Eur J Orthop Surg Traumatol (2014) 24:403–408
DOI 10.1007/s00590-013-1204-3

ORIGINAL ARTICLE

Management of open infected comminuted tibial fractures using Ilizarov concept

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Received: 21 August 2012 / Accepted: 25 February 2013 / Published online: 9 March 2013

Abstract
Background Bone loss is very common in high energy trauma. It could be treated either by amputation and prosthesis or by reconstruction of both bony and soft tissue structures. The choice of treatment in a given case must be based on the assessment of the local and general condition of the patient such as regional neurovascular supply, and the residual articular and muscular function. Reconstruction may require bone grafts, tibiofibular synostosis, free microvascular soft tissue or bone transplants. The use of Ilizarov concept gives another option for treatment of bone defects. In this study, infected tibial fractures were treated using Ilizarov concept.
Patients and methods Twenty-eight patients (20 males and 8 females) with open comminuted infected fracture of the tibia were included. After debridement, all cases had variable amount of bone defects and were treated using Ilizarov technique. Follow-up was for at least 1 year. Filling of the bone defect was achieved either by compression–distraction method in 13 cases (group I) or by means of bone transport in the other 15 cases (group II).
Results The results were judged as excellent in 16 patients, good in 9 and fair in 2, while one patient was of poor result. Type of fracture, age of the patient and sex had no statistically significant relation with the final end results. Furthermore, there was no significant difference between the two groups. The average external fixator index was 45 days/cm (range from 35 to 70 days/cm). The mean external fixator index was less in group I.
Conclusion In the management of infected comminuted tibial shaft fractures, bone transport is indicated for the treatment of major bone loss, whereas compression–distraction is suitable only for treating less extensive bone gaps.

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Keywords Ilizarov · Open fractures · Tibial fractures

Introduction

Post-traumatic bone loss can occur immediately during injury or as a result of debridement of devascularized or contaminated bone fragments. This could be treated by ablative techniques as amputation and prosthesis or by reconstruction of bony and soft tissue structures. Ablation therapy achieves results rapidly, whereas reconstruction involves a long treatment period [1, 2]. Reconstruction may require bone grafts [3], tibiofibular synostosis [4], free microvascular soft tissue or bone transplants [5]. The choice of treatment in a given case is based on the assessment of the local and general condition of the patient. Local factors which must be taken into consideration include regional blood and nerve supply, and the residual articular and muscular function. Reconstruction is indicated only if local factors suggest that a good functional recovery can be obtained. A good functional result depends on the restoration of the length and alignment of the injured bone. The technique proposed by Ilizarov permits progressive lengthening of the bony segment treated or the transport of a bony fragment of adequate size in line with the longitudinal axis of the bone [6].

Patients and methods

During the period between 2007 and 2009, 28 patients (20 males and 8 females) with open (up to Gustilo grade IIIA),

comminuted diaphyseal tibial fractures were treated using Ilizarov concept. All cases were presented with devitalized bone fragments and uncontrolled infection. Intra-articular fractures and fractures with vascular insult were excluded. The average age was 32 years (20–55 years). According to AO classification, 10 cases presented with type A1 fracture, 8 cases presented with type A2 fracture, 6 cases had type B1 fracture while the remaining 4 cases had type B2 fracture.

As a primary treatment, all cases were subjected to thorough debridement and removal of all the devitalized tissues. Primary stabilization of the fracture was achieved using casts in 8 cases and simple monolateral external fixator in the other 20 cases.

Definitive treatment started after the initial trauma by an average of 1 month (range 3–6 weeks) depending on the general condition of the patient and the local condition of the affected limb. By this time, all cases were complicated with infection with a variable amount of pus discharge. Debridement of all the remaining infected and loose bone fragments was performed. Filling of the bone defect was achieved using Ilizarov concept through one of two ways; either by bone transport or by means of compression-distraction.

The compression–distraction technique (Fig. 1) implies reconstruction of bone defect by initial compression and closure of the gap and thus shortening of the segment involved. Excision of a segment of the fibula makes acute compression easier. After acute compression was done, an interval of at least 30 min was left to assess the vascular condition. Vascular assessment was monitored by feeling of the pedal pulse, the use of pulse oximeter and Doppler blood flow. If any manifestations of ischemia started to occur, then redistraction to the original defect was made immediately and the fracture was treated by bone transport technique. After sufficient perfusion of the affected limb was repeatedly confirmed, bone graft was immediately applied to the compression site. Osteotomy was then performed in the submetaphyseal region. After a period of 1 week, gradual distraction was started at a rate of 0.5 mm/day for 10 days. A follow-up X-ray was made to assure good callus formation at the regenerate site. Distraction was then completed at a rate of 1 mm/day to gain the initial length of the bone.

In the bone transport group (Fig. 2), an osteotomy was performed at submetaphyseal area proximal or distal to the bone defect. After an interval of 1 week, gradual transport of the detached segment toward the bone gap was started at a rate of 0.5 mm/day for 10 days. A follow-up X-ray was made to assure good callus formation at the regenerate site. Transport was then completed at a rate of 1 mm/day till the segment reaches the end of the bone gap named the docking site. After the transport was completed,

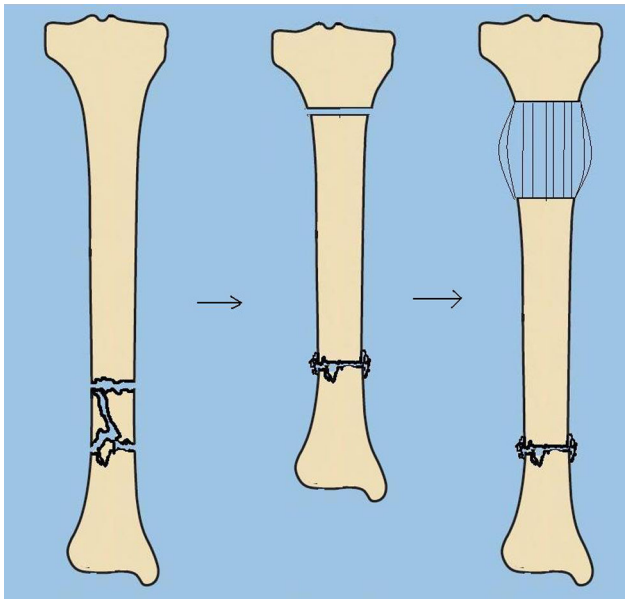

Fig. 1 Concept of compression distraction technique

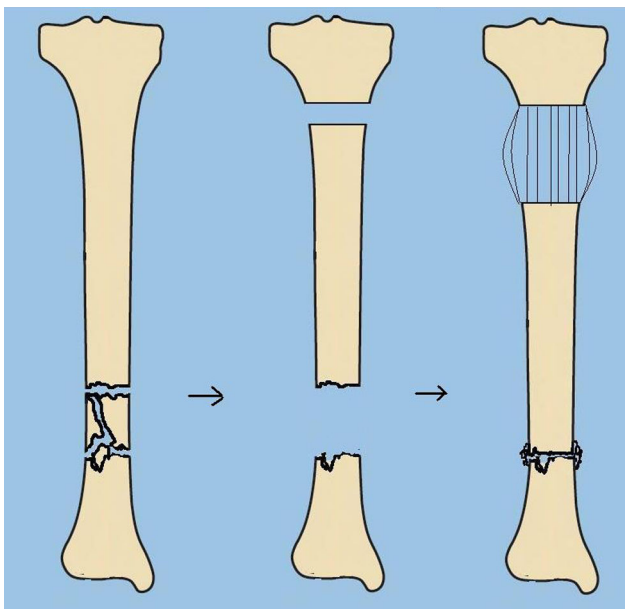

Fig. 2 Concept of bone transport technique

refreshment of the bony ends and bone grafting was performed. In both techniques, the frame was then left for more 3–6 months waiting for complete consolidation of the regenerate site.

The average size of bone defect was less than 3 cm in 2 patients, 3–5 cm in 20 cases and more than 5 cm in 6 patients (Table 1). The 6 cases with bone defects of more than 5 cm were treated primarily by bone transport technique, while cases with less amount of bone loss (22 patients) were subjected initially to trial of acute

compression with close monitoring of the limb vascularity both intra and postoperatively. Intraoperatively, 7 of these 22 patients developed vascular impairment and they were shifted to the bone transport technique. The remaining 15 cases were treated by compression–distraction method.

Postoperatively, 2 patients with a 4-cm bone defect, who were initially included in the compression–distraction group, developed manifestations of decreased limb perfusion manifested by sluggish Doppler flow and delayed capillary filling during the immediate postoperative period. In both cases, re-distraction at the fracture site was obtained and then bone transport was started and therefore they were added to the other group.

Patients were classified according to the method of definitive treatment into two groups, the compression–distraction group (group I) included 13 cases and the bone transport group (group II) included 15 cases. The aim of the work was to evaluate the results of treating post-traumatic infected bone defects in tibial fractures, using Ilizarov concept, and to determine whether there is a significant advantage of one method over the other. Furthermore, the aim was to detect the maximum length of the gap that could be closed acutely.

Patients were kept hospitalized in the first week postoperative to get training about wound and frame care and to learn how to make gradual lengthening of the distraction rod in the Ilizarov frame. Patients were sent home after one week, and a periodic follow-up was done regularly every 2 weeks to assure good progress of the distraction and the transport. Patients were allowed to bear weight partially using 2 crutches after 2 weeks of surgery.

Results

The results were assessed based on both the objective clinical and radiographic evaluation and the subjective limb function and patient's satisfaction of El-Rosasy modification of Paley's system of results evaluation [7]. The final results were considered excellent, good, fair or poor based on these findings in all cases.

Table 1 Distribution of the cases according to the size of bone defect

Size of bone defect after debridement (cm)	No. of cases
<3	2
3	8
3.5	3
4	2
4.5	2
5	5
>5	6

The results were judged as excellent in 16 patients, good in 9 and fair in 2, while one patient was of poor result. There was no significant relation ($P > 0.05$) between the end results and age or sex of the patients. Also, there was no significant effect ($P > 0.05$) of the AO type of the fracture on either the method of treatment or the final end results. The Ilizarov frame was placed for transport and until bone was solid in an average of 10 months (range 7–14 months). External fixator index, which is the number of months the patients wore the frame per cm of lengthening, ranged from 35 to 70 days/cm (average 45 days/cm). The mean external fixator index was less in group I. In group II, after complete transport of the bone fragment, all patients needed a second-stage refreshment and bone grafting at the docking site in order to enhance union.

An example of the first group is a 25-year-old male with a neglected open comminuted fracture of the proximal third of the left tibia (Fig. 3a). The defect was 3 cm after debridement. Acute compression was done with gradual distraction from a distal osteotomy (Fig. 3b). Complete consolidation was achieved within 4 months with excellent end result (Fig. 3c).

An example of the second group was a diabetic 45-year-old male who was presented 30 days after the initial trauma by an open infected mid-shaft fracture of the right tibia which was primarily stabilized by a monolateral external fixator (Fig. 4a). Thorough debridement and bone resection were done. The resulting defect was of 4 cm length. Gradual bone transport was performed (Fig. 4b). Bone grafting was done at the end of the transport, and consolidation was achieved after 7 months (Fig. 4c). His final end result was considered good.

Bending of the lengthening callus was observed in two cases in group II following the removal of the fixator. This required correction in a later operation and stabilization with another fixator. Their end results were considered good. Twenty patients suffered pin tract infection in one or more of the wires or pins, 12 of them were successfully treated by parenteral or locally injected antibiotics around the pin site while the other 8 cases were treated by reinsertion of the affected half-pins. Functionally, two other patients were complicated by stiff ankle because of the need to extent the frame down to the foot and this was improved by 4 months of physiotherapy with satisfactory final end results.

The case with the poor result was a diabetic, heavy smoker 45-year-old man who was presented by grade IIIA open comminuted fracture of the right tibia. At time of admission, he was treated by the same protocol of primary debridement. This was followed by bone transport after 3 weeks. During the process of bone transport, the patient developed extensive deep venous thrombosis and fulmination of infection. This necessitated removal of the frame

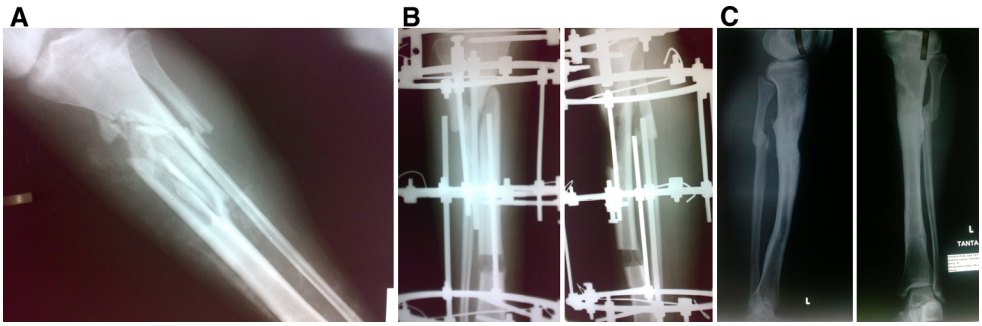

Fig. 3 25-year-old male with a neglected open comminuted fracture of the proximal third of the left tibia (**a**). The defect was 3 cm after debridement. Acute compression was done with gradual distraction from a distal osteotomy (**b**). Complete consolidation was achieved within 4 months with excellent end result (**c**)

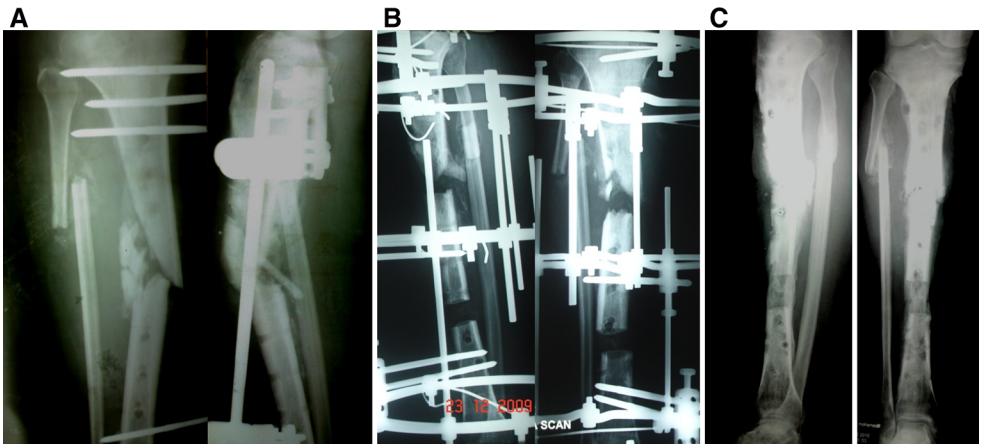

Fig. 4 Diabetic 45-year-old male who was presented 30 days after the initial trauma by an open infected mid-shaft fracture of the right tibia which was primarily stabilized by a monolateral external fixator (**a**). Thorough debridement and bone resection were done. The resulting defect was of 4 cm length. Gradual bone transport was performed (**b**). Bone grafting was done at the end of the transport, and consolidation was achieved after 7 months (**c**). His end result was considered good

and control of the DVT and infection. The patient developed severe peripheral ischemia which was ended by above knee amputation.

Discussion

Massive bone defects represent a challenge to the orthopedic surgeon. Numerous techniques have been used to fill these defects including autologous cancellous bone graft, allograft, ipsilateral vascularized fibular transport, bone transport and free vascularized fibular graft [1–6].

Autologous bone graft is good for small defects, but when the defect is large, more than one site may be used to harvest the graft, which adds to the morbidity of the patient. Allograft has its limitations in preparation and preservation, and free vascularized fibular transfer is a demanding technique. Furthermore, bone graft is not a valid option in the setting of infection. Bone transport to fill massive gaps is reliable, but has the disadvantage of having the frame on for long periods. It needs close follow-up to monitor the bone ingrowth, joint mobility and any pin tract infection, loosening or breakage. Physiotherapy is very important during and after bone transport until the frame is removed and the patient is back to normal activity [8].

Cierny and Zorn [9] compared the results of treating segmental tibial defects using Ilizarov bone transport and massive autologous bone graft, and the results were in favor of the Ilizarov method. Song et al. [10] compared the results of bone transport and vascularized bone graft in femoral defects and it was better in the bone transport group.

Different types of external fixators can be used for bone transport. Experimental and clinical experience showed that the most versatile system is the ring fixator with half-pin modifications. It can transmit gradual mechanical forces and movements of bone in any plane or any direction, and it has the potential to cross and protect active joints. Wires attached to the frame under tension, which can achieve stiffness equivalent to those of the much larger

diameter half-pins, exhibit unique self-tensioning effects that may facilitate load sharing with the supported bone either in distraction or in compression modes. As the use of half-pins results in half the number of sites of soft tissue transfixation, they can decrease the number of pin tract and soft tissue complications and can potentially improve the comfort of the patient and the tolerance to treatment [11, 12].

During the period between 2007 and 2009, a total of 28 patients, 20 males and 8 females, with neglected open comminuted tibial fractures with devitalized bone fragments and uncontrolled infection were treated using Ilizarov concept after thorough debridement of all devitalized and infected parts. The patients' average age was 32 years. All patients were treated using the Ilizarov circular frame in order to obtain the dual-benefit of stabilization of the limb and reconstruction of the defect in a minimum follow-up of 1 year.

According to El-Rosasy modification of Paley's system of results evaluation [7], the results of the present study were judged as excellent in 16 patients, good in 9 and fair in 2, while one patient was of poor result.

In this study, the external fixator index which is the number of days per centimeter of lengthened consolidated bone was 45 day/cm which is shorter than most studies [7, 8, 10, 11]. This is possibly due to the relatively young age of the patients in this study which is 32 years in average, and the fewer incidences of risk factors such as DM, smoking and osteoporosis which may have negative effect on the results were present in only two patients.

Patients were classified according to the method of definitive treatment into two groups, the compression–distraction group (group I) and the bone transport group (group II), to determine whether there is significant advantage of one method over the other. There was no significant difference ($P > 0.05$) between the end results of the two groups. However, the healing index was better ($P < 0.05$) in the compression–distraction group; this can be explained by the fact that the two bone ends are in contact from the beginning with no need for further time waiting for consolidation of the docking site. Saleh and Royston [13] compared the results of treating bone defects by bone transport with those of acute limb shortening followed by lengthening. They obtained excellent and good results in 75 and 25 % of their patients, respectively. They found a shorter treatment period and fewer complications with the limb shortening and relengthening method. They recommended that acute shortening should be considered for tibial defects less than 3 cm.

As regard the ambulation during the treatment period, patients in group II had better ambulation ability than patients of the other group, due to the absence of limb length discrepancy caused by acute shortening. The AO type of fracture had no effect on the final end results. This can be explained by the fact that all the intercalary loose infected fragments are removed which is the basis of bone apposition and comminution in AO classification.

The distance to which acute compression can be performed is judged by blood supply patency. Close monitoring of the vascularity of the limb is essential to avoid acute ischemia. In this series, two cases with 4-cm gap suffered doubtful perfusion patency during the immediate postoperative period after acute compression which was managed by making redistraction at the compression site after which rapid improvement of the vascularity has occurred. In this study, the maximum amount of bone defect which could be closed acutely was 3.5 cm. This is very close to what is reported in the literature. El-Rosasy [7] recommended that the safe limit for acute leg shortening is 3 cm, and a greater defect should be closed gradually to avoid neurovascular compression. However, a 0.5 cm more of acute compression was achieved in this study, which needs further future assessment in a larger series of patients. This may be of great value in managing bone defects. The limitation of this study and others was judged by potential limb vascularity after acute compression, which may have some individual variability and may be affected by some local factors such as vascular elasticity, atherosclerosis and adequate collaterals.

As with other studies [10, 12, 14], all the patients in group II (bone transport group) went through a second-stage bone grafting at the docking site at the completion of the transport. On the other hand, there was no need for this second procedure in group I. This is because grafting was made primarily in the first operation after acute compression.

The complication rate in the present study was minor in comparison with the devastating limb loss by amputation which may be a solution for these difficult situations. Twenty patients suffered pin tract infection in one or more of the wires or pins, 12 of them were successfully treated by parenteral or locally injected antibiotics around the pin site while 8 cases were treated by reinsertion of the affected half-pins. Functionally, two patients were complicated by stiff ankle because of the need to extent the frame down to the foot, and this was improved by 4 months of physiotherapy, with satisfactory final end results. Bending of the lengthening callus was observed in 2 cases in group II following the removal of the fixator. This required correction in a later operation and stabilization with another fixator with good end result.

In conclusion, Ilizarov concept is an effective procedure in the management of post-traumatic bone defects even in the presence of severe infection. While bone transport technique is effective for treating major post-traumatic bone loss, compression–distraction technique is only suitable for treating selected cases with less extensive bone

gaps, since compression may compromise the neurovascular structures.

Conflict of interest There is no conflict of interest in this study. This study was done in Tanta University. None of the authors received money for this research.

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