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Original Research Article

Correction of Neglected Clubfoot Using the Ilizarov Frame: Radiological and Functional Outcomes

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Abstract:

Background: Neglected clubfoot is a complex rigid deformity that may be difficult to correct using conventional methods. The Ilizarov technique permits gradual correction of multiplanar deformities through controlled distraction. This study evaluated the functional and radiological outcomes following Ilizarov frame correction of neglected clubfoot.

Methods: This prospective observational study included 50 patients with neglected rigid clubfoot treated using the Ilizarov external fixator. Clinical assessment included Dimeglio score, ankle range of motion, gait, pain, footwear tolerance, and achievement of a plantigrade foot. Radiological evaluation included talocalcaneal, talo–first metatarsal, tibiocalcaneal, and calcaneal pitch angles. Patients were followed for a minimum of 12 months after frame removal.

Results: The mean Dimeglio score improved significantly from 15.2 ± 2.1 to 4.1 ± 1.8 ($p<0.001$). Ankle dorsiflexion improved from −12.6° to 8.7° ($p<0.001$). Significant improvement was observed in all evaluated radiological parameters. A plantigrade foot was maintained in 90.0% of patients, while 84.0% achieved excellent or good functional outcomes. Pain during walking decreased from 64.0% to 14.0%, and abnormal gait from 92.0% to 22.0%. Pin-tract infection was the most frequent complication (30.0%), while residual deformity and recurrence occurred in 10.0% and 8.0%, respectively.

Conclusion: Ilizarov frame correction resulted in significant clinical, functional, and radiological improvement in neglected rigid clubfoot. Despite relatively frequent minor frame-related complications, the technique achieved a high rate of plantigrade correction and satisfactory functional outcomes.

Keywords: Neglected Clubfoot; Ilizarov Frame; External Fixation; Dimeglio Score; Plantigrade Foot; Radiological Correction; Functional Outcome.

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Introduction

Neglected clubfoot is a complex three-dimensional deformity characterized by persistent equinus, varus, adduction, and cavus, often associated with soft-tissue contracture, altered bony anatomy, and functional disability. In older children and adolescents, longstanding deformity becomes increasingly rigid, making correction difficult with conventional casting or limited soft-tissue procedures. The primary goal of treatment is to obtain a painless, stable, plantigrade, and functional foot while preserving as much mobility as possible. [1,2]

The Ilizarov technique provides an alternative for correction of severe, rigid, neglected, or recurrent clubfoot through gradual distraction of contracted soft tissues and progressive realignment of the foot. The principle of controlled distraction allows correction of complex deformities while minimizing extensive soft-tissue dissection and avoiding acute neurovascular compromise. Early experience with the Ilizarov method demonstrated satisfactory correction of resistant and neglected clubfoot deformities. [3-5]

Despite its advantages, Ilizarov treatment is technically demanding and requires prolonged frame application, regular adjustment, careful monitoring, and good patient compliance. Complications such as pin-tract infection, pain, edema, joint stiffness, residual deformity, and recurrence may occur. Nevertheless, the technique remains useful in selected patients with severe rigid deformities in whom conventional treatment is

unlikely to provide satisfactory correction. [6] Complex multiplanar foot deformities can also be addressed through appropriate configuration and sequential adjustment of the external fixation construct. [7] Assessment of treatment success should include both clinical function and objective radiological correction. Therefore, the present study was undertaken to evaluate the radiological and functional outcomes following correction of neglected clubfoot using the Ilizarov frame, with particular emphasis on deformity correction, achievement of a plantigrade foot, functional improvement, radiographic alignment, complications, and recurrence.

Materials and Methods

Study Design and Participants: This prospective observational study included 50 patients with neglected rigid clubfoot treated using the Ilizarov external fixation technique. Patients fulfilling the eligibility criteria were enrolled consecutively during the study period and followed for a minimum of 12 months after frame removal.

In patients with bilateral involvement, each affected foot was documented separately; however, patient-level characteristics and complications were analyzed by patient, and statistical methods accounting for paired observations were used when foot-level outcomes were analyzed.

Inclusion Criteria: Patients with neglected idiopathic clubfoot presenting beyond the usual age for primary Ponseti treatment, with a rigid or severe residual deformity requiring gradual correction, were included. Patients with persistent equinus, varus, cavus, and/or forefoot adduction who were considered suitable for Ilizarov correction were eligible.

Exclusion Criteria: Patients with active infection, severe peripheral vascular disease, neuropathic foot, untreated neuromuscular disorders, major congenital limb deficiency, previous arthrodesis preventing planned correction, or inability to comply with frame care and follow-up were excluded.

Preoperative Assessment: A detailed history was obtained regarding age at presentation, sex, laterality, previous treatment, and duration of deformity, pain, difficulty in walking, footwear problems, and limitation of daily activities.

Clinical examination included assessment of:

- Cavus
- Forefoot adduction
- Hindfoot varus
- Equinus
- Ankle and subtalar range of motion
- Callosities and skin condition
- Limb-length discrepancy, if present
- Gait and weight-bearing pattern

Severity of deformity was assessed using the Dimeglio scoring system. Functional status was documented using a standardized clinical functional assessment suitable for clubfoot.

Radiological Assessment: Weight-bearing anteroposterior and lateral radiographs of the affected foot were obtained before treatment, after correction, and during follow-up.

Radiological parameters included:

- AP talocalcaneal angle
- Lateral talocalcaneal angle
- Talo–first metatarsal angle
- Calcaneal pitch
- Tibiocalcaneal angle

Changes in these parameters were used to assess correction of hindfoot varus, forefoot adduction, cavus, and equinus.

Ilizarov Frame Application: The Ilizarov frame was applied under appropriate anesthesia. The construct consisted of tibial rings connected to appropriately positioned calcaneal and forefoot components using tensioned wires and/or half-pins.

The exact frame configuration was individualized according to the components and severity of the deformity. The tibial component provided proximal stability, while calcaneal and forefoot fixation permitted controlled correction of hindfoot and forefoot deformities.

Limited soft-tissue release, tendon lengthening, or osteotomy was performed in selected severe or rigid cases when gradual distraction alone was considered insufficient.

Gradual Correction Protocol: Gradual correction was initiated after a short postoperative latency period. Distraction was generally performed at approximately 1 mm/day, divided into multiple adjustments, and modified according to pain, soft-tissue tension, neurovascular status, and clinical response.

Correction was performed sequentially, addressing cavus and forefoot adduction followed by hindfoot varus and equinus as appropriate. Patients and caregivers were instructed regarding frame adjustment, pin-site care, and recognition of complications. Correction was continued until a satisfactory plantigrade, stable, and clinically aligned foot was achieved.

Postoperative Management: Regular pin-site care was performed, and patients were monitored for pin-tract infection, wire loosening, edema, pain, neurovascular symptoms, and skin complications. Weight-bearing was encouraged according to frame stability and patient tolerance. Following

satisfactory correction, the frame was maintained for an appropriate consolidation period before removal. After frame removal, patients were provided with a cast, brace, or orthosis where required to maintain correction.

Physiotherapy included ankle and foot range-of-motion exercises, muscle strengthening, gait training, and progressive weight-bearing.

Outcome Assessment: Patients were evaluated during frame treatment and after frame removal at 3, 6, and 12 months.

The primary outcome was achievement and maintenance of a plantigrade functional foot.

Secondary outcomes included:

- Improvement in Dimeglio score
- Correction of individual deformity components
- Improvement in ankle range of motion
- Improvement in walking ability
- Radiological correction
- Duration of frame application
- Patient satisfaction
- Residual deformity
- Recurrence
- Need for additional surgery

Functional outcome at final follow-up was categorized as excellent, good, fair, or poor according to clinical correction, pain, gait, footwear requirement, range of motion, and ability to perform daily activities.

Complications: Complications recorded during treatment and follow-up included pin-tract infection, wire loosening, pain, edema, skin problems, neurovascular complications, joint stiffness, residual deformity, recurrence, and requirement for additional surgical intervention.

Statistical Analysis: Data were analyzed using SPSS version 25.0. Continuous variables were expressed as mean ± standard deviation, while categorical variables were presented as frequencies and percentages. Pre- and post-treatment continuous variables, including Dimeglio scores and radiological angles, were compared using the paired Student's t-test or an appropriate non-parametric test.

Repeated-measures analysis was used for parameters assessed at multiple follow-up intervals.

Categorical variables were analyzed using the Chi-square test or Fisher's exact test. In bilateral cases, appropriate statistical methods were applied to account for clustering of two feet within the same patient. A p-value <0.05 was considered statistically significant.

Results

A total of 50 patients with neglected rigid clubfoot were treated using the Ilizarov external fixation technique and followed for a minimum of 12 months after frame removal. The mean age of the patients was 12.8 ± 3.6 years. Significant improvement was observed in clinical deformity, radiological alignment, functional status, and walking ability following treatment.

Table 1: Demographic and Clinical Characteristics of Patients

Variable	Number (n=50)	Percentage (%)
Age group (years)		
6–10	13	26.0
11–15	25	50.0
>15	12	24.0
Mean age (years)	12.8 ± 3.6	—
Sex		
Male	34	68.0
Female	16	32.0
Laterality		
Right	21	42.0
Left	19	38.0
Bilateral	10	20.0
Previous treatment/casting	18	36.0
Previous soft-tissue surgery	8	16.0
No previous treatment	24	48.0
Pain during walking	32	64.0
Difficulty with footwear	42	84.0
Abnormal gait	46	92.0
Mean preoperative Dimeglio score	15.2 ± 2.1	—

Half of the patients belonged to the 11–15-year age group, and males constituted 68.0% of the study population. Bilateral deformity was present in 20.0%. Nearly half of the patients had received no previous treatment. Abnormal gait and difficulty wearing conventional footwear were the most frequent functional problems.

Table 2: Clinical and Functional Improvement Following Ilizarov Correction

Outcome Parameter	Pre-treatment	Final Follow-up	p-value
Dimeglio score	15.2 ± 2.1	4.1 ± 1.8	<0.001
Ankle dorsiflexion (degrees)	−12.6 ± 7.8	8.7 ± 5.4	<0.001
Ankle plantar flexion (degrees)	28.4 ± 9.2	35.6 ± 8.5	<0.001
Pain during walking, n (%)	32 (64.0)	7 (14.0)	<0.001
Abnormal gait, n (%)	46 (92.0)	11 (22.0)	<0.001
Difficulty with footwear, n (%)	42 (84.0)	8 (16.0)	<0.001
Plantigrade foot, n (%)	0	45 (90.0)	<0.001
Able to perform routine activities without major limitation, n (%)	17 (34.0)	43 (86.0)	<0.001

The mean Dimeglio score decreased significantly from 15.2 ± 2.1 before treatment to 4.1 ± 1.8 at final follow-up ($p<0.001$). Ankle dorsiflexion improved from a mean equinus position of −12.6° to 8.7° of dorsiflexion. A plantigrade foot was achieved in 90.0% of patients. Pain, abnormal gait, and footwear difficulty also decreased significantly following correction.

Table 3: Comparison of Pre- and Post-treatment Radiological Parameters

Radiological Parameter	Pre-treatment	Final Follow-up	Mean Change	p-value
AP talocalcaneal angle (degrees)	13.8 ± 5.1	25.6 ± 4.8	+11.8	<0.001
Lateral talocalcaneal angle (degrees)	15.2 ± 5.7	29.4 ± 5.2	+14.2	<0.001
AP talo–first metatarsal angle (degrees)	27.6 ± 8.4	8.2 ± 4.3	−19.4	<0.001
Lateral talo–first metatarsal angle (degrees)	24.8 ± 7.9	7.6 ± 4.1	−17.2	<0.001
Tibiocalcaneal angle (degrees)	103.4 ± 9.8	82.7 ± 6.4	−20.7	<0.001
Calcaneal pitch (degrees)	32.6 ± 7.2	23.8 ± 5.6	−8.8	<0.001

Significant improvement was observed in all radiological parameters. Both AP and lateral talocalcaneal angles increased significantly, reflecting correction of hindfoot varus and improved talocalcaneal divergence. Talo–first metatarsal and tibiocalcaneal angles decreased significantly, demonstrating correction of forefoot adduction, cavus, and equinus deformities.

Table 4: Final Outcome and Treatment-Related Complications

Outcome/Complication	Number (n=50)	Percentage (%)
Final functional outcome		
Excellent	22	44.0
Good	20	40.0
Fair	6	12.0
Poor	2	4.0
Excellent/good outcome	42	84.0
Plantigrade foot maintained at 12 months	45	90.0
Patient/parent satisfied	44	88.0
Complications		
Pin-tract infection	15	30.0
Wire loosening	5	10.0
Transient edema	9	18.0
Joint stiffness	6	12.0
Residual deformity	5	10.0
Recurrence	4	8.0
Neurovascular complication	1	2.0
Additional surgical procedure	4	8.0

At final follow-up, excellent outcomes were observed in 44.0% and good outcomes in 40.0%, giving an overall excellent/good outcome rate of 84.0%. Correction to a plantigrade foot was maintained in 90.0% of patients at 12 months, and 88.0% of patients or parents were satisfied with treatment. Pin-tract infection was the most frequent complication, occurring in 30.0% of patients; most cases were superficial and responded to local pin-site care and antibiotics. Residual deformity occurred in 10.0%, while recurrence was observed in 8.0%. Four patients required an additional surgical procedure.

Discussion

The present study evaluated the radiological and functional outcomes of Ilizarov frame correction in 50 patients with neglected rigid clubfoot. Significant improvement was observed in clinical deformity, ankle movement, radiological alignment, gait, and functional status. A plantigrade foot was maintained in 90.0% of patients, while 84.0% achieved excellent or good functional outcomes at final follow-up.

The mean Dimeglio score decreased significantly from 15.2 ± 2.1 preoperatively to 4.1 ± 1.8 at final follow-up. Ferreira et al. [8] similarly reported satisfactory correction of severe recurrent clubfoot using a simplified Ilizarov construct, demonstrating that gradual distraction can effectively address complex multiplanar deformities. The technique permits progressive correction of contracted soft tissues while avoiding extensive acute surgical release.

Significant radiological improvement was observed in the present study. The AP talocalcaneal angle increased from 13.8° to 25.6°, while the lateral talocalcaneal angle increased from 15.2° to 29.4°. Talo–first metatarsal and tibiocalcaneal angles also improved significantly. Malizos et al. [9] demonstrated that the Ilizarov technique, combined with selective soft-tissue procedures when required, can achieve satisfactory correction in rigid relapsed clubfeet. These findings support gradual correction as an effective method for restoring anatomical alignment.

Functional improvement was also substantial. Pain during walking decreased from 64.0% to 14.0%, abnormal gait from 92.0% to 22.0%, and footwear difficulty from 84.0% to 16.0%. Ahmed [10] reported favorable outcomes following Ilizarov treatment of relapsed clubfoot, emphasizing its ability to obtain a plantigrade, functional foot in difficult deformities. Similarly, Mowafi et al. [11] reported satisfactory functional outcomes when the Ilizarov technique was used for residual and recurrent clubfoot deformities.

Despite these favorable outcomes, frame-related complications remain an important limitation. In the present study, pin-tract infection was the most common complication, occurring in 30.0% of patients, followed by transient edema, joint stiffness, and wire loosening. Ganger et al. [12] highlighted pin-tract infection, stiffness, pain, and recurrence as frequently encountered problems with external fixation in clubfoot treatment. Most pin-site infections are minor and can be successfully managed with appropriate local care and antibiotics. Residual deformity occurred in 10.0% of patients, while recurrence was observed in 8.0%. Khanfour [13] demonstrated that Ilizarov techniques combined with limited adjunctive surgical procedures can achieve satisfactory correction in recurrent or neglected clubfeet while minimizing the need for extensive soft-tissue release. Nevertheless, maintenance of correction requires appropriate frame application, gradual distraction, postoperative bracing, physiotherapy, and continued follow-up.

Gupta and Bither [14] also reported that the Ilizarov technique can provide useful correction in difficult relapsed clubfoot, although treatment is associated with considerable patient burden and frame-related complications. Therefore, careful patient selection and counselling regarding prolonged frame treatment and the possibility of minor complications are essential.

Overall, the present findings indicate that the Ilizarov method is an effective option for severe neglected and rigid clubfoot, particularly when conventional casting or limited surgical procedures are unlikely to achieve adequate correction. Gradual distraction allows correction of multiple deformity components while preserving foot length and avoiding extensive acute soft-tissue dissection.

Conclusion

The Ilizarov technique provided significant functional and radiological correction in patients with neglected rigid clubfoot. A plantigrade foot was maintained in 90.0% of patients, and 84.0% achieved excellent or good functional outcomes. Significant improvement was observed in Dimeglio scores, ankle motion, gait, footwear tolerance, and radiological alignment. Although minor complications, particularly pin-tract infection, were relatively common, most were manageable. The Ilizarov frame is therefore a useful option for selected patients with severe, rigid, or neglected clubfoot deformities.

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