Treatment of infected nonunion of forearm bones by ring external fixator

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Background
An infected nonunion in the diaphysis of the radius and ulna is a difficult problem to solve. Several methods and techniques have been suggested including repeated debridement followed by internal fixation and bone graft or through vascularized free tissue transfer. The results of treating infected nonunions of the forearm bones by a two-stage treatment strategy using the Ilizarov ring external fixators are reported. All cases were treated at the Menoufia University Hospital.

Patients and methods
Nine patients with an average age of 49 years (range, 45–52 years) with infected nonunions of one or both bones of the forearm were treated at this unit between August 2005 and September 2007. A staged protocol of treatment was adopted in case of active infection. The first stage included radical debridement of the site of nonunion followed by an interval of antibiotic treatment. The final stage included application of a ring external fixator. Three patients had nonunions of both the radius and ulna, another two had nonunion of the ulna, and four patients had nonunion of the radius. Autogenous cancellous bone graft was used in all patients to treat the defect caused by the nonunion and surgical resection. Patients were evaluated by The Disabilities of the Arm, Shoulder and Hand score.

Results
The mean period in the external fixator was 22.6±3 weeks (mean±SD). All fractures achieved full bony union with no evidence of deep infection at last review (mean follow-up period 34 months; range, 24–47), as well as vascular or neural compromise. The mean The Disabilities of the Arm, Shoulder and Hand score improved from 90.5 preoperatively to 41.4 postoperatively ($P<0.05$). One patient was not able to complete his treatment in the external fixator.

Conclusion
Staged treatment first involves radical debridement of infected bone and soft tissue, which allows eradication of infection. Bone defects can be dealt with through distraction osteogenesis, segment transport, or bone grafts in conjunction with using ring external fixators. The Ilizarov external fixator can be used to overcome bone defects and soft tissue contractures in the forearm, but special expertise in the technique and knowledge of the cross-sectional anatomy of the forearm are essential.

Keywords:
external fixator, forearm bones, infected nonunion

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Introduction

Nonunion of diaphyseal bones of the forearm is not uncommon [1,2]. Several factors are implicated in the etiology of nonunion, including disturbance of arterial supply to the cortical bones [3], infection, lack of stability, inadequate reduction, and the high level of forces transmitted through long levers [2,4,5]. The problem is more complicated if the nonunion is associated with infection.

An essential step in eradication of infection is debridement; this involves the removal of metal work in addition to all devitalized bony and soft tissues. A defect or loss of bone segment usually results after an adequate debridement [6,7]. Various methods have been advocated to overcome long bone defects, including autogenous bone graft, nonvascularized and vascularized fibula transfers, and osteogenesis through bone segment transport [1,7–9].

Autogenous bone graft can be used in filling small defects that are usually less than 2–3 cm. On the contrary, free vascularized transfer of the fibula is used for large bone defects that exceed 6 cm or more. Free fibular transfer is technically demanding, needing special skills for microsurgical anastomosis and has a risk of vascular compromise especially when only a single trunk (ulnar or radial) is patent [10].

The ring external fixator has successfully been used to overcome bone loss in different long bones using the concept of distraction osteogenesis and segment transport [7,11,12]. Although there is relatively a smaller number of publications in the upper limb, favorable outcomes have been reported [13,14]. The use of external fixation is an attractive alternative that avoids the use of internal metal work, which carries the risk of recurrence of infection [11]. However, safe corridors for wire insertion in the forearm are narrow and should be cautiously practiced [14]. This paper revisits the technique of ring and wire external fixation in the forearm and reports the results in a series of nine patients with nonunion of one or both bones of the forearm.

Patients and methods

Nine patients with average age of 49 years (range, 45–52 years) with an infected nonunion in one or both bones of the forearm have been treated in the Orthopaedic Department, Menoufia University Hospital. This clinical study was approved by the postgraduate and ethical committee at the Faculty of medicine, Menoufia University.

Three patients had nonunion of the radius and ulna at the junction of the middle and distal thirds with fixed contractures of the soft tissues that resulted in radial deviation and dorsal angulation deformities. They had undergone internal fixation of these fractures that were complicated by infection and the metal work removed and a debridement performed. A fine wire circular external fixator was applied and gradual correction of the deformity performed. Defining the plane of the deformities, axis for application of hinges and distraction and compression rods followed the standard methods published by Gladbach *et al*. [15] and Villa *et al*. [16]. The Centre of Rotation of Angulation was defined on preoperative radiography and used as a guide for setting up hinges during fixator application. Correction of angulation was performed at a rate of 2 mm per day.

Having corrected the soft tissue contracture, patients were taken to theater when fracture ends were refreshed and autogenous cancellous bone graft from the iliac crest was impacted at site of nonunion. Compression at the site of nonunion was performed.

Four patients had nonunion of the middle third radius and two other patients had nonunion of the ulna. The six patients had evidence of active infection with draining sinuses. A staged protocol of treatment was adopted in the six cases. The first stage included radical debridement at the site of nonunion with excision of infected bone and soft tissues in addition to removal of metal work. Following the first stage of debridement, patients were kept on antibiotics according to culture and sensitivity results of specimens taken at the time of debridement. Follow-up with clinical assessment and repeated erythrocyte sedimentation rate, C-reactive protein, and complete blood count was continued until clinical and laboratory results confirmed that infection became quiescent. Negative C-reactive protein result and reduction of the erythrocyte sedimentation rate curve to approach normal (<25 mm/h) in addition to a clinical picture of absence of infection were the criteria that determined the timing of the second stage.

The second stage of treatment included application of Ilizarov external fixator in the forearm and proximal corticotomy in the two cases of ulna nonunion. Gradual distraction at site of corticotomy commenced 7–10 days after the operation at a rate of 1 mm per day (0.25 mm every 6 h). In the four cases of radial nonunion, there was either angulation at site of nonunion or subluxation at the inferior radio-ulnar joint. Correction of radial angulation and shortening resulted in an increase in the length of bone defect.

To reduce time in the external fixator, bone graft was performed at the docking site in all cases as a separate procedure after completion of the segment transport and/or correction of alignment.

Patients were instructed to mobilize their fingers, elbows, and shoulders from the first day. The protocol for pin-site care was that of Davies *et al*. [17].

Results

The created bone defects ranged from 25 to 35 mm in the seven cases of non union with segment loss. The mean period of follow up was 34 months (range, 24–47 months).

The mean±SD period in the external fixator was 22.6 ±3 weeks. All patients accomplished solid bony union free of infection. No vascular or neural compromise occurred in any of these patients. A significant improvement in the upper limb function was noted;

the Disabilities of the Arm, Shoulder and Hand score was reduced from 90.5±4 preoperatively to 41.4±3 postoperatively (mean±SD, $P<0.05$).

Complications

One patient was not able to tolerate the protocol of treatment in the external fixator because of pain at the time of segment transport. The external fixator was removed after transporting the proximal fragment for 15 mm, and a small limited contact angle-stable plate (AO–ASIF) was used to bypass the site of nonunion and proximal regenerate. Bone graft was performed at both regenerate and bone defect sites (Fig. 1).

A cross-union between the radius and ulna was recorded in one case (Fig. 2) that produced a loss of forearm rotation. The patient was satisfied with the result and did not want further treatment for this limitation in forearm function.

A superficial pin-site infection was reported in at least one pin in all patients that resolved with frequent dressing and a short course of antibiotics.

Two patients needed adjustments of the external fixator with the addition of a half pin to the middle ring to increase the stability of the fixator. These adjustments were performed at the time of bone grafting of the docking site (Tables 1 and 2).

Discussion

Bone infection after fractures is a difficult problem to treat. The strategies that have evolved to eradicate infection include two fundamental steps: the first is a radical debridement that removes necrotic bone, soft tissue, and metal work, and the second is reconstructing defects created by the debridement using distraction histogenesis. The technique of distraction histogenesis has been successfully applied by surgeons after the pioneering experimental and clinical work of Ilizarov. Although most infected nonunions occur in the tibia, and this is where the dual strategy of debridement-reconstruction has been applied most frequently, the technique can be extrapolated to problems in the forearm. However, safe corridors for wire insertion are narrow in the forearm, and the application of a ring and wire fixator in the forearm is less frequently undertaken as when compared with the lower limb. Despite this difficulty, both the Ilizarov technique and fixator have been successfully used to lengthen and correct deformities of the forearm bones [14,16].

Nonunions of forearm bones are not an uncommon problem, but the majority are amenable to treatment by bone graft and compression plates [1]. However, cases with infection or segmental bony defects may require microsurgical techniques like free vascularized tissue (flap and bone) transfer [18]. This facility may not be readily available at all hospitals that receive patients needing treatment for infected nonunions. This article presents the results of treatment of infected nonunions of fractures of the forearm bones using an alternative method without recourse to microsurgery. The use of fine wire external fixators in the forearm carry a risk of neurovascular injury. This risk can be minimized: the patient should be anesthetized but not paralyzed, allowing the surgeon to detect a muscle twitch should a wire be passed close to a nerve; those wires inserted near major arteries (e.g. the proximal wire of the radial neck) can be inserted through a mini-open technique or if a hypodermic needle is introduced first along the intended path of the wire to make sure that no blood returned through the needle. Using these precautions, there were no incidences of nerve or arterial injuries in this series.

This protocol of treatment for infected nonunion has successfully achieved infection-free bony union in all cases at a mean follow-up of 34 months (range, 24–47 months).

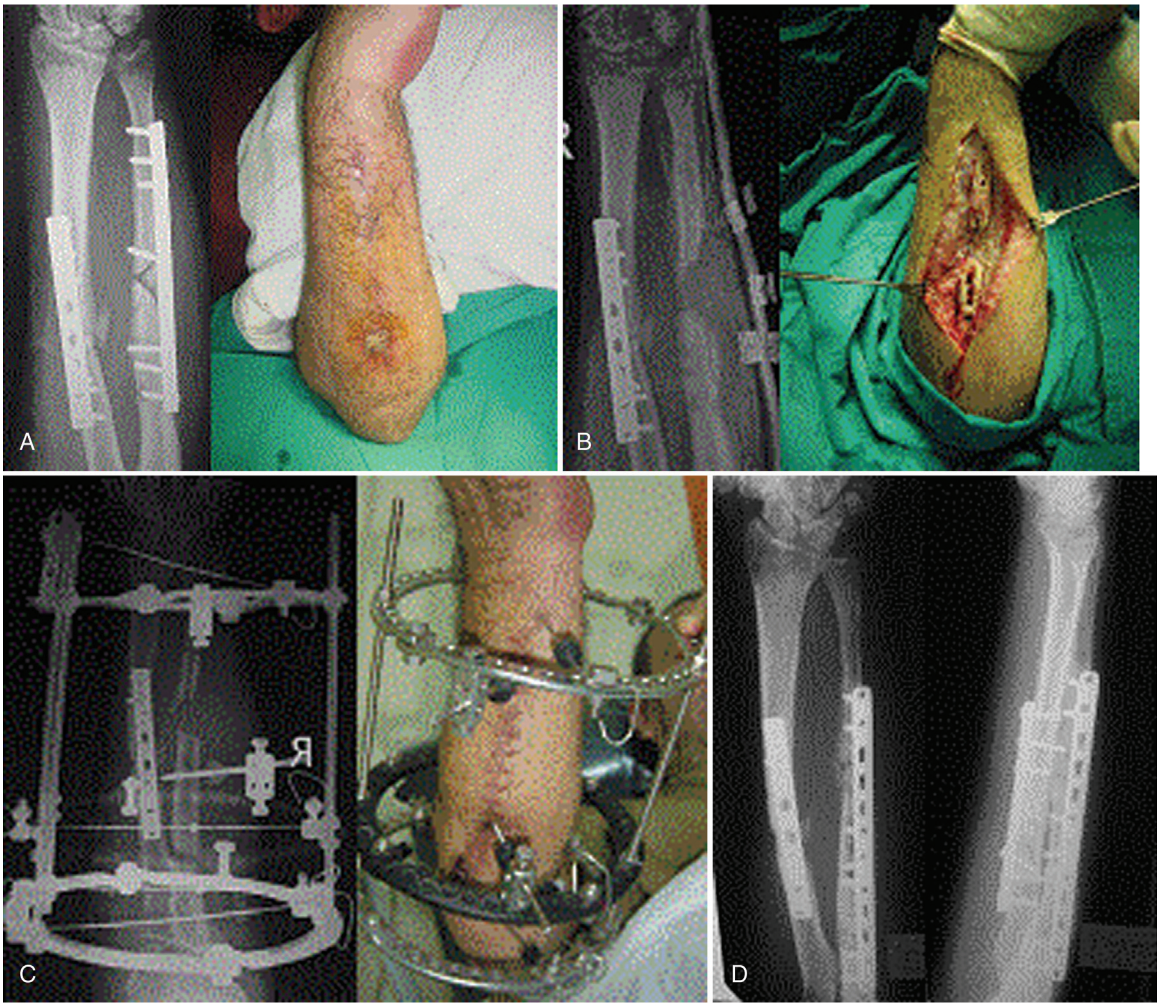
The staged protocol of treatment allowed collection of tissue samples at the first stage, and polymicrobial infection was identified in all cases that presented with draining sinuses. The accuracy of cultures collected from infected bone tissues in identifying the real organism is higher than swabs collected through the draining sinus or from the bone surface, especially in cases of polymicrobial infection. Identifying the infecting organism is an essential step in eradication of infection [19].

One patient in this series could not tolerate segment transport through the external fixator because of pain despite the use of strong pain killers. Therefore, it was necessary to remove the external fixator and modify treatment by using a plate to span the bone. Nevertheless, the external fixator was beneficial in reducing the length of the defect at site of nonunion from 3.5 to 2 cm, thereby making it feasible to use cancellous bone graft to fill defects at the site of nonunion and the new regenerate. The inability to tolerate treatment in an external fixator has previously been reported [20,21] and indicates that although ring fixators help in treatment of complex

Figure 1

(a) Preoperative radiography s and clinical picture show nonunion of the distal radius and ulna. The patient had three previous operations for attempted fixation that included K-wire that were complicated with infection and nonunion. There is obvious radial deviation, scars, and soft tissue contracture. (b) Proximal wires: anterior wire introduced through the neck of the radius 1 cm distal to the joint line. The forearm is supinated. The entry point lies ulnar to the posterior interosseous nerve and radial to the recurrent radial artery. To select the point of entry, a needle is used to penetrate the skin and touch the bone first. Position of the needle is confirmed by radiography, then a stab incision is performed and closed mosquito forces used to bluntly dissect a pass for the wire. A second wire is transfixing the radius and ulna and a third wire is passed through the ulna only. (c) Distal wires a wire inserted through the distal radius. Entry point is 1 cm proximal to the joint line and just radial to the tendon of the flexor carpi radialis. To avoid injury to the radial artery a needle is used to select site of insertion. A second wire transfixes the radius and ulna. (d) Fully constructed external fixator around the forearm. (e) Final radiography and clinical picture following the removal of the external fixation.

Figure 2



(a) Preoperative radiography and clinical picture of a 48-year-old man who had fracture of the radius and ulna 3 months before. There was evidence of nonunion of the ulna with bone resorption around proximal screws. Note the presence of a draining sinus over the subcutaneous border of the ulna. (b) Clinical picture at the time of first stage, which shows the bone defect following removal of metal work and debridement of necrotic and infected bone. Radiography shows the bone defect following the first stage. (c) Clinical picture and radiography show ring external fixator applied, proximal ulnar corticotomy performed, and segment transport commenced. (d) After a segment transport for 15 mm; a locked plate was applied to bypass the site of nonunion and the new bone regenerate. Bone graft was used at both sites and ended by free of infection solid bone union.

Table 1 Characterization of the nine patients who experienced infected nonunion in ? **one or both bones of the forearm and included in the current study**

Patient ID	Age	Affected side	Bone defect	Level of bone loss	Draining sinus	Organisms identified	Union after bone graft (weeks)	Follow up (months)
1	47	Dominant	30 mm	Proximal ulna	Yes	MRSA, *Klebsiella* spp.	12	47
2	43	Nondominant	15 mm	Midradius	Yes	MRSA, *Escherichia coli*	10	44
3	41	Dominant	20 mm	Distal radius and ulna	No	No	14	42
4	24	Nondominant	25 mm	Distal radius and ulna	Yes	*Pseudomonas*, *Staphylococcus aureus*	10	35
5	50	Nondominant	35 mm	Proximal ulna	Yes	MRSA, *Candida albicans*	16	34
6	35	Dominant	10 mm	Midradius	No	No	12	30
7	37	Dominant	20 mm	Midradius	Yes	MRSA, *E. coli*	14	28
8	51	Nondominant	10 mm	Distal radius and ulna	No	No	16	26
9	25	Dominant	10 mm	Midradius	Yes	MRSA, *Klebsiella spp.*	12	24

MRSA, methicillin resistant staph aureus.

Table 2 Characterization of the nine patients regarding organisms identified, antibiotics, and surgeries

Patient ID	Organism identified	Antibiotic used	Weeks on AB after debridement	Weeks on AB after external fixation	Number of surgeries performed before the index procedure
1	MRSA, *Klebsiella spp.*	Imipenem and	4	2	3
2	MRSA, *E. coli*	Imipenem and	6	2	2
3	MRSE	Vancomycin, rifampicin, and ciprofloxacin	4	2	3
4	*Pseudomonas*, *Staphylococcus aureus*	Imipenem	5	2	4
5	MRSA, *Candida albicans*	Vancomycin and diflucan	6	2	2
6	*Staphylococcus* and *E. coli*	Vancomycin, rifampicin, and ciprofloxacin	4	3	4
7	MRSE, *E. coli*	Imipenem and rifampicin	5	2	2
8	MRSE	Vancomycin, rifampicin, and ciprofloxacin	4	3	2
9	*Klebsiella spp.*	Imipenem	7	3	3
Average			5	2.3	2.8

MRSA, methicillin resistant staph aureus.

nonunions, they cannot be tolerated by all patients. Close patient–surgeon contact in addition to psychological support from the medical team and patients' families helps in completing the course of treatment.

This series of nine cases has affirmed important principles in treatment strategies for treating infected nonunions. A staged protocol of treatment simplifies and increases safety for a successful outcome in eradication of infection. Although it is possible to complete the reconstruction without recourse to bone grafting techniques, the use of cancellous bone graft reduces time in the external fixator and provides high rate of bony union at the docking site.

Conclusion

Staged treatment that involves radical debridement of infected bone and soft tissue allows eradication of infection before reconstruction. The bone defects produced after debridement can be compensated by distraction osteogenesis and bone transport using ring external fixators. The Ilizarov external fixator can be used successfully in treatment of such nonunions of the forearm but it needs to be selected for patients who are likely to be able to tolerate such a protocol of treatment.

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Conflicts of interest

There are no conflicts of interest.

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