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Original Article

One-stage management of post-traumatic tibial infected nonunion using bone transport after debridement

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Aim: To evaluate the results of the management of post-traumatic tibial infected nonunion using bone transport with external fixators.

Materials and methods: We retrospectively reviewed a consecutive series of 35 patients from 2000 to 2008 in our hospital who were treated for the post-traumatic tibial nonunion by bone transport with an external fixator. Thirty-two limbs (80%) were in active infected state. The mean amount of bone defect was 3.5 cm (range 1.0 to 7.8 cm) as measured on plain radiographs. The mean leg-length discrepancy was 4.4 cm (range 0 to 8.7 cm).

Results: The mean follow-up was 72.5 months (range 35-106 months). All the patients had bony union and the infection had been controlled. The mean external fixation index was 40.7 day/cm (range 34.2-46.9 day/cm). The mean length gained was 7.9 cm (range 4.0-10.5 cm). Based on the criteria recommended by Paley et al., 28 bone results were excellent, 5 good, 2 fair, and none poor; 30 functional results were excellent, 4 good, 1 fair, and none poor.

Conclusion: Bone transport with an external fixator is a safe, effective, and minimally invasive technique to treat post-traumatic tibial infected nonunion.

Key words: Bone transport, infected nonunion, external fixator, bone defect

Introduction

Infected nonunion was defined as a state of failure of union and persistent infection at the fracture site for 6 to 8 months (1,2). Open fractures and fractures caused by high-energy trauma are likely to develop nonunion. The tibia, being a subcutaneous bone, is the most commonly involved weight-bearing bone for open comminuted fracture and infected nonunion (3,4). For many years, infected nonunion has been one of the most difficult clinical situations despite major advances in the fixation technique, soft tissue management, and antibiotic therapy (5). Although many treatment modalities have been proposed (1-5), none has been accepted as the gold standard. In this report, 35 patients with post-traumatic tibial infected nonunion were treated by bone transport with external fixators, and the results of the treatment are presented.

Patients and methods

Thirty-five consecutive patients with post-traumatic tibial infected nonunion were treated from June 2000 to June 2008 in our institution. Bone transport with an external fixator was used in all patients. The mean age of the patients was 37.3 years (range, 18-64 years). There were 25 males and 10 females (Table 1). All the patients had comminuted open fractures caused by high-energy trauma in traffic accidents. The average interval between their initial treatment and

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Table 1. Clinical data of the patients before the treatment.

Case	Sex	Age (years)	Bone loss (cm)	Limb shortening (cm)	Number of previous tibial surgeries
1	M	19	4.0	0	2
2	F	20	1.3	5.3	3
3	M	32	3.5	7.0	4
4	M	33	4.5	0	3
5	F	51	2.0	6.4	2
6	M	28	2.5	7.0	2
7	F	58	3.0	6.7	4
8	M	18	5.0	0	2
9	M	39	1.5	8.0	4
10	M	35	2.5	5.9	2
11	F	40	2.7	8.7	5
12	M	52	3.0	7.5	2
13	M	34	6.5	0	3
14	M	21	4.5	0	1
15	F	38	3.5	6.5	2
16	M	41	4.0	5.5	3
17	M	37	5.0	0	2
18	M	42	3.5	6.3	6
19	F	25	3.0	4.2	1
20	M	31	5.4	0	2
21	M	39	2.5	7.0	3
22	M	22	3.0	5.0	4
23	M	54	5.6	0	3
24	M	38	4.7	5.5	3
25	F	35	2.9	7.3	2
26	F	62	4.8	0	2
27	M	30	1.0	6.8	4
28	M	32	2.5	6.8	2
29	F	24	3.0	5.5	2
30	M	55	3.0	6.4	3
31	M	64	7.8	0	3
32	M	39	2.0	5.7	2
33	F	50	3.7	6.4	3
34	M	38	2.6	6.5	2
35	M	29	4.3	0	1

administration to our hospital was 14.5 months (range 9-21 months). The sites of nonunion were proximal tibia in 6 cases, middle tibia in 10 cases, and middle-distal tibia in 19 cases. In the present study group, 7 patients had only a segment defect; 4 had deformity associated with a segment defect; 5 had a combination of a segment defect, deformity, and shortening; and 19 patients had a combination of a segment defect and shortening. The patients had an average of 2.7 surgical procedures (range 1-6 procedures) before presenting to our institution. Thirty-two limbs (80%) were in active infected state with sinus and drainage. The rest were quiescent. There were plates and screws left in 30 limbs. At the beginning of the treatment, the main clinical appearances were shortening, deformity, pseudarthrosis, limping, and pain. The mean amount of bone defect was 3.5 cm (range 1.0-7.8 cm) as measured on plain radiographs. The mean leg-length discrepancy was 4.4 cm (range 0 to 8.7 cm) (see Figures 1a-1d).

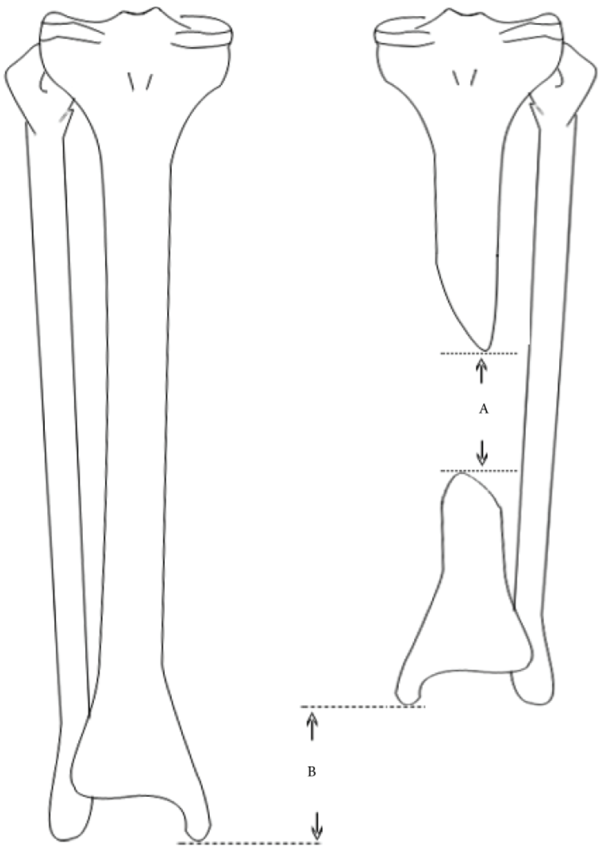

Figure 1a. Nonunion with bone loss and bone defect. ("A" shows the length of bone defect; "B" shows the length of leg shortening).

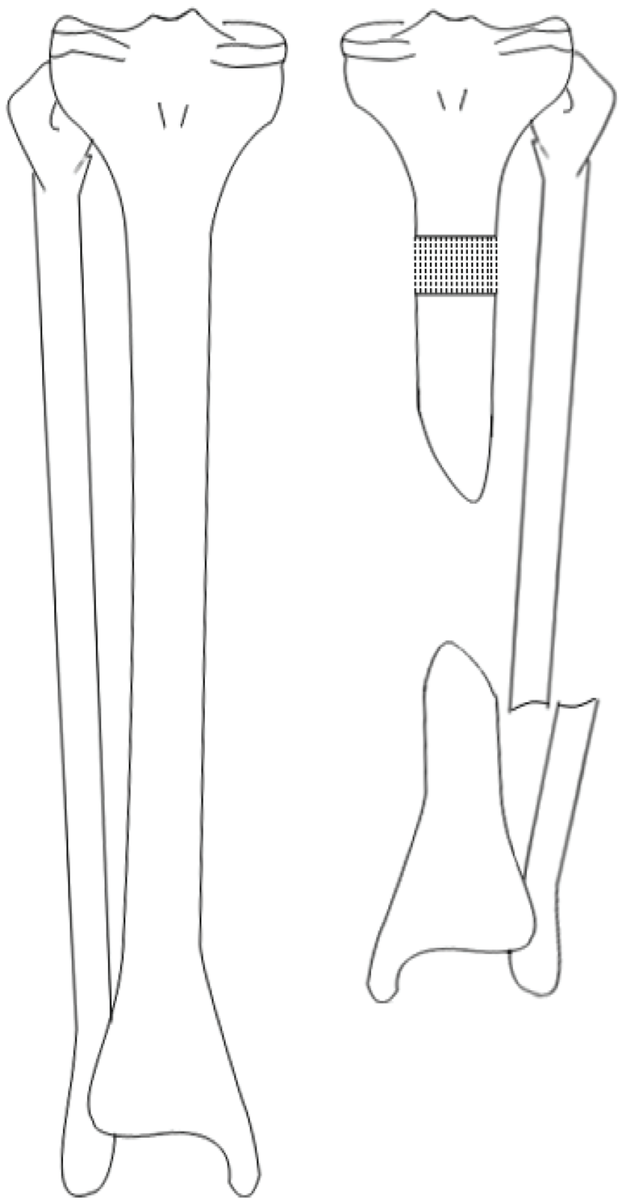

Figure 1b. Postcallus distraction.

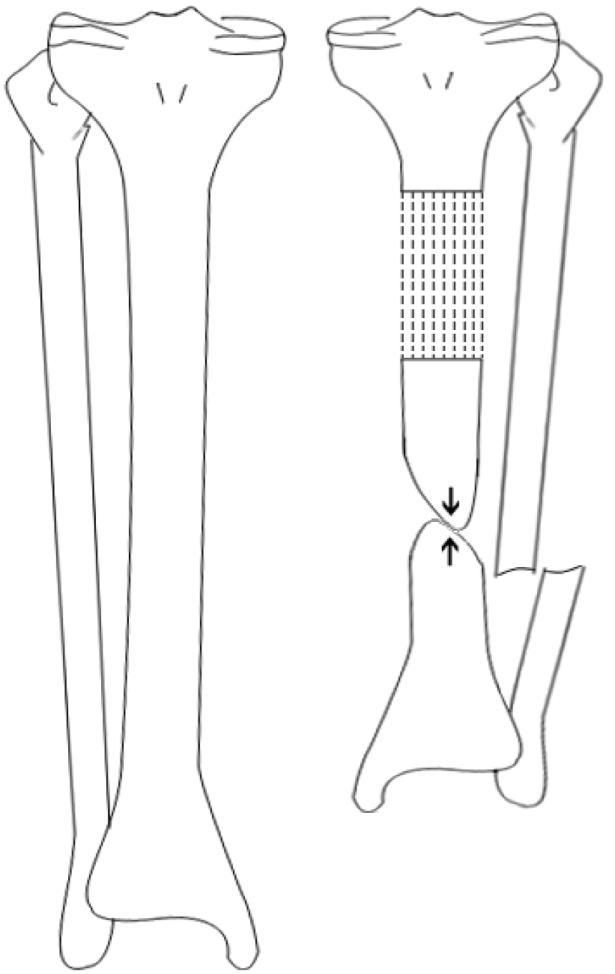

Figure 1c. Bone segments contacted.

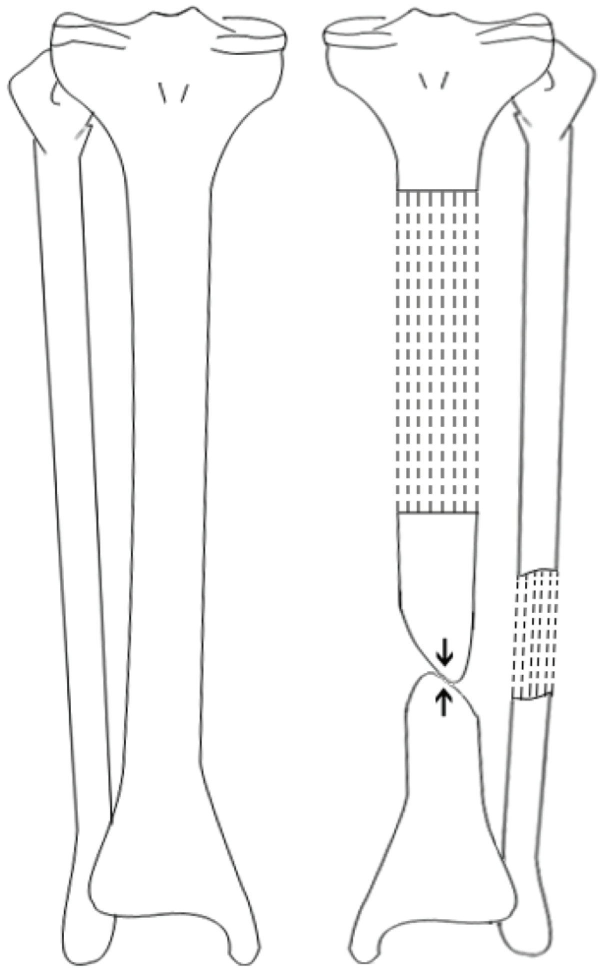

Figure 1d. Leg shortening corrected and bony union.

Surgical technique

Pre-operative radiographs were taken in the sagittal and coronal planes to assess the nonunion, to determine the osteotomy planes. Then one-stage management of infected nonunion was performed by bone transport after debridement.

Step 1: Eradication of infection and restoration of the tissue defects

For the infected limbs, particularly those that still had sinus and active drainages, hardware removal and radical resection of dead bone with debridement of the infected scarred soft tissue were performed, and representative tissue cultures, including the sinus tracts for all dead bones, were obtained. Cortical bleeding, described as the so-called paprika sign, was accepted as an indication of vital tissue. The dead space was filled with custom-made iodoform gauze. Systemic and local antibiotics were chosen on the basis of cultures. In 5 cases, to cover the large soft defects, local flaps or free-vascularized muscle flaps were employed.

Step 2: bone transport with external fixation

The distal lateral fibula was exposed and a subperiosteally transverse osteotomy was performed in the patients with deformity or shortening. Under image intensifier control, 1 or 2 pins 4.5 mm in diameter were inserted 2 cm to 5 cm above and below the pre-selected osteotomy site. If necessary 1 or 2 further pins also 4.5 mm in diameter were inserted in the other bone fragment. All these pins should be inserted in the same plane and perpendicular to the long axis of the tibia. At the same time, we fixed the fibula to the tibia with one of the pins if necessary. Then, after a 1-3 cm incision was made over the anterior tibial crest and the tibial shaft was exposed subperiosteally, a transverse osteotomy was performed at the site allocated before the operation. The periosteum was sutured and the wound was closed with a drainage tube. The external fixator was attached with a 2-cm gap between it and the leg to allow for swelling. The docking site was opened and the bone was grafted only when compression of the site failed to achieve union.

Postoperative care: All patients received intravenous aeschynomenous antibiotics for nearly 3 weeks postoperatively. Physiotherapy started on the second postoperative day. The used iodoform gauze was removed when the wound was ready to be cleaned and repacked. It was usually done once a day. The gauze should be easy to remove, and it should be disposed of properly once it is removed. The wound was repacked using an iodoform strip 1 to 3 cm shorter than the initial piece. Distraction began between 5 and 7 days after the operation at a rate of 0.25 mm per 9 h. When the length of bone regeneration had reached about 6.0 cm, the rate of the distraction was reduced to 0.25 mm every 12 h. Radiographs were taken every 2 weeks during the distraction period and every 4 weeks during the consolidation period. When the length of the regenerated bone was greater than 40% of the original limb length, the decision whether to stop or continue was taken depending on the state of the blood supply, sensation, and movement of the limb. Once the decision had been taken to stop lengthening or the required length had been achieved with bony consolidation, the external fixator was removed.

Results

The mean follow-up was 72.5 months (range 35-106 months). All the patients had bony union and the infection had been controlled. The mean external fixation index was 40.7 day/cm (range 34.2-46.9). The mean lengthening gained was 7.9 cm (4.0-10.5 cm) (Table 2, Figures 2a-2h).

The results were divided into bone and functional results according to the evaluation system previously reported by Paley et al. (1).

The results were assessed as bony or functional. For bone results, 5 criteria were evaluated as recommended by Paley et al. (1): union, infection, deformity, leg-length discrepancy, and the cross-sectional area of union of the regenerate bone and docking site. Bony union was achieved after initial treatment in 33/35 (95.7%). The persistent nonunions were re-treated with external fixator reapplication and cancellous bone grafting into the nonunion sites. A residual deformity >5° was present in 5 patients. No patient had a residual leg-length inequality of >2.5 cm. Three patients had failures in the form of recurrent drainage, which was cured by repeating debridement and the aeschynomenous antibiotic solution was used to make a continuous aspiration lavage drainage with 2 tubulars for 3 weeks. An excellent bone result was one in which there was union, no infection, deformity <5°, and leg-length discrepancy <2.5 cm, and a bone union wide enough not to require long-term bracing or protection. A good result was union without infection and failure to meet 1 of the other criteria; a fair result was union without infection and failure to meet 2 of the other criteria; a fair bone result was considered to have been achieved by any patient who required long-term post-treatment bracing or protection for a lower cross-sectional area of union of either the regenerate bone or the docking site; a poor result was nonunion and/or persistent or recurrent bone infection. Based on the criteria recommended by Paley et al. (1), 28 bone results were excellent, 5 good, 2 fair, and none poor.

The functional assessment was also based on 5 criteria according to the evaluation system previously reported by Paley et al. (1): pain; need for walking aids or braces; foot, ankle, or knee deformity or contracture; ankle and/or subtalar loss of range of motion as compared with the preoperative range; and ability to return to normal activities of daily living (ADL) and/or work. All patients could walk well without support. Four patients felt pain (requiring narcotics) after they walked a long distance (more than 2.5 km). Two patients had contracture of the ankle. An excellent functional result was one with which the patient had no pain or mild pain (not requiring narcotics); did not require a walking aid or brace; did not have equinus, heel varus, and/or knee contracture greater than 5°; did not lose more

Table 2. Results.

Case	Length gained (cm)	Healing index (day/cm)	Bone result	Functional result
1	4.0	35.7	E	E
2	6.5	37.1	E	E
3	10.5	41.7	G	G
4	4.5	39.2	E	E
5	8.5	42.5	E	E
6	9.5	45.7	E	E
7	9.7	45.3	G	E
8	5.0	39.7	E	E
9	9.5	42.3	E	E
10	8.5	40.6	E	E
11	11.5	46.9	F	F
12	10.5	42.3	E	E
13	6.5	40.5	E	E
14	4.5	37.2	E	E
15	10.0	41.5	E	G
16	9.5	40.1	E	E
17	5.0	35.2	E	E
18	10.0	46.2	G	G
19	7.0	35.0	E	E
20	5.5	36.7	E	E
21	9.5	37.8	E	E
22	8.0	42.5	G	E
23	5.5	41.3	E	E
24	4.7	40.0	E	E
25	10.0	45.6	G	E
26	5.0	43.2	E	E
27	8.0	40.2	E	E
28	9.5	43.8	E	E
29	8.5	39.4	E	E
30	9.5	42.6	E	E
31	8.0	46.5	E	E
32	7.5	42.4	E	E
33	10.0	45.6	F	G
34	9.0	37.8	E	E
35	4.5	34.2	E	E

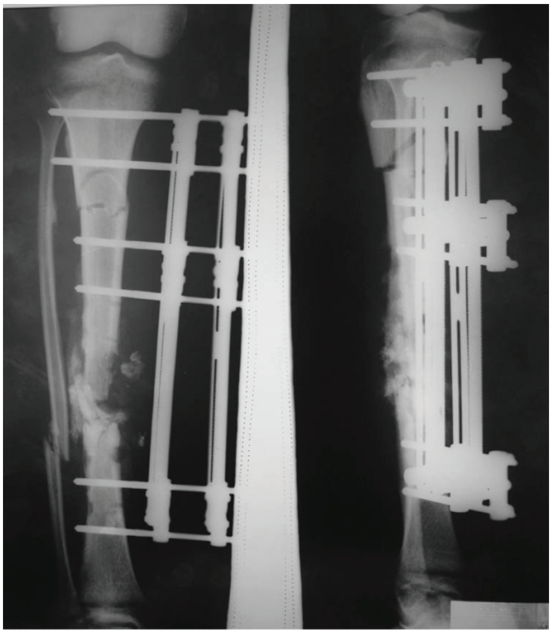

Figure 2a. Anteroposterior radiograph of a 22-year-old man who sustained comminuted fractures of middle-distal tibia and whose fibula had an infected tibial nonunion. It shows removal of the internal fixations, eradication of the necrotic bone and tissues, and application of the 3-segment unilateral external fixator. The wounds were packed with iodoform gauze additionally.

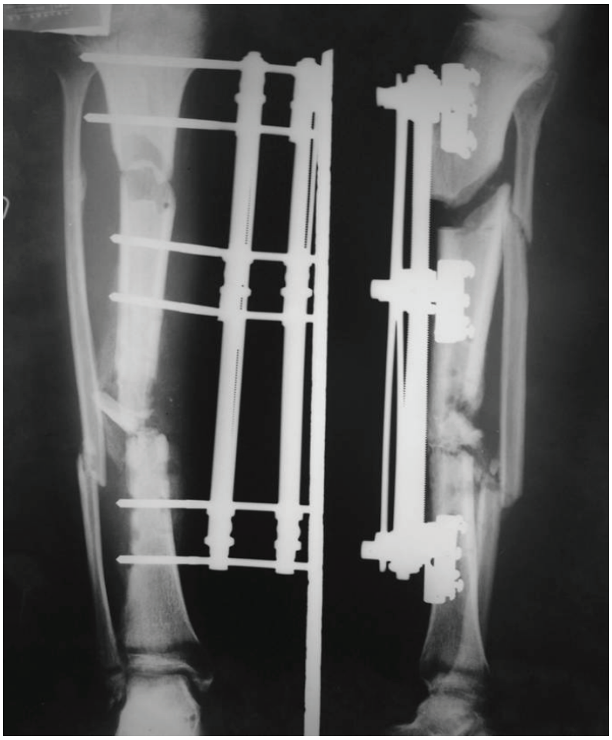

Figure 2b. One month after compression-distraction osteogenesis with the external fixator.

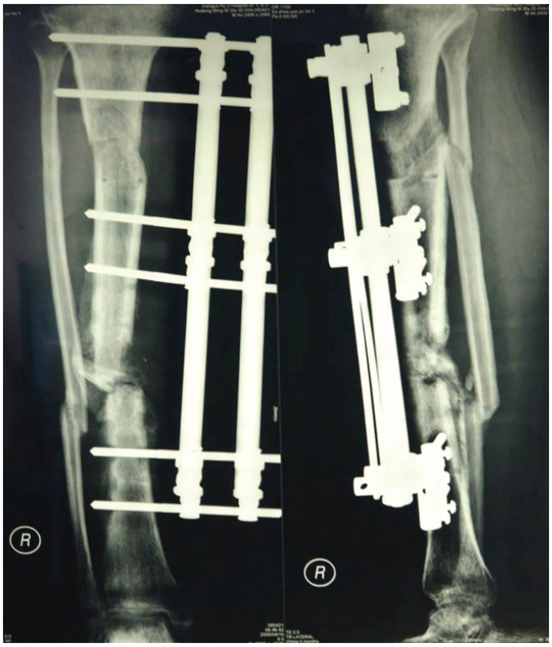

Figure 2c. Four months after compression-distraction osteogenesis with the external fixator, the bone defect was filled with the regeneration.

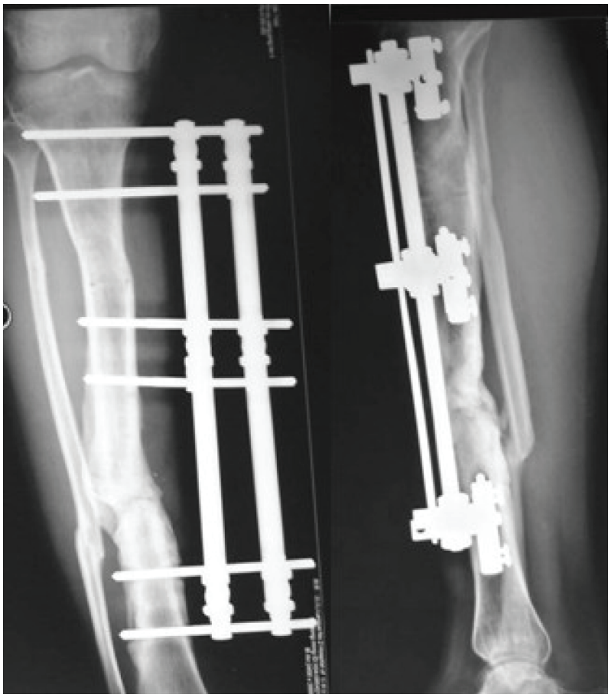

Figure 2d. After 8 months of the compression and distraction, the radiograph shows good consolidation of the regenerate and bone union at the docking site.

Figure 2e and Figure 2f. Excellent functional results after 9 months of treatment.

Figure 2h. Good clinical appearance and functional outcome of the patient.

Figure 2g. After 10 months of the operation, it shows complete bony union and removal of the fixator.

than 20° of motion at the tibiotalar and/or subtalar when compared with the preoperative range of motion; and was able to perform all previous ADL without difficulty. A good functional result was one with which the patient had mild or no pain, was able to perform almost all ADL with minimal difficulty, and failed to meet one of the other criteria. A fair functional result was one with which the patient had mild or no pain, was able to perform most ADL with minimal difficulty, and failed to meet 2 of the other criteria. A poor functional result was considered to have been achieved by any patient with significant pain (requiring narcotics), who was markedly limited in ADL, or who failed in 3 of the other criteria. Based on the criteria previously reported by Paley et al. (1): 30 functional results were excellent, 4 good, 1 fair, and none poor.

Complications

Pain was the most common complaint during the distraction period, which was observed particularly in patients requiring lengthening in excess of 4 cm, and was relieved consistently by oral analgesics. There were still 4 patients who felt pain (requiring narcotics) after they walked a long distance (more than 2.5 km). Twenty patients had a pin-track infection. Eighteen of them had local inflammation, which was settled with pin care and oral antibiotics. The other 2 had a purulent drainage, which was settled with intravenous antibiotics. Five patients developed transient ankle flexion in tibial lengthening and 3 improved after physiotherapy for a mean of 30 days (21-60 days). Pin loss occurred in 4 tibiae, which was treated by reapplication of the external fixator for further lengthening until sufficient consolidation was obtained in the regenerated bone area. After the treatment, there were still nonunions at the docking site in 2 patients. Cancellous bone grafting was performed and union was achieved at last. Three patients had failures in the form of recurrent drainage. They underwent repeated debridements, and the aeschynomenous antibiotic solution was used to make a continuous aspiration lavage drainage with 2 tubulars for 3 weeks. Soft-tissue defects resulting from repeated debridements were reconstructed with local gastrocnemius muscle flaps and split-thickness skin grafts in 5 patients. Subsequently, in 3 patients, the infection was eradicated and the nonunion was healed, resulting in good function and a good radiographic outcome. These 3 patients were fully able to walk without support at the time of the most recent follow-up.

There were no neurovascular complications and no joint subluxation.

Discussion

Post-traumatic tibial infected nonunion is one of the most challenging orthopedic problems. A review of the medical literature yielded many studies describing the techniques for the treatment of infected nonunion (4-7). Such patients usually have had numerous previous surgical interventions, resulting in bone defects and soft tissue compromise. The most common treatment for bone defect is bone grafting. Lu et al. (4) reported 38 cases of infected nonunion treated with immediate granulated cancellous bone autografting after debridement. At a mean follow-up of 44 months, 33/38 (86.8%) had an excellent outcome. Although autologous cancellous bone graft is effective for small defects, the bone graft is not enough to fill the defect when the defect is massive. In addition, the process of graft incorporation and corticalization to support body weight is lengthy and may never be completed. Vascular bone grafting has been proven useful in overcoming massive bone defects. Tu et al. (5) analyzed their clinical results in 48 patients treated with free vascularized bone-graft reconstruction for bone defects; 41% (20/48) of their patients had an active osteomyelitis, with the follow-up being an average of 6 years. The functional outcome was good in 43 patients. However, healing and remodeling of bone grafts are lengthy; osteopenia and joint stiffness due to prolonged remodeling may occur. Refracture and host–graft junction healing problems are another common complication with this type of grafting technique. Cierny et al. (6) compared the results of treating segmental tibial defects using Ilizarov bone transport and massive autologous bone graft, and the results were in favor of the Ilizarov method. Furthermore, if the patients have limb-length discrepancy, they might not be corrected with conventional bone grafting but bone transport.

In the present study, all the patients were treated by distraction osteogenesis. To avoid delayed bone-healing, complete cure of the infection is the main stay of treatment in infected nonunions. The most important principle in eradicating osteomyelitis is thorough and adequate debridement until live and bleeding bone is reached (7). Successful treatment of infected nonunion often combines radical debridement of the septic bone and soft tissue in addition to application of stable fixation to enhance soft tissue healing and bone union. Therefore, the radical removal of the necrotic and infected parts of both bone and soft tissues represents the most important element for the success of treatment by compression-distraction technique in severe infected nonunions of the tibia (3). Loose and sequestrated bone should be also removed (3). In our study, the infection had been controlled in all the patients.

It is a critical problem that whether the lengthening area will be infected secondarily when the bone is being debrided and lengthened in patients with infected nonunion, bone defect, and limb shortening. To our knowledge, there is no report on lengthening area infection in infected nonunion patients after simultaneous bone transport and debridement. In the present study, there was also no lengthening area infection. We adopted a remote osteotomy to start the distraction and sufficient drainage in the infective site. The osteotomy was performed in the healthy bone far from the infected bone to ensure good vascularity for consolidation.

Nonunion at the docking site is a common complication of bone transport. In adult patients, bone grafting is recommended at the time of docking to prevent the common complication of nonunion; however, there is no evidence that bone grafting is necessary at the docking site. Cattaneo et al. (8) reported that circular external fixation using the Ilizarov apparatus combined with internal bone transport or compression-distraction techniques were used to treat 28 patients with infected nonunions or segmental bone loss of the tibia. In all patients their infected extremities healed without the addition of cancellous bone graft, microvascular fibular, or soft-tissue grafting. Barbarossa et al. (9) described 30 patients with chronic post-traumatic osteomyelitis and infected nonunion with bone defects of the femur, none of whom underwent bone grafts at the docking site; no nonunion occurred. Dendrinos et al. (10) treated defects of the tibia in 28 patients using the Ilizarov bone transport method and compression at the docking site for bone union. Bone grafts were required in only 3 patients. In our previous study (11,12), the docking sites were not explored to freshen both bone ends. After 2 bone fragment docking, distraction was still performed to correct leg-length discrepancy and compression was applied to the docking site for simultaneous bone union. In the present study, there were 2 patients who required cancellous bone grafting in the docking site for union.

Conclusion

The technique of compression-distraction osteogenesis with the external fixator is a safe, effective, and minimally invasive management to treat post-traumatic tibial infected nonunion.

Acknowledgments

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