DOI: https://doi.org/10.30795/jfootankle.2024.v18.1789

Original Article

Single-stage management of Charcot neuroarthropathy and osteomyelitis in diabetic patients

Gonzalo Alvarez[1], Juan Pablo Randolino[1], Emanuel David Gonzalez[1], Laura Gaitan[1], Valeria Lopez[1]

1. Instituto Jaime Slullitel. Departamento de Cirugía de Pie y Tobillo, Rosario, Argentina.

Abstract

Objective: Describe our experience treating Charcot neuroarthropathy (CN) coexisting with concurrent bone infection in a single step, treated with external fixation, and report the mid-term radiographic and functional outcomes.

Methods: Retrospective case series of patients diagnosed with CN and osteomyelitis treated with a single-step approach consisting of necrotic bone debridement and fusion extended over the affected joints using a circular external fixator with a minimum of 18 months of follow-up.

Results: Six patients were evaluated, and three patients achieved excellent results and were able to walk outside their homes. One of them required a below-the-knee amputation due to persistent infection. Two patients had good results according to the Pinzur proposed evaluation scheme. All patients agreed that they would choose the reconstruction process for their deformity over an infrapatellar amputation.

Conclusion: We believe the results from our case series apply to the previously published literature on this therapeutic modality.

Level of evidence IV; Case series.

Keywords: Charcot; Diabetic foot; External fixation.

Introduction

Despite the long-standing recognition of osteomyelitis, its presence in the context of Charcot neuroarthropathy (CN) in the foot and ankle still poses a challenge regarding diagnosis, medical treatment, and reconstruction. The most significant risk factor for the concurrent occurrence of CN and osteomyelitis is a pre-existing ulceration in a patient with established neuropathy, which has been shown to increase the risk of limb loss dramatically. Furthermore, a severely dislocated and unstable foot or ankle due to CN also acts as a predisposing factor for the development of osteomyelitis, even though the most common cause of superinfection in this scenario is the critical initial contamination of a local ulceration site[1,2].

Massive bone defects in the retro or even midfoot due to CN, fractures or dislocations, avascular necrosis, or osteomyelitis may require reconstruction either in a single or sequential intervention based on the patient's clinical characteristics, comorbidities, local or systemic infection, and the severity of the condition. To avoid amputation and its concomitant reported increase in mortality from 38% to 68% at five years, the treatment of osteomyelitis in the context of CN in individuals with diabetes has been previously reported. Pinzur et al. achieved a salvage rate of 95.7% by performing a one-stage resection of osteomyelitic bone, correcting deformity, and using a circular external fixator in patients with CN and osteomyelitis. Similarly, in a retrospective study of 45 patients treated for CN and osteomyelitis, Dalla Paolla et al. concluded

Study performed at the Instituto Jaime Slullitel, Departamento de Cirugía de Pie y Tobillo, Rosario, Argentina.

Correspondence: Gonzalo Alvarez. 2534 San Luis St. Rosario, 2000, Santa Fe, Argentina. **Email:** alvarezgonzalojuan@gmail.com **Conflicts of interest:** none. **Source of funding:** none. **Date received:** April 30, 2024. **Date accepted:** June 04, 2024. **Online:** 30 August, 2024.

How to cite this article: Alvarez G, Randolino JP, Gonzalez ED, Gaitan L, Lopez V. Single-stage management of Charcot neuroarthropathy and osteomyelitis in diabetic patients. J Foot Ankle. 2024;18(2):227-32.

that using a circular fixator and arthrodesis of resected joints represents an alternative to early limb amputation[3-6].

The management of bone loss in the diabetic population with CN should be tailored to individual needs, and there are currently no gold standard or universally applicable treatment algorithms. Using external fixators is likely the preferred fixation strategy for single-stage reconstructions. Despite the existing Anglo-Saxon and European literature that has laid the groundwork for treatment, reports with South American experience are still scarce. Accordingly, the objective of this study is to describe our experience in treating Charcot neuroarthropathy coexisting with concurrent bone infection in a single surgical intervention, treated with external fixation, and report the mid-term radiographic and functional outcomes.

Methods

This is a retrospective case series including six diabetic patients diagnosed with Charcot neuroarthropathy. These patients were consecutively treated at our diabetic foot unit, presenting concomitant osteomyelitis and undergoing a one-stage procedure. The intervention involved ulcer debridement, excision of necrotic bone with sampling for cultures, and specific antibiotic treatment tailored to microbial isolates. Additionally, arthrodesis with an external circular fixator extending beyond the affected site was performed, with follow-up exceeding 18 months. The study received approval from the institution's ethics committee, and all patients or their family members signed the informed consent form.

Only patients diagnosed with diabetic Charcot arthropathy were included. Cases where a polymethylmethacrylate-coated antibiotic-laden intramedullary nail (PMMA) was used with the circular fixator were not excluded. The PMMA served as a non-degradable vehicle for local antibiotic delivery, and the stability of the construct was entrusted to the external fixator.

Retrospective data collection from medical and operative records was conducted to gather demographic information, details related to diabetes metabolic control, procedure specifics, comorbidities, active or recent smoking history, physical examination findings, and clinical outcomes. The presence and location of ulcers, type of deformity according to Brodsky's anatomical classification, arthropathy stage at the time of treatment according to Eichenholtz's classification, and the joints subjected to arthrodesis were documented. Table 1 summarizes the characteristics of these patients[7,8].

The clinical diagnosis of osteomyelitis was based on the fulfillment of one of the following three criteria: (a) an open wound over the deformity with exposed bone and chronic drainage; (b) a history of bone biopsy with positive cultures that, at the time of surgery, was not draining but had abnormally appearing bone in the area previously affected by osteomyelitis; or (c) a history of a previous wound over a deformity with clinically abnormal bone at the time of surgery. The diagnosis required intraoperative cultures in all cases. All diagnoses were confirmed through bone biopsy and examined by a pathologist. A biopsy sample consistent with bone necrosis or inflammatory changes was considered positive for osteomyelitis[5].

All patients underwent anteroposterior (AP) and lateral (L) radiographs of the affected foot and ankle. Relevant information from standard computed tomography (CT) scans, used to measure pre-existing bone defects and the position of the affected joints, was also collected. Magnetic resonance imaging (MRI) images were analyzed for patterns of edema, suspected bone necrosis, fistulous tracts, or deep collections. Arterial Doppler ultrasound with ankle-brachial index (ABI), conducted by a cardiologist experienced in vascular imaging, was included in the preoperative assessment. Patients with an ABI less than 0.9 were not considered candidates until arteriography was performed, providing evidence of perfusion in the angiosomes corresponding to the surgical wound sites.

In the early postoperative period, the assessment of arthrodesis status primarily relied on weight-bearing AP and L radiographs taken during follow-up visits. The radiographs were evaluated by the operating surgeon and a musculoskeletal radiologist.

During the final follow-up visit to evaluate clinical outcomes, we employed the method proposed by Pinzur, considering excellent results when the patient is free of ulcers and infections, capable of walking outside their home, and using commercial shoes with custom insoles. A good result is characterized by the absence of ulcers and infection, the ability to walk outside their home, and the requirement for custom-made shoes or a short orthosis that includes the foot and ankle. A poor result is defined when ulcers or infections

Table 1. Baseline characteristics of the six patients.

	Patient 1	Patient 2	Patient 3	Patient 4	Patient 5	Patient 6
Age	70	62	68	59	50	74
Ulcer	Midfoot plantar	Medial midfoot and hallux	Hallux and medial talus head	Pre ulcerative lesion	Lateral forefoot and midfoot	Lateral forefoot and midfoot
Eichenholtz	3	2	2	3	3	2
Brodsky	1	1	2	2	1	2
Comorbidities	HT	HT, PAD Obesity	HTA, PAD	HT, PAD	HT	HTA, PAD

HT: Hypertension; PAD: Peripheral arterial disease.

persist, requiring a Charcot restraint orthotic walker (CROW) or if a below-the-knee amputation has been performed. Additionally, the duration of external fixation, complications, the need for re-interventions, patient satisfaction (inquiring if they would choose the reconstruction surgery over a below-the-knee amputation), and the distance the patient can walk without difficulties were documented[9].

Surgical technique

The surgical procedure began with the excision of all necrotic-looking bone as the initial step, proceeding until obtaining bleeding bone, followed by sampling at six locations for culture of the remaining bone. Osteotomies were added at the center of rotation of the deformity, if needed for deformity correction, to prepare the articular surfaces and achieve a plantigrade foot position. Percutaneous Achilles lengthening was performed in all patients. After achieving the desired correction, temporary fixation with 1.5 mm pins was implemented. The circular external fixator was systematically placed, applying compression where necessary. Typically, two tibial rings were used, fixed with two pre-tensioned olive wires in the proximal ring, two olive wires in the opposite direction in the distal ring, and connected with four threaded rods. A metatarsal half-ring (attached to the foot with olive wires in opposite directions from the first to the fifth metatarsal, plus one non-olive wire in an oblique direction) was used. The tibial portion of the frame was fixed to the metatarsal half-rings with two threaded rods in the position of maximum deformity correction. A U-shaped adapter was placed on the calcaneus with four pre-tensioned non-olive wires in cases requiring subtalar compression. In cases where a polymethylmethacrylate-coated antibiotic-laden intramedullary nail (PMMA) was concurrently used, it was placed before the circular fixator assembly. Compression was applied intraoperatively and remained unchanged afterward in all cases.

In the immediate postoperative period, patients received intravenous antibiotics adjusted according to microbial rescue for at least one week. Upon discharge, the regimen was switched to oral administration by the infectious disease service based on microbiological rescue. Weight-bearing was restricted for the first 15 days, followed by partial weight-bearing with a walker for eight to ten weeks. The fixator was removed under sedation in the operating room, and patients were placed in an Aircast walking boot for at least 30 days, allowing 30% weight-bearing. Over the following 30 days, full weight bearing was authorized until the removal of the boot upon radiographic evidence of consolidation, stability of the arthrodesis site, and wound healing. Patients were then instructed to use commercial athletic shoes with custom insoles or orthopedic footwear based on the correction they had achieved.

Results

Our report included six patients with a mean age of 63.8 years (range 50 to 74 years) at the time of surgery, classified as stages II and III according to the Eichenholtz classification. The mean follow-up, excluding those who passed away, was 24.2 months (range 18 to 30 months). The results obtained are summarized in table 2.

Table 2. Patients characteristics. Operational details and evaluation.

	Patient 1	Patient 2	Patient 3	Patient 4	Patient 5	Patient 6
Affected Joints	TMT	TMT + CHOPART	TTC	TTC + CHOPART	TMT + CHOPART	CHOPART
Intraoperative cultures	Pseudomona aeruginosa + Aeromona spp + Enterobacter	Estafilococo coagulasa negativo + Bacilo no fermentador	Pseudomona aeruginosa + Enterococcus faecalis	Pseudomona aeruginosa	Escherichia hermanii + Streptococcus agalactiae	Estafilococo coagulasa negativo
Fixator removal	16 weeks	16 weeks	14 weeks	16 weeks	16 weeks	12 weeks
Complications	NO	Ulcer superinfection	NO	NO	NO	NO
Ulcer persistence	NO*	below cuboid needed MIS ostectomy	NO*	NO	NO	NO
Current osteomyelitis	NO*	NO	NO*	NO	NO	NO
Additional procedures	BKA	MIS ostectomy	NO	NO	MIS ostectomy	NO
Footwear		sports shoes with insoles	Sports shoes with insoles	Orthotic shoes	Sports shoes with insoles	Sports shoes with insoles
Accordance	yes*	yes	Deceased (family said yes)	yes	yes	yes
Walk	300 m* with equipment	400 m	400 m (until deceased)	600 m	without limitations	300 m
Follow-Up	deceased at 24 months post-op	24 months	deceased at 34 months post-op	25 months	30 months	18 months

TMT: Tarsometatarsal joint; TTC: Tibiotalocalcaneal; BKA: Bellow-knee amputation; MIS: Minimally invasive surgery. *: retrospective information despite the death of the patient.

Two patients died during the follow-up period due to causes unrelated to Charcot, so only retrospective evaluation of variables was possible for these patients. One of these patients required an infrapatellar amputation 15 months after surgery due to persistent ulcer and over-infection. The external fixator was maintained for a mean of 15 weeks (range 12 to 16 weeks) until removal. One patient required a new debridement and sampling at four weeks from the initial surgery due to the persistence of spontaneous discharge from the ulcer. None of the patients presented infectious complications associated with pin tracts that would have required surgical debridement. Two out of the six patients needed minimally invasive ostectomies after the removal of the external fixator due to the persistence of pre-ulcerative lesions in the plantar region of the cuboid. One of these patients had persistent trophic injury requiring successive sessions of platelet-rich plasma after normalization of ESR and CRP values and persistent negative cultures.

At the end of the follow-up, five out of the six patients were able to walk outside their homes. All patients showed normalization of CRP and ESR values. When interviewed, all patients agreed that they would choose the reconstruction process for their deformity over an infrapatellar amputation. Clinical results, evaluated using the approach proposed by Pinzur, indicate that three patients achieved excellent results, two patients had good results, and one had a poor outcome, which was the patient requiring below-knee amputation (Figures 1-3).

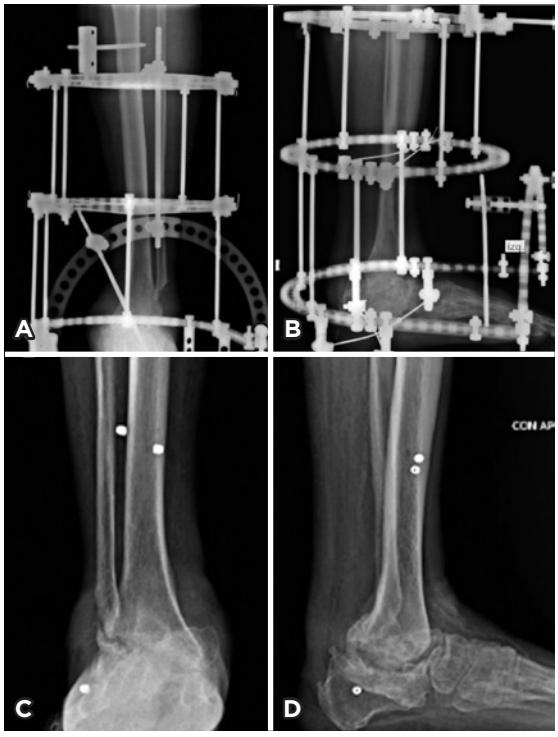

Figure 1. Diabetic patient with CN and concurrent osteomyelitis due to pseudomona. Immediate and last follow-up visit postoperative radiographs depicting good alignment.

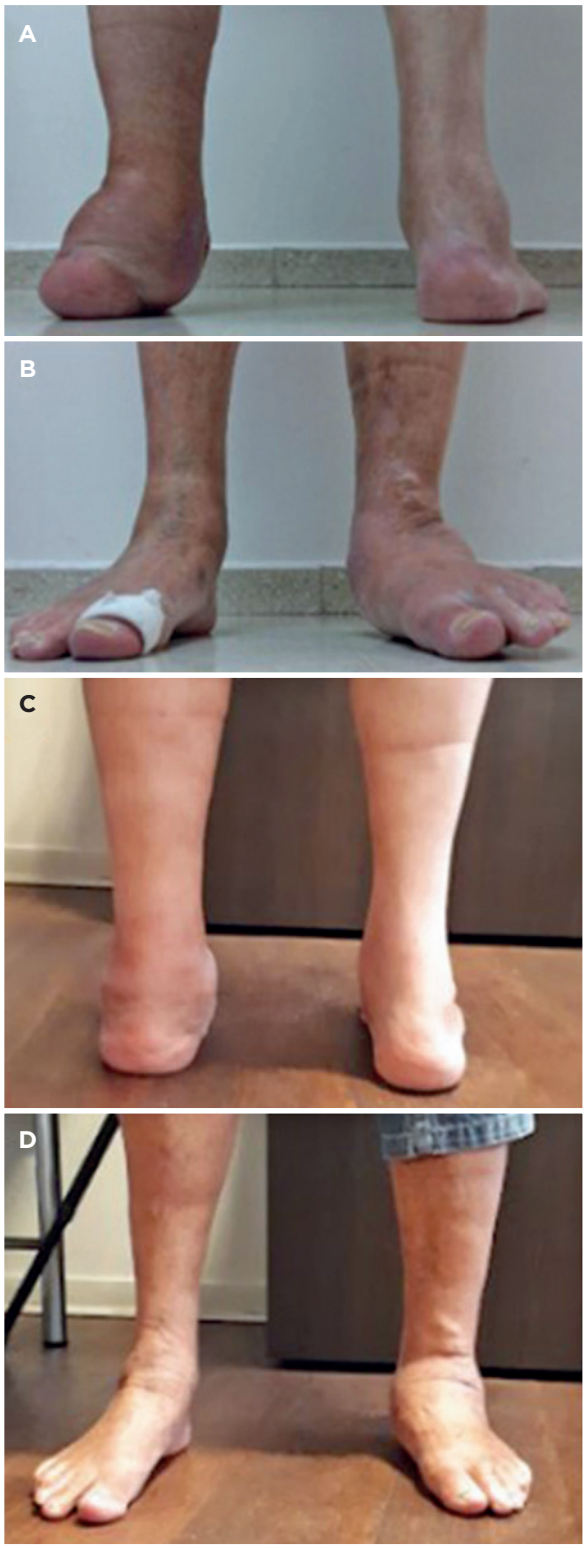

Figure 2. Clinical image of the same patient. (A and B) Preoperative photographs depicting unstable valgus of the hindfoot that difficult bracing. (C and D) Postoperative image at 32 months of follow-up.

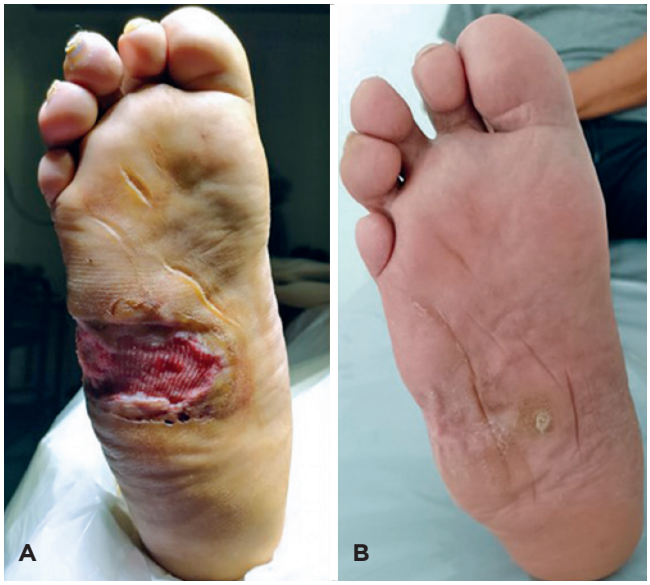

Figure 3. Pre-and postoperative images at 22 months of follow-up of a CN patient with concurrent osteomyelitis due to Staphylococcus Methicilin resistance.

Discussion

The already complex scenario of reconstructing CN in diabetic patients becomes even more challenging when it coexists with bone infection and loss of stock for fusion under ideal conditions. A local ulceration in a patient with CN should alert them of the imminent risk of osteomyelitis. The bone beneath the lesion site is exposed to bacteria that invade vascular channels, increasing intraosseous pressure and leading to bone necrosis. The less efficient immune response in diabetics is also implicated in the rapidly progressive worsening of these infections, increasing the risk of limb loss. Distinguishing between CN and osteomyelitis usually poses a significant problem as both entities present similar clinical and radiographic findings[10].

In CN coexisting with osteomyelitis cases, surgical debridement combined with systemic or oral antibiotic administration can provide an alternative for limb preservation. Resection of grossly infected or necrotic bone should be performed while preserving as much viable tissue as possible, considering the remaining structures' potential function. The possibility of performing this step together with definitive fixation in a single stage is certainly feasible and has been previously reported in case series. In 2012, Pinzur et al. published a review of 73 patients with CN and osteomyelitis who underwent reconstruction using a circular fixator. At the end of the follow-up, 68 patients (95.7%) maintained ambulatory capacity, with only 4.2% requiring amputation[2,5,11].

Although external fixators are still subject to comfort, surgeon experience, and local practices, there are undeniable advantages in this scenario, contributing to its increasing utilization. The external fixator provides rigid circumferential fixation while allowing dynamic axial compression, enabling surgeons to correct intraoperative errors or postoperative positional loss. It also allows compression through osteopenic bone, a common situation in CN, especially in osteomyelitis. Additionally, there are reports of bactericidal effects associated with the mechanical tension provided by the fixator[12].

While our series is a case report without the possibility of making statistically extrapolatable inferences, there is a trend toward favorable outcomes using the circular fixator. It is essential to highlight that accessory procedures, even after fixator removal, are often a common necessity in diabetic patients, and reporting them as complications aligns with published evidence.

Some complications related to fixator use are frequent, but their clinical relevance is questionable. The most common, with an incidence of 10% to 20%, is a superficial infection at the pin entry site, which typically resolves with local antimicrobials and site care. In our patient series, this did not differ from published data[13].

We believe the results from our case series apply to the previously published literature on the therapeutic modality in question. Despite the substantial variability in outcomes and the potential complexity associated with external fixator use, it is crucial to consider the inherently complicated nature of the treated pathology. We are dealing with patients of equivalent or greater complexity than the pathology itself, and our primary goal is to preserve the affected limb and improve the quality of life, objectives that we have significantly achieved.

Authors' contributions: Each author contributed individually and significantly to the development of this article: GA *(https://orcid.org/0000-0001-5826-690X) Participated in the reviewing process, wrote the paper; JPR *(https://orcid.org/0000-0003-3709-8163) Interpreted the results of the study, participated in the reviewing process; EG *(https://orcid.org/0000-0002-6109-1431), and LG *(https://orcid.org/0000-0002-1621-3081) Participated in the reviewing process; VL *(https://orcid.org/0000-0001-6345-5991) Conceived and planned the activities that led to the study, wrote the paper, participated in the reviewing process. All authors read and approved the final manuscript. *ORCID (Open Researcher and Contributor ID).

References

1. Sohn MW, Stuck RM, Pinzur M, Lee TA, Budiman-Mak E. Lower-extremity amputation risk after charcot arthropathy and diabetic foot ulcer. Diabetes Care. 2010;33(1):98-100.
2. Ramanujam CL, Stapleton JJ, Zgonis T. Diabetic charcot neuroarthropathy of the foot and ankle with osteomyelitis. Clin Podiatr Med Surg. 2014;31(4):487-92.
3. Short DJ, Zgonis T. Management of Osteomyelitis and Bone Loss in the Diabetic Charcot Foot and Ankle. Clin Podiatr Med Surg. 2017;34(3):381-7.
4. Richman J, Cota A, Weinfeld S. Intramedullary Nailing and External Ring Fixation for Tibiotalocalcaneal Arthrodesis in Charcot Arthropathy. Foot Ankle Int. 2017;38(2):149-52.
5. Pinzur MS, Gil J, Belmares J. Treatment of osteomyelitis in charcot foot with single-stage resection of infection, correction of deformity, and maintenance with ring fixation. Foot Ankle Int. 2012;33(12):1069-74.
6. Dalla Paola L, Brocco E, Ceccacci T, Ninkovic S, Sorgentone S, Marinescu MG, et al. Limb salvage in Charcot foot and ankle osteomyelitis: combined use single stage/double stage of arthrodesis and external fixation. Foot Ankle Int. 2009;30(11):1065-70.
7. Wukich DK, Raspovic K, Liu GT, Van Pelt MD, Lalli T, Chhabra A, et al. Are the Sanders-Frykberg and Brodsky-Trepman Classifications Reliable in Diabetic Charcot Neuroarthropathy? J Foot Ankle Surg. 2021;60(3):432-5.
8. Rosenbaum AJ, DiPreta JA. Classifications in brief: Eichenholtz classification of Charcot arthropathy. Clin Orthop Relat Res. 2015;473(3):1168-71.
9. Pinzur MS, Schiff AP. Deformity and Clinical Outcomes Following Operative Correction of Charcot Foot: A New Classification With Implications for Treatment. Foot Ankle Int. 2018;39(3):265-70.
10. Delamaire M, Maugendre D, Moreno M, Le Goff MC, Allannic H, Genetet B. Impaired leucocyte functions in diabetic patients. Diabet Med. 1997;14(1):29-34.
11. Schaper NC, van Netten JJ, Apelqvist J, Bus SA, Fitridge R, Game F, et al. Practical guidelines on the prevention and management of diabetes-related foot disease (IWGDF 2023 update). Diabetes Metab Res Rev. 2023;e3657.
12. Gubin AV, Borzunov DY, Malkova TA. The Ilizarov paradigm: thirty years with the Ilizarov method, current concerns and future research. Int Orthop. 2013;37(8):1533-9.
13. Rogers LC, Bevilacqua NJ, Frykberg RG, Armstrong DG. Predictors of postoperative complications of Ilizarov external ring fixators in the foot and ankle. J Foot Ankle Surg. 2007;46(5):372-5.