



Open segmental tibial bone defects treated with Ilizarov frame: a radiological and functional outcome study with average ten year follow-up

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Abstract

Purpose Surgical reconstruction of large post-traumatic tibial bone and soft tissue defects following high-energy trauma presents a significant challenge for orthopaedic surgeons. This study aimed to evaluate the functional and radiological outcomes of large post-traumatic tibial bone and soft tissue defects managed by single or double-level bone transport using the Ilizarov technique.

Material & methods 13 patients who underwent treatment for large tibial bone defects (Gustillo IIIa, IIIb, IIIc) along with soft tissue defects with Ilizarov from 2010 to 2020 A.D were included. ASAMI functional and radiological outcomes were assessed at the final follow-up to report the outcome.

Results The mean age was 27.38 (18–48). An average bone defect was 7.69 cm (5–13 cm). Based upon the Gustillo-Anderson classification (GA), 2 (15%) of them were GA – 3 A, 7 (54%) were GA – 3B, and 4 (31%) were GA – 3 C. The average time of distraction was 11.76 weeks (8–16). The average time for the union was 37 weeks (27–48 weeks). The average bone lengthening was 7.69 cm (5–13 cm). The mean final leg length discrepancy (LLD) at the final follow-up was 1.96 cm (0–4 cm). The primary union was achieved in eight cases, and five required bone grafting at the docking site. Using the ASAMI (Association for the Study of the Method of Ilizarov) scoring system, the functional results were excellent in six and good in seven cases, while the bony results were excellent in eight, good in four and fair in one case.

Conclusion Good to excellent functional and radiological scores (ASAMI) can be expected when using the Ilizarov frame for simultaneous treatment of the large tibial bone and soft tissue defect when this method is applied with correct principles.

Keywords Tibial bone defects · Ilizarov · Gustillo-Anderson · ASAMI

Introduction

Tibial diaphyseal fractures are among the most common open fractures, with more than half classified as high-energy Gustilo-Anderson type III fractures [1]. Surgical reconstruction of large post-traumatic tibial bone and soft tissue defects following high-energy trauma, along with bone and soft tissue necrosis and infection, presents a significant challenge for orthopaedic surgeons [2]. Amputation may be unavoidable without options for bone and soft tissue coverage and reconstruction [3]. As a result, finding effective

reconstruction methods to salvage the limb is critical. Based on the fundamental principle of soft tissue coverage with osseous reconstruction, surgeons must select a limb-salvage strategy that can potentially improve patients' quality of life [4].

Several bone defect repair methods are available, including allografts, cancellous bone autografts, pedicled vascularized iliac crest grafts, pedicled vascularized fibular transfers, and microvascular fibular transfers [5]. While the length of the bone defect limits other repair methods, Ilizarov's distraction osteogenesis method has proven particularly effective in large bone and soft tissue defect reconstruction [6]. The dynamic frame enables gradual lengthening, deformity correction and non-union or delayed union compression even in poor soft tissue coverage while remaining minimally invasive [7].

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Table 1 Demographics

Mean age	27.38 years
Male: Female	11: 2
Right: Left	7: 6
Mode of injury:	13
Road traffic accident	
Mean follow-up	10.69

Material & method

A retrospective review of patients with open tibial defects treated between January 2013 and December 2022 was done with prospective outcome scoring. Any patient with a history of trauma and with a tibial bone defect > 4 cm with soft tissue defects was included in the study. 13 patients met the inclusion criteria. There were 11 males and two females. The mean age was 27.38 years (18–48 years). Preoperatively, an average bone defect was about 7.69 cm, ranging from a minimum of 5 cm to a maximum of 13 cm. All the patients were followed up monthly for a minimum of 12 months after discharge.

All the injuries were related to road traffic accidents. All the soft tissue defects in 13 patients were treated without additional plastic surgery during the segment transfer.

Outcomes measured included bone union, complications, Association for the Study and Application of the Methods of Ilizarov (ASAMI) bone and functional scores.

All collected data were imported into the Statistical Package for the Social Sciences (SPSS version 26 for

cleaning, coding, and descriptive statistics). Descriptive statistics were used to describe and summarise the information. The mean and standard deviation were used to summarise the continuous variables. Categorical variables were summarised with frequency and percentage.

Before the study, institutional review board approval was taken from our hospital IRB, and informed consent was obtained from all the patients.

Results

The mean age was 27.38 years (18–48 years). There was a total of 13 patients, which included 11 males and two females. An average bone defect was 7.69 cm (5–13 cm). The injury was located in the left tibia in six cases and seven in the right (Table 1).

The fracture was located proximally in four cases (31%), mid-shaft in six (46%) and distally in three (23%). Based upon the Gustillo-Anderson classification [8] (GA), 2 (15%) of them were GA – 3 A, 7 (54%) were GA – 3B (Fig. 1), and 4 (31%) were GA – 3 C. Primarily, eight (62%) of these patients were treated at our centre with an external fixator as a method for damage control, and five (38%) of them were treated elsewhere with an intra-medullary interlocking nail (IMIL) and were referred to our centre. The corticotomy was done proximally in 7 (54%), distally in five (38%) and bifocal in one (8%).

Fig. 1 (A) Twenty-three-year-old male with a right mid-shaft tibia Gustillo-3B fracture following a road traffic accident. (B) After the first radical debridement, the necrotic tissue and bones were excised, and the Ilizarov frame was applied. (C) Corticotomy was done at the distal third tibia, and distraction started. (D) The total frame time seven months with complete regeneration of bone and union at the docking site. (E) Radiograph taken after frame removal, 18 months after frame application

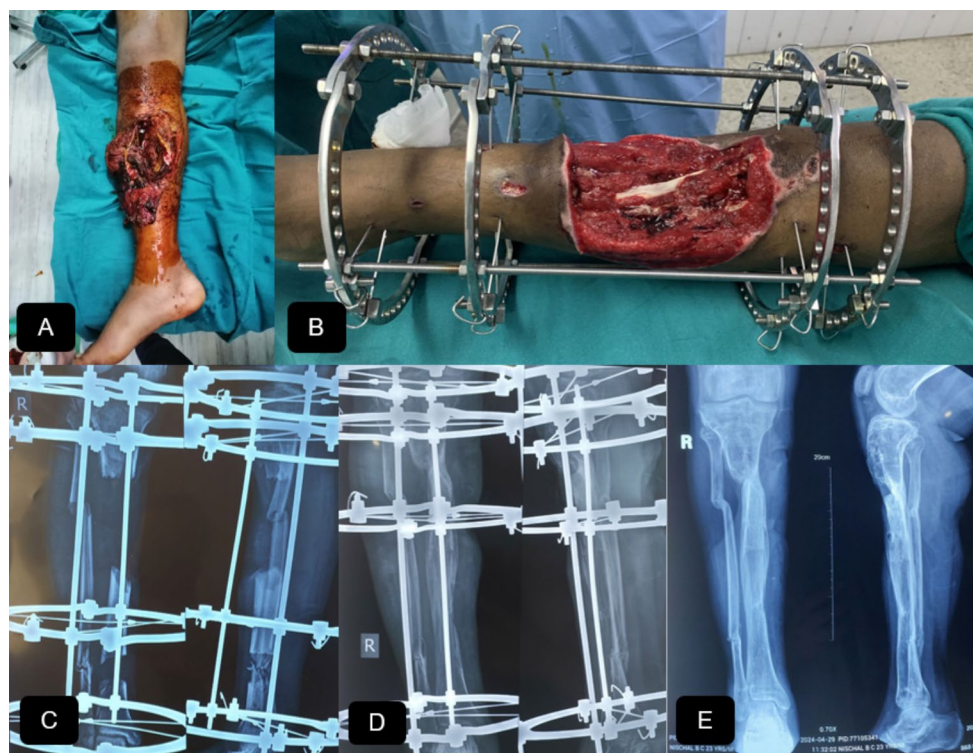


Table 2 Baseline data of study patients

Mean bone & soft tissue defect (cm)	7.69 ± 2.83
Mean distraction time (weeks)	11.76 ± 2.22
Mean amount of bone lengthening (cm)	7.84 ± 2.47
Mean LLD after treatment (cm)	1.96 ± 1.23
Mean union time (weeks)	37 ± 6.21
Mean time in frame (weeks)	37 ± 6.21

The average time of distraction was 11.76 weeks (8–16). The average time for the union was 37 weeks (27–48 weeks). The average bone lengthening was 7.69 cm (5–13 cm). The mean final leg length discrepancy (LLD) at the final follow-up was 1.96 cm (0–4 cm) (Table 2).

The primary union was achieved in eight cases, and five required bone grafting at the docking site. Using the ASAMI scoring system, the functional results were excellent in 6 (Fig. 2) and good in seven cases, while the bony results were excellent in eight, good in four and fair in one case (Table 3). An average follow-up was 8.62 years (3–12).

Pin-tract infection was seen in four cases and managed with dressing and antibiotics.

Table 3 ASAMI functional and bony results

ASAMI functional results	
Excellent	6 (46.15%)
Good	7 (53.84%)
Fair	0
Poor	0
ASAMI Bony results	
Excellent	8 (61.53%)
Good	4 (30.76%)
Fair	1 (7.69%)
Poor	0

Discussion

Tibial defects remain a complex problem for orthopaedic surgeons. Due to its anatomical position and scanty soft tissue coverage, the tibia is the most common site for open fracture in the long bones. Complications are common with GA type 3 fracture of the tibia and may include infection, non-union, necrotic bone, soft tissue loss, deformities, and limb length inequalities [9]. The Ilizarov method effectively provides stability while enhancing soft tissue closure and filling of bony defects by bone transport procedure [10]. Ilizarov ring fixator effectively addressed segmental bony defects with soft tissue defects in our case series, achieving

Fig. 2 Clinical pictures taken at 5 years follow-up

a complete union in all 13 cases with complete soft tissue coverage and healing.

In our case, five required bone grafting at the docking site. All these were mid-shaft tibial defects, which eventually docked at the distal third after distraction osteogenesis. Borrelli Jr et al. have stated in their study that the proximal and distal metaphyseal areas of the tibia have a rich extraosseous blood supply provided primarily by branches of the anterior tibialis artery and the posterior tibial artery compared to poor supply in the mid-shaft region [11]. It might explain the reason for non-union at the docking site in our case series, and all of them were high-velocity injuries. Several authors have described different technique to address non-union and ischaemic bone regeneration. A. Kahled et al. reported a Masquelet technique followed by Ilizarov fixator for infected tibial non-union in 32 cases with successful reconstruction reported in 30 cases (94%) in their series [12]. Similarly, D.Y Burzunov et al. has described two mechanical solutions to salvage failed distraction osteogenesis in large bone defect. The first solution is by adding additional osteotomy near failed regeneration site and transport is directed towards an ischaemic regenerate to produce its compaction until its bony parts contact each other. The other being compaction of the regenerate intermediate connective tissue zone by applying step-wise compression with the same frame with oblique osteotomy of intact fibula by 1 cm [13].

The mean bone and soft tissue defect gap were 7.69 ± 2.83 (5–13) cm and correlated with the amount and time of bone lengthening.

Ilizarov's method effectively secured infection-free union in the most challenging cases, with long defects and poor soft tissues [14]. After thorough debridement, the combined bone and soft tissue gaps were treated simultaneously by distraction osteogenesis. Miraj et al. achieved similar results in 14 cases with mean bone defects of 14.07 cm and soft tissue defects [9].

Previously, the Ilizarov external fixation technique was the most commonly used technique for large bone defects without soft tissue defects [15]. Many recent studies have reported that bone transport with external fixation can simultaneously treat massive bone and soft tissue defects [16, 17]. The technique of bone transport combined with soft-tissue transport (open bone transport) was first proposed by Suger [18]. It is a process of the skin and subcutaneous tissue being stretched by pins and screws of Ilizarov ring along with the bone distraction. Then, the soft-tissue defect was covered by the newly formed skin tissue before the bone ends contact at the docking site. Also, Paley et al. reported soft tissue defect coverage in seven of eight cases using the Ilizarov frame alone [19].

Kemal et al. in their case series of 24 patients with large bony tibial defect (> 5 cm) along with soft tissue defect, reported 15 (58%) had excellent, nine (38%) had good and one (4%) had fair ASAMI functional outcome; bony results were excellent in 12 (50%), good in eight (33%), fair in two (8%) and poor in two (8%) using Ilizarov technique [16]. In our series, according to ASAMI functional criteria, six (46.15%) had excellent results, and seven (53.84%) had good results. Similarly, eight (61.53%) had excellent bony results, four (30.76%) had good results, and one (7.69%) had a fair bony result. We did not encounter any refracture, nor was any amputation required compared to the 4% rates of refracture and amputation reported by Yin et al. in their review [20].

Nine out of 13 patients could return to their previous jobs, highlighting this method's efficacy in treating these complex injuries.

In conclusion, good to excellent functional and radiological scores (ASAMI) can be expected when using the Ilizarov frame for the treatment of open tibial defects along with soft tissue defects. Docking site non-union can be addressed with bone grafting. Simultaneous bone and soft tissue defect treatment can be achieved when this method is applied with correct principles, precluding the need for more invasive surgical procedures to cover the soft tissue defect.

Author contributions BBC: Conceptualization, Methodology, Project administration, Resources, Visualization, Writing – original draft, writing – review & editing, Final approval of the version to be published. AR: Investigation, Data curation, Validation, Resources, Investigation, Software, Project administration, Formal analysis, Data analysis. AKB: Conceptualization, Supervision, Visualization, Final approval of the version to be published. BBA: Data interpretation & analysis, methodology, Data curation, Supervision, Final approval of the version to be published.

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Declarations

Ethics approval and consent to participate It is an observational study. The Institutional Review Board has confirmed that no ethical approval is required. Informed consent was obtained from all individual participants included in the study.

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References

1. Rozbruch SR, Adam M, Weitzman JT, Watson P, Freudigman HV, Katz SI (2006) Simultaneous treatment of tibial bone and soft-tissue defects with the Ilizarov method. *J Orthop Trauma* Mar 20(3):197–205. <https://doi.org/10.1097/00005131-200603000-00006>

2. Kadhim M, Holmes L, Gesheff MG, Conway JD (2017) Treatment Options for Nonunion with Segmental Bone Defects: Systematic Review and Quantitative Evidence Synthesis. *J Orthop Trauma*. 2017;31(2):111–119. <https://doi.org/10.1097/BOT.0000000000000700>
3. Mackenzie MBEJ, Lawrencw JFKARB, Webb X, Marc F, Swiontkowski RWS, Marl ALJ, Brendan PAA, Patterson M, McCarthy ML, Thomas GT, Renan C, Castillo. An analysis of outcomes of reconstruction of amputation of leg-threatening injuries. *N Engl J Med*. 2002;347(24):1924–1931. <https://doi.org/10.1056/NEJMoa012604>
4. Cao Z, Zhang Y, Lipa K, Qing L, Wu P. Ilizarov Bone transfer for treatment of large tibial bone defects: clinical results and management of complications. *Journal Personalized Med*. 2022;12(11):1774. <https://doi.org/10.3390/jpm12111774>
5. Eward WC, Kontogeorgakos V, Levin LS, Brigman BE. Free vascularized fibular graft reconstruction of large skeletal defects after tumor resection. *Clin Orthop Relat Res*. 2010;468(2):590–598. <https://doi.org/10.1007/s11999-009-1053-x>
6. Quinnan SM. Segmental bone loss Reconstruction using Ring fixation. *J Orthop Trauma*. 2017;31(10):S42–S46. <https://doi.org/10.1097/BOT.0000000000000985>
7. Krappinger D, Irenberger A, Zegg M, Huber B. Treatment of large posttraumatic tibial bone defects using the Ilizarov method: a subjective outcome assessment. *Arch Orthop Trauma Surg*. 2013;133(6):789–795. <https://doi.org/10.1007/s00402-013-1712-y>
8. Kim PH, Leopold SS. Gustilo-Anderson classification. *Clin Orthop Relat Res*. 2012;470(11):3270–3274. <https://doi.org/10.1007/s11999-012-2376-6>
9. Miraj F, Nugroho A, Dalitan IM, Setyarani M. The efficacy of ilizarov method for management of long tibial bone and soft tissue defect. *Ann Med Surg*. 2021;68:102645. <https://doi.org/10.1016/j.amsu.2021.102645>
10. Papakostidis C, Bhandari M, Giannoudis PV. Distraction osteogenesis in the treatment of long bone defects of the lower limbs: effectiveness, complications and clinical results; a systematic review and meta-analysis. *Bone Joint J* 2013;95 B(12):1673–1680. <https://doi.org/10.1302/0301-620X.95B12.32385>
11. Borrelli J, Prickett W, Song E, Becker D, Ricci W. Extraosseous blood supply of the tibia and the effects of different plating techniques: a human cadaveric study. *J Orthop Trauma*. 2002;16(10):691–695. <https://doi.org/10.1097/00005131-200211000-00002>
12. Khaled A, El-Gebaly O, El-Rosasy M. Masquelet–Ilizarov technique for the management of bone loss post debridement of infected tibial nonunion. *Int Orthop*. 2022;46(9):1937–1944. <https://doi.org/10.1007/s00264-022-05494-y>
13. Borzunov DY, Shastov AL. Mechanical solutions to salvage failed distraction osteogenesis in large bone defect management. *Int Orthop*. 2019;43(5):1051–1059. <https://doi.org/10.1007/s00264-018-4032-6>
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(10):S47–S54. <https://doi.org/10.1097/BOT.0000000000000987>
15. Pipitone PS, Rehman S. Management of traumatic bone loss in the Lower Extremity. *Orthop Clin North Am*. 2014;45(4):469–482. <https://doi.org/10.1016/j.ocl.2014.06.008>
16. Aktuglu K, Erol K, Vahabi A. Ilizarov bone transport and treatment of critical-sized tibial bone defects: a narrative review. *J Orthop Traumatol*. 2019;20(1):1–14. <https://doi.org/10.1186/s10195-019-0527-1>
17. Aktuglu K, Günay H, Alakbarov J. Monofocal bone transport technique for bone defects greater than 5 cm in tibia: our experience in a case series of 24 patients. *Injury*. 2016;47:S40–S46. [https://doi.org/10.1016/S0020-1383\(16\)30838-5](https://doi.org/10.1016/S0020-1383(16)30838-5)
18. Suger G, Fleischmann W, Hartwig E, Kinzl L. Open segmental bone transport. A therapeutic alternative in post-traumatic and osteitis soft tissue and bone defects. *Unfallchirurg*. 1995;98(7):381–385
19. Paley D, Maar DC. Lizarov bone transport treatment for tibial defects. *J Orthop Trauma*. 2000;14(2):76–85. <https://doi.org/10.1097/00005131-200002000-00002>
20. Yin P, et al. A systematic review and meta-analysis of Ilizarov methods in the treatment of infected nonunion of tibia and femur. *PLoS ONE*. 2015;10(11):1–12. <https://doi.org/10.1371/journal.pone.0141973>

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