

Treatment of complex nonunion of the shaft of the tibia using Ilizarov technique and its functional outcome

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ABSTRACT

Background: A complex nonunion of the shaft of the tibia is a major cause of morbidity and mortality in patients with lower extremity injuries. **Aims:** The aim of this study was to evaluate the outcome of the functional and radiological outcome of complex nonunion shaft of tibia, treated by radical debridement, Ilizarov ring fixator with compression and distraction osteogenesis. **Methods:** From 2005 to 2010, sixty cases of complex nonunion shaft of tibia were included in our study. All infected nonunions were managed by radical debridement, fixed with Ilizarov ring fixator, monofocal/bifocal compression, and distraction osteogenesis. The average duration of follow-up is 36 months (26–50 months). The functional evaluation was done by using Association for the Study and Application of Methods of Ilizarov (ASAMI) scoring system and bone union with serial radiographs. **Results:** All patients had a successful union. The mean time for union was 7 months (5–9 months). The mean time of fixator removal is 12 months (8–14 months). Every patient had pin tract infections which were successfully treated with oral antibiotics. Four patients had an equinus deformity, one patient had insignificant limb shortening (1.5 cm), and three patients had soft tissue dystrophy. Using the ASAMI scoring system, we obtained 45 excellent, 10 good, 3 fair, and 2 poor functional results. **Conclusions:** The Ilizarov technique for complex nonunions has a high rate of success in achieving union and eradicating infection, bone loss, and malalignment. Radical debridement is the key step to control bone infection.

Key words: Complex nonunion, debridement, distraction osteogenesis, Ilizarov

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INTRODUCTION

The complex nonunion is defined as an established nonunion (of at least 6 months duration) with one or more of the following criteria, infection at the site of nonunion, a bone defect of more than 4 cm (defect nonunion), an attempt to achieve union that failed to heal after one supplementary intervention. The radical debridement of the infective site eradicates infection more efficiently and increases the vascularity at the nonunion site; however, it creates bone defect. Ilizarov fixator is an external fixation device used in the orthopedic surgical procedure to lengthen or correct the angular deformities in limb bones and to treat compound or open bone fractures and infected nonunion fractures.¹ The prevalence of

nonunion in closed tibial fractures is 2.5% and it increases 5–7-fold for open fractures with gross contamination and extensive soft tissue damage.² The bone defect is filled by bone transport, as described by Ilizarov corticotomy and distraction technique that forms new bone at the trailing end, also known as distraction osteogenesis. The Ilizarov ring fixator provides multiplanar stability, helps in the correction of angulation, and rotation at the nonunion site much effectively.^{3,4} Thus, the Ilizarov is mostly used as a salvage option in the treatment of complex nonunion of tibia. The current study aims to evaluate the outcome of the functional and radiological outcome of complex nonunion

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shaft of tibia, treated by radical debridement, Ilizarov ring fixator with compression and distraction osteogenesis.

METHODS

This prospective study was carried out at Orthopedics Department of School of Medical Sciences and Research, Sharda University from December 2010 to July 2015. It was approved by the Institutional Medical Ethics Committee. Sixty patients were treated for nonunion shaft of tibia. The patients who fulfilled the criteria for complex nonunion were included in the study. A written informed consent was obtained from all the patients; they were explained about treatment plan, cost of operation, hospital stay after surgery, and complications of anesthesia. Patients were followed up after surgery and were clinically and radiologically assessed for fracture healing, joint movements, and complications. Patients with intraarticular involvement and periarticular nonunion were excluded from the study. All patients had established infective nonunion and failed surgical intervention. In addition, 12 patients also had bone loss with a mean defect of 3 cm (2–5 cm). Fifty patients were males and ten were females. The mean age of the patients was 37.5 (25–45). The average duration between injury and index surgery (Ilizarov surgery) was 9 months (7–14 months). The average number of surgical intervention, including the soft tissue procedures, before the index surgery was 3.5 (2–5). The infection was active in forty (25 + 15) patients with signs of purulent discharge, inflamed, indurated skin, and quiescent in twenty (15 + 5) defined as healed sinus [Table 1] with or without sequestrum in the radiograph and normal or elevated laboratory markers such as erythrocyte sedimentation rate and C-reactive protein. According to Gustilo-Anderson classification⁵ for open injuries, 15 patients had Grade II, 30 patients had Grade IIIA, 10 patients had Grade IIIB, and 5 patients had closed injury. The mechanism of the initial injury was road traffic accident in all the patients. There were 45 patients treated with external fixation initially, 4 fractures treated initially by plating, and 11 with intramedullary nailing. Fifteen patients had soft tissue procedure with ten patients having local rotation flap, three patients split skin transfer, and two patients free flap. Ten patients were chronic smoker and seven were addicted to alcohol. All the patients underwent radical debridement at the infective nonunion site until the observation of punctuate bleeding (paprika sign). The third generation intravenous cephalosporine was given. The fracture site was acutely docked or acutely shortened without

compromising distal vascularity. A bifocal compression distraction technique⁶ (compression for nonunion with distraction at the corticotomy) was used in 45 patients. Of the 45 patients, 40 patients had acute docking and 5 patients had acute shortening followed by gradual compression at the fracture site. Monofocal compression and distraction were used in 15 nonunions. Bone grafting was used in twenty patients at the docking site. At the time of docking, bone grafting was used at the docking site to avoid nonunion because the leading edge of the transported segment was relatively avascular. The corticotomy (bifocal) was done simultaneously in thirty patients and as the second procedure in 15 patients after an average of 4 days. The corticotomy at proximal tibial metaphysis was done in rest of the 15 patients (monofocal compression distraction technique). The distraction at corticotomy started between 7 and 10 days of osteotomy. Patient hospitalized for an average of 10 days (7–14 days). The distraction was done at the rate of 1 mm per day. The distraction was stopped if one of the following such as expected limb length, vascular or neural compromise, and contracture of the adjacent joint occurred. Neurovascular damage might arise during the distraction phase. Rapid distraction could cause stretching of the nerves with sensory manifestations and very rarely, motor manifestations. Very rarely spasms of the vessels occurred. All patients received a course of sensitive antibiotic for 2–4 weeks in intravenous route. They were encouraged to partial weight bearing with crutches, isometric muscle, and joint range of motion exercises on the 2nd day after operation to minimize the soft tissue contractures. The Ilizarov ring fixator was maintained for twice the period of distraction to consolidate the union. The amount of distraction and bone formation was assessed with follow-up radiographs in anteroposterior and lateral views once in 2 weeks during distraction [Figures 1a-c and 2a-d]. Once the union was consolidated, the dynamization was done for 2 weeks with patient allowed full weight bearing. The fixator was removed if the patient was able to walk without pain.⁷ At final follow-up, we assessed the patients for gait, limb length discrepancy and range of movement of the adjacent joints. Functional and radiological outcomes were assessed using the Association for the Study and Application of Methods of Ilizarov (ASAMI) criteria described by Paley *et al.*⁸ [Table 2]. In order to assess patient satisfaction, we used a visual analog scale from 0 to 100, with 0 being completely unsatisfied and 100 being completely satisfied. This method was used by Chapman *et al.*⁹ [Table 3]. Our definition of union was the presence of bridging trabeculae on three cortices, absence of pain on dynamization.

Table 1: Type of infected nonunion

Type of infected nonunion (cm)	Number of cases
A1, quiescent infection, defect <4	25
A2, quiescent infection, defect >4	15
B1, actively discharging sinus, defect <4	15
B2, actively discharging sinus, defect >4	5

RESULTS

All patients came for regular follow-up. The mean follow-up time was 36 months (26–50 months). None was lost to follow-up. All sixty patients had a successful

union. The average time for successful union was 7 months (5–9 months). The average distraction at corticotomy was 1.1 cm/month. The average duration of consolidation period was 8 months (7–9 months). The average duration for frame removal was 12 months (8–14 months) in bifocal compression distraction and 6 months (5–9 months) in monofocal compression distraction. The bone union and functional results were assessed at final follow-up using ASAMI scoring system [Table 2]. The mean satisfaction score on a numerical scale from 0 to 100 was 85. Only fifty patients were able to return to work, eight patients modified the occupation, and two patients failed to return to work. Every patient had pin tract infection of which eight patients were taken for debridement. Pin tract infection was successfully treated with oral antibiotics. All patients were put in course of antibiotics and *Staphylococcus aureus* was the most common infecting organism. One patient had refractured within 2 months after removal of frame and

the Ilizarov ring was reapplied. All fracture showed both radiological and clinical union. Secondary bone grafting was done on 22 patients. One patient had persistent infection, four patients had equinus deformity, one patient had insignificant limb shortening (1.5 cm), two patients had deformity, three patients had limping, three patients had soft tissue dystrophy, and four patients had pain in the lower limb. No patients developed neurovascular injury, compartment syndrome, or deep vein thrombosis.

DISCUSSION

Infected tibia nonunion is common in clinical practice, and there are usually some coexisting problems of bone and soft tissue loss, deformities, limb length inequalities, and polybacterial infection.^{10,11} Up to now, the treatment of infected tibial nonunion has still been a challenge for orthopedic surgeons.¹² Ilizarov method has gained popularity for the treatment for infected nonunion. The

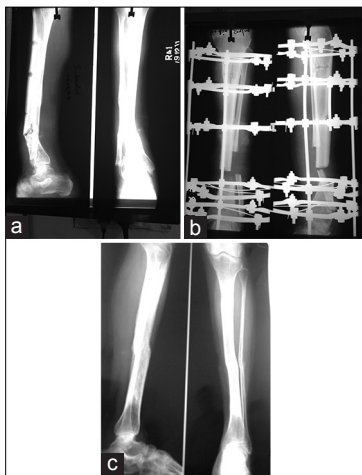


Figure 1: (a) Preoperative anteroposterior and lateral view of infected nonunion of the right tibia. (b) Gap nonunion was treated with Ilizarov using proximal tibial corticotomy (monofocal compression and distraction osteogenesis) and distraction osteogenesis. (c) After 24 months of the surgery, it showed complete bone union and the Ilizarov was removed



Figure 2: (a) Preoperative view of fracture atrophic nonunion of the right tibia. (b) Postoperative view of corticotomy (bifocal compression and distraction osteogenesis) of the right tibia and tibia fixed with Ilizarov. (c) Postoperative view of the right leg showing Ilizarov fixation. (d) After 24 months of the surgery, it showed complete bone union and the Ilizarov was removed

Table 2: Association for the Study and Application of the Methods of Ilizarov scoring system

ASAMI scoring system	Description	Score
Bone results		
Excellent	Union, no infection, deformity <7°, limb-length discrepancy <2.5 cm	50
Good	Union + any two of the following: Absence of infection, <7° deformity, and limb-length inequality of <2.5 cm	7
Fair	Union + only one of the following: Absence of infection, deformity <7°, and limb-length inequality <2.5 cm	2
Poor	Nonunion/re-fracture/union + infection + deformity >7° + limb-length inequality >2.5 cm	1
Functional results		
Excellent	Active, no limp, minimum stiffness (loss of <15° knee extension/<15° dorsiflexion of ankle), no RSD, insignificant pain	45
Good	Active, with one or two of the following: limp, stiffness, RSD, significant pain	10
Fair	Active, with three or all of the our figures show wing: limp, stiffness, RSD, significant pain	3
Poor	Inactive (unemployment or inability to return to daily activities because of injury)	2
Failures	Amputation	0

ASAMI – Association for the Study and Application of Methods of Ilizarov; RSD – Reflex sympathetic dystrophy

Table 3: Patient rating (n=60) of services provided in multidisciplinary pain treatment program

Item	Scale	Response (%)
Overall satisfaction with pain services	Low	37.7
	Medium	43.4
	High	18.9
Overall effectiveness of pain services	Not effective	31.1
	Somewhat effective	48.4
	Very effective	20.5
Change in pain condition	Worsened	32.8
	Unchanged	33.6
	Improved	33.6
Change in quality of life	Worsened	32.0
	Unchanged	37.7
	Improved	30.3

technique bases on a biological principle which has been termed the tension stress effect by Ilizarov. It entails a segmental bone transport in which corticotomy is performed in the metaphysis and the bone is gradually distracted. Ilizarov methods mainly have three techniques, including bone transport, acute compression, and lengthening, and compression osteosynthesis. Compression osteosynthesis is suitable for small defects or no defects.^{13,14} The application of the technique of acute compression and lengthening is also limited for the extent of bone defects. It was reported by a literature that a 4–5 cm acute shorting of the tibia was the limit for compression-distraction if adequate safety was to be guaranteed.¹⁵ Because acute compression beyond the limit could cause overmuch soft tissue stacking and arteriolar occlusion, which could affect new bone information and the healing of fracture ends. Another literature reported, bone defects (<6 cm) were suitable for adopting the technique of acute compression and lengthening.¹⁶ However, Magadam *et al.*¹⁷ treated successfully all large tibia defects (mean 10 cm, maximum 17 cm) by acute compression and distraction. They did not report any neurovascular complication and any additional surgery due to axial deviation or need for bone grafting. But then a letter questioned the research outcomes.¹⁸ Therefore, whether large tibia defects can be treated by acute compression and lengthening without neurovascular is still debatable. Bone transport could achieve good results in the treatment of both small and massive bone defects, so bone transport has no limit for the extent of bone defects.¹⁹⁻²¹ There is a controversial view on regular bone grafting at the docking site. Our study did not adopt regular bone grafting and bone grafting was required in only 22 patients. Pin track infection and the axial deviation were common complications in the course of bone transport in previous reports and these complications also happened frequently in our study. In our experience, some important aspects of bone transport should be paid attention. (1) Ilizarov external fixator should be assembled preoperatively under the image intensifier control. If we do not do this before the resection of infected bone, the reduction will become very difficult because of loss of reference object. (2) Debridement should be performed

radically in order to avoid the recurrence of infection. This is the key step to control bone infection. (3) Distraction usually begins between 7 and 10 days after the operation at a rate of 0.25 mm per 6 h. If regenerate quality is poor, the speed of distraction will slow down. (4) X-ray films should be reviewed every 2 weeks during the distraction period and monthly during the consolidation period in order to supervise the regenerate quality, the stability of external fixation, the axis of the traction on the segment, and the mineralization of the distracted area. Thus, we can correct these promptly with efficient measures. (5) Patients should be encouraged to conduct partial weight beat with crutches, isometric muscle, and joint range-of-motion exercises on the 2nd day after operation. When the callus mineralization completes, patients can gradually conduct full weight beat and remove the external fixator after 4–8 weeks.

CONCLUSION

Our study and the current evidence suggested that Ilizarov methods in the treatment of infected tibial nonunion acquired satisfied effects in bone results and functional results. Radical debridement is the key step to control bone infection. However, our study lack of direct comparison with any other treatment options, further randomized controlled trials are needed to draw more valuable conclusion. In our study, the average time for successful union is 7 months (5–9 months). The average distraction at corticotomy is 1.1 cm/month. The average duration of consolidation period is 8 months (7–9 months). The average duration for frame removal is 12 months (8–14 months) in bifocal compression distraction and 6 months (5–9 months) in monofocal compression distraction. The mean satisfaction score on a numerical scale from 0 to 100 was 85. Only fifty patients were able to return to work, eight patients modified the occupation, and two patients failed to return to work. In the study by Paley *et al.*,⁸ cases of tibial nonunion were treated with Ilizarov fixators which show excellent bone results in 18 cases, good in 5, and fair in 2 based on union, persistent infection in 3 cases, deformity in 4, and limb shortening in 1 case. Functional results were excellent in 16 cases, good in 7, fair in 1, and poor in 1 based on return to daily activities, limp in 4 cases, equinus in 5 cases, dystrophy in 4 cases, pain in 4 cases, and amputation for neurogenic pain in 1 case. In another study, 11 on 17 patients with tibial pseudoarthrosis, 14 cases had full union, 1 patient was still using orthosis, and 3 patients were in need of re-operation with bone transplantation. Mean time of treatment was 5.2 months (2–11.5 months), while the overall treatment time was 9.8 months (3–19 months). In this study, the Ilizarov method of treatment of pseudoarthrosis had a good stimulation of healing but experience with fixator system and aggressive treatment of various minor complications are essential for successful outcome. Our study shows comparable results with international literature.^{7,22} Our figures show 83.33% went back to work [Table 4]. In our

Table 4: A comparison of the results using the Association for the Study and Application of Methods of Ilizarov criteria

Authors	Subjects studied	Scores, % E, G, F, and P		Return to work, (%)
		ASAMI bone	ASAMI functional	
Dendrinis <i>et al.</i>	Infected tibial nonunions	50, 28, 4, and 18	26, 41, 15, and 18	82
Maini <i>et al.</i>	Infected nonunions	70, 10, 0, and 20	27, 40, 10, and 23	77
Patil <i>et al.</i>	Infected tibial and femoral nonunions	42, 34, 10, and 14	44, 44, 6, and 6	22
Shahid <i>et al.</i>	Infected tibial nonunions	83, 17, 0, and 0	50, 33, 0, and 17	63
Present study	Infected tibial nonunions	50, 7, 2, and 1	45, 10, 3, and 2	83.33

ASAMI – Association for the Study and Application of Methods of Ilizarov; E – Excellent; F – Fair; G – Good; P – Poor

study, excellent bone results were in fifty cases, good in 7, and fair in 2 based on union, persistent infection in 1 case, deformity in 2, and limb shortening in 1 case. Functional results were excellent in 45 cases, good in 10, fair in 3, and poor in 2 based on return to daily activities, limp in 3 cases, equinus in 4 cases, dystrophy in 3 cases, and pain in 4 cases. In this study, all patients had infected nonunion of the shaft of the tibia due to either compound wound or by infection followed by the primary fixation. Patients with infected wound and soft tissue and bone loss were treated with flap cover and corticotomy with distraction done, respectively. Our success in the eradication of chronic infection, with no recurrences after a median follow-up of 25 months, is very satisfactory. We believe that this was because we were able to apply the basic surgical principle of the treatment of infection by the excision of all unhealthy tissue. Some required excision of a segment of bone which was then re-grown from regions of good vascularity, avoiding the use of avascular cancellous graft. Five of our 21 cases underwent segmental excisions of a median length of 5 cm. It is possible that such radical treatment excised some bone unnecessarily, but we had no failures and consider that the risk was justified. We believe that early selection of cases and prompt treatment will help in acceptable results and return to their occupation.

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Conflicts of interest

There are no conflicts of interest.

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