Distraction Osteogenesis Using Ilizarov External Fixator for Radical Treatment of Post-Traumatic Osteomyelitis of the Tibia

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Abstract: Callus distraction used technique for the reconstruction of intercalary defects of the femur and tibia after radical debridement of post-traumatic chronic osteomyelitic foci is an excellent technique for management of resistant diaphyseal infections of long bones. The aim of this study is to summarize our experience with distraction osteogenesis performed with Ilizarov device for the treatment of bone defects resulting from radical debridement of post-traumatic chronic osteomyelitis. Our study was carried out in Sohag University Hospital during the period from January 2009 to July 2011. In our study we reported thirty patients (25 males and 5 females) with age range from 22 to 50 years with compound diaphyseal fractures of the tibia, treated elsewhere with plate and screws, intramedullary nails or external fixators and presented to our department with infected non-union of the tibial fracture after failure of one or more of the these procedures. The fractures evolved towards post-traumatic osteomyelitis, growing methicillin-resistant *Staphylococcus aureus* (MRSA); combined with a large overlying soft tissue gap. The infected fractures were treated by debridement including removal of implants and bone resection, and longitudinal bone transport after doing proximal or distal corticotomy of the tibia. An Ilizarov frame was used to treat both the bone and the skin defects. Infection was eradicated in all cases, and union was achieved in all thirty cases (100%). Mean duration of treatment was 13 months. Both the bone and the soft tissues healed without further complications. According to ASAMI (Association for the study and application of the method of Ilizarov) criteria, bone results were excellent in all patients. Functional results were excellent in 26 patients, good in 3, and fair in 1 patient. From our study it can be concluded that; distraction osteogenesis performed with Ilizarov device is an excellent technique for bridging large post-traumatic infected tibial defects by resection of the infected segment, and gradual bone transport.

[Abdel Rahman Hafez and Mona Fattouh. **Distraction Osteogenesis Using Ilizarov External Fixator for Radical Treatment of Post-Traumatic Osteomyelitis of the Tibia.** *J Am Sci* 2012;8(7):756-763]. (ISSN: 1545-1003). http://www.americanscience.org.111

Keywords: Ilizarov, Treatment, Osteomyelitis, Tibia.

1. Introduction

Large segmental defects of the tibia caused by debridement of infected non-union present a significant challenge to the orthopedic surgeons. Tibial non unions have been treated with a variety of surgical methods including plate osteosynthesis with bone graft ***(Chin et al., 2003),*** intramedullary nailing ***(Richmond et al., 2004)*** and external fixation ***(Feldman et al., 2003*)**. They are often unsuccessful due to limitations including: quantity of graft available, donor-site morbidity, poor vascularity, persistence of infection, and extensive bone defects and deformity ***(Krishnan et al., 2006)***. The Ilizarov method has gained many advocates for the treatment of tibial non-unions over the last 2 decades, particularly hypertrophic non-unions ***(Kocaoglu et al.,2003)*** and non-unions associated with bone loss ***(Pugh and Rozbruch, 2005)***, infection ***(Marsh et al.,1997)*** , and a poor soft-tissue envelope ***(Rozbruch et al.,2006)***. The Ilizarov technique entails a segmental bone transport in which corticotomy is performed in the metaphysis and the bone is gradually distracted. The bone is thus lengthened by callus distraction and the defect gradually closed ***(Ilizarov and Ledyaev ,1992)***. The Ilizarov technique can be used in a variety of conditions but it is most useful in restoring bone loss following resection of osteomyelitic or tumour bone. This is the only technique that can address infection, bone loss, non-union, deformity and length simultaneously ***(Ilizarov, 1992)***. In this study we reported our experience in treating massive post-traumatic infected non union of the tibia with bone defects using bone transport by the Ilizarov technique where traditional orthopedic techniques are often inadequate. The treatment goal was bony union and eradication of infection.

2. Patients and Methods

Our study was carried out in Sohag University Hospital during the period from January 2009 to July 2011.Thirty patients (25 males (83.3%) and 5(16.7%) females) with age range from 22 to 50 years; suffering from infected non-unions of tibial shaft fractures. Ten cases (33.3%) were caused by motor cycle accidents, 9 cases (30%) were caused by motor car accidents, 6 cases (20%) motor vehicle accidents and 5 cases (16.7%) were caused by fall. The right side was involved in 19 cases (63.3%) and the left side was involved in 11 cases (36.7%). The average number of previous failed surgical attempts at union was 2 per patients (range 1- 4). The range of time interval between injuries to application of ring fixator was 6 months to three years (mean 21 months); 6 months to 1 year in sixteen cases (53.3%), 1 year to 2 years in 8 cases (26.7%), and over 2 years in 6 cases (20%). At presentation:-

- A full history was obtained for details of the initial injury and previous surgical interventions.
- The patients were examined for presence of shortening, neurovascular deficiency; condition of soft tissue; active infection, and function of relevant joints was documented. Patients were further classified as having an actively infected non-union if there was a discharging sinus and/or a positive culture swab from tissue obtained at debridement.
- Radiological evaluation was done to determine the fracture pattern, plane of deformity, alignment and to look for signs of osteomyelitis.
- Laboratory investigations were done to the patients; they are useful in diagnosis and monitoring the response during treatment. Full blood count (FBC), C-reactive protein (CRP) and erythrocytes sedimentation rate (ESR) were done to all patients. The ESR and CRP are helpful in monitoring progress during treatment.
- The patients were informed about the approximate duration of treatment and the associated complications prior to reconstructive surgery.
- The affected site was the tibial diaphysis in all patients. All patients were treated by resection of the osteomyelitic and necrotic bone. The defect size ranged between 4 cm and 9 cm (average: 6.5 cm). All of these defects were treated with the Ilizarov device by bone transport through a separate corticotomy site and subsequent compression of the nonunion sites after completion of the bone transport to bridge the defect. The external fixation time ranged from 8 months to 18 months (average: 13 months). Every one cm required two months duration for complete consolidation.

Operative technique

In all patients frames were assembled preoperatively for all patients and modified intra-operatively if required. Tourniquet was applied to the thigh but was not inflated during assembly of the Ilizarov frame. Smooth Kirschner wires 1.8 mm in diameter were the only hardware used for frame application. An Ilizarov ring of suitable diameter was then mounted to that K-wire and secured using two slotted bolts. The wire was tensioned to 110-130 kg using a dynamometer. A second wire was then advanced on the same ring with an angle of about 90º as much as the anatomical plane allowed to the first wire and was mounted to the ring and tensioned in the usual way. Using two threaded rods, a second Ilizarov ring was attached to the first one and then secured to the bone using two tensioned 1.8 mm K-wires. Both the first and the second rings were adjusted proximal to the fracture site. A third ring was attached to the second one using 4 threaded rods and was adjusted to be distal to the fracture site and was secured to the bone using two tensioned 1.8 mm K-wires. A fourth ring was attached to the third one using 4 threaded rods and was adjusted to be just proximal to the ankle joint and was secured to the bone using two tensioned 1.8 mm K-wires. The tourniquet was then inflated. Through a 1.5-2 cm skin incision, an oblique osteotomy was done in the mid shaft of the fibula. Another small incision of 1.5-2 cm was made at the lower border of the tibial tuberosity (proximal corticotomy) or just above the fourth ring (distal corticotomy). Proximal or distal corticotomy was done according to the length of the healthy bone segment whether it was longer proximal or distal respectively. The periosteum of the tibia was incised and raised carefully. Multiple drill holes were made in the tibia with a 3.2 mm drill bit. Using a 10 mm osteotome, the medial and lateral cortices were osteotomised. The threaded rods were then disassembled from the first and second rings. The posterior tibial cortex was fractured indirectly by twisting the proximal two rings. The two rings were attached to each other again and a compression was applied to the corticotomy site to increase its stability. The periosteum was carefully sutured again and the subcutaneous tissue and the skin were closed in layers. An incision was done in the infected nonunion site and all patients were subjected to radical debridement involving resection of nonviable bone ends. Intra-operative cultures were sent and antibiotics were administered accordingly.

Microbiological analysis

Pus swabs were collected from all thirty patients. All together 30 pus swabs were subjected in parallel to the following methods of detection: microscopic examination, culture, biochemical reaction tests, and antibiotic sensitivity testing**.**

- The swabs were immediately sent to the laboratory, streaked on Blood agar, MacConkey's medium and mannitol/salt agar plates (MSA) (bioMerieux, France) and incubated at 37° C for 48 hours.
- All isolates were identified as *S. aureus* (Complete β-haemolytic colonies on blood agar and Mannitol-fermenting colonies (i.e., those that were yellow or gold) on mannitol/salt agar plates).
- The isolates were confirmed as *S. aureus* by Gram stain and positive results of catalase test and coagulase test.
- The susceptibility of isolates to different antibiotics was carried out by the disc diffusion

method (Modified Kirby- Bauer method) according to the Clinical Laboratory Standards Institute (CLSI) guidelines ***(CLSI, 2010)***.The antibiotics included were penicillin (10 U), oxacillin (1 µg), cefoxitin (30 µg), amikacin (30 µg), ciprofloxacin (5 µg), vancomycin (30 µg), teicoplanin (30 µg), linezolid (30 µg), and trimethoprim/ sulfamethoxazole (1.25/23.75 µg). The sensitivity of *S. aureus* isolates to the tested antibiotics was shown in table 1.

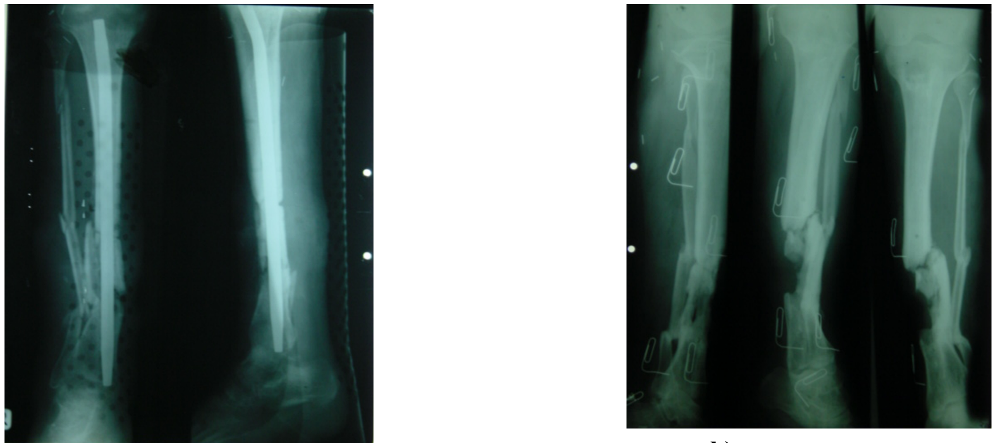
Table 1: Antibiotic susceptibility testing of *S. auerus* isolates by Modified Kirby- Bauer method.

Antibiotic	*S. auerus* (N =30)		
	Sensitive	Intermediate	Resistant
Penicillin	-	-	30 (100%)
Oxacillin	-	-	30 (100%)
Cefoxitin	-	-	30 (100%)
Amikacin	6 (20%)	1 (3.3%)	23 (76.7%)
Ciprofloxacin	11 (36.7%)	2 (6.7%)	17 (56.7%)
Vancomycin	12 (40%)	10 (33.3%)	8 (26.7%)
Teicoplanin	17 (56.7%)	6 (20%)	7 (23.3%)
Linezolid	30 (100%)	-	-
Sulfa-trimethoprim	2 (6.7%)	-	28 (93.3%)

All *S. aureus* strains were methicillin-resistant *Staphylococcus aureus* (MRSA); as they were resistant to penicillin, oxacillin and cefoxitin while susceptible to linezolid. The rates of resistance to amikacin, ciprofloxacin, vancomycin, teicoplanin, and trimethoprim/sulfamethoxazole were 76.7%, 56.7%, 26.7 %, 23.3%, and 93.3% respectively.

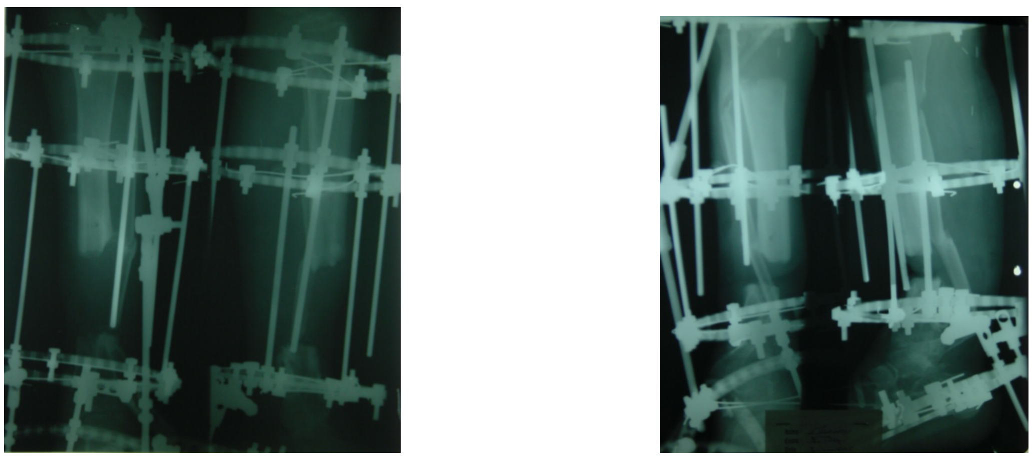
Postoperative management

Starting from the first postoperative day, patients were allowed non weight bearing ambulation on crutches with full range of motion of the knee and ankle. Straight leg raising and quadriceps strengthening and ankle dorsiflexors and plantar flexors strengthening exercises were encouraged. Patients were discharged on the second postoperative day after careful instruction about daily pin site care. Distraction was started gradually on the 7th postoperative day at a rate of 0.25 mm / 6 hours. Post operatively, routine use of antibiotics according to culture and sensitivity results for two weeks. Follow-up radiographs were obtained weekly during the transport phase until both ends of the fracture site meet each other (docking site). Near the end of transport, another radiograph was ordered to assess the transported segment and alignment of the leg and further compression in the docking site one millimeter every week was done for four weeks. The patients were then allowed partial weight bearing and increased as tolerated till full weight bearing was achieved. The construct was then left in place and follow- up radiographs were obtained monthly to follow the consolidation of the new regenerate and union at the docking site. With radiographic consolidation, the construct was removed gradually by removing one K-wire from each ring every week. The last 3 K-wires (one on each ring) were removed at once. During this dynamisation, the patients were fully weight bearing on the extremity. Another radiograph was obtained following frame removal. Vigorous physiotherapy was not usually needed, because patients had already maintained a good range of knee and ankle motion. All laboratory parameters to measure active infection eradiaction such as C- reactive protein levels, the erythrocyte sedimentation rate, and the white blood-cell count and differential obtained in the follow up period. C - reactive protein levels and the erythrocyte sedimentation rate returned to normal by six weeks after the radical debridement. Bone healing and the functional results were assessed according to criteria given by ASAMI. Bone healing was evaluated based on union, infection, deformity, and limb length discrepancy (Table 3) and classified as excellent, good, fair and poor (Table 3). The functional results were evaluated according to 5 criteria which include limp, range of motion of adjacent joints, sympathetic dystrophy, and return to activity, and classified as excellent, good, fair and poor (Table 4) ***(Chaddha et al., 2010).***



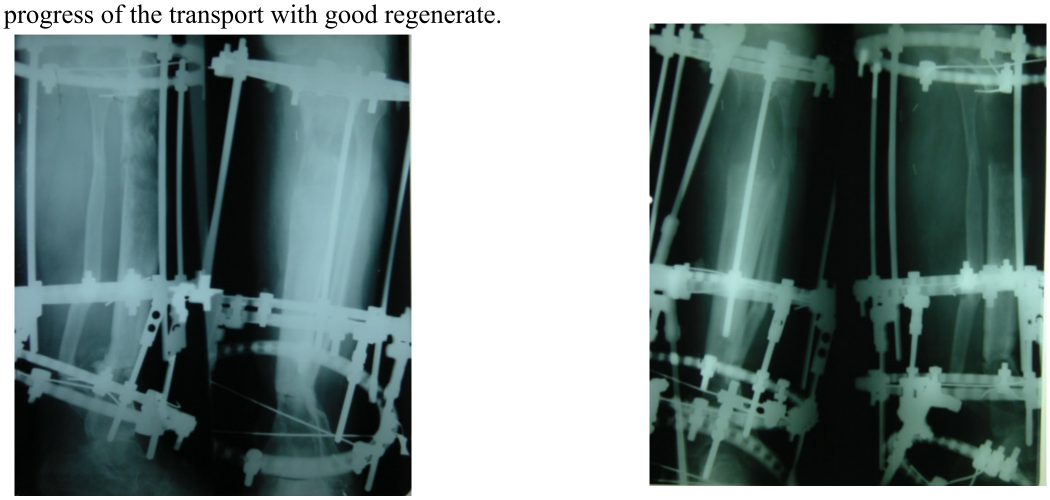
a) b)

Figure 1: Thirty five years old male with motor car accident with fracture shaft tibia and two operations were done to him; in the first one plate and screws were applied. In the second one intramedullary nail was applied **(a)**. **(b)** After removal of the intramedullary nail large sequestra in the distal third of the tibia with infected non union.



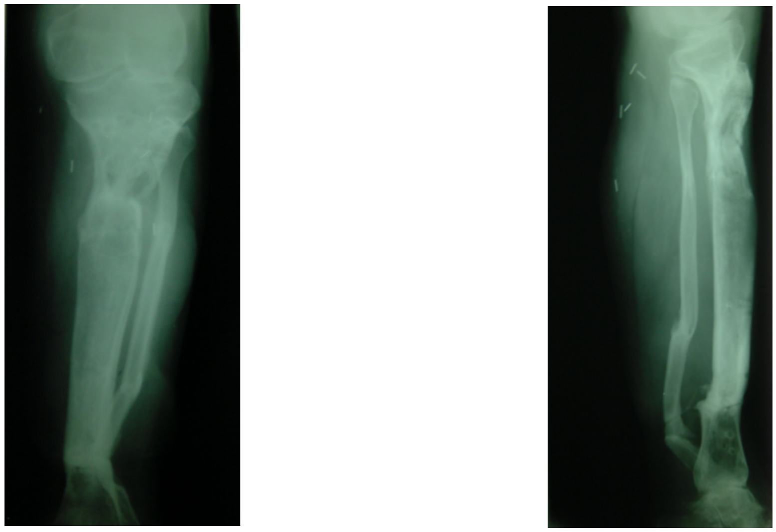
a) b)

Figure 2 (a): Four-ring construct was applied, and proximal tibia metaphyseal corticotomy performed. **(b):** follow up x -ray showing the progress of the transport with good regenerate.



a) b)

Figure 3 (a): Follow up x-ray showing compression at the docking site and good regenerate. **(b):** Follow up x-ray showing union at the docking site and consolidated regenerate.



a) b)

Figure 4: (a) Anteroposterior and **(b)** lateral views of the tibia after Ilizarov removal with complete consolidation of regenerate and solid union at the docking site.

3. Results

Our study was carried out in Sohag University Hospital during the period from January 2009 to July 2011. Thirty patients (25 males (83.3%) and 5 (16.7%) females) with age range from 22 to 50 years; suffering from infected non-union of tibial shaft fractures. The maximum number of study group (43.3%) was in the age group of 30-40 years. The average number of previous failed surgical attempts at union was 2 per patients (range 1- 4). The presence of bone infection correlated with initial failure and persistent nonunion.

Table (2): Age distribution among the study group.

Age groups	Number	Percentage %
22 - < 30	11	36.7
30 - < 40	13	43.3
40 - < 50	6	20
Total	30	100

The median time between injury and application of the frame was 21 months. The mean length of bone defect at the time of frame application was 6.5 cm (range: 4-9 cm). The mean external fixation time (EFT) was 13 months (range: 8 to 18 months). Union was achieved in all patients and no patient required bone graft. Infection was controlled in all patients. Total resolution of the infection is demonstrated by a return of the C-reactive protein level and erythrocyte sedimentation rate to values to within normal limits, usually within six weeks. According to ASAMI criteria, bone results were excellent in all patients (100%) (Table 3). Functional results were excellent in 26 patients (86.7%), good in 3 (10%), and fair in 1 patient (3.3%). (Table 4).

Table 3: Results using the scoring system of the Association for the Study and Application of the Methods of Ilizarov (ASAMI) *(Chaddha et al., 2010).*

Bone results	Criteria	No. of patients
1. Excellent	Union, no infection, Deformity < 7°, Limb length discrepancy (LLD) < 2.5 cm	30
2.Good	Union + Any two of the following Absence of infection < 7° deformity LLD < 2.5 cm	0
3. Fair	Union + Any one of the following Absence of infection < 7° deformity LLD < 2.5 cm	0
4. Poor	Non-union/Refracture/ union + Infection + Deformity > 7° + LLD > 2.5 cm	0

Table 4: Functional Results *(Chaddha et al., 2010).*

Functional results	Criteria	No. of patients
1. Excellent	Active, no limp, Minimum Stiffness (Loss of < 15° knee extension/ < 15° ankle dorsiflexion), no Reflex Sympathetic Dystrophy (RSD), Insignificant pain	26
2. Good	Active with one or two of the following Limp Stiffness RSD Significant Pain	3
3. Fair	Active with three or all of the following Limp Stiffness RSD Significant Pain	1
4. Poor	Inactive (unemployment or inability to return to daily activities because of injury)	0
5.Failure	Amputation	0

Complications:

The most common complication was pin tract infection which occurred in 23 patients (76.7%). All of these pin site problems responded well to local pin site care and oral antibiotics. No patients required removal or a change of wires. There were no cases of deep infection or persistent discharge, or infection following frame removal. The next most common complication was ankle and knee stiffness in 4 patients (13.3%). More than 15° loss of ankle dorsiflexion occurred in 2 patients. Loss of range of motion of the knee occurred in 2 patients, with one patient having 5° of knee flexion deformity and one patient with a 10° flexion deformity.

4. Discussion

Infected non-union of a long bone remains a therapeutic challenge. Such patients usually have had numerous previous surgical interventions, resulting in bone defects and soft-tissue compromise. The results of conventional treatment of infected non-union of the tibia are poor, due to high velocity primary trauma, multiple surgeries, late presentation, bone and soft tissue infection, bone loss, poor vascularity, associated deformities, and shortening. The most important of these being unsuccessful eradication of infection ***(Maini et al.,2000)***. Infection has been reported to be the main cause of delayed union or non-union ***(Conway et al.,2004).*** Thus, complete cure of the infection is the mainstay of treatment in infected non-unions. ***Cierny et al.,2003,*** reported that the only cure for osteomyelitis is radical debridement until live and bleeding bone is reached. 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. The Ilizarov technique is a salvage procedure for these difficulties. According to Ilizarov, gradual traction on living tissues creates stress that stimulates and maintains regeneration and active growth of tissues (bone, muscle, fascia, tendon, nerve, vessels, skin and its appendages) ***(Krishnan et al., 2006)***. The Ilizarov method has several advantages over conventional reconstructions. First, the bone regenerate is exactly the right size for the anatomic site. Second, wound margins are approximated by these methods. Soft tissues are recruited by the transport segment(s). Wounds heal by secondary intention ***(Krishnan et al., 2006)***. This study was carried out in Sohag University Hospital during the period from January 2009 to July 2011. Thirty patients (25 males (83.3%) and 5 (16.7%) females) with age range from 22 to 50 years; suffering from infected non-union of tibial shaft fractures. All patients were treated by resection of the osteomyelitic and necrotic bone. The site was also cultured to confirm eradication of infection. The defect size after debridement ranged between 4 cm and 9 cm (average: 6.5 cm). All of these defects were treated with the Ilizarov technique by compression of the non-union sites and bone transport through a separate corticotomy site. The average EFT was 13 months. A study from Korea by ***Song et al. (1998)*** reported 27 cases with an average defect of 8.3 centimeters. They published an average EFT of 8 months and recommended bone grafting at the docking site in order to shorten the duration of treatment and to prevent refracture and non-union. Cancellous bone grafting or refreshing of bone ends may be required at the site of docking ***(Barbarossa et al., 2001).*** Nonetheless, bone grafting or refreshing was not required in our patients. ***Paley and Maar (2000)*** stated that once transport is completed and docking has been achieved, proceeding with bone grafting sooner rather than later (in contradiction to Ilizarov's initial principles) in order to decrease treatment time. The overall increase in the treatment time in our study probably because we did not use any bone grafting procedures in any of our patients. Union was achieved in all patients, and according to ASAMI criteria, bone results were excellent in all patients (100%).

Functional results were excellent in 26 patients (86.7%), good in 3(10%), and fair in 1 patient (3.3%). The bone result was always better than the functional result, which is in keeping with other reports ***(Song et al., 2003).*** Our results agreed with the results of ***Cattaneo et al., 1992*** who reported 28 patients with infected non-unions and segmental defects treated with the Ilizarov frame. They achieved bony union in all patients. Good to excellent functional results were noted in 21 patients. Another valuable reconstruction method for the treatment of an infected non-union in a long bone is the use of vascularized bone grafts ***(Yajima et al., 2004).*** One study has noted a mean time to bone-healing of approximately seven months in the femur and six months in the tibia ***(Yajima et al.,2004).*** With a large total number of major complications, such as recurrence of infection and graft failure, which is not reported in the present study. Infection was eliminated in all patients in the current series; all patients demonstrated a normal C-reactive protein level and erythrocyte sedimentation rate by six weeks after the radical debridement. Eradication of infection was established by the radical debridement of all infected tissues and administration of antibiotics depending on the results of antibiotic sensitivity testing of the MRSA demonstrated by cultures of tissue obtained from the bone ends during the reconstructive procedure. In our study the complications discovered were pin tract infection which occurred in 23 patients (76.7%). All of these pin site problems responded well to local pin site care and oral antibiotics. No patients required removal or a change of wires. These results agreed with ***Bobroff et al., 2004*** who reported that; by far, the most common minor complication was pin tract infection. Almost universally (75%), patients develop this complication, which can be effectively treated with enteral or parenteral antibiotics. In our study; most patients presented late, having had multiple previous surgeries with major damage to muscles, joints, and bone, and already having developed a variable amount of joint stiffness. This explained the second most common complications we found in our results which are ankle and knee stiffness. Which were found in 4 patients (13.3%). More than 15^{o} loss of ankle dorsiflexion occurred in 2 patients. Loss of range of motion of the knee occurred in 2 patients, with one patient having 5^{o} of knee flexion deformity and one patient with a 10^{o} flexion deformity. Overall, Ilizarov bone transport is an effective salvage tool in obtaining union in patients with an infected nonunion and as a primary tool in patients with large segmental bone loss due to trauma. The lengthy treatment time must be fully understood by both the surgeon and the patient prior to undertaking this complex treatment process.

Summary and Conclusion

High-energy tibial trauma with extensive bone and soft-tissue damage continues to be a surgical challenge. Wound contamination is common, and infected tibial non-union can complicate injuries, even resulting in limb amputation. In our study we described a successful alternative technique for the treatment of the challenging problem of post-traumatic osteomyelitis of the tibia. A philosophy of 'infection-elimination first' is a definite way of eradicating or controlling infection, together with using Ilizarov distraction osteogenesis to bridge the defect without the need for any bone grafting procedure. One can comprehensively approach tibial nonunions with the Ilizarov method which is particularly useful for addressing the spectrum of tibial non-union pathology for eradicating infection and achieving union.

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6/20/2012