Evaluation of ilizarov role in correction of relapsed clubfoot

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Background
About 20% of operated clubfeet develop recurrence or show a marked residual deformity. The failure of concentric reduction at the time of initial surgery has to be considered as a main factor. Residual forefoot adduction and supination are the most common persistent deformities. Methods of classification, assessment, and treatment of this problem were advanced over many years. Conventional management techniques tend to have many disadvantages including neurovascular injury, soft tissue problems, and a shortened foot.

Patients and methods
We present our experience in correction of 20 relapsed clubfeet deformities managed by gradual correction using Ilizarov frame without soft tissue release or bony procedures. The age at the time of operation ranged from 3 to 7 years with a mean of 4.4±1.31 years. The duration of use of fixators for correction ranged from 6 to 8 weeks with a mean of 7.09±0.37 weeks. This was followed by 6 weeks of leg cast. The patient was followed up with the use of custom-made shoes. The follow-up period ranged from 24 to 31 months, with a mean of 27.68±1.91 months.

Results
In all, 8 ft (40%) achieved excellent results, 6 ft (30%) achieved good results, 4 ft (20%) achieved fair results, and 2 ft (10%) achieved poor results. Complications were reported as pin tract infection in 6 ft, residual forefoot adduction in 4 ft, joint stiffness in 4 ft, toe flexion deformity in 2 ft, and radiological osteopenia in 2 ft.

Conclusion
The Ilizarov technique in relapsed complex foot deformity correction enables correction of individual components of the deformity at rates that may be tailored to achieve accurate three-dimensional control using an easy-to-handle, light, cheap, and simple frame.

Keywords:
complex foot deformities, gradual correction, ilizarov, relapsed

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Introduction

Complex foot deformity is described as a foot with multiplanar deformities with or without foot shortening, and has been managed through extensive soft-tissue release, osteotomies, or arthrodesis [1]. Conventional techniques have many complications including neurovascular injury, soft-tissue problems, and a shortened foot. The management of these deformities after one or more surgical procedures is difficult [2]. The aim of the treatment of congenital talipes equinovarus (CTEV) is to obtain a functional, pain-free, and plantigrade foot, which is able to wear a normal shoe [3].

Conservative treatment includes Ponseti method [4], French method [5], and Botox [4]. The surgical management of CTEV remains a major challenge [6]. Various methods of surgical treatment of CTEV depend on their proponents, view of the etiology, and pathoanatomy [7]. The age of the patient at operation is an important factor in the long-term outcome. Therefore, most orthopedists prefer to consider this at 3–6 months of age. Cumming and colleagues recommend Ilizarov as a procedure for reintervention in patients aged 8–10 years old at the time of revision [8,9].

The Ilizarov procedure was used for the treatment of complex foot deformities because it permits correction of the deformity in three orthogonal planes, the rate of which may be tailored to the type and severity of deformity. It causes minimal surgical morbidity without shortening of the foot and allows the surgeon to manipulate the rate and direction of the correction [10]. Determining the plane of deformity and its severity is an important factor, which should be assessed before applying any fixators [11]. The

indications of the Ilizarov method in children with foot deformity include relapsed or untreated CTEV, neurological rigid foot deformities [12], and foot deformity associated with limb deficiency [13].

There are two approaches for correction of foot deformities by Ilizarov: soft-tissue distraction of the deformity and distraction of an osteotomy. In the first one, the deformity is corrected by eliminating pre-existing contractures and by distracting across joints to bring them into a new congruous relationship to a plantigrade position. In the second approach, the distraction occurs through osteotomies. The joints remain undisturbed with osteotomy distraction techniques. The choice of which technique to use depends on many factors: patient age, the presence or absence of fixed bony deformities, and the stiffness of the deformity [14].

The advantages of ring external fixation for correction of complex deformities of the foot and ankle include the ability to correct severe deformity, perform gradual correction, modify treatment during correction, and minimize neurovascular damage. External fixation can provide opportunities to operate scarred and contracted tissues, preserve joints and joint function, maintain or gain foot length, and allow weight bearing during treatment [15].

Possible complications of Ilizarov method are pin tract infection, flexion deformities of the toes, joint subluxation [13], epiphysiolysis [16], psychological disturbances [12], bone cysts and osteopenia [17], reflex sympathetic dystrophy [18], intermittent or persistent pain [12], vascular complications, and neurological complications [13].

Patients and methods

In this work we are presenting the results of correction of relapsed clubfeet using Ilizarov non-osteotomy technique of 20 relapsed clubfeet deformities in Orthopedic and Traumatology Department of Suez Canal Univerisity Hospital. The aim of treatment is to achieve a plantigrade stable foot that is painless and allows patients to achieve good function. Our faculty institutional research board (IRB)/Ethics committee approval was done and patients? consent was taken. Ilizarov non osteotomy technique (unconstrained method) was applied on twenty feet with congenital relapsed talipes equinovarus using the Ilizarov frame. All included patients are below the age of 8 years. We excluded patients presenting with any of syndromic, neurological, acquired or infected foot deformity, patients requiring a bony procedure to attain correction of the deformity, and inadequate follow-up patients. Male patients contribute 60% (12 ft) of the studied population: 40% (8 ft) were female with a ratio of 1.5 : 1. Fourteen feet (70%) were unilateral and 6 ft (30%) were bilateral. In bilateral feet, we operated each foot in a separate operation. The patients' age ranged from 3 to 7 years with a mean age of 4.4±1.31 years.

Clinical and radiological assessments were done preoperatively for the selected patient foot. The patients were followed up by postoperative assessment with the same parameters. The clinical parameters are passive ankle joint dorsiflexion, passive subtalar joint motion, hindfoot position during standing, forefoot appearance, gait, shoe type, function, pain, and flexor tendon function. Anteroposterior and lateral radiographs of the whole foot and ankle in neutral position were obtained in all cases. Radiographs were analyzed for the talocalcaneal angle (TCA) in both views. The talocalcaneal index was measured as the sum of TCA measured on lateral and anteroposterior radiographs. Talo-first metatarsal angle was also measured in anterioposterior view.

Eight feet (40%) had one previous surgery, 3 ft (15%) relapsed after two operations, 7 ft (35%) relapsed after three surgical interventions, and 2 ft (10%) relapsed after four surgeries. All the patients were followed up using the same regimen. The follow-up period ranged from 24 to 31 months, with a mean of 27.68±1.91 months.

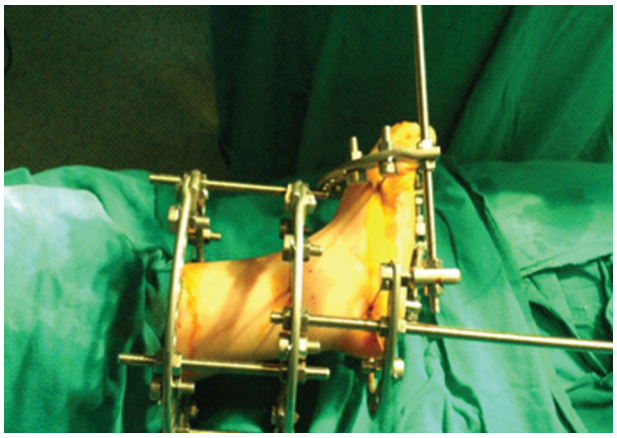
Operation setup

The surgical technique involves supine positioning of the patient under general anesthesia on an ordinary table without fluoroscopic control, and a tourniquet was not used in any case.

Frame application and surgical technique

We used the traditional or the simple frame. The frame was composed of one tibial ring (simple frame) or two tibial rings (traditional frame) (Figs. 1 and 2) with two Schanz, calcaneal half ring and metatarsal 5/8 ring. The calcaneal half ring is attached to the tibial ring with an anterolateral threaded rod that ends distally with a universal hinge situated in an anterolateral position to the ankle and subtalar joints. On the opposite side of this rod (posteromedial to the ankle and subtalar joints), a distractor rod is applied. The calcaneal half ring and the metatarsal 5/8 ring are connected by two threaded rods, one on each side of the foot. Each one is attached proximally to a uniplanar hinge, which is connected to the free end of the calcaneal half ring. The frame is assembled in a way that is comparable to the degree of deformity.

Figure 1



Traditional frame.

Figure 2

Simple frame.

With more equinus than varus deformity, the rod between the tibia and the calcaneus is positioned in a more posterior than medial position and vice versa. The calcaneal half ring is the first applied ring. Centralization of the frame starts with fixation of the calcaneal half ring with transverse wires parallel to the foot sole. This is considered to be the cornerstone in the frame application. The half ring around the calcaneus is secured with transverse wire and one or two Schanz screws for more stability. Then, the tibial ring is secured with a single wire and two Schanz screw for more stability.

With a great attention to local vascular and nerve anatomy, wires and pins were inserted percutaneously perpendicular to the long axis of the bone at different levels and angles. The use of either one (simple frame) or two tibial rings (traditional frame) and one or two Schanz screws in the calcaneus varies according to the age of the patient and severity of the deformity. On calcaneal and tibial ring application, ensuring that the universal hinge is located anterolateral to the ankle and subtalar joints is important. The calcaneal half ring was applied followed by tibial and metatarsal rings. The metatarsal 5/8 ring is then secured to the forefoot with two crossing wires, one crossing all metatarsals and the other penetrating only the first ray to prevent cut-through. The metatarsal 5/8 ring is attached to the calcaneal half ring by two rods on each side medial and lateral situated at the level of midtarsal joints using two mobile posts. All wires are tensioned to up to 90–100 kg, followed by bending of the wires. Then, we proceed with complete review of the frame fixation to the foot and leg.

In our procedure, we used the modified steps during repetition of our procedure like the metatarsal wire, whereas in most of the literature they used only one wire passing through all metatarsals and we found many cases of cut-through, for which we used a second wire. In addition, we used only one tibial wire with two Schanz screws or two wires and one calcaneal wire with one Schanz screw or two wires, which is not mentioned in any literature, and we did not face any case of wire loosening or loss of tension. In addition, we did not use the anterior rods between the tibial ring and the metatarsal ring, which is used in most literature frames because they may block correction of the forefoot adduction and may prevent swinging of the forefoot over the hindfoot to realign the talus with the first metatarsus. The advantages of our frame are that it is simple, cheap, light, easy to apply, and easy to be managed by the parents.

Postoperative care

Gradual distraction is started at the first day after surgery on variable rates on each rod: posteromedial rod at a rate of 2 mm/day; distraction of the medial rod at a rate of 1.5 mm/day; and lateral rod at a rate of 0.5 mm/day. Regarding the rate of distraction per day, it could be once per day or could be divided every 6 h; this depends on the patient's pain threshold and the status of neurovascular bundle. Pin care with sterile saline solution was taught to parents during hospitalization. The children were usually discharged home on the second or third day postoperatively. All children were reviewed at weekly intervals while correction was proceeding and the frame adjustment made as required. Radiographs were taken at 4-week intervals, and the position of the talus was monitored. Wire tension was checked at follow-up visits and retensioning was not needed in any case. Correction of supination of the forefoot was obtained by supinating the metatarsal ring (changing the position of the rods connecting it to the calcaneal half ring at the end of correction) or during cast application after frame

removal. Supination is readily corrected as varus corrected. When the foot is plantigrade, the child is allowed to bear weight in the frame using a cushioned sole. The fixator time used for correction and maintenance of correction was 6–8 weeks with a mean of 7.09±0.37 weeks. Frame removal was performed under general anesthesia. This is followed by above or below knee plaster cast for 6 weeks to maintain the correction in 10–15° of dorsiflexion, valgus heel, and abducted forefoot with instructions for patient or his/her parents to start full weight bearing. After removal of the cast the patient and his/her parents were instructed for manipulation of the foot and ankle with application of an ankle-foot night splint, and the patient was made to wear a custom-made shoe and the parents were instructed to manipulate the foot and ankle using night splint for 12 months.

Results

According to functional rating score by Lehman *et al.* [8] modified by Cummings *et al.* [9], the feet were graded. Total score in this system is 100 points. A classification of 85–100 points will be excellent, 70–84 points will be good, 60–69 points will be fair, and less than 59 points will be poor.

The final results of the current study were as follows: 8 ft (40%) achieved excellent results, 6 ft (30%) achieved good results, 4 ft (20%) achieved fair results, and 2 ft (10%) achieved poor results. The total satisfactory results of excellent to good were seen in 14 ft (70%) out of 20 ft. These results obtained after the follow-up period ranged from 24 to 31 months with a mean of 27.68±1.91 months.

Six feet (50%) of the male cases had excellent outcome, whereas the remaining 50% were equally distributed between the good (2 ft), fair (2 ft), and poor categories (2 ft); on the other hand, 2 ft (25%) of the female cases had excellent outcome, whereas the remaining 75% were equally distributed between good (4 ft) and fair (2 ft).

The results of 14 unilateral cases were as follows: 6 ft (42.9%) had excellent outcome, 4 ft (28.6%) had good outcome, 2 ft (14.3%) had fair outcome, and 2 ft (14.3%) had poor outcome. On the other hand, the bilateral cases (6 ft) were equally distributed between excellent, good, and fair categories (33.3%) for each. The differences between the groups were not statistically significant.

The clinical and radiological parameters (according to functional rating score by Lehman *et al.* [8] modified by Cummings *et al.* [9]) are measured preoperatively and postoperatively, and the results were compared. All feet, in the preoperative status, are rated as poor according to these parameters, reflecting the severity of the deformity.

Improvement of postoperative clinical parameters (passive ankle joint dorsiflexion, passive subtalar joint motion, hindfoot position during standing, forefoot appearance, gait, shoe type, function, pain, and flexor tendons function) were noticed (Table 1). These results were statistically significant.

Radiological assessment using both anterioposterior and lateral foot view

Postoperatively the talocalcaneal index was improved to more than 40° in 13 ft (65%). The talo-first metatarsal angle showed improvement with realignment of the long axis of the talus with the first ray. The TCA showed improvement with realignment of the long axis of the talus with the long axis of the calcaneus. The differences between the groups were statistically significant (Table 2).

The most common complication was pin tract infection. This complication occurred during follow-up in 6 ft with various degrees of infections. However, all of them responded to oral antibiotics and proper pin hygiene by daily cleaning the wires and Schanz using saline and toothbrush. None of them required removal of the infected pin or additional procedure. Residual forefoot adduction had occurred in 4 ft. Joint stiffness had occurred in 4 ft, which was managed by physiotherapy. Toe flexion deformity had occurred in 2 ft, which was managed by percutaneous flexor tenotomy. Radiological osteopenia had occurred in 2 ft, which was managed by medical treatment.

Discussion

CTEV is a relatively common birth defect, occurring in about one case in every 1000 live births. Approximately half of the patients with clubfeet are bilateral. It occurs in boys twice as frequently as in girls [19]. Although the treatment method and outcome will depend on the severity and the type of deformity, open surgery with soft-tissue releases (with or without bone osteotomies) is associated with many complications [20].

In our study, Ilizarov nonosteotomy technique was done for patients, who had a congruous joint, with no significant fixed bony deformities and younger than 8 years of age, and this was in agreement with the study by Kocaoglu [21].

Table 1 Preoperative and postoperative clinical parameters

Clinical parameters	Preoperative [*n* (%)]	Postoperative [*n* (%)]	*P*-value
Passive ankle dorsiflexion			
Group 1 (PADF>90°)	0 (0)	18 (90)	<0.001
Group 2 (PADF=90°)	4 (20)	2 (10)	
Group 3 (PADF<90°)	16 (80)	0 (0)	
Subtalar stiffness			
Group 1: subtalar motion 15°	0 (0)	2 (10)	<0.001
Group 2: subtalar motion <15°	3 (15)	17 (85)	
Group 3: subtalar motion 0	17 (85)	1 (5)	
Hindfoot position			
Group 1: hindfoot valgus 0–5°	0 (0)	16 (80)	<0.001
Group 2: hindfoot varus	20 (100)	4 (20)	
Forefoot appearance			
Group 1: neutral	0 (0)	14 (70)	<0.001
Group 2: <5° abduction or duction	7 (35)	6 (30)	
Group 3: >5° abduction or duction	13 (65)	0 (0)	
Gait results			
Group 1: normal heel and toe walk	0 (0)	16 (80)	<0.001
Group 2: cannot heel walk	11 (55)	3 (15)	
Group 3: cannot heel or toe walk	9 (45)	1 (5)	
Pain			
Group 1: no pain	0 (0)	12 (60)	<0.001
Group 2: pain does not affect function	3 (15)	6 (30)	
Group 3: disabling pain	17 (85)	2 (10)	
Shoe type			
Group 1: regular shoes without complaint	0 (0)	18 (90)	<0.001
Group 2: regular shoes with complaint	15 (75)	2 (10)	
Group 3: foot orthosis	5 (25)	0 (0)	
Ankle function			
Group 1: normal ankle function	0 (0)	15 (75)	<0.001
Group 2: limited	9 (45)	4 (20)	
Group 3: stiff	11 (55)	1 (5)	
Flexor tendon function			
Group 1: full flexor tendon function	0 (0)	17 (85)	<0.001
Group 2: partial or no flexor tendon function	20 (100)	3 (15)	

Table 2 Radiological assessment using both anterioposterior and lateral foot view

Radiological parameters	Preoperative [*n* (%)]	Postoperative [*n* (%)]	*P*-value
Talocalcaneal index			
Group 1: TCI>40°	0 (0)	9 (45)	<0.001
Group 2: TCI<40°	20 (100)	11 (55)	
T-first metatarsal angle			
Group 1: T-first metatarsal angle <10°	0 (0)	13 (65)	<0.001
Group 2: T-first metatarsal angle >10°	20 (100)	7 (35)	

TCI, talocalcaneal index.

According to the modified functional rating system [9] applied in our study 8 ft (40%) were rated excellent, 6 ft (30%) were rated good, 4 ft (20%) were rated fair, and 2 ft (10%) were rated poor. Lehman *et al*. [8], used the Ilizarov technique to treat 34 recurrent clubfeet in 31 children, among which 26 (76.4%) cases were rated good, four (11.7%) were rated fair, and four (11.7%) were rated poor. Bradish and Noor [18], reported that the result of the management of 17 relapsed clubfeet in 12 children using the Ilizarov method with gradual distraction was excellent to good in 13 ft, which means that the satisfactory results were 75%. Freedman *et al*. [22], reported 86% fair to poor outcome with Ilizarov method for relapsed clubfoot. This result may be related to a markedly reduced time in the frame (28 days) and no postoperative splintage. Ferreira *et al*. [23], reported that 77% had good results of 35 recurrent clubfeet.

The target in our treatment of relapsed clubfoot is to obtain a fully plantigrade, corrected, and mobile foot without stiffness at maturity, and this was in agreement with the study by Lloyd-Roberts *et al*. [24], and also with the study by Hosny [25], who reported that 23 foot deformities were treated by nonosteotomy technique with the Ilizarov; all of his patients had a plantigrade foot, and this result also agreed with the study by Nakase *et al*. [26], who reported that among 6 ft with relapsed clubfoot treated by Ilizarov, 5 ft achieved and maintained plantigrade position.

In our work we achieve distraction by frame at 6–8 weeks, and then short leg cast for 6–8 weeks, followed by foot orthosis, whereas Franke *et al*. [27], reported 4–10 weeks of distraction with an additional 8–10 weeks in a frame with the foot in a fixed position. Correction with a plantigrade foot and normal shoe wearing were achieved in all cases, and this was in agreement with the clinical research done by Refai *et al*. [28].

We did not face any major complication, especially the neurovascular complications, which is mentioned in most of the literature and our explanation is because of our simple frame with reduced number of wires and rings, which avoids most of the reported complications. The complications that we faced in our work include residual or recurrence of deformity (4 ft), pin tract infection (6 ft), stiffness (4 ft), toe flexion (2 ft), and radiological osteopenia (2 ft), whereas Atar *et al*. [20], reported pin tract infection, dyaesthesia, pain during treatment, sublaxation of a tarsal bone, transient nerve palsies, joint contracture, and others. Choi *et al*. [16], reported the occurrence of epiphysiolysis of the distal tibial epiphysis and advised transfixion of the distal tibial epiphysis during correction of severely deformed foot. In our work, relapse of the deformity is observed in approximately about 20% (4 ft) of operated cases who developed recurrences or show marked residual deformity. Residual forefoot adduction and supination are the most common persistent deformities, and this was in agreement with the study by Tarraf and Carroll [29]. El Barbary *et al*. [30], reported that 8 ft in seven patients showed recurrence of the forefoot adduction. Utukuri *et al*. [31], reported 70% (12 out of 17) recurrence rate after soft-tissue distraction and 55% (five out of nine) following bony distraction. Ferreira *et al*. [22], reported 35 recurrent clubfeet in older children (age: 14 years) and recurrence was noted in one-third of the patients and 13 ft required arthrodesis. In our work, no cases of wire cut-through occurs and acute intraoperative distraction was done. El Barbary *et al*. [30], reported this complication and regard this complication for acute distraction, and thus they do not recommend acute intraoperative distraction.

One major limitation in our work is the short time of follow-up (not more than 31 months); this may affect the superiority of our results in comparison with results of other authors who mentioned longer follow-up periods (range: 31–58 months) [8,23,30].

Conclusion

The results in our work, which included 20 ft, showed that the simplified Ilizarov frame technique is effective in management of the relapsed or untreated foot deformities in young and older children, and this indicates that the simple frame can achieve the correction reported in other reports. The technique is well suited to the management of severe relapsed foot deformities when more dissection or surgical intervention is contraindicated because of the size of the foot or the vascularity, the number of previous operations, the age of the patient, and compromise of the soft tissues.

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Conflicts of interest

There are no conflicts of interest.

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