The treatment of infected non-union of the tibia by compression-distraction techniques using the Ilizarov external fixator

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Abstract. *Circular external fixation using the Ilizarov apparatus combined with compression-distraction techniques was used to treat 11 patients with infected non-union and segmental bone loss of the tibia. The series comprised 8 males and 3 females, with an average age of 27 years (range 17–51 years). The average number of previous failed surgical attempts at union was 2 per patient (range 1 to 4). Three infected non-unions without shortening were treated with complete resection of the site and conversion of the diaphysis into a segmental defect. The functional results were excellent in 5, good in 3, fair in 2 and poor in one patient. No additional procedures were used in any of the patients.*

Abstract. *La fixation circulaire externe utilisant les appareils d' Ilizarov avec la méthode de compression-distraction a été utilisé dans le traitement de 11 malades souffrants d'une pseudarthrose infecté, la longueur moyne de la régénération était 3.7 cm (de 1.5 à 4.9 cm). Les resultats fonctionnels étaient excellents pour 5 patients, bons pour 3, moyens pour 2 et mauvais pour un seulement. On n'a pas en recours à des méthodes de greffe supplémentaire. Parmi les patients 8 était du sexe masculin et 3 du sexe féminin avec une moyen d'âge de 27 ans (une marge de 17 à 51 ans). Le chiffre moyen des précédents échecs des tentatives chirurgicales étaient deux par patients (de 1 à 4) parmi les 11 patients.*

Introduction

Difficult or resistant infections usually require a radical debridement of the septic bone and soft tissues in addition to the application of stable fixation to enhance soft-tissue healing and bone union [3]. The alternatives which are available for the management of chronic diaphyseal infection include extensive debridement with local soft-tissue rotational flaps, packing the defect with antibiotic impregnated beads, Papineau-type open cancellous bone grafting, tibiofibular synostosis, cancellous allograft in fibrin sealant mixed with antibiotics, and/or free microvascular soft-tissue and bone transplants [4].

During the past 30 years, Ilizarov [9] has developed the technique of distraction osteogenesis for the regeneration of large deficiencies in bone. This process is begun locally by a corticotomy and controlled externally by a ring fixator. The application of Ilizarov techniques to the treatment of an infected non-union [10] depends on whether it is hypertrophic or atrophic, the extent of infection and the condition of the soft tissues.

The purpose of this study is to describe our experience with the treatment of infected diaphyseal tibial defects using the techniques of debridement resection of non-viable bone and compression-distraction osteosynthesis.

Materials and methods

Eleven patients with 11 infected tibial shaft fractures were treated. Eight were males and 3 females with an average age of 27 years (range 17–51 years). Five of the fractures had resulted from motor cycle accidents, 4 from car accidents, one from a fall and one at work.

The right side was involved in 7 and the left in 4. The average number of previous failed surgical attempts at union was 2

Table 1. Infected segmental defects of tibia (8 cases)

Case	Number of previous operations	Duration of infection (months)	Results (According to Cattaneo et al. Table 3)
1	1	4	U1 I2 F2
2	2	6	U1 I1 F2
3	1	5	U1 I2 F2
4	1	7	U1 I2 F2
5	2	3	I1 I2 F2
6	2	5	U1 I1 F2
7	3	7	U1 I0 F1
8	4	10	U1 I0 F1
Average	3	10	
Minimum	1	3	
Maximum	4	10	

Table 2. Resected segmental defects of tibia (3 cases)

Case	Number of previous operations	Duration of infection (months)	Results (According is Cattaneo et al. Table 3)
1	1	5	U1 I2 F2
2	2	6	U1 I2 F2
3	4	9	U1 I0 F2
Average	2	7	
Minimum	1	5	
Maximum	4	9	

per patient (range 1 to 4). The average length of time for the original injury to application of the Ilizarov fixator was 9 months (range 6–16 months).

Aseptic non-unions with a bone defect [9] were classified into 3 types:

- The length of the limb is preserved with a bone gap (type B1).
- The segments are in contact with shortening of the limb (type B2).

- A shortened limb plus a bone gap (type B3).

We used three types of management:

- Bone transportation by means of an intermediate ring.
- Bifocal bone transportation by means of proximal and distal metaphyseal corticotomies in patients with specific skin-related conditions or those with a bone defect greater than 5–6 cm.
- Extensive bone transportation with longitudinal olive wires.

Of the 11 patients, eight had chronic tibial defects: one had a normal length (type B1); five had shortening associated with bone fragment contact (type B2) and two had bone loss in excess of the amount of shortening (type B3). These defects were all treated with compression of the site of non-union and lengthening of the leg through a separate corticotomy site with bone transport (Table 1). Three infected non-unions without shortening (type B1) were treated with complete resection of the site of non-union and conversion of the diaphysis into a segmental defect (Table 2).

Aerobic and anaerobic cultures and sensitivity tests were undertaken when patients were admitted 15 days before the application of the Ilizarov fixator. The culture was positive in 3 patients (*Staph. aureus*), and they subsequently received a course of intravenous cephalosporin for 10 days after operation. The infected area had been radically debrided of septic bone and soft tissue with resection of the sequestrae, removing all non-viable tissue. Continuous suction was then used for 3 days with irrigation using normal saline and cephalosporins. Antibiotics were not routinely administered in the other 8 patients after the application of the Ilizarov frame but if a pin tract infection occurred, antibiotics were given alone or in combination with incision and drainage.

Technique of corticotomy

Corticotomies were performed in the proximal metaphyses in 10 patients and in the diaphyseal portion of the bone in one.

The technique of corticotomy was a modification of that performed by Aldegheri et al. [1]. A skin incision of about one cm was made over the planned area of corticotomy and a direct longitudinal periosteal incision was made just medial to the tibial crest. The periosteum was carefully elevated from the cortex, and the medial cortical pillar broken with a sharp 5-mm osteotome. At the posterior end of the medial cortex, the osteotome was rotated through 90° while the assistant manipu-

Fig. 1. Diagram of assembly for bone transportation osteosynthesis with osseous gap and shortening (treatment type B3) [13]

Fig. 2. Male aged 17 years, with an infected non-union of the lower tibia and shortening of 2.5 cm; he had undergone 4 previous procedures

Fig. 3. Debridement of the site of non-union and corticotomy of the upper tibia after application of the fixator

Fig. 4. Union at the fracture site 3½ months later. After completing the bone transport, lengthening from the upper ring was continued in order to correct tibial shortening

Fig. 5. Complete lengthening before removal of the Ilizarov apparatus

Fig. 6. Final result

lated the distal part to produce a greenstick fracture of the medial region of the posterior cortex. This manoeuvre was repeated on the lateral cortex, the periosteum was sutured and the skin was closed.

Bone transportation osteosynthesis

All patients were placed in the Ilizarov fixator. On average, 4 rings were used per patient. In this type of frame, pairs of wires are placed in the proximal and distal tibia and each is fixed to an appropriate ring. A third pair of wires, connected to an intermediate ring, is placed into the transport bone closer to the leading end but leaving enough bone protruding so as not to interfere with subsequent compression.

The transverse transport wires, which are 1.5 millimetres in diameter, gradually cut through the skin and soft tissues, with spontaneous healing of the tract. After contact between the two bony segments has been obtained, inter-fragmentary compression is performed in order to stabilise the entire frame (Fig. 3). Bifocal osteosynthesis is indicated where there is shortening due to bone if a gap between the bony segments is present. The distance between the segments should not exceed

one to 1.5 centimetres. They must be brought into immediate contact in compression and then concurrent bifocal osteosynthesis applied with combined compression and distraction. When slow uninterrupted distraction (1 mm/day) is applied to the bone fragment, the resulting distraction gap regenerates new tissue and undergoes ossification within this newly created space. The newly regenerated bone can be stretched in virtually any direction by progressive manipulation of groups of Ilizarov rings in order to accomplish lengthening, reconstruction of the gap, and axial and torsional correction.

Results

All the infections healed following application of the Ilizarov frame (Fig. 2). The average length of time in external fixation for all patients was 8.5 months (range 5.5 to 16 months) and they were followed-up for an average of 13 months (range 10–24 months). The average number of operations per patient was 2.7 (range 2 to 5) including the original corticotomy and application of the fixation. Additional procedures in-

Table 3. Evaluation of results of clinical-follow-up (Cattaneo et al. [2])

Union:	
U0:	Failure to obtain union
U1:	Solid union
Infection:	
I0:	Unchanged infection
I1:	Persistent minimal drainage
I2:	Complete clinical remission of infection
Function:	
F0:	Invalid function
F1:	Able to perform all daily activity
F2:	Complete recovery

Table 4. Results at follow-up

No. of patients	Results				
5	Excellent	U1	I2	F2	
3	Good	U1	I1	F2	
2	Fair	U1	I1	F1	
1	Poor	U1	I1	F0	
Total	11				

cluded one wire exchange, three adjustments after frame for alignment and incision and drainage for a pin site abscess in two patients. The average number of frame adjustments for modification were two per patient (range 1–5). At the end of treatment, five patients had their frame removed without the need for anaesthesia.

All the patients eventually obtained clinical and radiological evidence of union and none required bone grafting at the fracture or at the corticotomy site.

The average length of regenerated gain was 3.7 cm (range 1.5 to 4.9 cm). Of the eight patients who had significant varus or valgus angulation before bone transport, six had significant correction of angulation. In the sagittal plane, only one patient showed a significant residual deformity of 18° after treatment. Subjectively, seven of the eleven patients had little or no discomfort while walking bone transport, three experienced intermittent to moderate discomfort and one had severe discomfort.

The results were assessed at follow up using the criteria of Cattaneo et al. (2 [Table 3]). Of the 11 patients, 5 had ratings of U1-I2-F2 and were regarded as having excellent results. Three patients received ratings of U1, I1, F2 and were considered to have a good outcome. Two patients, although healed and returned to a functional level, had persistent drainage and were rated as having fair outcomes. Union of the defect and elimination of the infection occurred in one patient who was unable to return to a functional level and was rated as having a poor result. The results are summarised in Table 4.

Satisfactory results were obtained in eight patients; the outcome was unsatisfactory in three.

Complications

The most common complication was infection at the wire-site which occurred in eight patients. Before treatment with empirical broad spectrum antibiotics, aspiration of pus for culture and sensitivity was undertaken in each. The causative organisms were *Staph. aureus* in six instances and *Staph. albus* in two. Five patients were treated by antibiotics only, while two required incision and drainage plus antibiotics.

One patient experienced loosening of the Kirschner wires which were then removed and reinserted 1 cm away from the infected site.

Two patients had paraesthesiae in the distribution of the peroneal nerve. These sensory symptoms resolved after the bone transport was stopped for one or two days.

There was only one instance of substantial limb oedema associated with the treatment and no motor deficit, sensory loss, compartmental syndrome or arterial injury occurred.

Two patients developed 15° knee flexion contractures. This deformity was resolved by physiotherapy in the form of passive stretching exercises of the affected muscle groups, active exercises, and electrical stimulation to stimulate muscle regeneration.

Discussion

The methods of Ilizarov, including compression distraction and osteosynthesis offer alternatives to the standard treatment of infected non-unions of bone. Use of the Ilizarov circular frame allows resection of the infected bone, repair of the defect and stabilisation to consolidation while maintaining or restoring the length of the limb. Joint function is encouraged while the apparatus is worn and functional loading can be initiated within the first few days after application of the frame [10]. The Ilizarov apparatus is very resistant to torsion and bending forces but is adaptable to axial loading [5].

Union achieved by repairing defects with cancellous bone grafts, as recommended by Johnson et al. [11] and Lack et al. [12], may be satisfactory but the biomechanical structure of the restored bone may require years of remodelling to achieve the radiological appearance that is obtained by distraction regeneration by the Ilizarov method [9].

In his series, Cattaneo et al. [2] reported that 5 of 28 patients had mild intermittent drainage after achieving union and that infection resolved without antibiotic therapy in 23 of 28 patients. Three of 11 patients had mild intermittent drainage after achieving union and arguably could have benefited from long-term antibiotic therapy. In 9 of 11 patients, the infections resolved completely without antibiotic treatment.

We agree with Green et al. [7] that the largest number of complications are associated with wire tract infection which may lead to its loosening with

associated bony infection or osteolysis. Sepsis and loosening cause frame instability, which results in interference with the ability to walk and therefore slows ossification. The control of infection in the wire tract is vital in the management of a patient in an external fixator for the purpose of bone transport.

Delay in the ossification or maturation of the regenerate new bone in the distraction gap will necessitate prolonged application of the fixator [13]. In our series, the frames were in place for an average of 9 months, and the average length of regenerate bone formation was 3.7 cm. Because healing of the target site does not begin until intercalary lengthening of the fragment is complete, patients requiring bone transport are maintained in external fixation longer than those needing comparable limb elongation. Nevertheless, the total treatment time will be prolonged unnecessarily if the regenerate new bone is slow to mature. In general, delays in regenerate ossification are caused by limited weight-bearing and reduced functional use of the limb while in external fixation. Inability to bear weight is usually caused by pain [6]. As experience is gained with application of the fixator improved wire techniques lead to greater patient comfort in the frame [8], and an awareness of possible soft-tissue tension and necrosis at the time of wire insertion leads to a steady decline in wire sepsis.

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