necrotic bone in 13 and excision of a tumour in 2. Twenty-two of the patients had been operated on previously using internal or external fixation in other hospitals.

In 23 patients the Ilizarov fixator was our primary method of treatment. The soft tissue defects in 7 patients were treated without additional plastic surgery during the transfer of the segment. Free flaps were applied in 4 cases with grade-IIIB open fractures at least two months before applying the circular external fixator. The remaining 12 patients were treated with fasciocutaneous flaps and skin grafts at the same time as the application of the fixator.

Distraction at the corticotomy site and compression at the docking site (bifocal method) was performed in 41 patients, and distraction at two corticotomy sites with compression of the docking site (trifocal method) was carried out in two others.

Technique of operation

Scaled radiographs were used to determine limb length discrepancy and the length of the bone loss. The levels for pin fixation to accommodate the four rings of the CEF were deter-

Table 1. Details of 45 patients who had Ilizarov treatment for tibial bone defects

Case	Age	Side	Fracture type	Infection	Bone loss (cm)	Delay between trauma and starting CEF use (months)	Period of CEF treatment (months)	Follow-up (months)
1	23	L	III-A	–	6	1	5	28
2	22	L	III-B	+	11	4	10	37
3	20	R	III-C	–	5	2	4	30
4	21	R	III-B	+	15	4	18	52
5	24	R	III-A	–	8	5	9	42
6	20	L	III-A	–	8	1	10	40
7	24	R	III-C	++	10	1	10	40
8	23	R	III-A	+	2	2	6	36
9	38	L	III-A	–	7	6	11	46
10	21	L	III-A	–	6	2	10	45
11	24	L	III-B	–	8	3	13	42
12	26	L	III-A	–	6	2	9	42
13	27	L	III-B	+	11	3	20	58
14	23	L	III-A	++	8	12	11	45
15	28	L	III-B	–	10	8	17	58
16	44	L	III-B	–	14	4	22	62
17	21	L	II	++	15	16	24	98
18	30	R	III-B	–	8	4	12	44
19	24	L	III-B	–	8	1	12	44
20	22	L	III-C	+	8	2	11	46
21	29	R[a]	III-C	+	15	1	22	62
22	39	L	III-C	++	14	4	21	62
23	24	R	III-B	–	10	6	17	52
24	21	R	III-A	–	8	2	9	40
25	23	L	III-B	–	13	3	20	58
26	27	R	III-B	+	15	6	28	62
28	28	L	III-B	–	7	2	11	66
30	23	L	III-B	–	12	4	20	59
31	14	L	III-A	+	15	3	24	58
32	22	R[a]	III-B	+	15	5	28	62
33	22	L	III-A	–	11	–	18	59
34	18	R	III-B	–	8	–	18	59
35	30	R	III-B	–	14	6	22	58
36	29	L	III-B	+	9	2	14	46
37	21	L	III-A	+	10	2	12	46
38	21	R	III-B	–	11	4	18	58
39	23	R	III-B	–	10	3	10	46
40	22	L	III-B	+	8	4	11	46
41	21	R	III-B	+	8	3	10	46
42	24	R	III-B	–	8	2	11	46
43	38	L	III-A	–	6	1	8	40
44	21	L	III-A	+	8	2	6	34
45	20	L	III-A	–	8	2	10	38

[a] with major complication

mined preoperatively. The appropriate diameter of the ring was chosen according to the diameter of the calf of the patient. The ideal diameter allows 1 cm of space between the ring and the calf anteriorly and 3 cm posteriorly, in order to prevent eventual oedema. The transport ring was fixed with three threaded rods connected to the proximal and distal rings, while another ring was connected with the frame with three other rods.

The operation was performed under general or spinal anaesthesia. Through an anterolateral approach necrotic and infected bone was excised. The proximal and distal ends of the defect were divided transversely to obtain viable bone. The fibrous and granulation tissue was excised, and the wound irrigated with antibiotic solution. A suction drain was installed and the skin closed.

Two 18 gauge K-wires from each ring were passed from the head of the fibular, crossing each other, so that they were positioned in the middle of the transport bone, running from the posterolateral to the anteromedial line. An additional transverse K-wire was inserted proximally and distally from where the proximal and distal osteotomies were planned. We did not use a calcaneal ring. Low speed hand drills were used for the cortices, and a hammer for the rest of the procedure, in order to lessen the neurovascular injury. We performed the circumferential subperiosteal corticotomy proximally in order not to cause direct damage to the medullary canal and to leave it in alignment. The procedure was usually carried out just distal to the attachment of the patellar tendon, but in 8 cases it was made to the distal third of the tibia. Corticotomy was carried out through a small anterior incision.

We used the intact fibular to maintain stability, but a distal fibular osteotomy was used when extreme lengthening was required in 9 patients. We then made a gap of 0.5–1 cm in the fibular to prevent early union. An osteotomy of the fibular was also required to correct mal-alignment if necessary.

On the 7th day after operation, internal distraction was started at a rate of 0.25 mm (one turn of the nut to 45°) four times a day, giving a total of 1 mm per day. External lengthening was also carried out at the same rate. Radiographs were taken every 15 days to monitor the formation of periosteal and endosteal callus and the opening of the corticotomy site.

The patients were allowed to walk, partial weightbearing, 48 hours after operation, and an intensive programme of physiotherapy was arranged to prevent stiffness in the knee and ankle. Full weightbearing was allowed 20 days after operation.

When union appeared to have been achieved, the frame was dynamised for three weeks, and later the whole apparatus was removed without anaesthesia. A cast was then applied for one month to prevent refracture. Antibiotics were not used.

Results

Treatment was completed in all patients. Radiographs of three cases are show in Fig. 1–3. The follow-up period after removal of the apparatus was for between 28 and 98 months, with a mean of 50 months. Satisfactory union was obtained in 40 cases. No more than 1 cm of discrepancy of limb length was found. All infected cases healed without a second operation. An angular deformity of more than 5° was not seen. Twelve out of 18 patients with stiffness of the ankle or knee joint regained their full movement after early weightbearing and exercises. No neurological complications were seen. All the patients were satisfied with their results. Thirty two of the 43 patients returned to their previous jobs. The remainder required different employment. The results of treatment and the complications encountered were assessed according to the criteria described by Paley [9, 10].

Pain, which responded to medication, was the most frequent complaint, being encountered in 25 cases. There were eight pin tract infections which healed with local care. Equinous deformity of the foot occurred in 4 cases and was treated by lengthening of the tendoachillis 1.5 months after removal of the fixator. Delayed ossification of the docking site was seen in 5 cases and was managed by alternating 5 days of compression with 5 days of distraction for about 25 days. Flexion contracture occurred in 2 knees and was treated by arthroscopic release. Four patients had unacceptable scarring which was managed by excision and grafting.

Three major complications occurred. In 2 patients refracture at the docking site occurred following premature removal of the apparatus. They were successfully treated by reapplication of the external fixator. In another patient stability was lost because of extensive porosis leading to a fracture of the regenerate bone site with malunion. Reoperation is planned.

Discussion

The repair of defects of the tibial bone with autogenous cancellous bone graft, as recommended in the literature [7, 8], can be regarded as an alternative to this method. Reconstruction by means of vascularised bone grafts has yielded successful results in the treatment of nonunion [12]. Bone morphogenic protein has gained popularity in the treatment of segmental bone defects and nonunion [3]. The functional limitation in these methods due to the relatively long period needed for union and remodelling is a major disadvantage, and is contraindicated in the presence of infection.

The long period of application of the Ilizarov apparatus may seem to be a disadvantage, but does not present a problem in practice [11]. Most patients returned to their normal daily activities. Early weightbearing and functional use of the limb prevent osteoporosis, which is a frequent problem with other methods requiring long term stabilisation. This dynamic system of osteosynthesis allows axial compression of the fracture site, and this probably stimulates the generation of bone.

Delayed union of the target site, limb length discrepancy, refracture, axial deformity, joint stiffness, skin and pin tract problems and difficulties with adaptation to the frame may be encountered [4].

The prerequisites for a successful outcome with a low incidence of complications are a good knowledge of the apparatus and technique, careful preoperative preparation, a skilled surgical team, and close follow up of the patients after operation. Patient compliance is a decisive factor. Preoperative psychological evaluation and detailed explanation of the procedure, with the long follow-up needed, are required to achieve this.

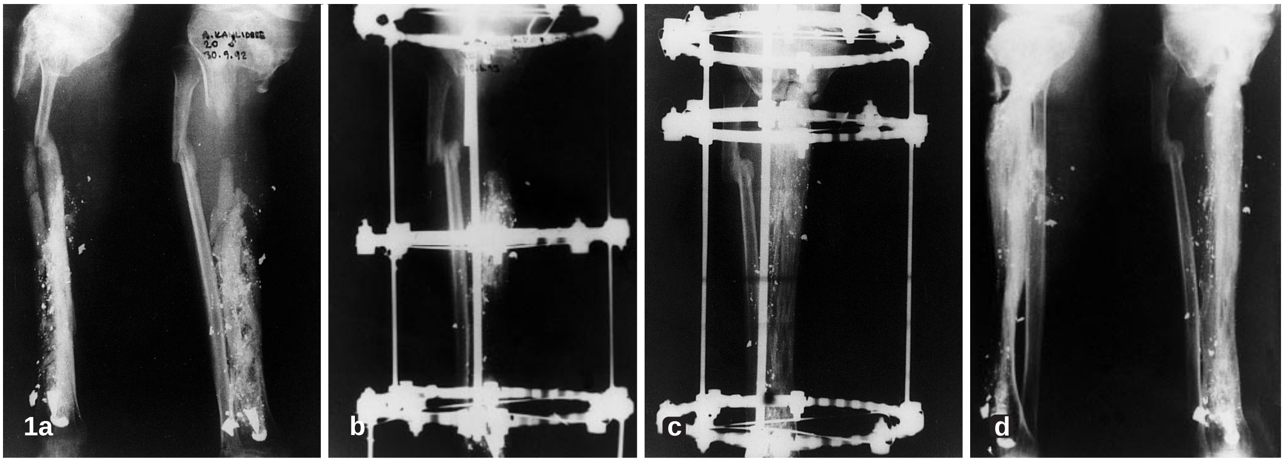

Fig. 1. Case 4. **a** Preoperative radiograph. **b** At 9 months after surgery. **c** At 16 months after surgery. **d** After removal of apparatus

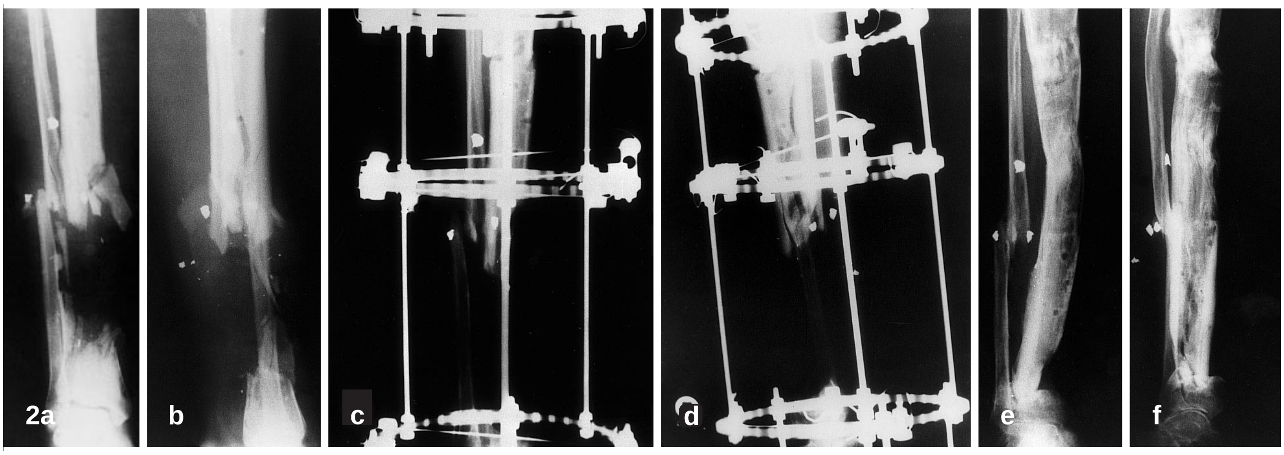

Fig. 2. Case 23. **a, b** Preoperative AP and lateral radiographs. **c, d** The AP and lateral views at 2 weeks after surgery. **e, f** The AP and lateral views at 7 months after removal of the apparatus

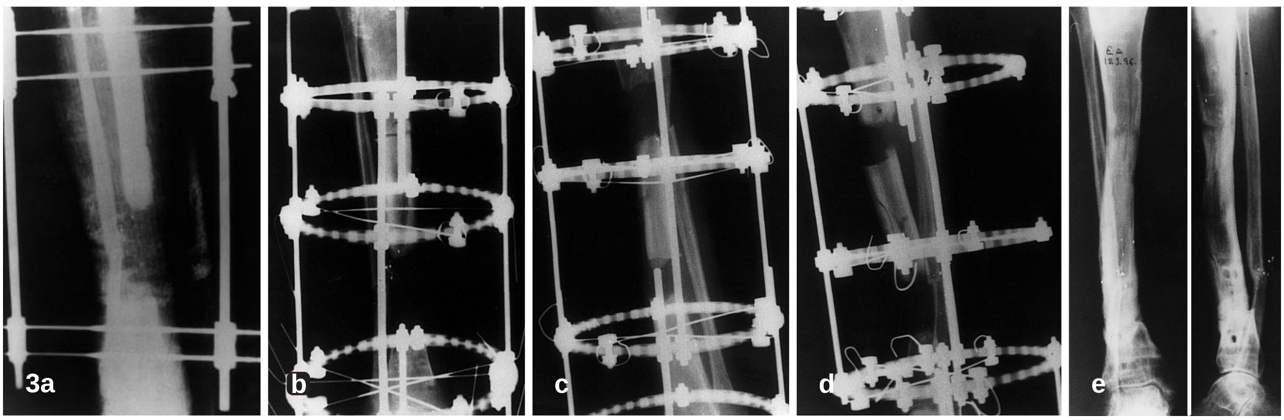

Fig. 3. Case 24. **a** Preoperative radiograph. **b** At 2 weeks after surgery. **c, d** The AP and lateral views at 3 months after surgery. **e** Appearance 6 months after removal of the apparatus

Our success in the treatment of the 18 infected cases without antibiotics probably depended upon the aggressive serial debridement of necrotic and infected bone, as well as the increased intramedullary blood flow following corticotomy. Although this procedure may be against the philosophy of Ilizarov, our method prevents infection and promotes rapid healing.

We have found the Ilizarov technique to be effective in the treatment of complicated defects in tibial bone. It allows for the simultaneous treatment of bone loss, infection, nonunion and deformity. Although most authorities prefer to transport with four rods for greater stability, we have found three threaded rods to be quite satisfactory for internal and external lengthening.

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