A single-stage operation in the treatment of tibial chronic osteomyelitis with the use of the Ilizarov technique

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Background
Treatment of chronic osteomyelitis of the lower extremity presents one of the most difficult challenges for a reconstructive surgeon. Appropriate radical debridement requires excision of all necrotic bone and soft tissue, which often results in a large bone defect. The unstable situation requires some type of fixation and reconstruction of the resultant bone and soft-tissue defects. The aim of this study was to summarize my experience with distraction osteogenesis performed using an Ilizarov fixator for the treatment of tibial bone defects and limb shortening resulting from radical debridement of chronic osteomyelitis.

Materials and methods
Sixteen patients ranging in age from 9 to 55 years underwent radical debridement for the treatment of chronic osteomyelitis of the tibia. The lesions were classified, according to the Cierny–Mader classification system, as type IVA (12 cases) and type IVB (four cases). The resulting segmental defects and any limb-length discrepancy were then reconstructed by distraction osteogenesis using the Ilizarov technique. In all patients infection was eradicated, except four, who required a second procedure. At the time of the last follow-up, functional and radiographic results were evaluated using the criteria of Paley and colleagues.

Results
The mean size of the defect was 5.25 cm (range 3–8 cm) in the tibia. The mean external fixator index was 43.8 days/cm (range 33.7–60 days/cm). The mean total duration of external fixation was 7.5 months (range 4–11 months). At a mean follow-up of 21.9 months (range 6–38 months), 11 of the 13 patients showed excellent bone results and the functional assessment of nine patients indicated excellent results. There were four recurrences of infection that required a second procedure for all of the four patients; subsequently, the infection was controlled and the bone was consolidated.

Conclusion
The clinical experience with the 16 patients showed that this one-stage surgical procedure with a short duration of hospital stay and excellent long-term results seems to be a promising strategy for the definite treatment of chronic osteomyelitis. All well-known disadvantages of a multistage approach, such as repeated operations, prolonged morbidity with the many ensuing psychological changes, and increasing medical costs, can be avoided by using the described method of a single-stage operation, which leads to rapid rehabilitation and recovery in addition to increased quality of life and decreased medical costs.

Keywords:
Ilizarov technique, osteomyelitis, tibial chronic

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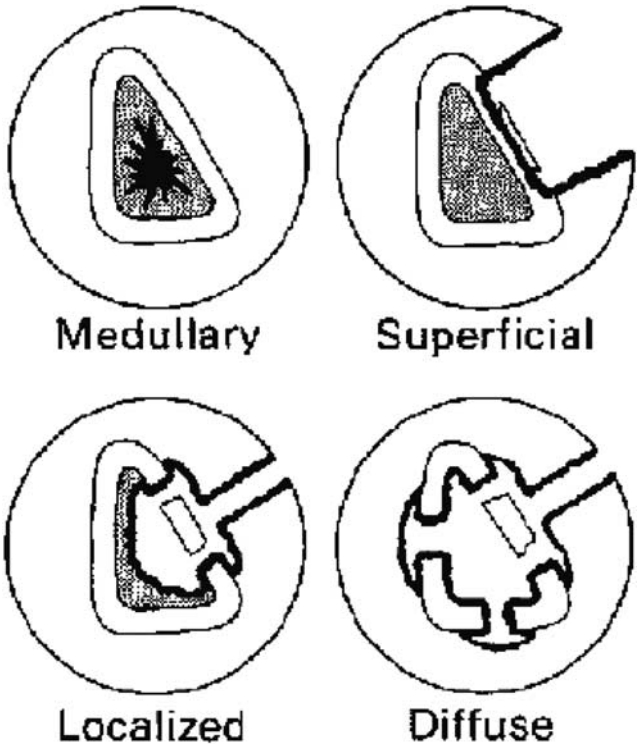
Introduction

Chronic osteomyelitis leads to necrosis of bone and soft tissues to a variable extent. The dead bone forms a nidus for hosting pathogens. Moreover, the host defense mechanisms are often not in an optimal condition to deal with microorganisms, and the delivery of antibiotics to the site of infection may be impaired because of poor circulation [1]. Cierny and colleagues classified chronic osteomyelitis into four anatomical types, a system known as the Cierny–Mader classification, and further staged the pathology according to the extent of the local and systemic compromise in the patient. They developed guidelines for management according to the system [2].

Appropriate radical debridement requires excision of all necrotic bone and soft tissue, often resulting in a large bone defect. The unstable situation requires some type of fixation and reconstruction of the resultant bone and soft-tissue defects. Since the introduction of distraction osteogenesis by Ilizarov, the technique has been used successfully to achieve union, correct deformity, re-establish

limb-length equality, and reconstruct segmental defects [3]. In the treatment of chronic osteomyelitis, the major aim of the surgery is removal of the sequestrum and granulation tissue. In the conventional method, excessive removal of the bone that creates a bone defect is not recommended; thus, complete removal of infected foci cannot be achieved [4]. In this work, the bone transport technique with the Ilizarov method was used in patients with chronic osteomyelitis who required extensive debridement.

Figure 1



Anatomical classification of adult osteomyelitis [2].

Materials and methods

Between September 2006 and December 2010, a retrospective review was carried out of the surgical treatments chosen for chronic open tibial osteomyelitis in 16 consecutive patients treated by one surgeon. The Ilizarov method of distraction osteogenesis after radical debridement of necrotic bone was utilized. Patients with osteomyelitis in sites other than the tibia were excluded from the study. The data reviewed included age, sex, nature of the original injury, number of previous surgeries, Cierny–Mader classifications (Fig. 1), site of infection in the tibia, culture results, and the result of treatment at the last follow-up. At the time of referral, the mean age of the patients was 29.3 years (range 9–55 years); nine patients were males and seven were females (Table 1). All patients were referred after a previous surgical intervention in other hospitals. The fibula was not affected by infection in any of the patients. All patients had active infection with elevated C-reactive protein levels and an elevated erythrocyte sedimentation rate ranging from 45 to 90 mm at the beginning of the Ilizarov treatment. The culture and antibiotic susceptibility test were positive in all patients, except three, who were receiving empirical antibiotics before presentation to the clinic. The pathogen was *Staphylococcus aureus* in seven, MRSA in five patients, and *Pseudomonas* spp. in one. The patients had an average of 2.4 surgical procedures (range 1–6 procedures) before presenting to our clinic. Six patients had drainage of the tibia from acquired hematogenous osteomyelitis since childhood. Open fractures were present in four, plates in four, and intramedullary rods in two patients.

Operative technique

The treatment protocol included sequestrectomy and radical debridement, appropriate antibiotic therapy, and bifocal treatment (one osteotomy site) with the Ilizarov method. All cases were classified as Cierny–Mader type IV. Hardware removal and radical resection of dead bone with debridement of the infected scarred soft tissue were performed, and representative tissue cultures, including

Table 1 Patients data

Cases	Age (years)/sex/ side	Etiology	Site	Findings on culture	Cierny–Mader stage	External fixator time (month)	Previous operation
1	9/F/R	Hematogenous	Middle, distal	MRSA	IVA	4	4
2	31/M/L	Postplating	Distal	*S. aureus*	IVA	7	2
3	23/M/L	Hematogenous	Middle	*S. aureus*	IVA	10	2
4	29/M/R	Open fracture	Distal	*S. aureus*	IVA	8	4
5	55/M/L	Open fracture	Distal	*Pseudomonas* spp.	IVB	8	1
6	34/F/L	Postnailing	Proximal	MRSA	IVB	8	6
7	17/M/R	Hematogenous	Distal	MRSA	IVA	9	2
8	21/F/L	Hematogenous	Middle	No growth	IVA	6	2
9	28/F/L	Postnailing	Distal	*S. aureus*	IVA	7	1
10	40/M/L	Open fracture	Distal	MRSA	IVA	11	2
11	34/M/L	Open fracture	Distal	MRSA	IVB	6	1
12	27/F/L	Postplating	Middle	*S. aureus*	IVA	9	2
13	43/M/R	Postplating	Proximal	No growth	IVA	5	5
14	13/F/L	Hematogenous	Middle	*S. aureus*	IVA	9	2
15	29/F/R	Hematogenous	Middle	*S. aureus*	IVA	6	1
16	36/M/R	Postplating	Middle	No growth	IVB	7	3

F, female; L, left; M, male; MRSA, methicillin-resistant *Staphylococcus aureus*; R, right.

the sinus tract for all dead bone, were obtained (Fig. 2a–f). Cortical bleeding, described as the so-called paprika sign, was considered as an indication of vital tissue [5]. In most of the cases, fibular osteotomy and the small fibular segment were excised to prevent premature fibular union to allow dealing with the segmental tibial defect. Finally, after aggressive resection, bone gap ranged from 3 to 8 cm in an aligned limb segment. This gap was dealt with in three ways: acute closure of bone gaps measuring 5 cm or less, followed by lengthening. Elliptical transverse incision was used for acute closure of the soft-tissue defect with excision of the sinus discharging pus (Fig. 3a–d). Bone transport was carried out by the segment transfer technique in gaps more than 5 cm to avoid neurovascular compromise. Lengthening at the osteotomy site was carried out on the metaphyses of the longer bone fragment (12 proximal and four distal) during the same operation in all patients (Fig. 4a–c). Distraction was begun after a latency period of 7–10 days; the rate of the distraction was 1 mm/day, divided into four equal increments. Bone transport was

Figure 2

(a) Case 1: A 9-year-old child with Cierny–Mader type IVA chronic osteomyelitis of the tibia, a preoperative radiograph. (b) Clinical photograph. (c) Intraoperative photograph showing bone defect after sequestrectomy. (d) Photograph showing the excised sequestrum. (e) Clinical photo showing closure of defect and no limb-length discrepancy. (f) Radiograph showing full consolidation after segment transfer.

Figure 3

(a) Case 11: A 34-year-old man with Cierny–Mader type IVB chronic osteomyelitis of the tibia, an intraoperative photograph of elliptical skin incision. (b) Excision of the skin including sinuses. (c) Radical sequestrectomy. (d) Closure of the skin without tension after acute closure of bone gaps and application of the Ilizarov frame.

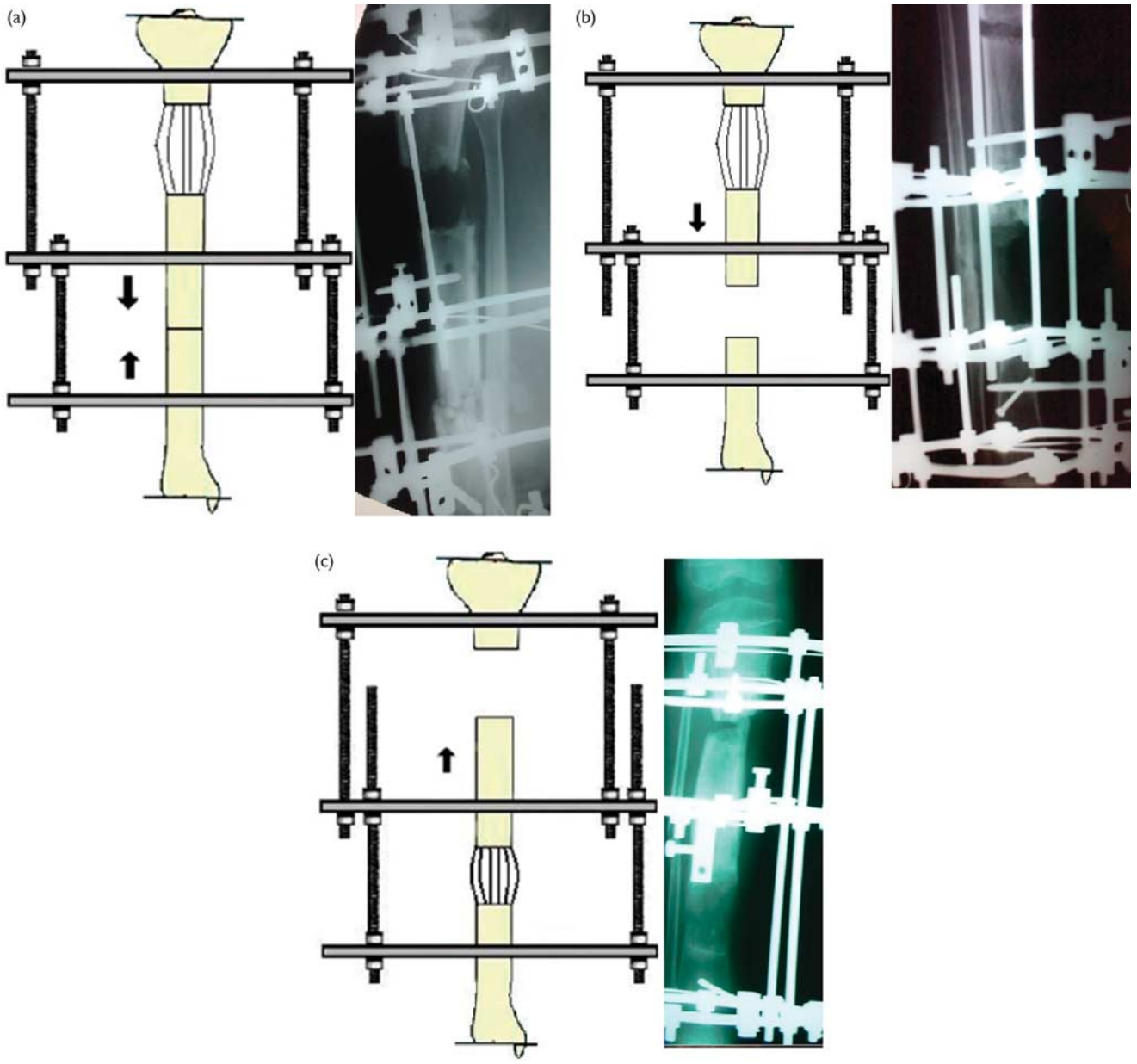
achieved by transverse pulling by transverse tensioned Kirschner wires in all patients. At the end of the segment transport, bone grafting and refreshing procedures were not required at the docking site in any of the patients. Patients were allowed to bear weight during treatment.

Postoperative care

All patients received antibiotics for 2 weeks according to culture and sensitivity results. Physiotherapy was started on the second postoperative day with passive and active range of motion exercises to the knee and ankle joints, together with quadriceps and hamstring strengthening exercises. Gait training was also started with partial weight bearing, using crutches, as tolerated by the patient, which progressed to full weight bearing with progressive consolidation.

In the outpatient clinic, patients were screened for local signs and symptoms of infection and sinus formation or drainage, and the erythrocyte sedimentation rate and

Figure 4



(a) Left: The frame utilized for acute bone gap closure, followed by proximal osteotomy and lengthening. Right: Radiograph of case 5. (b) Left: The frame utilized for segment transfer and proximal osteotomy. Right: Radiograph of case 7. (c) Left: The frame utilized for segment transfer and distal osteotomy. Right: Radiograph of case 1.

C-reactive protein levels were monitored. Conventional radiographs were obtained every 2 weeks during the distraction phase and once every month during the consolidation phase. Patients were instructed on how to distract at the osteotomy after a latency period of 7–10 days, at a rate of 1 mm/day (0.25 mm every 6 h). Patients were followed up weekly during distraction, and then every 2 weeks until consolidation. The external fixation index was calculated as the duration of external fixation in days divided by the total amount of bone transported and/or the amount of lengthening in cm.

Radiological union was judged by the absence of a radiolucent line at the nonunion and filling of a bone defect with new bone [6] at a minimum of three cortices on standard anteroposterior and lateral radiographs [7]. After healing, the fixators were removed with sedation. Patients were restricted to partial weight bearing without braces for 2 to 3 weeks, and then followed by full weight bearing.

A functional assessment was carried out using the criteria of Paley *et al.* [8]. The functional results were based on five criteria: substantial limp, equinus rigidity of the ankle, soft-tissue dystrophy (skin hypersensitivity, insensitivity of the sole, or decubitus), pain, and inactivity (unemployment because of the leg injury or an inability to return to daily activities because of the leg injury). The result was considered excellent when the patient was active and had none of the other four criteria, good when

Figure 5

Postoperative anteroposterior and lateral radiograph following frame removal of case 7 (a) and case 11 (b).

the patient was active and had one or two of the other four criteria, and fair when the patient was active and had three or four of the other criteria or had undergone an amputation. The bone was assessed for union, infection, deformity, limb-length discrepancy, and mechanical insufficiencies at the docking site. The result was considered excellent when the following criteria were fulfilled: union, no infection, a deformity of less than 7°, and a length discrepancy of less than 2.5 cm in the tibia and femur. The result was considered good when there was union and any two of the other criteria, fair when there was union and one of the other criteria, and poor when there was nonunion or refracture or none of the other criteria. Patients who were not available for follow-up were not evaluated with respect to the final outcome.

Results

Sixteen patients treated with the Ilizarov technique were followed for a mean of 21.9 months (range 6–38 months). The mean hospital stay was 7.8 days (range 4–14 days). The mean bone gap was 5.3 cm, ranging from 3 to 8 cm in an aligned limb segment. The mean total duration of external fixation was 7.5 months (range 4–11 months). The average external fixation index was 43.8 days/cm (range 33.7–60 days/cm). There were four cases of failure defined by recurrent drainage and elevated erythrocyte sedimentation rates and C-reactive protein levels. The four cases had the bone consolidated; three of these cases responded to debridement and soucerization. One case required revision by the Ilizarov technique; the infection was eradicated but the patient did not remove the Ilizarov frame at the last follow-up. Fourteen patients were apparently disease-free and able to walk without support at the time of the final follow-up. All 16 patients were evaluated with respect to the functional and bone results. Using the criteria described above, the results in terms of bone results were excellent in 11 patients, good in three patients, and fair in two patients. The function results were excellent for nine patients, good for five patients, and fair for two patients. Complete union was achieved in all patients (Fig. 5a and b). Refracture was not observed after the removal of the frame. The demographic data of our patients are shown in Table 2.

Complications

Using the classification system of Paley [9], minor complications were the problems that did not require additional surgery and major complications were identified as either obstacles that resolved with additional surgery or true complications or sequelae that remained unresolved at the end of the treatment period (Table 3).

Superficial pin-tract infection was the most common problem that occurred in almost all patients and it was

Table 2 Patients results

Cases	Hospital stay (days)	Follow-up (month)	Lengthening index (days/cm)	Bone gap (cm)	Shortening at the latest follow-up	Bone status	Functional status at the latest follow-up
1	7	22	30	4	0	Excellent	Excellent
2	5	18	42	5	0	Excellent	Good
3	5	24	42.8	7	3	Good	Fair
4	6	27	40	6	1	Excellent	Excellent
5	8	32	48	5	0	Good	Excellent
6	12	36	48	5	0	Excellent	Excellent
7	4	22	33.7	8	2	Excellent	Excellent
8	7	26	45	4	0	Excellent	Good
9	9	12	42	5	0	Excellent	Good
10	14	24	47.1	7	3	Fair	Fair
11	10	6	60	3	0	Excellent	Excellent
12	9	38	45	6	0	Excellent	Excellent
13	8	20	50	3	0	Excellent	Good
14	5	8	38.5	7	1.5	Excellent	Excellent
15	7	12	36	5	0	Good	Excellent
16	9	24	52.5	4	0	Fair	Poor

Table 3 Patients' complications

Complications[a]	Number of patients	Complication rate (%)
Minor complication		
Pin-site infection	16	100
Delayed consolidation	3	18.7
Limitation of ankle motion	7	43.7
Major complication		
Ankle equines	4	25
True complication		
Flaring of infection	4	25

[a]Complications were classified according to the system of Paley [9].

resolved by the administration of oral antibiotics and local care. Pin-tract infection was classified as grades 1 and 2 according to Paley *et al.*'s [8] classification. No neurovascular complications occurred as a result of wire insertion, acute docking, or lengthening osteotomy.

Delayed consolidation at the nonunion site that required refreshment of the edges and callus massage occurred in three patients. Four patients had equinus deformity; the frame was extended to the foot for gradual correction. Seven patients had mild–to–moderate limitation of ankle range of movement at presentation and one patient had transient knee contracture of about 20°; all these patients showed variable improvement with physiotherapy, with no additional limitation in movement or joint stiffness. Malalignment was observed in two cases: valgus 15°, case number 4, and recurvatum less than 15°, case number 1. Two patients had recurrence of infection with bone union and required revision of the operation.

Discussion

Normal bone is highly resistant to infection, which can only occur as a result of very large inocula, trauma, or the presence of foreign bodies. Certain major agents of infection, such as *S. aureus*, adhere to bone by expressing receptors for components of bone matrix. *S. aureus* that has been internalized by cultured osteoblasts can survive intracellularly. The intracellular survival of bacteria may explain the persistence of bone infections [10]. The inflammatory foci are surrounded by sclerotic bone with a poor blood supply and are covered by a thick, relatively avascular periosteum and scarred muscle and subcutaneous tissue. Antibiotics reach such tissue mainly by diffusion, in insufficient concentrations, and sensitive organisms may survive and become active again after the therapy is discontinued. Secondary infection with organisms that are more resistant to antibiotics than the primary infecting agent is not uncommon [11].

The first step of treatment for chronic osteomyelitis is radical debridement of all infected tissues and the use of appropriate antibiotics. The major goal of the radical debridement is to achieve a viable and vascular environment by sequestrectomy and to resect all infected bone and soft tissue. Incomplete sequestrectomy and debridement may lead to recurrence of infection. Daoud and Saighi-Bouaouina [12] concluded that the condition of the periosteum of the bone involved is important. The condition of the periosteum is best assessed on the basis of the presence or absence of an involucrum following drainage. The absence of an involucrum indicates inadequate periosteum and poor periosteal healing progress [4,12]. The formation of an involucrum requires a prolonged immobilization period (2–8 months). It is believed that persistence of a sequestrum has no beneficial effect on the development of an involucrum. Some authors have advised early sequestrectomy to help control the infection because a sequestrum contributes to the persistence of the infection and impairs the formation of an involucrum. Others have recommended that sequestrectomy be delayed to ensure maximum development of the involucrum and revascularization of the sequestrum [12].

Today, as a result of changing concepts and advanced reconstruction techniques, chronic osteomyelitis can be cured. The concept of burning an infection in the fire of an Ilizarov device, as described by Ilizarov [13], has changed to the current philosophy that the only cure for osteomyelitis is radical debridement until live and bleeding bone is

reached, as described by Cierny *et al.* [2,14]. All patients in the current series were managed according to the principles of Cierny and colleagues. The extent of debridement necessary to obtain live and uninfected bone usually results in a bone defect, which requires complex reconstruction. This challenge can often be addressed by distraction osteogenesis.

Several methods have been described for filling bone defects after radical debridement of chronic osteomylitis: open bone grafting, fibular transposition, and vascular bone grafting. The open bone grafting technique consists of three surgical stages and requires prolonged immobilization [15]. In vascular bone grafting, however, healing and remodeling of bone graft needs a long time, and prolonged protection by a cast or an orthotic device is necessary. Refracture and host–graft junction healing problems are another complication with this type of grafting technique. Osteopenia and joint stiffness because of prolonged immobilization, limb-length discrepancy, angular deformity of the bone, nonunion, and recurrence of the infection are major disadvantages of these classic methods [16]. The Ilizarov technique of distraction osteogenesis is carried out in an attempt to solve all these problems simultaneously.

Acute docking has been recommended by several authors [17–21] as it has favorable results over bone transport in terms of a shorter treatment time and fewer complications. Safe limits of acute docking should be individualized according to the condition of the limb, excessive scaring of the soft tissue, previous vascular insult, and the quality of pulsations compared with the healthy leg. Intraoperatively, circulation should be checked and compared with the healthy leg. Acute docking of 3 cm has been recommended by some authors [19,20]; others [18] have reported acute shortening of as much as 6 cm to be safe. On the basis of clinical and Doppler ultrasound assessments, the safe limits of acute shortening were estimated according to the level of fracture to be 3 cm in the proximal third of the tibia, 3–5 cm in the middle third, and 6 cm in the distal third [17]. In this work, acute docking was carried out for nine patients with a gap of 5 cm or less and bone transport was carried out in patients with defects more than 5 cm (seven patients). In these seven patients, acute shortening of 5 cm or less was carried out to reduce of the defect and improve soft-tissue closure, and later, lengthening was carried out to correct shortening after the transported segment of bone had reached the docking site. The skin incision technique used in this work in acute compression allowed better scaring and easier skin closure without tension. Postoperative monitoring of peripheral circulation is as important as intraoperative assessment of pulse because soft-tissue edema can result in late neurovascular compromise.

Patients with bone loss 5 cm and less underwent gap closure by acute docking. They had a shorter treatment time and better functional results as the frame had greater stability because of good bone contact. They were able to comply better with the physiotherapy program, especially weight bearing. Acute docking, followed by lengthening is simpler than bone transport and should be used whenever it is possible.

In this series of patients, the bone results were excellent in 11 patients (68.7%), good in three patients (18.7%), and fair in two patients (12.5%). The functional results were excellent in nine patients (56.2%), good in four patients (25%), fair in one patient (6.25%), and poor in (6.25%). These results were comparable with those obtained by Dendrinos *et al.* [22], Sen *et al.* [18], and Paley *et al.* [21], who also described the bone results to be superior to functional results. They agreed that the ability to achieve an excellent bone result did not ensure a good functional result as the latter was predetermined by the condition of soft tissues and joints.

Heavy smoking has a deleterious effect on the maturation of new bone formation during distraction and healing at the docking site [22]. Three patients were heavy smokers and had a relatively longer period of treatment; all of them were instructed to stop smoking. Two of them failed to quit smoking but they reduced their consumption to less than five cigarettes per day. The sites of docking were stimulated by callus massage, by alternating short periods of progressive distraction with periods of compression (0.5 mm of distraction a day for 7 days, followed by 1 mm of compression a day for 7 days, over a 4-week period). The result was net compression with slight shortening [23].

According to Paley's [9] classification of complications, problems in this work were pin-tract infection that occurred in almost all patients and responded well to nonoperative treatment. Obstacles were encountered in four patients who had to undergo an operative intervention with no late sequelae. In this work, infection was successfully eradicated in all patients except four. In the four patients who developed flaring up of uncontrolled infection, the bone consolidated but active infection still persisted. Three of these patients responded to debridement and soucerization. One patient required revision by the Ilizarov technique in two stages using an antibiotic-impregnated bone cement wire, followed by a second-stage Ilizarov technique, and the infection was eradicated. All patients received antibiotics for 2 weeks according to culture and sensitivity results. There was no need to continue antibiotics for a longer period as the type and duration of treatment with antibiotics did not correspond to the eradication of infection [20].

Dendrinos *et al.* [22] reported one patient with refracture 3 months after the removal of the fixator; this patient later underwent amputation. In this series of patients, the use of the Ilizarov method offered limb salvage, with no need for arthrodesis or amputation.

The clinical experience in this work with the 16 patients showed that this one-stage surgical procedure with a short duration of hospital stay and excellent long-term results seems to be a promising strategy for the definite treatment of chronic osteomyelitis. All well-known disadvantages of a multistage approach, such as repeated

operations, prolonged morbidity with the considerable ensuing psychological changes, and increasing medical costs, can be avoided by performing the described method of a single-stage operation, which leads to rapid rehabilitation and recovery, in addition to increased quality of life and decreased medical costs.

Acknowledgements

Conflicts of interest

There are no conflicts of interest.

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