Ankle fusion by Ilizarov external fixator

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Introduction
Arthrodesis is a salvage procedure for patients with a destroyed, painful ankle joint to restore pain-free ambulation. The paper aimed to evaluate the results of ankle arthrodesis using the Ilizarov external fixator to treat end-stage tibiotalar arthritis.
Patients and methods
This retrospective study included 20 patients who had been treated with ankle fusion by Ilizarov fixator performed from December 2007 to January 2014. Their mean age was 44.95 years. Eight patients were females. The underlying pathology was septic ankle destruction, post-traumatic osteoarthritis, and rheumatoid arthritis. Avascular necrosis of talus was present in three cases. Seventeen patients had previous surgical procedures with a mean of 2.15 surgeries. Five patients had a failed previous arthrodesis. Six patients had associated equinus deformity. The mean preoperative American Orthopaedic Foot and Ankle Society Ankle-Hind foot score was 26.
Results
The mean follow-up period was 28.15 months. The mean external fixation period was 15.75 weeks. Sound fusion was achieved in all patients without additional operative procedures. Infection was controlled in all septic ankles. Pin-tract infections were observed in seven cases. In three cases, wires or half-pins needed to be removed. One ankle was fused in mild varus. One patient reported moderate daily diffuse pain. The mean postoperative American Orthopaedic Foot and Ankle Society Ankle-Hind foot score was 75.45. Patients reported functional satisfaction with the results.
Conclusions
The use of the Ilizarov external fixator provides a successful salvage method that offers solid bony fusion, optimal alignment, and eradication of infection in complex ankle pathology or failed previous arthrodesis.

Keywords:
ankle fusion, arthrodesis, external fixator, Ilizarov

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Introduction

Damage to the ankle joint from trauma, infection, or disease can result in progressive loss of ankle joint motion, weight-bearing pain, and functional disability. Despite great evolution in the field of ankle arthroplasty, ankle arthrodesis is usually considered the 'gold standard' treatment for end-stage ankle osteoarthritis (OA) [1,2]. The most common indication for ankle arthrodesis is painful arthritis owing to primary OA, posttraumatic arthritis, inflammatory or infectious arthritis, and failed arthroplasty [3]. The goals of the procedure are to have a stable, pain-free ambulation with proper alignment and functional independence, and to eradicate infection in septic cases. A variety of surgical techniques for ankle fusion have been described over the years with inconsistent fusion rates. The most common of these procedures rely on internal fixation [4–9].

Septic ankle arthritis is a challenging problem. In spite of debridement, irrigation-suction drainage, and combined antibiotic therapy, septic damage of articular surfaces and subchondral osteitis are typically irreversible [10]. In patients with ankle joint destruction after complex fractures and chronic active infection, many arthrodesis techniques become less appropriate, complications occur more frequently, and solid fusion is more difficult to obtain [11,12]. Adding to the complexity of the problem is the failed previous arthrodesis which is a significant operative endeavor and has less predictable results than those of primary arthrodesis. For failed infected ankle arthrodesis, amputation may be the only solution available [4,6].

External fixation is the treatment of choice for patients undergoing arthrodesis for a pre-existing septic joint

and can be performed in poor bone and soft tissue conditions. It can be used in the presence of active infection as a one-stage procedure [13–15]. Ilizarov and Okulov [16] reported in 1976 on the use of external fixation in ankle arthrodesis. The Ilizarov apparatus confers sufficient stiffness in bending and torsion to allow weight-bearing immediately postoperatively and allows application of dynamic and multidirectional forces to deal with all aspects of post-traumatic ankle reconstruction [8,12].

The purpose of this study was to evaluate the results of ankle fusion using the Ilizarov external fixator in patients with end-stage ankle arthritis.

Patients and methods

This retrospective study was done at Benha University Hospital, Egypt. After approval of the Institutional Ethics Committee. From December 2007 to January 2014, ankle fusion using Ilizarov external fixator was performed for 20 patients (Table 1). The mean age was 44.95 (SD: 7.82; range: 34–60) years. The series included 12 males and eight females. The right ankle was arthrodesed in 11 patients and the left ankle in nine patients. The ankle damage was caused by chronic septic ankle arthritis following open reduction and internal fixation (ORIF) of ankle fractures (11 cases) and after traumatic open ankle injury (one case), post-traumatic OA (five cases), and rheumatoid arthritis (three cases). Three cases of the septic ankles were quiescent, and the remaining nine were active with draining sinus. Patients lost to follow-up were excluded from the study.

Thorough clinical and radiographic evaluation was carried for full assessment of the condition. A computerized axial tomography scan was obtained for better identification of the state of bones and of the presence or absence of avascular necrosis of the talus (Figs 1, 2). The ankle was stiff and painful in all cases, with severe limitations of daily activities using a

Table 1 Characteristics of patients

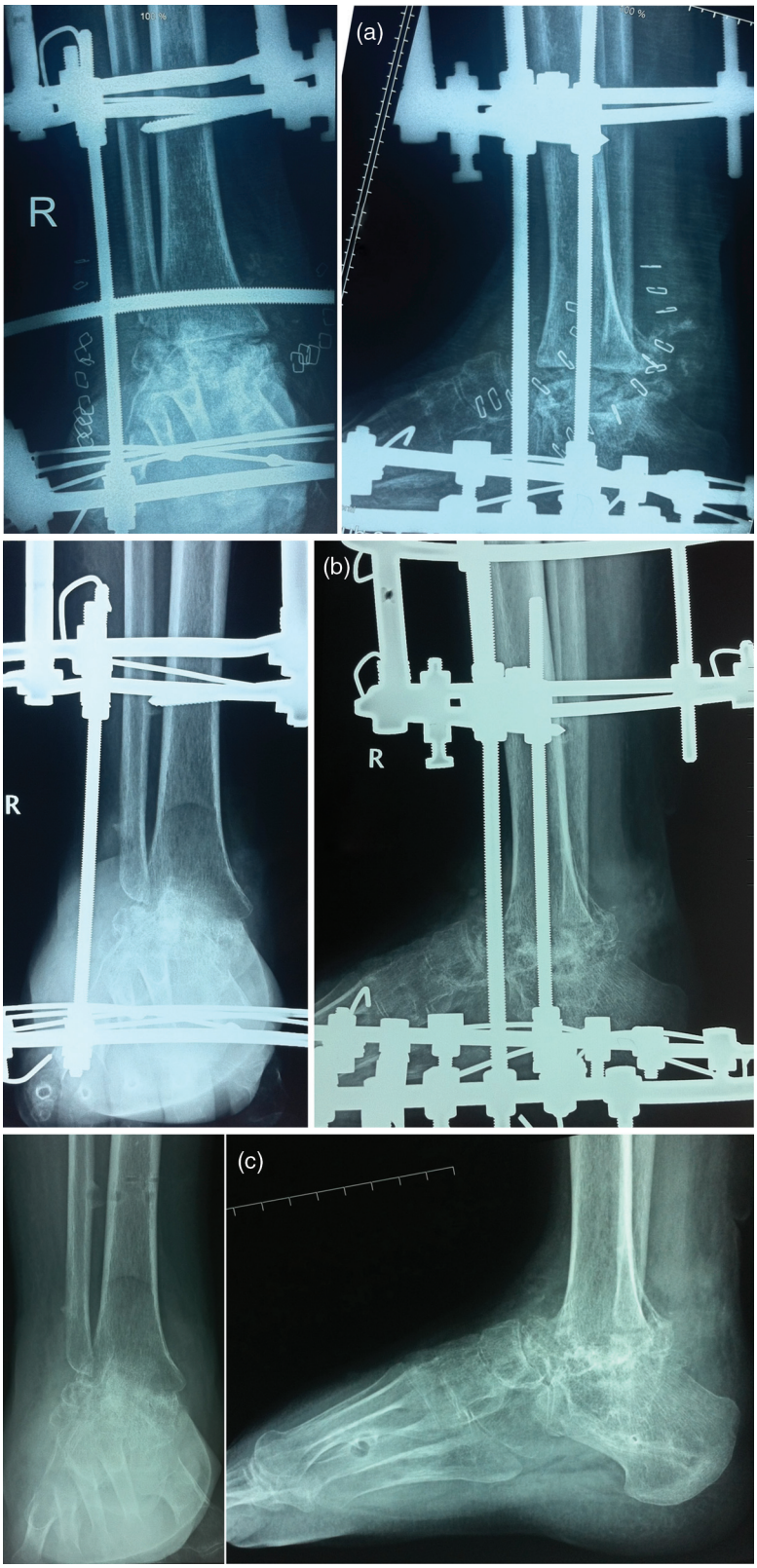
Patients	Age (years)	Sex	Side	Co-morbidity	Underling pathology	Previous surgery
1	45	M	R	–	Septic ankle	3
2	50	M	R	DM	OA	0
3	37	M	L	–	Septic ankle	3
4	47	F	R	DM	Septic ankle	3
5	40	M	R	–	Septic ankle	2
6	39	M	R	–	RA	1
7	38	F	L	DM	Septic ankle	3
8	45	M	R	–	Septic ankle	4
9	36	F	L	DM	OA	1
10	53	F	R	–	Septic ankle	4
11	43	M	R	–	Septic ankle	3
12	41	F	L	–	Septic ankle	4
13	53	M	R	–	OA	0
14	56	M	L	–	RA	2
15	41	F	L	DM	Septic ankle	2
16	56	F	R	–	OA	1
17	35	M	L	–	Septic ankle	3
18	60	M	L	–	RA	2
19	34	F	R	–	Septic ankle	2
20	50	M	L	–	OA	0

DM, diabetes mellitus; F, female; L, left; M, male; OA, osteoarthritis; R, right; RA, rheumatoid arthritis.

Figure 1

(a) Preoperative radiographs of a quiescent case of septic ankle arthritis complicating open reduction and internal fixation of talar fracture and AVN of talus. These radiographs were after implant removal. (b) Computed tomography scan showing the extent of the talar AVN which was more than that anticipated from the radiographs.

Figure 2



(a) Immediate postoperative radiographs after debridement, fibular graft, and Ilizarov fixator application. (b) Radiographs showing sound fusion before frame removal. (c) Radiographs after frame removal.

walker or wheelchair and a brace. Three patients had associated avasular necrosis (AVN) of the talus following ORIF of talar fractures. Two of them were associated with posttraumatic OA and the third was in quiescent septic arthritis after previous debridement and implant removal. Equinus deformity was present in six cases. Five patients were diabetics, and seven were heavy smokers. Seventeen patients had

one or more previous surgical procedures, with a mean of 2.15 (SD: 1.31; range: 0–4). The surgeries included ORIF, external fixation, repeated debridement, implant removal, synovectomy of rheumatoid ankles, or failed arthrodesis. Five patients had a failed previous ankle arthrodesis using unilateral external fixators or Kirschner (K) wires.

The American Orthopaedic Foot and Ankle Society (AOFAS) Ankle-Hind foot Scale was used for assessment [17]. The AOFAS ankle-hind foot scale, an assessment tool widely accepted in the orthopaedic foot and ankle community, is a 100-point score comprising 40 points for pain, 50 points for function, and 10 points for alignment. The preoperative AOFAS ankle-hind foot score ranged from 20 to 35, with a mean of 26 (SD: 4.76).

Blood sugar control in diabetics and quitting smoking were essential before surgery. The procedure and the various possible complications with Ilizarov external fixation were discussed in details with the patients before surgery. Informed consent was obtained from all patients.

Operative technique

The operation was performed under spinal or general anesthesia. The patient was positioned supine with a small bump under the ipsilateral hip to allow easier access to the fibula. The tourniquet was used during debridement. The ankle arthrodesis was performed through a two-incision transfibular exposure with adequate thickness of skin flabs to avoid wound problems. The first incision was made directly over the fibula, and the fibula was osteotomized 2–3 cm above the ankle joint. The second incision was made along the anterior third of the medial malleolus. Osteophytes and degenerative scar tissue were removed. In septic ankles, all necrotic and infected tissues including the sinus tracts were debrided. Internal fixation implants were removed. The articular cartilage and any avascular bone were removed down to bleeding bone. The medial malleolus was osteotomized flush with the tibial plafond and removed. Two parallel cuts, through the distal tibia and through the talar dome, were done with an oscillating saw to create flat broad opposing cancellous bony surfaces.

In the three patients with talar AVN, the necrotic part of the talus was removed. The upper calcaneal surface was denuded till exposure of bleeding cancellous bone. The lateral malleolus was used as a bone graft to partly fill the defect between the distal tibial surface and the remaining viable talar remnant and calcaneus. In cases of active septic arthritis, a bone graft was not used.

Then, the ankle joint was temporarily fixed from the calcaneus through the talus to the tibia using two 3-mm K-wires, and skin flabs were temporarily approximated with small towel clips and the tourniquet was deflated. The Ilizarov external fixator was then applied to the leg and the foot. One ring block formed by two rings was fixed to the tibia by two K-wires in each ring and one half-pin dropped off the ring. The foot frame was formed by a calcaneal half ring with forward extension by two straight plates that were connected by a transverse rod through two male posts to close the construct. This frame was fixed by two crossing olive wires in the calcaneus, atalar wire, and one or two metatarsal wires.

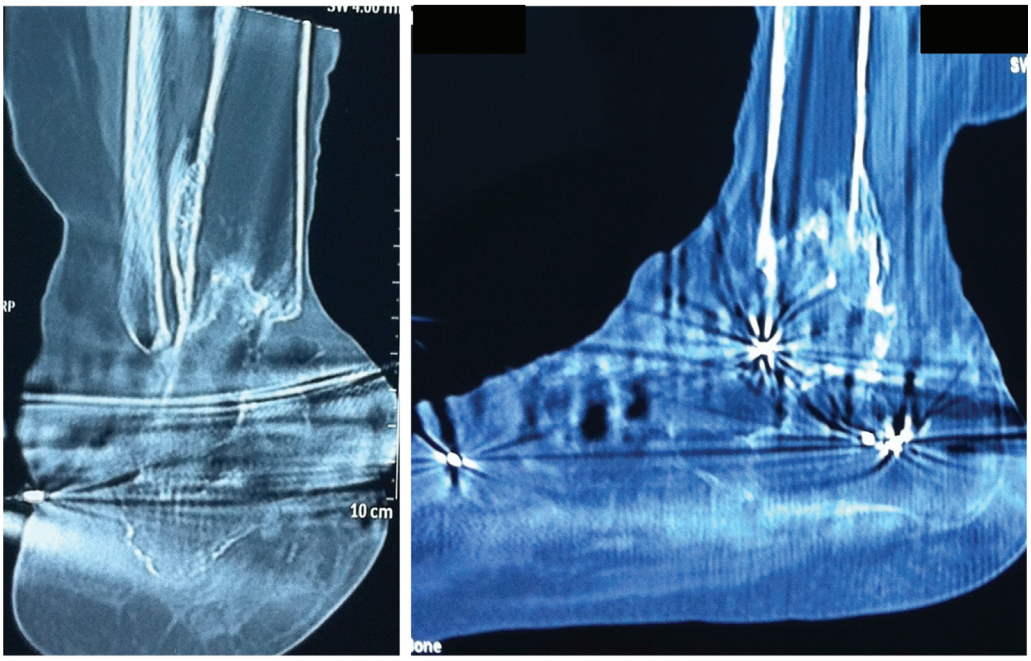
Once the fixator was anchored, the towel clips and the temporary K-wires were then removed, and the foot frame was connected to the distal tibial ring by rods and compression was done across the prepared fusion site. The ankle was positioned in neutral flexion, 5–10° of external rotation, and slight valgus (5°). External rotation was compared with the other leg. Correct positioning of the talus and coaptation of surfaces were verified visually and radiographically under image intensifier. The wounds were washed and closed in layers over suction drain.

Postoperative care

Postoperatively, weight-bearing was allowed as tolerated on the second postoperative day with a modified shoe wear to prevent the foot frame from touching the ground on ambulation. Clinical and radiographic assessments of the patients were done weekly for the first month, biweekly for the second month, monthly until fusion, and then every 6 months. The patients were monitored for pin care, maintenance of position and alignment, progression of fusion, and the need for further compression or repeated cycles of compression and distraction to enhance fusion. Alignment was fine-tuned as necessary.

The Ilizarov fixator was maintained in place until solid fusion was apparent (Fig. 2). This was judged radiographically by loss of lucency and formation of trabeculae across the line of arthrodesis and clinically by painless weight-bearing with a loosened frame. Computed tomography scan was used if the radiographs were not conclusive regarding solid arthrodesis (Fig. 3). The frame was then removed and a below-knee walking cast was applied for 4 weeks. The outcome was assessed by the

Figure 3



Computed tomography scans showing sound tibiotalar fusion in spite of the metal artifacts.

achievement of radiographic fusion and clinically by the AOFAS Ankle-Hind foot Scale.

Statistical analysis

The descriptive statistics were done in the form of frequencies and percentages for categorical variables, and means, SD, and ranges for continuous variables. Statistical analysis was done to compare the mean preoperative and postoperative AOFAS ankle-hind foot scores using paired-samples *t*-test. Spearman's correlation coefficient was used to test the correlation between the postoperative AOFAS score and smoking, diabetes mellitus, and the underlying pathology. Level of significance was set at *P* less than 0.05. The descriptive analysis and statistical analysis were performed with IBM SPSS Statistics for Windows, Version 22.0 (IBM Corp., Armonk, New York, USA).

Results

The results are summarized in Table 2. Patients were followed up for an average of 28.15 (SD: 7.76; range: 18–42) months. The average external fixation period, from the date of surgery to fixator removal, was 15.75 (SD: 2.38; range: 12–20) weeks. Gradual correction of postoperative residual valgus deformity was done in three patients. Successful arthrodesis was achieved in all patients without additional operative procedures. Perfect alignment was achieved in all ankles except one patient who had a mild varus deformity of 5°. Three patients had persistent infection, which was healed after repeated debridement. Pin-tract infections were observed in seven cases. Most of these infections responded to local pin-site care and oral antibiotics. In three cases, wires or half-pins needed to be removed in the outpatient clinic, without compromising the stability of the frame. The infected pin tracts healed few days after pin removal without further complications. The mean leg length discrepancy (LLD) was 1.48 (SD: 0.3796; range: 1–2)cm. A shoe-lift was used in five patients.

At the final follow-up, the AOFAS ankle-hind foot score ranged from 46 to 83, with an average of 75.45 (SD: 9.99) with statistically significant improvement from the mean preoperative score of 26 ($P<0.001$). The mean AOFAS domain scores were 36.5 (SD: 5.87; range: 20–40) for pain, 29.4 (SD: 4.09; range: 21–33) for function, and 9.75 (SD: 1.12; range: 5–10) for alignment (Fig. 4). There was a positive correlation between the postoperative AOFAS score and the underlying pathology (Spearman's $\rho=0.536$, $P=0.015$). There was no correlation between the postoperative AOFAS score and smoking (Spearman's $\rho=-0.075$, $P=0.752$) or between the postoperative AOFAS score and diabetes mellitus (Spearman's $\rho=0.415$, $P=0.069$). One diabetic patient reported moderate daily diffuse pain. That patient had also associated manifestations of diabetic neuropathy. Five patients reported mild discomfort.

Table 2 Patients' results

Patients	Follow-up (months)	External fixation period (weeks)	Leg length discrepancy (cm)	Postoperative AOFAS Ankle-Hind foot score			
				Pain	Function	Alignment	Total score
1	19	12	1.5	40	33	10	79
2	34	14	1.0	20	21	5	46
3	40	16	2.0	40	31	10	81
4	18	15	1.5	30	26	10	66
5	26	14	1.5	40	27	10	77
6	36	15	1.5	40	33	10	83
7	32	17	2.0	30	26	10	66
8	24	19	2.0	40	33	10	83
9	18	12	1.0	40	33	10	83
10	36	14	1.5	30	26	10	66
11	30	13	2.0	30	30	10	70
12	24	19	1.5	30	21	10	61
13	24	19	1.0	40	33	10	83
14	42	16	1.0	40	33	10	83
15	30	17	2.0	40	26	10	76
16	30	18	1.0	40	33	10	83
17	18	14	1.5	40	27	10	77
18	38	15	1.5	40	33	10	83
19	24	16	1.5	40	33	10	83
20	20	20	1.0	40	30	10	80

Figure 4

Clinical pictures of the patient while standing on one leg with ankle arthrodesis after frame removal.

They had radiographic evidence of subtalar OA. Other patients reported no pain. Three patients used a cane for outdoor activities. They had associated OA of both knees. The patients were asked whether they were satisfied with their situation, and all patients stated they were satisfied with the procedure.

Discussion

Arthrodesis is a well-established part of the surgical armamentarium that has been used to treat destruction of the ankle joint [13,18]. It restores the stability and alleviates pain from degeneration of the joint providing

a relatively normal gait and limited functional loss. In addition, it eliminates motion that may contribute to recalcitrant or recurrent infection in septic ankle arthritis [19,20]. Arthrodesis of septic ankle destruction is complicated and often must be accomplished in stages [14,21].

Radical debridement and stable fixation are prerequisites for successful fusion [22]. Meticulous debridement is one of the most important initial steps in the treatment of infected bone and soft tissue. The limits of debridement have classically been determined by the 'paprika sign,' which is characterized by punctuate cortical or cancellous bleeding [23]. In this series, the ankle arthrodesis was performed through a two-incision transfibular exposure. This allowed better visualization of the joint and improved access for bone resection, adequate debridement of infection in septic cases, and correction of deformity. However, its drawbacks are the large incisions and the amount of soft-tissue stripping required.

The importance of fusion site stiffness and compression for successful arthrodesis has been well-established. Popular methods for stabilizing an ankle fusion include crossed lag screws, plate and screws, retrograde intramedullary nailing, Kirschner wires, external fixation, and arthroscopic ankle fusion [6–9,12,24]. However, in the presence of chronic infection, implanted hardware may result in recurrent infection and premature hardware failure. An external fixator is typically used in such cases [20,25]. The Ilizarov external fixator has several advantages over unilateral external fixators being versatile and more comprehensive to manage complex ankle pathology. Maintenance of the mechanical axis can be continually monitored and corrected by adjustment of the frame. Progressive postoperative compression of the fusion site is possible to improve union. It provides excellent stability allowing immediate weight-bearing that keeps the bone mechanically active and reduces the risk of nonunion. Additionally, patients are more mobile, improving proprioception and minimizing recumbence and associated risks, such as deep vein thrombosis and deconditioning. Problems with poor skin and poor bone quality are minimized, and it can be used in the presence of active infection as a one-stage procedure [4,6,8,15]. Problems with the Ilizarov frame include complexity of application, a bulky frame requiring patient compliance, and the risk of specific complications such as pin-tract infection [8,12,20].

In this study, 20 ankle arthrodeses were done using the Ilizarov fixator. Successful fusion was achieved in all patients. Nonunion is a known complication with ankle fusion. In a publication that analyzed 30 studies of ankle arthrodesis with greater than 20 patients, an overall nonunion rate of 22.6% (range: 0–41%) was reported [18]. Nonunion may be owing to insufficient debridement, inadequate fixation, poor bony apposition, local infection, talar AVN, diabetes mellitus, sensory neuropathy, or smoking [4,14]. The high rate of fusion in the present study may be explained by meticulous debridement, stable fixation, early weight-bearing, and postoperative compression or cycles of compression distraction with strict smoking cessation and good blood sugar control. The excised distal fibula was used for grafting after debridement of the three cases with talar AVN. Supplemental bone graft and, recently, a trabecular metal spacer have been used to achieve ankle arthrodesis [26]. However, this should be avoided in patients with active infection [6]. This fusion rate is comparable to other studies of ankle arthrodesis using the Ilizarov frame. Some authors reported fusion of all ankles [3,4,12]. Fragomen *et al.* [27] reported fusion in 76 of 91 patients. Salem *et al.* [6] reported two nonunions in 22 cases that necessitated revision and renewed frame application. Gessmann *et al.* [13] reported five nonunions of 37 cases with a re-arthrodesis performed in four of them using the Ilizarov fixator. Moore *et al.* [20] reported five nonunions of 19 fusions done using internal fixation and four nonunions of 13 fusions performed with external fixators. Amputation may eventually be needed in recalcitrant cases [6,11,20]. Moore *et al.* [20] reported amputation in three of 32 cases of septic ankles. In the current study, amputation was not indicated for any patient.

In the present study, mean external fixation period was 15.75 weeks and the mean LLD was 1.48 cm. Bek *et al.* [3] reported 3.5 months, Gessmann *et al.* [13] reported 116.7 days, and Onodera *et al.* [12] reported 117.8 days for that period. However, Kovoor *et al.* [28] reported a mean external fixator period of 335 days. This longer period may be explained by the bone transport needed for the associated big defects and shortening. Kolling *et al.* [25] reported an average shortening of ~25 mm. Bek *et al.* [3] reported an average LLD of 1.4 cm.

In the current study, infection control required repeated debridement in three patients but was eventually achieved in all cases. Salem *et al.* [6] reported persistent infection in three ankles; two of which healed after repeated debridement. Gessmann *et al.* [13] reported persistent infection in two of 37 cases. Richter *et al.* [22] combined internal stabilization with screws or plates with a transfixing, triangular, AO external fixator for arthrodesis of the infected ankle and

subtalar joint. They reported persistent infection in nine of 45 patients.

In the present series, one ankle was fused in mild varus. Hendrickx *et al.* [29] reported perfect alignment in 24, fair in 26, and poor alignment in 10 cases after arthrodesis by a three-screw technique. Eylon *et al.* [4] reported one varus malunion of 17 ankles fused by Ilizarov fixator. Gessmann *et al.* [13] reported equinus in seven, valgus in two, and varus in one of 37 cases.

The mean postoperative AOFAS ankle-hindfoot score in this series was 75.45. This average score was less than that reported by Smith *et al.* [30] who reported a score of 84±12 after arthrodesis by screws. However, they did not explain the highest score in spite of loss of the points for the ankle motion. Because ankle motion was eliminated by arthrodesis, the 14 points allocated for ankle and hindfoot motion were eliminated, leaving a maximal attainable score of 86 [4]. Some authors reported a lower score. Doets and Zürcher [24] reported a score of 62 after using four methods of internal fixation. Hendrickx *et al.* [29] reported a score of 67, and Gessmann *et al.* [13] reported a score of 67.9. The results of the present study were comparable to other studies. Midis and Conti [31] reported a score of 73, and Fragomen *et al.* [27] reported scores of 71.

Conclusion

Arthrodesis achieved dramatic improvement in the function and quality of life in patients with end-stage ankle arthritis. The use of the Ilizarov external fixator provides a successful salvage method that offers solid bony fusion, optimal alignment, and eradication of infection in complex ankle pathology or failed previous arthrodesis.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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