Acute compression and lengthening by the Ilizarov technique for infected nonunion of the tibia with large bone defects

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ABSTRACT

Purpose. To assess the Ilizarov technique in treating large infected tibial defects by resection of the infected focus, its acute compression, and gradual distant site lengthening.

Methods. 27 men (mean age, 39 years) with infected nonunion and large bone defects of the tibia underwent complete resection of the nonunion site, debridement, sequestrectomy, lavage, and Ilizarov ring fixator application. Patients underwent acute compression of the defect site, followed by distant site metaphyseal corticotomy for simultaneous lengthening. The mean length of resection was 10 (range, 6–17) cm. The mean follow-up was 27 (range, 25–39) months.

Results. The mean lengthening achieved was 10 cm, mean union time 6.3 months, and mean duration of consolidation 10.2 months. Functional results were excellent in 19 patients and good in 5. The union time was longer in older patients.

Conclusion. Acute compression and simultaneous lengthening can be used safely for treatment of large bone defects in the tibia. This avoids secondary operations at the docking site and reduces the duration of treatment.

Key words: bone lengthening; fixators, external; Ilizarov technique; osteogenesis, distraction

INTRODUCTION

Management of bone loss following severe open tibial shaft fracture is a challenge for orthopaedic surgeons. Secondary skeletal defects due to infected nonunion may require bone grafts, extensive debridement and local soft tissue rotational flaps, packing of the defects with Papineau-type open cancellous bone grafting, tibiofibular synostosis, and free microvascular soft tissue and bone transplants. The Ilizarov technique entails a segmental bone transport in which corticotomy is performed in the metaphysis and the bone is gradually distracted. The bone is thus lengthened by callus distraction and the defect gradually closed.

Segmental bone transport is used for large bone defects of >6 cm. Smaller defects (<6 cm) are treated by acute compression at the defect site with gradual lengthening by metaphyseal corticotomy. Many
authors have reported high complication rates, having to resort to further secondary procedures, and lengthy external fixation times with bone transport.\textsuperscript{13–18} Delay in the formation of regenerate at the distracted gap prolongs the external fixation time. The healing at the target site does not begin until intercalary fragment lengthening is achieved. Instability of the frame may cause delay in the regenerate formation and require additional procedures to maintain alignment, such as wire exchange and frame adjustment. Malunion and malalignment at the docking site can occur because of improper application of the Ilizarov assembly. Soft tissue interposition at the docking site prevents good compression. The transported segment of bone may deviate as it passes through soft tissue; this may lead to translation at the docking site. Bone grafting is necessary if the contact area at the docking site is small. The leading edge of the transported segment is relatively avascular.\textsuperscript{19} This may delay union unless the sclerotic end is trimmed. The choice between acute compression and bone transport for large bone defects has not been widely discussed.\textsuperscript{12} The safety margin for the amount of acute compression at the defect site has not been described in the literature. We aimed to demonstrate the success of treating large infected tibial defects by resection of the infected focus, acute compression of the focus, and subsequent gradual distant site lengthening.

**MATERIALS AND METHODS**

Figure 1 illustrates the surgical technique of acute compression of the nonunion site and gradual distraction of the distant site. All patients underwent complete resection of the infected/necrotic bone, debridement of the soft tissue, and lavage. At the nonunion site, in 21 patients a transverse skin incision was used for debridement and resection, and a curvilinear-shaped incision was made for the same purpose in the remaining 6. These types of incisions were employed to avoid the problems of wound closure associated with a longitudinal incision. The mean length of the resections was 10 (range, 6–17) cm; part of the fibula at the nonunion site was resected to facilitate the process of acute compression. A pre-assembled Ilizarov ring fixator was applied after thorough debridement. A 4-ring apparatus was usually used: pairs of 1.8-mm wires were placed in the proximal tibia with adequate tensioning; a second ring was placed below the level of proximal corticotomy with a pair of tensioned wires; a third pair of wires connected to an intermediate ring formed with a pair of adequately tensioned transosseous wires. Acute compression was maintained after verifying the approximation between the segments and checking the alignment of the bone under an image intensifier. As soft tissue redundancy (induced by acute shortening) could cover the debrided site, any such excess skin was excised to achieve a good wound closure. To attain gradual simultaneous limb lengthening and to restore loss of length at the defect, acute compression of the site was followed by proximal site metaphyseal corticotomy. The site of surgery was at mid-tibia in 17 patients. 13 patients had had previous treatment of soft tissue for redundancy. 17 patients had diffuse infections, and in the remaining 10 the infections were localised.

Figures 2 and 3 show preoperative and postoperative radiographs of different stages of treatment process. Of the 27 patients, 10 underwent corticotomy at the same stage at which the Ilizarov ring fixator was applied, 17 at the second stage (after a mean interval of 15 days following control of the active infection). On postoperative day 10, the corticotomy site was distracted at a rate of 0.5 mm twice a day. The rate of distraction was modified according to the quality of the regenerate formed. All patients underwent active physiotherapy of the knee and ankle. Weight bearing was permitted with a footplate extension and...
crutches. Transmetatarsal half-ring wire stabilisation was performed to prevent equinus deformity associated with gradual distraction. The Ilizarov ring fixator was removed after complete consolidation of the regenerate and fracture union. The time taken to accomplish radiographic and clinical union was recorded and all difficulties (such as hardware complications, pin tract infections, wound infections, and malalignment) were noted. Patients were followed up every 2 weeks until consolidation. The mean follow-up period was 27 (range, 25–39) months. The frames were removed once full healing was achieved, and the limbs immobilised in a patellar tendon-bearing cast for 6 weeks.

Figure 4 shows the clinical results of a patient during treatment. Figure 5 shows the functional results of a patient after treatment. Bone healing and functional results were evaluated according to a modified Association for the Study and Application of the Method of Ilizarov (ASAMI) classification. For bone healing, 4 criteria (union, infection, deformity, and leg-length discrepancy) were evaluated. An excellent result was defined as one with union, no infection, deformity of <7°, and leg-length discrepancy of <2.5 cm in the tibia. A good result was defined as union plus any 2 of the last 3 features of excellent union and a fair result as union plus any one of the latter features. A poor result was defined as nonunion, refracture, or none of the above-mentioned features. Functional results were based on 5 criteria: significant limp, equinus rigidity of the ankle, soft tissue dystrophy (skin hypersensitivity, insensitivity of sole decubitus/pressure sores), pain, and inactivity. An excellent result implied a fully active individual; good and fair results indicated progressively lesser degrees of activity/mobility.

The independent sample t test was used to compare the means of any 2 groups. When the variances of the groups under comparison were heterogeneous, the t test was used with modified degrees of freedom. One-way analysis of variance was used to compare the means of more than 2 groups. Correlations between quantitative variables were performed using Pearson’s product moment procedure. Level of significance for all inferences was set at p<0.05. All tests of hypotheses, wherever applicable, were 2-tailed.
RESULTS

27 men (mean age, 39; range 15–65; SD 14 years) with infected nonunion and large bone defects in the tibia were treated between January 1997 and March 2000 inclusive. The mean number of failed previous surgical procedures for union per patient was 2 (range, 1–4). According to the Cierny clinical staging of adult osteomyelitis, nine patients had type III-A and 16 had type IV-A lesions.

The mean lengthening achieved after surgery was 10 (range, 6–17) cm. The mean union time was 6.3 (range, 4–12) months and the mean duration of consolidation was 10.2 (range, 4.5–24) months.

According to the modified ASAMI classification of bone and functional results, 19 patients had excellent results and in 5 they were good. Two patients had a residual deformity and one had nonunion. Two others defaulted follow-up (Table).

In this study dependent variables included union time, length achieved, duration of consolidation, presence of deformity, and the ASAMI score for bone healing and function. The last 3 were omitted from further analysis because of a lack of variance: most patients had good or excellent results, only 2 had minor residual deformity.

Age correlated significantly with union time ($r=0.68$, df=22, $p<0.001$); being longer in older patients. There was no significant relationship between union time and (i) length of shortening ($r=0.13$, df=22, $p>0.05$) and (ii) length achieved ($r=0.09$, df=22, $p>0.05$).

There was a highly significant correlation between length of shortening and length achieved ($r=0.98$, df=22, $p<0.001$), indicating a high degree of 1:1 success in achieving the desired length (given the prevailing amount of shortening).

Age correlated significantly with the duration of regenerate consolidation ($r=0.67$, df=23, $p<0.001$); the duration was longer in older patients. Length of shortening ($r=0.50$, df=23, $p<0.01$) and length achieved ($r=0.42$, df=22, $p<0.05$) were both associated with a longer duration of consolidation. A longer duration of consolidation was also associated with a longer time to union ($r=0.66$, df=23, $p<0.001$).

A 27-year-old patient underwent an above-knee

Figure 3 Infected nonunion of the middle third of the tibia in a 35-year-old man: (a) preoperative anteroposterior and lateral radiographs revealing infected nonunion with diffuse chronic osteomyelitis; (b) immediate postoperative radiographs showing acute compression of 16 cm and proximal metaphyseal corticotomy; radiographs showing distant site lengthening at (c) 2 week, (d) 5 week, (e) 10 week, (f) 18 week, (g) and 23 week; (h) and (i) consolidation phases of the distracted regenerate; (j) follow-up radiograph 27 months after the removal of the Ilizarov ring fixator.
amputation. He presented with an infected nonunion of the proximal tibia and underwent the first part of the treatment, i.e. debridement, sequestrectomy, Ilizarov ring fixator application, and acute compression. He did not continue with the treatment of corticotomy and distraction. Instead he requested an above-knee amputation because of the financial burden of the former procedure and its long duration. One patient had a 25° flexion deformity of the knee and 20° ankle equinus, which was treated with passive stretching and active mobilisation exercises. One patient had nonunion of the acute docking site because of persistent infection; he did not present for further treatment (repeat debridement, resection, application of Ilizarov ring fixator, and acute compression). One patient had a 10° fixed flexion deformity, but no significant disability. 21 patients had minor pin tract infection during the whole treatment course, involving a mean of 5 pin sites per patient. Four patients developed moderate to severe degrees of pin tract infection (a mean of 3 sites each), for which antibiotic treatment was prescribed.

**DISCUSSION**

Reconstruction of segmental bone defects remains a difficult problem. Bone transport is one of the most innovative contributions of Ilizarov to orthopaedic surgery.21–28 With the different methods of segmental bone transport, long osseous tissue can be reconstructed without the need for bone grafting. The newly formed bone rapidly ossifies and becomes corticalised.

In previous studies, bone transport has been reserved for large bone defects.12 The acute compression and simultaneous lengthening method has been tried for smaller defects of <6 cm in the tibia and femur.12 Doubts have been expressed concerning the safety of acute compression for larger defects in the
tibia. Most studies of bone transport for large bone defects of the tibia have demonstrated a high complication rate, because of a delay in contact and compression and the gradual closure of the defect. When the frame is applied, the proximal and distal fragments must be aligned with each other in all planes and parallel to the longitudinal rods of the configuration. If this principle is not followed, the intercalary fragment will not dock properly with the target fragment at the end of the bone transport.

Soft tissue interposition also prevents compression and new bone formation at the docking site. Bone grafting will be necessary if the contact area at the docking site is small. Studies have reported that 80% to 100%, 10%, and 50% of cases have required bone grafting at the docking site. The leading edge of the transported segment is relatively avascular. This can delay union, unless the sclerotic end is trimmed and 50% of patients reportedly undergo debridement of the leading edge of the transported segment.

Delay in the formation of the regenerate at the distracted gap may prolong the duration of the fixator application. Healing at the target site does not begin until intercalary fragment lengthening is finished. Treatment becomes unnecessarily prolonged if the regenerate bone forms slowly. Pin-tract infection increases the risk of wire loosening, due to the weight borne by the external fixator, causing frame instability. Increased instability of the frame delays regenerate formation, and may necessitate additional procedures, such as wire exchange and frame adjustments for alignment. An average of 2.3 frame adjustments per patient to correct the alignment was reported; more than 60% of patients required wire exchange. Thus, many authors report high complication and secondary operation rates after bone transport.

The choice between acute compression and bone transport has not been widely discussed. A procedure of initial shortening of part of the defect, followed by a safety transport has been reported. Saleh and Rees compared the results of compression and distraction with bone transport, with a mean follow-up of 24 months. The mean treatment period was 9.8 months for compression and distraction and 16 months for bone transport. They recommended acute compression for tibial defects of <3 cm.

In this study, acute compression was performed for all large tibial defects; the largest being 17 cm. The mean length of resection was 10 (range, 6–17) cm, without immediate or late neurovascular compromise. This method has no translation problems because the defect was closed at the primary operation; by obtaining good bony apposition at that procedure, the healing process was initiated from the day of surgery. None of our patients needed any additional surgery (such as bone grafting or scar release) at the docking site, which contrasts with studies using bone transport that reported a high rate of bone grafting at the docking site.

Secondary adjustment to the ring fixator was not made during the entire treatment course. All the patients had achieved union at the compression site before consolidation of the regenerate at the distracted site. This method produces earlier shared stability between the bone ends and the fixator, which offloads the fixator and reduces the likelihood of fixation failure. We recorded a low rate of severe pin tract infection and there was no wire loosening. A transverse incision at the debridement site was used to facilitate good wound closure and to prevent complications of wound healing. No re-fracture was encountered at the union site.

Our early experiences with acute compression and simultaneous lengthening for infected nonunion of the tibia showed that the technique produces union and restores leg length. This technique addresses both alignment and length in a single treatment with fewer complications. It also reduces complications associated with bone transport and is safe for larger tibial defects; no neurovascular complications were encountered during acute docking or follow-up. The rate of severe pin-tract infection was very low, because from the early on during treatment, stability is shared between the acute compression site and the fixator. No secondary operations (such as bone grafting) were needed to achieve union at the docking site. Moreover, during the whole treatment course, no secondary adjustments were performed on the frame. The technique requires good compliance and cooperation from the patient, who should understand the procedure fully and be mentally prepared.

REFERENCES