Evaluation of soft tissue and bone healing of high-energy open distal third and periarticular tibial fractures managed using the Ilizarov technique

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Received 14 December 2010
Accepted 10 January 2011

Egyptian Orthopedic Journal 2012, 47:424–430

Study design

Retrospective study.

Objective

This work evaluated the results of 25 patients who were treated with an Ilizarov external fixator for type II, IIIA, and IIIB open comminuted distal tibial fractures not involving the ankle articular surface. The aim of this study was to evaluate the results and efficacy of the external fixation technique using Ilizarov fixators in treating high-energy comminuted open distal leg fractures not involving the ankle joint integrity.

Patients and methods

Twelve Gustillo grade II, eight IIIA, and five IIIB comminuted tibial fractures in patients aged between 21 and 52 years (22 men and three women) treated with Ilizarov fixators were analyzed. All patients were candidates for reconstruction according to the NISSSA scoring system (score below 14). They were followed up for 12–18 months at monthly regular sessions. Each session included careful clinical evaluation using ASAMI evaluation criteria, fixator care procedure, skin and soft tissue healing progression, and radiological evaluation of fracture union.

Results

The mean duration of intraoperative application of the frame was 149.8 min (120–180 min) and the mean follow-up time was 12.48 months (12–18 months). After removal of frames, patients experienced minimal ankle pain and stiffness, which required short-term rehabilitation. All fractures healed between 20 and 32 weeks (mean 27.2 weeks) without additional bone grafting. Timing of removal of the frame varied between 6 and 8 months (6.44). Eight patients required a second operative procedure in the form of debridement, soft tissue reconstruction, and readjustment of the fixator to promote healing and correct deformity. Fifteen patients experienced wire-tract infection (60%), which recovered when treated using local procedures. Varus angulation of 7–9° occurred in five fractures (20%) and was corrected gradually to achieve 3–4° just before frame removal. We evaluated the results of this technique using ASAMI criteria, which revealed 21 cases with excellent outcome, three with good outcome, and a single fair result.

Conclusion

On the basis of this work, we recommend this method for retaining the function of the limb after high-energy injuries to the distal leg. The Ilizarov fixator is safe, versatile, effective in providing stability, and allows proper soft tissue handling with easy postoperative correction of any residual deformity and early rehabilitation with relatively good cost-effectiveness.

Keywords:

high-energy tibial fractures, Ilizarov technique for tibial fractures, periarticular tibial fractures

Egypt Orthop J 47:424–430

1110-1148

Introduction

Open fractures of the distal one-third of the tibia-fibula are relatively common fractures of long bones, having been frequently recorded in Egyptian hospitals in the last few decades as a result of traffic accidents. Because of variations in their types, etiologies, limited soft tissue coverage, and blood supply, these fractures often lead to union and soft tissue problems such as persistent infection, deformity, shortening, bone loss, joint stiffness, and limb disability [1].

Conventional forms of treatment in the form of multiple extensive debridements and coverage of tissue defects with flaps or skin grafts, antibiotic bead packing of the defects, Papineau open cancellous grafting, tibiofibular synostosis, and free tissue transfer including bone transplants address the problem of infection and nonunion. Late secondary procedures are often required for correction of bone defects and/or deformity. This eventually results in multiple surgeries and scarring of tissues with joint stiffness and chronic lymphatic obstruction, which interfere with an optimal or even satisfactory limb function [2,3].

Although bone loss, soft tissue injury, infection, and associated multiple injuries will negatively affect the prognosis, delayed, insufficient union, or malunion, are the most common problems in these fractures [1,4].

The Ilizarov method can solve all those pitfalls simultaneously while minimizing the need for multiple operative exposures for patients, which consequently decreases morbidity, mortality, and the cost of treatment [5].

Moreover, the immediate stability of this method of fixation allows weight-bearing ambulation and free joint mobilization. Progressive osteogenesis and histogenesis following frame application help in filling bone gaps, in eradicating infection, and in promoting fracture union [6,7].

Cases in which the soft tissue defect considerably exceeds bone loss may require simultaneous or second-session simple or reconstructive soft tissue procedures without marked endangerment of frame stability by using tensioned transfixion wire in a small bone segment, as a result of which multiple wires can be inserted and tightened, resulting in strong fixation of the bone [1,4,6–8].

Further, once the wound is healed, osseous deformity length and residual malalignment are gradually corrected in outpatient clinics by distraction osteogenesis [9].

Patients and methods

Twenty-five patients (22 men, three women) with a mean age of 34.3 years with open comminuted fractures of the distal third of the tibia-fibula were treated using Ilizarov fixators between January 2006 and August 2007 in Ain-Shams University Hospitals and Naser Institute. This technique was applied in patients with distal tibial fractures that were unsuitable for internal fixation. The etiologies of the fractures were as follows: 22 cases of road traffic accidents, a single case of a gun shot injury, and two cases in which patients had fallen from heights. All the fractures were open. On the basis of the AO classification of the fracture type, modified by Müller, six were A1, eight were A2, and 11 were A3 (Illustration 1).

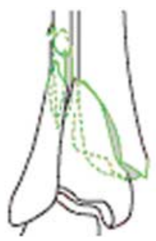
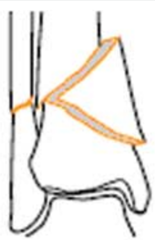
As regards the soft tissue involvement, 12 patients of Gustillo grade II, eight of grade IIIA, and five of grade IIIB were included in this study. Patients with neurovascular and tendon injuries were excluded from this study (Fig. 1).

The mean arrival time of the patients at the hospital was 8.6 h and the mean outset time for operation was 26.8 h. The frames were assembled preoperatively guided by three standard radiological views. Any suspected intra-articular extension was excluded by computed tomography scanning of the ankle joint.

Figure 1

Case no. 21: Grade IIIB Gustillo open fracture of the distal leg.

Illustration 1

Extra-articular	A1 metaphyseal simple	A2 metaphyseal wedge	A3 metaphyseal complex
			

Modified AO classification of distal leg fractures.

While preparing the Ilizarov ring fixator, two rings were placed proximal to and one more ring was placed distal to the fracture site. The distal ring was fixed by multiple wires, hydroxy-apatite shanzes – to promote healing and minimize infection – proximally and sometimes distally to the fracture site if an adequate bone stock was available. Under suitable anesthesia, the patients were placed in the supine posture. A tourniquet was never used.

The management of soft tissues includes proper debridement, irrigation with antibiotic solution, excision of loose tiny bony fragments, and meticulous handling of deep tissues so as not to strip the bone. Primary repair of muscular tissue was performed, leaving the skin for evaluation after application of the frame.

Acute shortening in five cases (cases 5, 7, 12, 21, and 24) of an average of 1.5 cm (1.1–1.9) was carried out in cases of severe soft tissue loss (grade IIIB) to help in primary and delayed primary closure of wounds following consultation for plastic surgery. Accuracy of reduction was controlled with an image intensifier. Several and varied maneuvers were made to cover the exposed part of the bone with soft tissue based on the type of trauma with concomitant consultation with a plastic surgeon (Figs 2 and 3).

Initially, fibular alignment was established either by one-third tubular plates (if there were no overlying skin problems) (13 fibulae), by an intramedullary long retrograde 2.4 mm K-wire in open fibular fractures (eight fibulae) (Fig. 4), or by distraction of K-wires applied to proximal and distal rings in highly comminuted fibular fractures (three fibulae). In a single case of comminuted fibular fracture, wherein fibular length was not achieved by distraction, combined reduction and fixation was obtained using a retrograde Steinmann pin.

In all cases, 1.8-mm bayonet-pointed K-wires were used in the tibial diaphysis, and sharp-pointed K-wires were used for the metaphyseal region. Olive K-wires were used for the reduction of floating fragments whenever necessary.

Two swabs were obtained from the wound, first on patient admission and the other intraoperatively from three different sites; the antibiotic regimen was changed according to culture and sensitivity. Combined antibiotic prophylaxis (third-generation cephalosporin and metronidazole generics for anerobic coverage) was started on patient admission and rationalized until definitive culture results were obtained.

Regular pin tract cleaning was advised and followed (twice a day minimally) using only warm saline solution and a soft toothbrush.

Ankle and knee activity exercises were started from the second postoperative day. They were mobilized with controlled partial weight bearing for 14 days and gradually progressed to full load at the end of the second month postoperatively. Follow-up radiographs were obtained on the first, seventh, 14th, and 28th postoperative day and monthly thereafter.

Serial wound dressing at intervals of 48–72 h and repeated operative debridements whenever needed (seven wounds), wound and fracture-site compressions (13 fractures), and split-thickness skin grafts (eight wounds) with frame adjustment were used to accomplish wound closure performed within 3 weeks of primary surgery.

The progress of bony union was assessed clinically and radiologically at monthly intervals until the union became solid. The radiological bony union was satisfactory when there was good evidence of periosteal bridging and obliteration of the fracture line by endosteal callus formation. The clinical assessments of the union were mainly based on complete absence of pain and tenderness at the fracture site.

Figure 2

(a) (b)

Case no. 5: (a) pattern of fracture (Table 1); (b) intramedullary realignment of the fibula using a percutaneous retrograde long wire.

Figure 3

Case no. 18: (a) pattern of fracture; (b) immediately after surgery; (c) following frame removal at 6 months; (d) progression of soft tissue healing from the second month to the fifth month; (e) clinical photograph of soft tissue status at the end of the follow-up period.

Satisfactory wound healing and good amount of endosteal and periosteal callus formation were taken as the criteria for removal of fixator.

Following frame removal, all patients were instructed to apply ankle cam orthosis with full weight bearing for another 3 weeks with vigorous exercises of all joints and muscles of the involved extremity. The orthosis was taken off while sitting and while in bed.

Results

The demographic details of patients are shown in Table 1 and include age, sex, AO classification of fracture pattern, Gustello grading of associated soft tissue injury, additional procedures (soft tissue debridment, frame readjustment, and/or skin reconstructive surgeries), duration of operation, treatment, and follow-up.

As regards the pattern of fractures, radiological evaluation following modified AO descriptive classification in this work group showed the following results: six patients with A1, eight with A2, and 11 with A3 type of fractures. Soft tissue injury was evaluated by the Gustillo grading system and showed 12 patients with II, eight with IIIA, and five patients with IIIB pattern. Additional procedures were performed on different occasions when needed for 14 patients.

All fractures were healed. The mean time of removal of the external fixator was 6.44 months. Mean age of the work group was 35.5 years. Mean duration of operation was 149.8 min, whereas mean duration of treatment was 6.44 months. The duration of follow-up was extended to 18 months with a mean of 12.48 months.

Delayed union occurred in seven patients with A3 pattern of fracture and required distraction-compression and frame dynamization maneuvers. Other complications included three patients with symptomatic mild subtalar arthritis managed by local corticosteroid injection and stiffness of the ankle joint in three patients that needed rehabilitation. All radiological evaluations showed normal alignment, except in seven patients, four of whom had greater than 7-degree varus angulation during the postoperative follow-up, which was revised by frame readjustment. The range of ankle joint motion was optimum in 22 cases, whereas in three patients there was asymptomatic loss of the last 10° of dorsiflexion.

We obtained satisfactory results in 20 and suboptimum results in four patients in terms of radiological bone assessment. According to ASAMI, functional results were evaluated for shortness, angulation, rotation, ankle stiffness, pain, and infection (Tables 1 and 2). Results were excellent in 21 patients, good in three patients, and fair in a single case. No rotational deformity was seen. None of the patients required amputation. There was no refracture after frame removal. Pin tract infection occurred in 19 out of the 24 patients. There were no incidents of chronic osteomyelitis secondary to pin tract infection in any of the cases. There were no cases of implant failure.

Figure 4

Case no. 21: (a) pattern of fracture; (b) immediately after surgery (radiological and clinical); (c) 2 months postoperatively on radiological and clinical evaluation; (d) 7 months after surgery following frame removal; (e) 18-month postoperative radiographs; (f) clinical photograph following frame removal.

Discussion

Fractures of the distal third of the tibia-fibula of a periarticular pattern, which are accepted as unstable fractures, have a wide range of treatment modalities from closed reduction to an external fixator. The objectives of the treatment of these fractures are rapid and ideal healing, minimization of loss of function, and prevention of any deformity [3,5].

When dealing with open fractures, meticulous debridement with wide excision of the involved bone and accompanying soft tissue is critical in the surgical management of high-energy leg trauma. The elimination

Table 1 Demographic data of the work and functional ASAMI outcome

Case	Age	Sex	AO	Gustello	Duration of operation (minutes)	Duration of treatment (months)	Duration of follow-up (months)	Additional operative procedure	ASAMI
1	29	M	A3	IIIA	120	6	14	D–R	Excellent
2	33	M	A1	II	150	6	16	–	Excellent
3	50	M	A1	II	120	6	12	–	Excellent
4	21	F	A3	IIIA	145	6	13	R	Excellent
5	24	M	A2	IIIB	180	6	14	S–R	Excellent
6	32	M	A3	IIIA	150	7	12	D	Excellent
7	38	M	A3	IIIB	180	6	12	S	Fair
8	39	M	A2	II	150	8	12	–	Excellent
9	32	F	A2	II	120	6	18	–	Excellent
10	52	M	A1	II	120	6	14	–	Excellent
11	33	M	A1	II	150	6	16	–	Excellent
12	43	M	A2	IIIB	180	6	12	D–S	Good
13	33	M	A2	II	120	6	12	R	Excellent
14	46	M	A3	IIIA	180	7	12	S	Excellent
15	51	M	A2	IIIA	180	6	12	–	Excellent
16	39	M	A3	II	150	8	14	–	Excellent
17	30	M	A1	II	120	7	18	–	Excellent
18	27	M	A3	II	120	8	12	–	Excellent
19	29	F	A3	IIIA	180	6	15	D–R	Excellent
20	32	M	A3	IIIA	180	6	12	S–R	Excellent
21	45	M	A2	IIIB	150	6	12	D–S–R	Good
22	36	M	A1	II	120	6	12	–	Excellent
23	21	M	A2	II	180	8	18	R	Excellent
24	44	M	A3	IIIB	150	6	13	D–S	Good
25	32	M	A3	IIIA	150	6	15	D–S	Excellent

of potentially infected bone and necrotic tissue and improvement of the local blood supply with soft tissue coverage are important principles for proper functional limb salvage and avoidance of infected nonunion [6,9,10].

After proper handling of the soft tissue defect, the Ilizarov technique, alone or in combination with soft tissue reconstructive procedures, may be used effectively to treat those types of fractures, with researchers reporting between 75 and 100% success [3,5,11,12]. The Ilizarov external fixator, along with either primary or delayed primary closure followed by early mobilization and weight bearing, is a sound treatment method for open distal leg fractures. Acute shortening, using the Ilizarov technique followed by progressive lengthening, is one of the methods used to treat complex fractures combined with severe soft tissue injuries [6,13].

Despite technical difficulties and problems associated with pin tract infections, the Ilizarov external fixator may be the preferred technique for treating open tibial fractures because of high union rates, the use of thin K-wires with minimal traumatic effect, and more successful functional results [10,13–17].

Complications such as pin tract infection and stiffness are characteristics of this technique, although functional results were better in the upper fourth and distal fourth tibial fractures than in upper and shaft fractures [6,11,12,17].

Many researchers accept shortness up to 2 cm after treatment of fractures of the distal one-third of the tibia-fibula [3,5,11,12]. Risk of alignment loss is higher in the distal one-third of tibia fractures than in any other part of the tibia [5,11]. Five degrees of varus–valgus and 10° of procurvatum–recurvatum deformities are usually considered acceptable [3,5,11,12].

Table 2 ASAMI criteria for evaluation of treatment efficacy

Excellent	Union No infection Deformity $<7^\circ$ Limb-length discrepancy <2.5 cm
Good	Union + any two of the following Absence of infection $<7^\circ$ deformity Limb-length discrepancy of 2.5 cm
Fair	Union + one of the following Absence of infection $<7^\circ$ deformity Limb-length discrepancy of 2.5 cm
Poor	Nonunion Refracture Union + infection + deformity $>7^\circ$ + limb-length discrepancy >2.5 cm
ASAMI	Association for the Study and Application of the Method of Ilizarov

Therefore, on using this technique, all results were comparable to those of previous studies using open reduction and internal fixation, provided that the frame design was long, including the entire leg segment, and every effort was made to preserve the total arc of range of motion by sparing and not bridging the ankle joint [8,10,14,17,18].

Some researchers denied the need for further comprehensive plastic or reconstructive soft tissue reconstruction, provided there was proper initial handling of soft tissue coverage [6,19].

The results of this study in terms of soft tissue healing and bony union were similar to those of other studies. In addition, the rate of complications was restricted to minimum with no residual pain or infection. Residual shortening and deformity were accepted in terms of ASAMI criteria, and patient satisfaction was optimum.

In the study by Kumar and colleagues, bony union was significantly different between fracture types; distal one-fourth tibial fractures took the longest duration to unite with a minimum of 1 cm of shortening, and a single case developed 10° of equines. Pin tract infection occurred in 21% of cases and resolved after treatment with oral antibiotics and care of pin sites. There was no loosening of frame due to pin tract infection [3].

In the study by Dagher and Roukoz, union was achieved in all nine patients. The mean interval between operation and union, which ranged from 6 to 10 months (mean 7.7), was not related to the length of the bony comminution. No final leg-length discrepancy exceeded 10 mm and all infected cases healed without a second operation.

There were no neurological complications, and all the wounds healed successfully. All the patients were satisfied with their result, and seven of the nine patients were able to resume their previous occupations. There was only one incidence of refracture, which was attributed to the early removal of the apparatus after 5 months without preliminary loosening of the bolts. The apparatus was replaced for an additional 4 months, which resulted in union with no further operations [20].

Demirlap and colleagues presented similar results in their work. Their patients' mean framing time was 14.1 ± 1.8 weeks (range, 12–19 weeks), and the mean treatment time was 18.8 ± 2.2 weeks (range, 15–24 weeks). The patients were followed up for 36–78 months (mean follow-up time, 51.9 ± 10.4 months). Their results were evaluated for shortness, angulation, rotation, ankle stiffness, pain, and infection; after removal of the frames, 11 patients had ankle pain and stiffness, and three patients had loss of range of motion in the ankle even after rehabilitation. None of the patients suffered any complications such as shortness, angulation, rotational deformity, and infection, and none had loss of motion in the knee [5].

All researchers agreed with the possibility of correcting any angular deformity using this method, either intraoperatively using stop wires or postoperatively using hinge systems [3,5,11,12]. In addition, axial compression by early weight bearing minimizes the delayed union and nonunion [5].

Conclusion

This technique has several advantages. First, it permits definitive treatment using an external fixator device, enabling the possibility of early functional loading. Second, functional results were good in grade III soft tissue injury and excellent in grade II whatever the pattern of fracture.

On the basis of this work, we suggest using this method for functional limb salvage after extensive complex high-energy injuries. This fixator is safe, versatile, effective in providing stability, and allows early rehabilitation.

Acknowledgements

Conflicts of interest

There are no conflicts of interest.

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