

Ilizarov-Assisted Ankle Arthrodesis in Charcot Neuroarthropathy

Dr. Nazmul Huda Shetu^{1*}, Dr. B. M. Rahgir Mahmud², Dr. Md. Maruf Al Hasan³, Dr. Md. Syedur Rahaman⁴, Dr. Ohidul Islam⁵, Dr. Razib Ahmed⁶, Dr. Nitya Ranjan Balo⁷, Dr. Md. Emdadul Haque⁸

¹Assistant Professor, Ilizarov & Defomity Correction Unit, National Institute of Traumatology and Orthopaedic Rehabilitation (NITOR), Sher-E-Bangla Nagar, Dhaka, Bangladesh

²Junior Consultant, Department of Orthopaedic Surgery, Upazila Health Complex, Kumarkhali, Kushtia

³Medical Officer, Department of Orthopaedic Surgery, National Institute of Traumatology and Orthopaedic Rehabilitation (NITOR), Sher-E-Bangla Nagar, Dhaka, Bangladesh

⁴Registrar, Department of Orthopaedic Surgery, National Institute of Traumatology and Orthopaedic Rehabilitation (NITOR), Sher-E-Bangla Nagar, Dhaka, Bangladesh

⁵Junior Consultant, Department of ILIZAROV and Orthopaedic Surgery, National Institute of Traumatology and Orthopaedic Rehabilitation (NITOR), Sher-E-Bangla Nagar, Dhaka, Bangladesh

⁶Junior Consultant, Ilizarov & Defomity Correction Unit, National Institute of Traumatology and Orthopaedic Rehabilitation (NITOR), Sher-E-Bangla Nagar, Dhaka, Bangladesh

⁷Indoor Medical Officer, Department of Orthopaedic Surgery, Kurmitola General Hospital, Dhaka, Bangladesh

⁸Assistant Professor, Department of Orthopaedic Surgery, National Institute of Traumatology and Orthopaedic Rehabilitation (NITOR), Sher-E-Bangla Nagar, Dhaka, Bangladesh

DOI: <https://doi.org/10.36348/sjmpps.2026.v12i06.001>

Received: 06.04.2026 | Accepted: 23.05.2026 | Published: 04.06.2026

*Corresponding author: Dr. Nazmul Huda Shetu

Assistant Professor, Ilizarov & Defomity Correction Unit, National Institute of Traumatology and Orthopaedic Rehabilitation (NITOR), Sher-E-Bangla Nagar, Dhaka, Bangladesh

Abstract

Background: Charcot neuroarthropathy (CN) is a progressive, non-infectious disorder characterized by bone and joint destruction, most commonly seen in patients with diabetes and peripheral neuropathy, and can lead to joint instability, ulceration, osteomyelitis, and increased risk of amputation. The purpose of the study is to evaluate the effectiveness of Ilizarov-assisted ankle arthrodesis in achieving stable fusion and functional outcomes in patients with Charcot neuroarthropathy. **Methods:** This prospective observational study was conducted at the Department of Orthopaedics, National Institute of Traumatology and Orthopaedic Rehabilitation (NITOR) along with selected private hospitals, Dhaka, Bangladesh, from January 2020 to December 2024, and included 15 patients with Charcot neuroarthropathy of the ankle. All patients underwent Ilizarov-assisted ankle arthrodesis, and outcomes including fusion, limb salvage, complications, and functional recovery (AOFAS score) were assessed over a mean follow-up of 24.5 ± 6.3 months. **Results:** Fifteen patients with Charcot neuroarthropathy underwent Ilizarov-assisted ankle arthrodesis. Ankle fusion was achieved in 80.0%, limb salvage in 86.7%, and limb shortening occurred in 73.3%. The most common complication was pin-tract infection (40.0%). Among surviving patients ($n = 13$), mean follow-up was 24.5 months, AOFAS scores improved from 36.8 to 68.9, and 69.2% achieved full weight-bearing. **Conclusion:** Ilizarov-assisted ankle arthrodesis provides reliable fusion, effective limb salvage, and meaningful functional improvement in patients with Charcot neuroarthropathy despite procedure-related complications.

Keywords: Ilizarov, Ankle Arthrodesis, Charcot Neuroarthropathy.

Copyright © 2026 The Author(s): This is an open-access article distributed under the terms of the Creative Commons Attribution 4.0 International License (CC BY-NC 4.0) which permits unrestricted use, distribution, and reproduction in any medium for non-commercial use provided the original author and source are credited.

INTRODUCTION

Charcot neuroarthropathy (CN) is a progressive, non-infectious disorder characterized by bone and joint destruction caused by osteolysis, with patients who have peripheral neuropathy following long period DM being particularly susceptible. Multiple neuropathic conditions can lead to CN, but diabetes

mellitus is currently recognized as the most common underlying cause [1,2]. The collapse of the talar body and associated joint instability in CN predispose patients to ulcer formation around the ankle, and without timely intervention, these ulcers may progress to osteomyelitis. When osteomyelitis is present, the likelihood of eventual amputation significantly increases [3]. To restore a

Citation: Nazmul Huda Shetu, B. M. Rahgir Mahmud, Md. Maruf Al Hasan, Md. Syedur Rahaman, Ohidul Islam, Razib Ahmed, Nitya Ranjan Balo, Md. Emdadul Haque (2026). Ilizarov-Assisted Ankle Arthrodesis in Charcot Neuroarthropathy. *Saudi J Med Pharm Sci*, 12(6): 362-371.

stable, weight-bearing limb and reduce the risk of future amputations, arthrodesis of the ankle joint is indicated in CN, as it can correct alignment, promote healing of existing ulcers, prevent new ulceration, and enable patients to achieve a plantigrade, functional extremity [4].

Patients with comorbidities such as diabetes, CKD, osteomyelitis, bone defects, deformity, peripheral vascular disease, rheumatism, or a history of smoking often demonstrate impaired bone healing and are frequently managed nonoperatively or by amputation [5]. While there is no universally accepted standard for fixation during reconstructive procedures, both internal fixation (IF) and external fixation (EF) are employed to achieve a stable, ulcer-free, and plantigrade limb [4]. Internal fixation is generally sufficient for ankle arthrodesis in many cases; however, situations involving chronic infections (e.g., osteomyelitis, tuberculosis), severe ankle deformity or limb length discrepancy, compromised soft tissue, deficient bone stock, or neurological impairment can render internal fixation suboptimal. In these complex cases, the Ilizarov fixator is preferred [6-8].

Various techniques have been described for ankle arthrodesis, including crossed screws (two screws inserted from the distal tibia into the talus), intramedullary nails, plates, and external fixation frames. Despite this range of options, the optimal approach for achieving rigid, stable fixation while allowing compression under functional weight bearing and restoring a plantigrade foot remains debated [9-12]. Each technique carries potential complications, including malalignment, infection, nonunion, and osteoarthritis of adjacent joints [6].

The Ilizarov fixator is a versatile external fixation system, providing circumferential rigidity combined with dynamic axial compression, which allows surgeons to correct intraoperative errors or postoperative positional loss. It is a minimally invasive, reliable method for addressing complex ankle arthrodesis cases, permitting early weight bearing. The Ilizarov technique has demonstrated high union rates in ankle arthrodesis, and various weight-bearing protocols do not appear to significantly affect outcomes [13,14]. The Ilizarov ring fixator (IRF) offers additional benefits, such as early and safe weight bearing, promotion of soft tissue regeneration, and the ability to adjust the frame postoperatively to maintain proper foot alignment [15-17]. It has been reported as an effective and minimally invasive method for complex ankle arthrodesis, providing immediate weight-bearing capability. Moreover, tension-stress applied by the Ilizarov apparatus can have bactericidal effects by stimulating biosynthetic processes, which aids in managing osteomyelitis and may reduce the need for systemic antibiotics [18,19].

Despite the reported advantages of Ilizarov-assisted ankle arthrodesis, the existing literature is limited by small sample sizes, heterogeneous patient populations, and variations in surgical techniques and follow-up protocols. Most studies focus on midfoot or hindfoot Charcot deformities, with fewer specifically evaluating outcomes in ankle CN. Furthermore, there is a lack of comprehensive data assessing both radiographic fusion and functional outcomes, including weight-bearing ability, ambulation status, and limb salvage, in patients undergoing Ilizarov-assisted ankle arthrodesis. Consequently, there remains uncertainty regarding the reproducibility of outcomes, the optimal management of complications, and the long-term functional benefits of this technique in diabetic patients with complex ankle deformities. The purpose of the study is to evaluate the effectiveness of Ilizarov-assisted ankle arthrodesis in achieving stable fusion and functional outcomes in patients with Charcot neuroarthropathy.

Objective

To evaluate the effectiveness of Ilizarov-assisted ankle arthrodesis in achieving stable fusion and functional outcomes in patients with Charcot neuroarthropathy.

METHODOLOGY & MATERIALS

This prospective observational study was conducted at the Department of Orthopaedics, National Institute of Traumatology and Orthopaedic Rehabilitation (NITOR), along with selected private hospitals, Dhaka, Bangladesh, from January 2020 to December 2024. A total of 20 patients with Charcot neuroarthropathy of the ankle were initially assessed for eligibility. Among them, 5 patients were excluded due to incomplete medical records or loss to follow-up, leaving 15 patients who fulfilled the predefined inclusion and exclusion criteria and were included in the final analysis. Data were collected on demographic, clinical, and radiological parameters to evaluate the outcomes of Ilizarov-assisted ankle arthrodesis, including fusion rates, functional recovery, and postoperative complications.

Inclusion Criteria

- Patients diagnosed as unstable ankle due to diabetic Charcot neuroarthropathy of the ankle following prolonged Diabetes.
- Patients planned for Ilizarov-assisted ankle arthrodesis due to deformed ankle with varus or valgus deformity of ankle
- Age ≥ 28 and ≤ 70 years
- Patients willing and able to comply with follow-up and postoperative care.

Exclusion Criteria

- Severe comorbidities rendering the patient unfit for anesthesia or surgical intervention.
- Incomplete medical records or loss to follow-up.

- Patients refusing consent or unwilling to comply with postoperative protocol.

Preoperative Assessment

Demographic and clinical data were recorded, including age, sex, duration of disease, presence of diabetes mellitus, and peripheral neuropathy. The Eichenholtz stage was determined for all patients based on standard preoperative radiographs (RTG), alongside the assessment of preoperative deformity type (varus, valgus, or neutral). Clinical evaluation was also performed to assess ankle stability and soft tissue condition.

Surgical Technique

All patients underwent ankle arthrodesis using a circular Ilizarov external fixator under spinal or general anesthesia. Bone resection and deformity correction were performed as indicated. Operative time and intraoperative complications were recorded. Postoperative frame management followed standard Ilizarov protocols, with gradual weight-bearing as tolerated.

Postoperative Care and Follow-Up

Patients were followed at regular intervals for clinical and radiological assessment of fusion, limb length, and deformity correction. Functional outcomes were evaluated using the American Orthopaedic Foot & Ankle Society (AOFAS) ankle-hindfoot score. Complications, including pin-tract infection, wound infection, refracture, frame loosening, deep infection, amputation, and mortality, were documented. Limb salvage, limb shortening, and need for shoe raise were recorded. The mean follow-up duration for surviving patients was 24.5 ± 6.3 months.

Duration of diabetes mellitus (years since diagnosis) was recorded for all patients to assess chronic disease burden. Renal function was evaluated using renal function tests (RFT), including serum creatinine and urea levels, and was considered as part of preoperative and follow-up medical assessment.

Outcome Measures

The primary outcome was successful ankle fusion, defined radiographically and clinically. Secondary outcomes included limb salvage, functional improvement (AOFAS scores), complications, limb shortening, and ambulation status. Data were summarized using frequencies, percentages, and means with standard deviations.



Figure 1: Preoperative anteroposterior and lateral weight-bearing radiographs (RTG) demonstrating advanced Charcot neuroarthropathy (Eichenholtz Stage II/III) with significant talar collapse and ankle joint architectural distortion



Figure 2: Preoperative clinical photograph demonstrating severe ankle deformity and soft tissue swelling in a patient with Charcot neuroarthropathy



Figure 3: Immediate postoperative clinical photograph showing the application of the multi-ring Ilizarov external fixator and the surgical incision site following ankle arthrodesis



Figure 4: Postoperative view showing the Ilizarov external fixator in situ with protective dressings applied to the surgical incision and pin sites

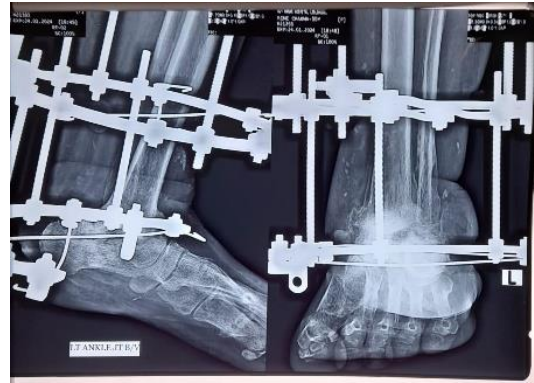


Figure 6: Final follow-up radiographs (RTG) demonstrating successful ankle arthrodesis with stable bone fusion and maintained plantigrade alignment



Figure 5: Postoperative clinical photograph demonstrating the stabilization of the Charcot ankle with the Ilizarov circular external fixator, maintaining neutral plantigrade alignment during the healing phase



Figure 7: Final clinical photograph following the removal of the Ilizarov external fixator, demonstrating a stable, plantigrade, and functional foot with well-healed surgical and pin-site scars

RESULTS

Table 1: Demographic and Preoperative Characteristics of the Study Participants (n = 15)

Variable	Frequency (n)	Percentage (%)	
Age (years)	≤ 50	3	20.0
	51–60	7	46.7
	> 60	5	33.3
	Mean ± SD	57.6 ± 5.6	
Sex	Male	11	73.3
	Female	4	26.7
Diabetes mellitus	Present	15	100.0
Peripheral neuropathy	Present	15	100.0
Chronic Kidney Disease (CKD)	Present	13	86.7
Duration of Charcot disease (months)	≤ 12 months	6	40.0
	> 12 months	9	60.0
	Mean ± SD	19.2 ± 5.9	
Preoperative deformity	Varus	5	33.3
	Valgus	8	53.3
	Neutral	2	13.3

The majority of patients were aged 51–60 years (7 patients, 46.7%), followed by those older than 60 years (5 patients, 33.3%) and those aged 50 years or

younger (3 patients, 20.0%), with a mean age of 57.6 ± 5.6 years. Male patients predominated (11 patients, 73.3%). All patients had diabetes mellitus and peripheral

neuropathy (15 patients each, 100.0%). Chronic kidney disease was present in 13 patients (86.7%). Disease duration exceeded 12 months in 9 patients (60.0%), with a mean duration of 19.2 ± 5.9 months. Regarding

preoperative deformity, valgus was the most common pattern (8 patients, 53.3%), followed by varus deformity (5 patients, 33.3%) and neutral alignment (2 patients, 13.3%).

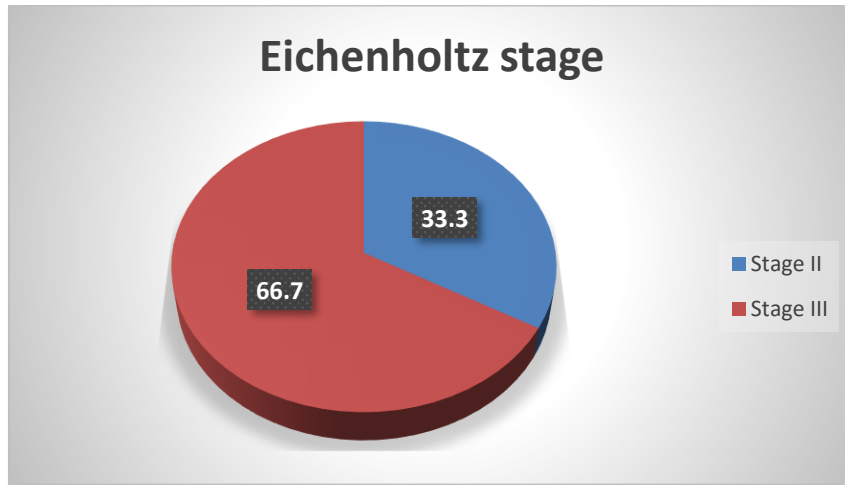


Figure 8: Distribution of Patients According to Eichenholtz Stage of Charcot Neuroarthropathy (n = 15)

According to the Eichenholtz classification, 10 patients (66.7%) were in Stage III and 5 patients (33.3%) were in Stage II.

Table 2: Operative and External Fixator–Related Parameters (n = 15)

Parameter	Frequency (n)	Percentage (%)
Fixation method (Circular Ilizarov external fixator)	15	100
Mean operative time (minutes)	135 ± 20	
Bone resection performed	11	73.3
Deformity correction	14	93.3
Limb shortening correction	13	86.7
Mean frame duration (weeks)	24.8 ± 4.2	

All patients were treated with a circular Ilizarov external fixator (15 patients, 100.0%). Bone resection was required in 11 patients (73.3%), while deformity correction was achieved in 14 patients (93.3%) and limb

shortening correction in 13 patients (86.7%). The mean operative time was 135 ± 20 minutes. The mean duration of frame application was 24.8 ± 4.2 weeks.

Table 3: Fusion Outcomes and Limb Length Changes Following Ilizarov-Assisted Ankle Arthrodesis (n = 15)

Outcome	Frequency (n)	Percentage (%)
Successful ankle fusion	12	80.0
Delayed union	2	13.3
Non-union	1	6.7
Mean time to fusion	22.6 ± 4.5 weeks	
Limb salvage	13	86.7
Limb shortening	11	73.3
Mean limb shortening	2.1 ± 0.6 cm	
Patients requiring shoe raise	12	80.0

Successful ankle fusion was achieved in 12 patients (80.0%). Delayed union occurred in 2 patients (13.3%), while non-union was observed in 1 patient (6.7%). The mean time to fusion was 22.6 ± 4.5 weeks. Limb salvage was accomplished in 13 patients (86.7%). Postoperative limb shortening was noted in 11 patients

(73.3%), with a mean shortening of 2.1 ± 0.6 cm. Shoe raise was required in 12 patients (80.0%) to address limb length discrepancy. Most patients with postoperative limb shortening reported satisfactory ambulation with the use of a shoe raise or customized sole modification.

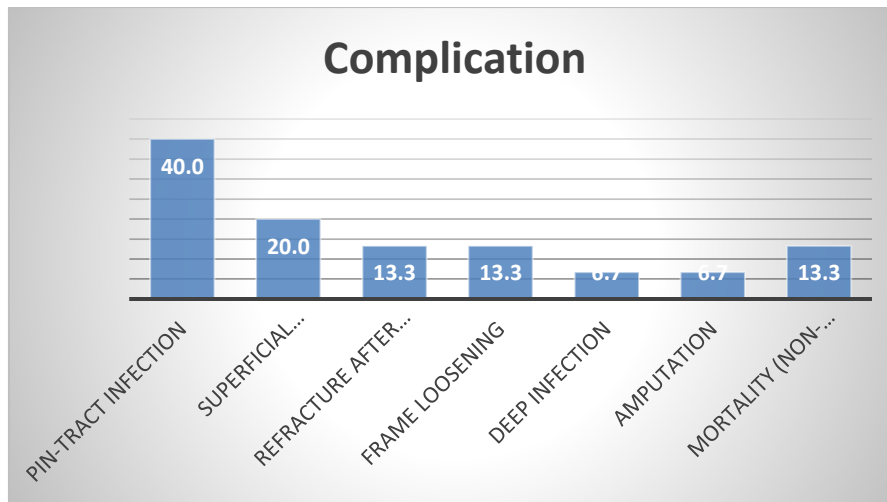


Figure 9: Postoperative Complications and Mortality Following Ilizarov-Assisted Ankle Arthrodesis (n = 15)

Pin-tract infection was the most common complication, occurring in 6 patients (40.0%). Superficial wound infection was observed in 3 patients (20.0%). Refracture following frame removal and frame

loosening occurred in 2 patients each (13.3%). Deep infection and amputation were noted in 1 patient each (6.7%). Mortality unrelated to the surgical procedure was recorded in 2 patients (13.3%).

Table 4: Functional Outcomes and Follow-Up Assessment Among Surviving Patients (n = 13)

Parameter	Value
Mean follow-up duration (months)	24.5 ± 6.3
Mean AOFAS score (preoperative)	36.8 ± 7.1
Mean AOFAS score (final follow-up)	68.9 ± 8.6
Full weight-bearing	9 (69.2%)
Ambulation with assistive device	4 (30.8%)

Among the 13 surviving patients, the mean follow-up duration was 24.5 ± 6.3 months. The mean AOFAS score improved from 36.8 ± 7.1 preoperatively to 68.9 ± 8.6 at final follow-up. Full weight-bearing ambulation was achieved in 9 patients (69.2%), while 4 patients (30.8%) required assistive devices for ambulation.

DISCUSSION

Charcot neuroarthropathy of the ankle is a progressive and destructive musculoskeletal condition that can result in severe joint deformity, instability, and ulceration if not appropriately managed. Ankle involvement, particularly in patients with diabetes and peripheral neuropathy, poses a high risk for complications such as osteomyelitis, limb shortening, and eventual amputation. The findings of this study demonstrate that Ilizarov-assisted ankle arthrodesis can achieve stable fusion, correct deformity, and improve functional outcomes, as evidenced by limb salvage rates, radiographic union, and increased AOFAS scores in the majority of patients. These results highlight the clinical value of Ilizarov-assisted arthrodesis in managing complex Charcot ankle deformities and restoring a functional, plantigrade, weight-bearing extremity.

The demographic and preoperative characteristics of our cohort are consistent with

previously reported findings in Charcot neuroarthropathy. The mean age of patients in this study was 57.6 ± 5.6 years, with the majority falling within the 51–60-year age group (46.7%) and a clear male predominance (73.3%), findings that closely align with Galhoum *et al.* [20], who reported a similar mean age of approximately 55 years and male predominance in a large cohort of 405 cases. All patients in the present study had diabetes mellitus and peripheral neuropathy (100.0%), underscoring the well-established association of these comorbidities with Charcot arthropathy, as also demonstrated by Vinogradov *et al.* [21], who observed a high prevalence of both conditions in their series of 96 patients. Chronic kidney disease was also frequently observed in our cohort (86.7%), further reflecting the burden of systemic comorbidities in advanced diabetic foot disease. The duration of Charcot disease exceeded 12 months in the majority of patients (60.0%), indicating late presentation in most cases. Preoperative deformity patterns were predominantly valgus (53.3%), followed by varus (33.3%) and neutral alignment (13.3%), highlighting the heterogeneous yet characteristic structural deformities associated with Charcot neuroarthropathy. Overall, these findings corroborate previously reported demographic trends, comorbidity profiles, and disease characteristics, supporting the representativeness of our study population.

Regarding disease severity, 66.7% of our patients presented in Eichenholtz Stage III, comparable to the distribution patterns reported by Vinogradov *et al.*[21] and Galhoum *et al.*[20], demonstrating that advanced-stage disease is frequently encountered at presentation.

In the present study, all 15 patients (100.0%) underwent ankle arthrodesis using a circular Ilizarov external fixator, with a mean operative time of 135 ± 20 minutes. Bone resection was required in 11 patients (73.3%), while deformity correction was achieved in 14 patients (93.3%) and limb shortening correction in 13 patients (86.7%). The mean duration of frame application was 24.8 ± 4.2 weeks. These findings are consistent with previous reports, such as Yontar *et al.* [22], who demonstrated that external fixation is a widely accepted approach in Charcot ankle arthrodesis, providing satisfactory limb salvage and union outcomes with long-term follow-up. Similarly, Chen *et al.* [23] reported fusion times averaging 16.8 weeks using the Ilizarov technique, highlighting the effectiveness of circular external fixation in correcting complex deformities, addressing limb length discrepancies, and maintaining stability. This closely aligns with the operative parameters and frame duration observed in our cohort. Overall, these results support the efficacy and reliability of Ilizarov-assisted ankle arthrodesis in achieving stable correction and functional reconstruction in patients with Charcot neuroarthropathy.

Successful ankle fusion was achieved in 12 of 15 patients (80.0%), with a mean time to fusion of 22.6 ± 4.5 weeks, while delayed union occurred in 2 patients (13.3%) and non-union in 1 patient (6.7%). Limb salvage was accomplished in 13 patients (86.7%), with postoperative limb shortening observed in 11 patients (73.3%) and a mean shortening of 2.1 ± 0.6 cm; shoe raise was required in 12 patients (80.0%) to address leg length discrepancy. These outcomes are comparable to those reported by Siddiqui *et al.*[24], who achieved a 93.3% arthrodesis rate in 15 Charcot patients with a mean fusion time of approximately 20.5 weeks, and ElAlfy *et al.*[25], where 12 of 14 patients ($\approx 86\%$) in the Ilizarov group achieved union. The similarity in fusion rates and limb salvage between our study and these cohorts supports the effectiveness of Ilizarov-assisted ankle arthrodesis in achieving stable fusion and functional restoration in patients with Charcot neuroarthropathy.

Postoperative complications following Ilizarov-assisted ankle arthrodesis were observed in 15 patients, with pin tract infection being the most common (6 patients, 40.0%), followed by superficial wound infection in 3 patients (20.0%). Refracture after frame removal and frame loosening each occurred in 2 patients (13.3%), while deep infection and amputation were noted in 1 patient each (6.7%). Mortality unrelated to surgery was recorded in 2 patients (13.3%). These

findings are consistent with previous literature reporting notable complication rates associated with external fixation in Charcot neuroarthropathy. ElAlfy *et al.*[25] reported pin tract infections in 57%, pin loosening in 21%, and wound infections in 21% of patients treated with Ilizarov external fixation, while limb salvage and union rates remained favorable. Similarly, Cianni *et al.*[26] demonstrated that external fixation techniques are frequently associated with hardware- and wound-related complications, including pin site infections and wound breakdown, with a higher overall complication prevalence compared to internal fixation methods. Overall, despite the incidence of these manageable complications, limb salvage and functional outcomes remain satisfactory, supporting the continued use of Ilizarov-assisted arthrodesis in this high-risk patient population.

The functional outcomes observed in this study demonstrate a marked improvement following Ilizarov-assisted ankle arthrodesis. Among the 13 surviving patients, the mean AOFAS score increased from 36.8 ± 7.1 preoperatively to 68.9 ± 8.6 at a mean follow-up of 24.5 ± 6.3 months, with 9 patients (69.2%) achieving full weight-bearing and 4 patients (30.8%) ambulating with assistive devices. These results are consistent with Osman *et al.*[27], who reported a mean postoperative AOFAS score of 72.4 ± 10.41 at 35.7 ± 9.5 months follow-up, and Chen *et al.*[23], who documented scores of 72.5 ± 6.4 at 23.3 months in 12 patients treated with the Ilizarov technique. Collectively, these findings reinforce that Ilizarov-assisted ankle arthrodesis provides significant mid-term improvement in functional outcomes, enabling most patients to regain weight-bearing ability and enhanced ambulation.

Limitations of the study

The study had a few limitations:

- The sample size was relatively small, which limits the generalizability of the findings and the ability to detect fewer common complications.
- The study was conducted at a single center, which may limit the applicability of results to other settings or populations.

CONCLUSION

Ilizarov-assisted ankle arthrodesis is an effective limb-salvage procedure for patients with Charcot neuroarthropathy, providing reliable ankle fusion and meaningful functional improvement in a complex high-risk population. In this study, the technique achieved a high rate of stable fusion along with satisfactory limb salvage, with most patients demonstrating significant improvement in AOFAS scores at mid-term follow-up. Although postoperative complications such as pin-tract infection, wound-related issues, and limb shortening were frequent, they were generally manageable and did not preclude functional recovery. A substantial proportion of patients required shoe raise or sole modification; however, most were able

to achieve full or assisted weight-bearing ambulation with acceptable functional adaptation. Overall, despite a notable comorbidity burden including a high prevalence of chronic kidney disease, the Ilizarov method proved to be a reliable and effective option for managing complex Charcot ankle deformities, particularly in advanced disease stages where internal fixation is often unsuitable.

REFERENCES

- Ögüt T, Yontar NS. Surgical treatment options for the diabetic Charcot hindfoot and ankle deformity. *Clinics in Podiatric Medicine and Surgery*. 2017 Jan 1;34(1):53-67.
- Johnson J, Klein S, Brodsky J. *Mann's Surgery of the Foot and Ankle*. Coughlin M, Saltzman C, Anderson R, editors. Vol. 2014. Philadelphia, PA: Mosby Elsevier.
- Panagakos P, Ullom N, Boc SF. Salvage arthrodesis for Charcot arthropathy. *Clinics in Podiatric Medicine and Surgery*. 2012 Jan 1;29(1):115-35.
- Dayton P, Feilmeier M, Thompson M, Whitehouse P, Reimer RA. Comparison of complications for internal and external fixation for Charcot reconstruction: a systematic review. *The Journal of Foot and Ankle Surgery*. 2015 Nov 1;54(6):1072-5.
- Chahal J, Stephen DJ, Bulmer B, Daniels T, Kreder HJ. Factors associated with outcome after subtalar arthrodesis. *Journal of orthopaedic trauma*. 2006 Sep 1;20(8):555-61.
- Yasui Y, Hannon CP, Seow D, Kennedy JG. Ankle arthrodesis: a systematic approach and review of the literature. *World journal of orthopedics*. 2016 Nov 18;7(11):700.
- Illgner U, Budny T, Frohne I, Osada N, Siewe J, Wetz HH. Clinical benefit and improvement of activity level after reconstruction surgery of Charcot feet using external fixation: 24-months results of 292 feet. *BMC Musculoskeletal Disorders*. 2014 Nov 22;15(1):392.
- Grivas TB, Magnissalis EA. The use of twin-ring Ilizarov external fixator constructs: application and biomechanical proof-of principle with possible clinical indications. *Journal of Orthopaedic Surgery and Research*. 2011 Aug 11;6(1):41.
- Goldberg AJ, Zaidi R, Thomson C, Doré CJ, Skene SS, Cro S, Round J, Molloy A, Davies M, Karski M, Kim L. Total ankle replacement versus arthrodesis (TARVA): protocol for a multicentre randomised controlled trial. *BMJ open*. 2016 Sep 1;6(9):e012716.
- Castagnini F, Pellegrini C, Perazzo L, Vannini F, Buda R. Joint sparing treatments in early ankle osteoarthritis: current procedures and future perspectives. *Journal of Experimental Orthopaedics*. 2016 Jan 15;3(1):3.
- Caixeta TB, Júnior MO, de Castro RV, Martins JS, Costa EN, Albieri AD, de Moraes FB. Tibiototalcalcaneal arthrodesis with retrograde intramedullary nailing: 29 patients' clinical and functional evaluation. *Revista Brasileira de Ortopedia (English Edition)*. 2014 Jan 1;49(1):56-61.
- Slater GL, Sayres SC, O'Malley MJ. Anterior ankle arthrodesis. *World journal of orthopedics*. 2014 Jan 18;5(1):1.
- Thordarson DB, Markolf K, Cracchiolo 3rd A. Stability of an ankle arthrodesis fixed by cancellous-bone screws compared with that fixed by an external fixator. A biomechanical study. *JBJS*. 1992 Aug 1;74(7):1050-5.
- Khanfour AA. Versatility of Ilizarov technique in difficult cases of ankle arthrodesis and review of literature. *Foot and Ankle Surgery*. 2013 Mar 1;19(1):42-7.
- Li J, Li B, Zhang Z, Wang S, Liu L. Ilizarov external fixation versus plate internal fixation in the treatment of end-stage ankle arthritis: decision analysis of clinical parameters. *Scientific Reports*. 2017 Nov 23;7(1):16155.
- Hasan O, Fahad S, Sattar S, Umer M, Rashid H. Ankle arthrodesis using Ilizarov ring fixator: a primary or salvage procedure? An analysis of twenty cases. *Malaysian Orthopaedic Journal*. 2018 Nov;12(3):24.
- Potter MJ, Freeman R. Postoperative weightbearing following ankle arthrodesis: a systematic review. *The bone & joint journal*. 2019 Oct 1;101(10):1256-62.
- Paevskii SA. A means for determining the bactericidal activity of the tissues during the treatment of orthopedic patients by transosseous osteosynthesis methods. *Klinicheskaja Laboratornaia Diagnostika*. 1993 Sep 1(5):25-9.
- Gubin AV, Borzunov DY, Malkova TA. The Ilizarov paradigm: thirty years with the Ilizarov method, current concerns and future research. *International orthopaedics*. 2013 Aug;37(8):1533-9.
- Vinogradov VA, Osnach SA, Protsko VG, Obolenskiy VN, Tamoev SK, Kuznetsov VV, Zagorodniy NV, Makinyan LG. Outcomes of Hindfoot and Ankle Arthrodesis in Patients with Charcot Neuroarthropathy. *Traumatology and Orthopedics of Russia*. 2025 Jun 11;31(2):67-76.
- Galhoum AE, Trivedi V, Askar M, Tejero S, Herrera-Pérez M, AlRashidi Y, Valderrabano V. Management of Ankle Charcot Neuroarthropathy: A Systematic Review. *J Clin Med*. 2021 Dec 17;10(24):5923.
- Yontar NS, Ögüt T. Ilizarov External Fixator Versus Internal Fixation for Ankle Joint Arthrodesis in Diabetic Charcot Neuroarthropathy. *Cerrahpaşa Medical Journal*. 2022 Jun 7;46(2):101-3.
- Chen P, Guan H, Feng E, Liang J, Xu Y, He J, Huang W, Xie J. [Clinical study on Ilizarov technique combined with steel needle internal fixation for 12 patients with Charcot neuroarthropathy of foot and ankle]. *Zhongguo Xiu Fu Chong Jian Wai Ke Za Zhi*. 2025 Aug 15;39(8):1008-1013.
- Siddiqui NA, Millonig KJ, Mayer BE, Fink JN, McClure PK, Bibbo C. Increased Arthrodesis Rates in Charcot Neuroarthropathy Utilizing Distal Tibial Distraction Osteogenesis Principles. *Foot Ankle Spec*. 2022 Aug;15(4):394-408.
- ElAlfy B, Ali AM, Fawzy SI. Ilizarov External Fixator Versus Retrograde Intramedullary Nailing for Ankle Joint Arthrodesis in Diabetic Charcot Neuroarthropathy. *J Foot Ankle Surg*. 2017 Mar-Apr;56(2):309-313.
- Cianni L, Bocchi MB, Vitiello R, Greco T, De Marco D, Masci G, Maccauro G, Pitocco D, Perisano C. Arthrodesis in the Charcot foot: a systematic review. *Orthopedic reviews*. 2020 Jun 25;12(Suppl 1):8670.
- Osman AE, El-Adly W, Haroun KM, Khaled M, Khalifa AA. Locally obtained autologous bone grafts are effective for achieving arthrodesis while managing foot and ankle Charcot's neuroarthropathy: short to mid-term results from a specialized north African foot and ankle surgery unit. *Journal of Orthopaedic Surgery and Research*. 2024 Sep 16;19(1):570.