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Original article

Infected Tibial Nonunion: Assessment of compression distraction Ilizarov technique without debridement

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ABSTRACT

Background: The treatment of infected nonunion requires radical debridement with stable fixation. Sever soft tissue compromise of the nonunion site might interfere with radical debridement. This study discussed the outcome of treatment of infected tibial nonunion with sever soft tissue compromise by a cyclic compression distraction technique using Ilizarov without radical debridement.

Methods: This study comprised 17 patients with unilateral infected tibial nonunion; 10 with diaphyseal and 7 with metaphyseal locations. Their mean age was 21.9 years. There were 12 males and 5 females. The right side was affected in 11 patients and the left side in 6 patients. According to Gustilo and Anderson classification, all patients were grade III. The mean limb shortening was 1.3 cm. All patients were treated initially in another institute by uniplanner external fixator with rotational skin flap done in 11 patients and thiersch graft in 6 patients. One patient had common peroneal nerve affection. Distal circulation was sufficient in all patients. None of our patients had chronic diseases. Two to three cycles of gradual distraction compression were done. Each cycle consisted of distraction, followed by compression, then distraction, and lastly compression. The mean follow up period was 29.35 months.

Results: Union was achieved in all patients at a mean time of 23.9 weeks. According to Hammer et al.; there were 8 patients with grade 1, and 9 patients with grade 2. According to Johner and Wruhs' criteria; the outcome was excellent in 6 patients, good in 3 patients, poor in 4 patients, and fair in 4 patients. Complications had occurred as pin tract infection (47.1%), persistent discharging sinus (5.9%), and valgus ankle deformity (11.8%). Refracture did not occur in any case till the final follow up.

Conclusion: Although debridement is essential in the treatment of infected tibial nonunion, it could harm the limb in severe soft tissue compromise. Cyclic compression distraction by Ilizarov had a satisfactory outcome in the treatment of such cases through enhancement of a biological environment to achieve union.

Level of evidence: IV; prospective case series.

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1. Introduction

The treatment of infected nonunion of long bones is still a challenge in orthopedic surgery. There is a consensus that radical debridement of the necrotic bone and infected soft tissue with stable external fixation is mandatory for management of such complex problem [1].

Infected nonunion is considered a multifactorial problem that needs biological and mechanical treatment to address bony union, scared soft tissue, eradication of infection, correction of concomi-

tant deformity and shortening [2]. Several alternatives had been used to treat infected nonunion of long bones, including massive debridement with skin rotational flap, Papineau technique, Masquelet or biological membrane technique with cancellous bone graft, tibio fibular synostosis or bone transport using external fixator [3,4]. The soft tissue coverage is a hallmark in treatment of infected nonunion, as sever soft tissue compromise at the site of nonunion might interfere with open radical debridement of the infected site, and would change the surgeon's decision in treatment of such cases [4].

The Ilizarov fixator and methods have been successfully used to manage infected nonunion by providing mechanical stability and biological enhancement through corticotomy and bone transport

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Table 1
The patients demographics.

Patient No	Age (y)	Gender	Side	Site	Gustilo Classification	Mechanism of Injury	Associated injuries	Previous TTT	Interval between Trauma&Surgery (w)
1	14	M	RT	M	IIIB	MCA		UEF+RSF	17
2	16	F	RT	D	IIIA	MCA		UEF+TG	25
3	13	M	RT	D	IIIB	MCA		UEF+RSF	20
4	20	M	LT	D	IIIA	MCA		UEF+TG	26
5	33	F	LT	M	IIIB	MCA	Common peroneal nerve	UEF+TG	19
6	22	M	LT	D	IIIB	MCA		UEF+RSF	18
7	27	F	RT	M	IIIB	MCA		UEF+RSF	22
8	25	M	RT	M	IIIA	MCA		UEF+RSF	21
9	21	M	RT	D	IIIA	MCA		UEF+RSF	20
10	19	M	RT	D	IIIC	MCA	Posterior tibial artery	UEF+TG	33
11	31	F	RT	D	IIIB	MCA		UEF+RSF	18
12	20	M	LT	M	IIIA	MCA		UEF+TG	25
13	19	M	LT	D	IIIA	MCA		UEF+RSF	27
14	20	M	RT	D	IIIB	MCA		UEF+TG	26
15	22	M	RT	M	IIIB	MCA		UEF+RSF	23
16	24	M	LT	M	IIIB	MCA		UEF+RSF	20
17	26	F	RT	D	IIIB	MCA		UEF+RSF	20

No: number; Y: year; M: male; F: female; RT: right; LT: left; M: metaphysis; D: diaphysis; MCA: motor car accident; TTT: treatment; UEF: uniplanner external fixator; RSF: rotational skin flap; TG: thiersch graft; w: weeks.

or through compression distraction that provides new angiogenesis through distraction and osteogenesis by compression [5,6].

Most recent publications focused on radical debridement as a key for successful treatment of infected nonunion with subsequent corticotomy and bone transport [7–9]. Our hypothesis is that radical debridement is not mandatory in management of infected nonunion. The purpose of this study is to present the outcome of treatment of infected nonunion of the tibia with sever soft tissue compromise by a cyclic compression distraction technique using Ilizarov external fixator without open radical debridement.

2. Materials and methods

Between March 2013 and August 2016; 17 patients with infected nonunion fracture tibia were enrolled in the current study. Inclusion criteria included infected tibial non union with soft tissue compromise that hinders the ability of open surgical debridement of the nonunion site. Patients with aseptic nonunion, or tibial shortening more than 5 cm were excluded from this study.

The nonunion was diagnosed when the fracture failed to progress to union or has little or no potential for further healing without additional intervention, six months has to be achieved before consider a failed union [10]. All patients were diagnosed infected due to presence of a drainage sinus.

The mean age of the patients at the time of presentation was 21.9 years (range:13–33). There were 12 males (70.5%) and 5 females (29.5%). The right side was affected in 11 patients (64.7%) and the left side in 6 patients (35.3%). In all patients, the initial injury was due to motor car accident resulting in open fracture tibia with 10 patients (58.8%) with diaphyseal location and 7 patients (41.2%) with metaphyseal location. According to Gustilo and Anderson classification [5] for open fracture, there were 6 patients (35.3%) with grade IIIA, 10 patients (58.8%) with grade IIIB, and one patient (5.9%) with grade IIIC at the time of initial trauma. All male patients were smokers.

All patients were treated initially by uniplanner external fixator with rotational skin flap done in 11 patients (64.7%) and thiersch graft in the other 6 patients (35.3%), and received antibiotics according to culture and sensitivity All these procedures were done

in other hospitals before referral to our center with persistent infection and nonunion. The mean time interval between the initial injury and the definitive surgery was 22.35 weeks (range: 17–33).

The mean limb shortening was 1.3 cm (Range:0–3). One patient had common peroneal nerve affection dating since the initial trauma and persists till presentation to our institute. Electromyography studies showed that the injury was neurotmesis with no signs of regeneration. Table 1 demonstrates detailed patients demographics and clinical data. The study was approved by the ethical institute and all patient have signed informed consent.

2.1. Surgical technique

Under regional anesthesia, patients were positioned supine with the affected limb draped as usual without use of the tourniquet. The site of draining sinus was covered with sterile dressing. The drainage sinus was not approached at all. Swab was taken after draping from the draining sinus for bacteriological stains, culture and sensitivity tests.

Under image control, Ilizarov external fixator was applied; two complete rings above and two below the nonunion site, wires were tensioned up to 120–130 kg. The site of nonunion was acutely compressed intraoperatively with no open debridement done.

2.2. Post-operative care

Immediate postoperative neurovascular examination, and plain X-rays of the affected leg including knee and ankle joints were performed to confirm compression of the nonunion site. All the patients were instructed to start weight bearing on the affected limb, and ROM exercises of knee and ankle joints as tolerated. The patients were discharged from the hospital after a mean of 4.58 days postoperatively (range:4–5).

One week postoperative, cyclic distraction compression was done (Fig. 1). Each cycle consisted of four phases; gradual distraction (1st phase), followed by gradual compression (2nd phase), then gradual distraction (3rd phase), and lastly gradual compression (4th phase). Each phase was done by turning the nuts by a rate of 0.5 mm every 12 hours for 4 days. Plain x-ray was obtained after the end of each phase. All patients underwent 2 repeated cycles; with one-week interval. Only 2 patients (11.8%) needed an additional 3rd

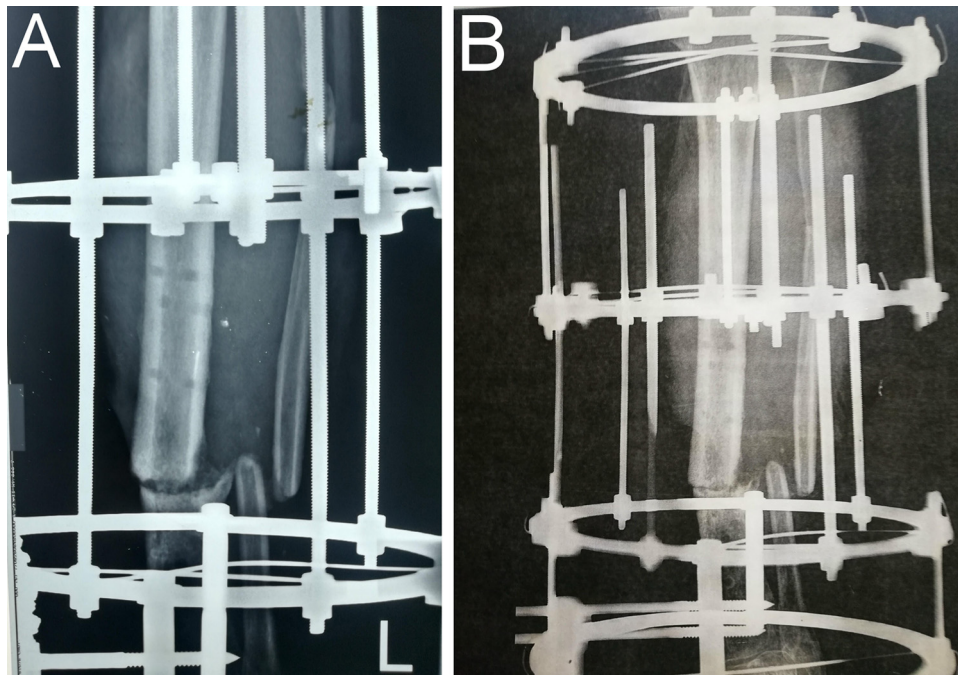


Fig. 1. A. Plane X-ray antero-posterior view shows cycle of distraction. B. Plane X-ray Antero-posterior view shows the cycle of compression.

cycle one month after the 2nd cycles there were no radiographic signs of union. After the last cycle, compression was done till complete bony apposition was reached. All the patients had been taught how to do gradual distraction and compression though the nuts that were marked with a red colour.

Patients were followed in the clinic every 2 weeks to check the union progress clinically and radiologically. Antibiotics were given according to results of culture and sensitivity for at least 6 weeks and till CRP drop to normal and sinuses close under supervision of infection disease team.

Radiological assessment of callus formation was evaluated according to Hammer et al. [11] (Table 2). After union, the Ilizarov fixator was dynamized by gradually removing the connecting rods between the fracture rings; one every day. The fixator was then removed under general anesthesia without pop.cast application because of bad soft tissue conditions. The patients were instructed to wear a removable leg brace for the next three months.

At final follow up, clinical and radiological outcomes were evaluated using Johner and Wruhs' criteria [12](Table 3). Statistical analysis was done using IBM SPSS Statistics for Windows, Version 22.0 (IBM Corp., Armonk, NY, USA).

3. Results

The mean follow up period was 29.35 months (range: 24–38). During compression distraction cycles, all patients noticed increased in the amount of discharge from the sinus in the 1st three weeks, and then the discharge became less in amount over two weeks before its disappearance after 5 to 8weeks. Also, 10 patients noticed that small fragments of necrotic bones came out of the sinus before its closure.

Union was achieved in all patients at a mean time of 23.9 weeks (range: 20–30).According to Hammer et al. [11] grading of radiological callus formation, there were 8 patients (47.1%)with grade 1, and 9 patients (52.9%)with grade 2.

According to Johner and Wruhs' criteria [12], there were 6 patients (35.3%) with excellent outcome, 3 patients (17.7%) with good outcome, 4 patients (23.5%) with poor outcome, and 4 patients (23.5%) with fair outcome.

Pin tract infection occurred in 8 patients (47.1%) that were improved with oral antibiotics and pins care. Persistent discharging sinus was present in one patient (5.9%) who refused any additional procedures. Valgus ankle deformity was present in 2 patients (11.8%); one with 11.8° and the other with 8°. Refracture did not occur in any case till the final follow up. Table 4 outlines the outcome of the patients and their complications.

4. Discussion

Open fracture is considered the most common cause of the infected nonunion. The tibia is the most common bone involved in infected nonunion in association with openfractures and implant surgeries [2]. Since nineties of the last century, Ilizarov external fixator have gained popularity to become the method of choice in management of infected non union of the tibia with very good results [13].

Although the Ilizarov techniques involve compression, compression distraction, or bone transport [5,14], most series uses bone transport with very few are publishing the results of compression distraction. That may be due to the common practice of radical debridement among orthopedic surgeons inspite of Ilizarov statement that “infection burns in the flame of regeneration” [15]. Radical debridement resulted in large bone defects that render acute shortening with scarred soft tissue impossible, and longer times of bone transport and the need of second surgery to bone graft the docking site is common. Moreover, some cases with scared and very poor soft tissue are better treated by less invasive techniques and avoid open radical debridement

In the current series,we treated 17 patients with infected nonunion tibia by cyclic compression distraction using Ilizarov circular external fixator without debridement (bloodless technique).

Table 2
Hammer et al. [11] classification of fracture healing.

Grade	Callus formation	Fracture Line	Stage of Union
1	Homogeneous bone structure	Obliterated	Achieved
2	Massive bone trabeculae crossing the fracture line	Barely discernible	Achieved
3	Apparent Bridging of fracture line	Discernible	Uncertain
4	Trace No bridging of the fracture line	Distinct	Not achieved
5	No callus formation	Distinct	Not achieved

Table 3
Johner and Wruhs's criteria [12] for clinical and radiological outcome.

Parameter	Excellent	Good	Poor	Fair
Nonunion, osteomyelitis, amputation	None	None	None	Yes
Neurovascular disturbances	None	Minimal	Moderate	Severe
Deformity				
Varus/valgus(°)	None	2–5	6–10	□ 10
Anteversion/recurvation(°)	0–5	6–10	11–20	□ 20
Rotation (°)	0–5	6–10	11–20	□ 20
Shortening (mm)	0–5	6–10	11–20	□ 20
Mobility (°)				
Knee	Normal	□ 80	□ 75	< 75
Ankle	Normal	□ 75	□ 50	< 50
Subtalar	□ 75	□ 50	< 50	
Pain	None	Occasional	Moderate	Severe
Gait	Normal	Normal	Insignificant limp	Significant Limp
Strenuous activity	Possible	Limited	Severely limited	Impossible

Table 4
The patients' outcome.

Patient No	No of Cycles	Shortening (cm)	Union achievement	Time to union (w)	Hammer et al. grade	Outcome (Johner and Wruhs's)	Complications	Follow up (m)
1	2	2.6	Yes	20	2	Fair	Valgus ankle 11°	26
2	2	0.5	Yes	25	1	Excellent		29
3	2	0	Yes	30	2	Excellent	PTI	33
4	2	2	Yes	22	1	Poor	PTI	35
5	2	0	Yes	21	2	Excellent	PTI	38
6	2	1.8	Yes	27	1	Poor		36
7	2	0	Yes	26	2	Excellent	PTI	26
8	2	0	Yes	25	2	Excellent	PTI	25
9	2	2.9	Yes	27	1	Fair	PTI	30
10	2	3	Yes	21	2	Fair	Discharging sinus Valgus ankle 8°	28
11	2	2.5	Yes	20	1	Fair		31
12	2	1.5	Yes	22	1	Poor		24
13	2	1	Yes	26	1	Good		30
14	3	1	Yes	24	2	Good	PTI	28
15	3	0.5	Yes	22	2	Excellent	PTI	25
16	2	0.8	Yes	24	1	Good		27
17	2	2	Yes	24	2	Poor		28

No: number; cm; centimeter; w: weeks; PTI: pin tract infection; m: months.

there was a special situation; where there was infected nonunion of the tibia resulted from open fractures with skin and soft tissue compromise that was treated initially by unplanned external fixator and skin flaps or grafts that make surgical intervention for debridement of the infected site hazardous (Fig. 2). Union was achieved in all cases in an average of 23.9 weeks (range: 20–30) (Fig. 3).

Cyclic compression distraction (the accordion maneuver) had been described by Ilizarov himself to accelerate the weak regenerate in distraction osteogenesis in bone lengthening [16]. Distraction transforms the crushed scarred tissue at the nonunited site into the fibrovascular tissue, where repeated distraction stimulates the collagen fiber and osteoblastic cell production and stimulate bone formation by intramembranous ossification [17]

Biomechanical studies had tried to understand the effect of cyclic compression distraction technique on the nonunion site, they concluded that bone respond to dynamic compression rather than static compression and the bone ends stop sending biochemical signals with static compression as they adapted to this maintained force. The bone ends requires what is called (time off) period, which is formed by a cyclic compression distraction technique that help the bone ends to be released from this adaptation. The forces applied to bone ends also have different effects; as compression leads to osteogenesis, fibrous tissue formation and intramembranous ossification, while distraction leads to angiogenesis, chondrogenesis and endochondral ossification and bone formation [18].

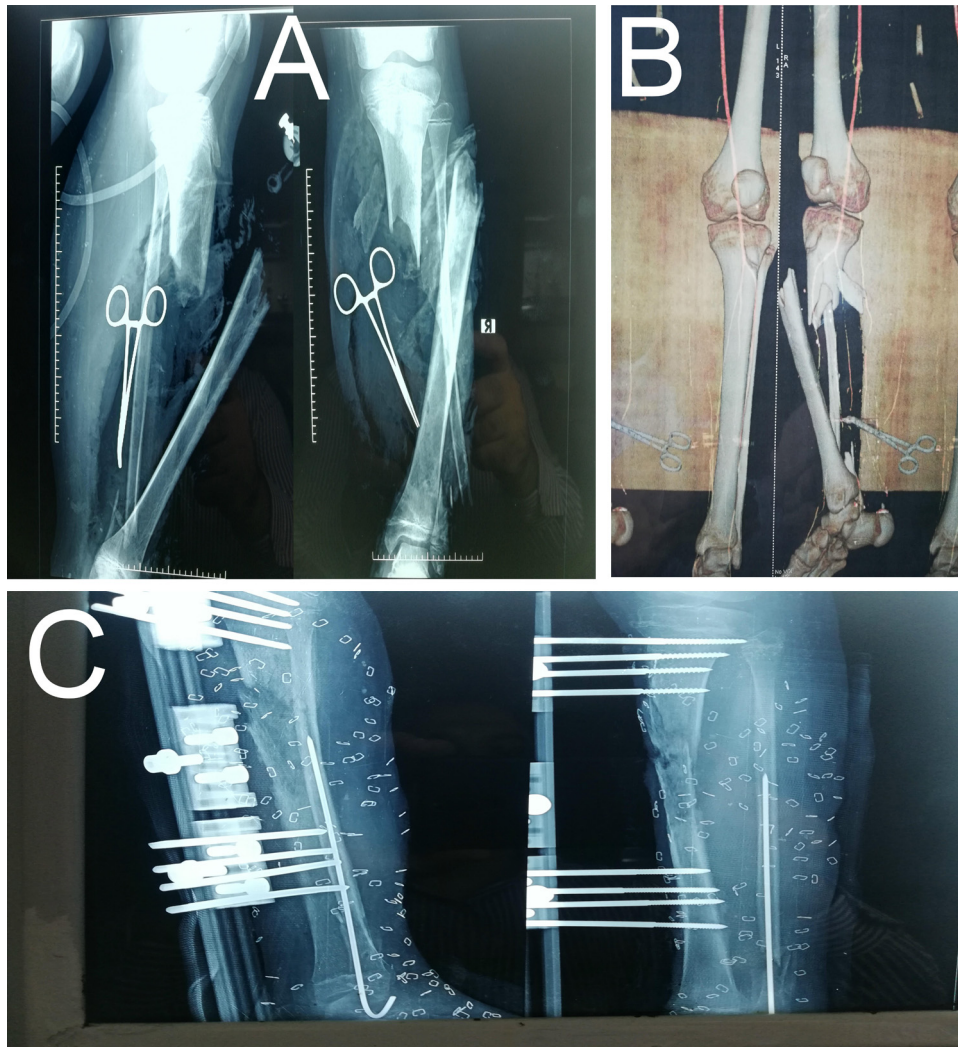


Fig. 2. A. Plane X-rays Antero-posterior and lateral views at the time of the initial trauma show severely displaced proximal metaphysis-diaphyseal fracture of the tibia, with fracture at the distal fibula. B. C.T. Angiography shows the fracture and associated vascular injury that had been holding with arterial clamp. C. X-rays Antero-posterior and lateral views show the fracture fixation with monoplane external fixator with metallic shadows of staples for a skin graft.

Several studies have reported satisfactory outcome of this technique with acceleration of bone regenerate and stimulation of bone formation in the context of fracture union, without a sufficient description of the technique [19–22].

Zhang et al. [19] used compression distraction technique with minimally invasive percutaneous drilling of the bone ends in treating 20 patients with aseptic non union tibia and the result was excellent in 9 patients, good in 6, fair in 4 and poor in one patient.

Inane et al. [20] had treated 11 patients with femoral nonunion with cyclic compression distraction technique and the results were excellent in all cases. Baruah et al. [21] reported results of compression distraction technique in 23 patients with nonunion with union achieved in all cases.

Very few reports described use of Accordion maneuver together with debridement in management of infected non union tibia. Sakale et al. [22], reported management of 6 cases with infected nonunion tibia and bone defect <2.5 cm with debridement and cyclic compression and distraction with union achieved in all cases.

To the author's knowledge, this is the first clinical report on the application of the principle of cyclic compression distraction technique in treatment of patients with infected nonunion of the tibia without debridement due to severe soft tissue affection with a satisfactory outcome. The main limitation of the study was the small number of patients and the short follow up period.

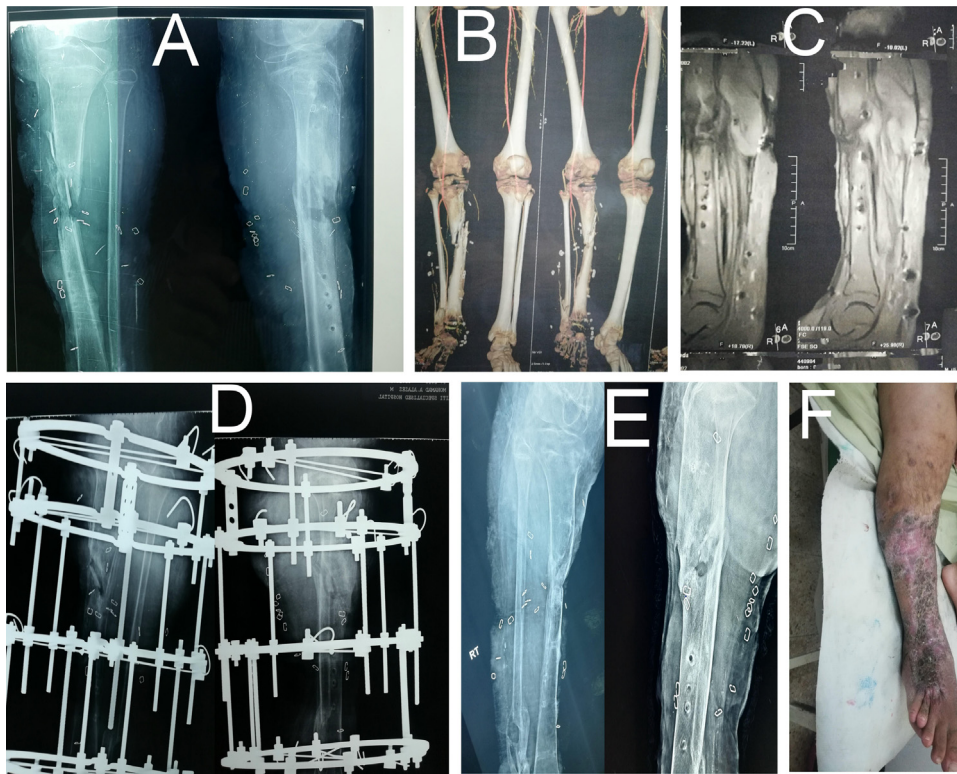


Fig. 3. A. Plane X-rays Antero-posterior and lateral views show site of infected nonunion after fixator removal. B. C.T.angiography of the injured lower limb after fixator removal show adequate blood supply of the limb. C. C.T. Shows the site of infected non union and the sequestrum. D. Plane X-rays show application of Ilizarov external fixator with compression distraction technique. E. Plane X-rays Antero-posterior and lateral views show union had achieved and the apparatus was removed. F. Clinical photos from medial and lateral side show the extent of the skin graft and clinical outcome.

5. Conclusion

Cyclic compression distraction by Ilizarov without debridement showed a satisfactory outcome in the treatment of infected non union tibia with compromised soft tissue with low complication rates.

Ethical approval

The study was approved by ethical committee of the University and was in accordance with the ethical standards of the institutional and national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Informed consent

Informed consent was obtained from all individual participants included in the study.

Disclosure of interest

The authors declare that they have no competing interest.

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Author contribution

All authors have contributed to the study

References

- [1] Struijs PA, Poolman RW, Bhandari M. Infected nonunion of the long bones. *J Orthop Trauma* 2007;21:507–11.
- [2] Bell A, Templeman D, Weinlein JC. Nonunion of the femur and tibia: an update. *Orthop Clin North Am* 2016;47:365–75.
- [3] Uzel AP, Lemonne F, Casoli V. Tibial segmental bone defect reconstruction by Ilizarov type bone transport in an induced membrane. *OrthopTraumatol Surg Res* 2010;96:194–8.
- [4] Bauer T, Klouche S, Grimaud O, Lortat-Jacob A, Hardy P. Treatment of infected non-unions of the femur and tibia in a French referral center for complex bone and joint infections: Outcomes of 55 patients after 2 to 11 years. *OrthopTraumatol Surg Res* 2018;104:137–45.
- [5] Paley D, Catagni MA, Argnani F, Villa A, Benedetti GB, Cattaneo R. Ilizarov treatment of tibial nonunions with bone loss. *Clin OrthopRelat Res* 1989;241:146–65.
- [6] Hosny G, Shawky MS. The treatment of infected nonunion of the tibia by compression-distraction techniques using the Ilizarov external fixator. *Int Orthop* 1998;22(5):298–302.
- [7] Green SA, Aronson J, Paley D, Tetsworth KD, Taylor JC. Management of fractures, nonunions, and malunions with Ilizarov techniques. In: Chapman MW, editor. *Chapman's orthopaedic surgery*. 3rd ed. Philadelphia: Lippincott Williams & Wilkins; 2011. p. 1002–17.
- [8] Sanders J, Mauffrey C. Long bone osteomyelitis in adults: fundamental concepts and current techniques. *Orthopedics* 2013;36:368–75.
- [9] Simpson AH, Deakin M, Latham JM. Chronic osteomyelitis. The effect of the extent of surgical resection on infection-free survival. *J Bone Joint Surg Br* 2001;83:403–7.
- [10] Galle SE, Zamorano DP. Tibial nonunions. In: Agarwal A, editor. *Nonunions diagnosis, evaluation and management*. New York: Springer ScienceBusiness Media LLC; 2018. p. 287–308.
- [11] Hammer RR, Hammerby S, Lindholm B. Accuracy of radiologic assessment of tibial shaft fracture union in humans. *Clin OrthopRelat Res* 1985;199:233–8.
- [12] Johner R, Wruhs O. Classification of tibial shaft fractures and correlation with results after rigid internal fixation. *Clin OrthopRelat Res* 1983;178:7–25.
- [13] Whittle AP. General principles of fracture treatment. In: Azar F, Canale ST, Beatty J, editors. *Campbell's operative orthopaedics*. 13th ed. Philadelphia: Elsevier/Mosby; 2017. p. 2656–711.
- [14] McNally M, Ferguson J, Kugan R, Stubbs D. Ilizarov treatment protocols in the management of infected nonunion of the tibia. *J Orthop Trauma* 2017;31:S47–54.
- [15] Golyakhovsky V, Frankel V. *Operative Manual of Ilizarov Techniques*. Saint Louis: Mosby-Yearbook, Inc; 1993. p. 146–8.

- [16] Ilizarov GA. Clinical application of the tension-stress effect for limb lengthening. *Clin OrthopRelat Res* 1990;250:8–26.
- [17] Neidlinger-Wilke C, Wilke HJ, Claes L. Cyclic stretching of human osteoblasts affects proliferation and metabolism: a new experimental method and its application. *J Orthop Res* 1994;12:70–8.
- [18] Greenwald JA, Luchs JS, Mehrara BJ, et al. Pumping the regenerate': an evaluation of oscillating distraction osteogenesis in the rodent mandible. *Ann Plast Surg* 2000;44:516–21.
- [19] Zhang Q, Zhang W, Zhang Z, et al. Accordion technique combined with minimally invasive percutaneous decortication for the treatment of bone nonunion. *Injury* 2017;48:2270–5.
- [20] Inan M, Karaoglu S, Cilli F, Turk CY, Harma A. Treatment of femoral nonunions by using cyclic compression and distraction. *Clin Orthop Relat Res* 2005;436:222–8.
- [21] Baruah RK, Patowary S. Accordion maneuver: a bloodless tool in ilizarov. *J Limb Lengthen Reconstr* 2018;4:11–9.
- [22] Sakale H, Agrawal AC, Kar B. Management of infected nonunion of tibia by ilizarov technique. *J OrthopTraumatolRehabil* 2018;10:1–6.