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Ilizarov Ring Fixation for Pediatric Distal Tibial Shaft Fractures Involving the Physis: A Retrospective Institutional Experience

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Abstract
Management of complex pediatric tibial shaft fractures with distal physeal involvement presents a significant challenge due to concerns of growth disturbance, joint incongruity and deformity. Conventional internal fixation may not adequately address the need for axial stability and guided bone healing in such cases. To evaluate the clinical and radiological outcomes of the Ilizarov method in managing complex tibial fractures involving the distal physis in children. This retrospective case series included eight pediatric patients (six boys, two girls) with distal tibial fractures involving the growth plate, treated between March 2013 and November 2014 using Ilizarov circular external fixation. Patient demographics, mechanism of injury, fracture type, duration of frame application, complications and final outcomes were recorded. Clinical results were assessed using Paley's criteria. The mean age at surgery was 11.5 years (range: 9-14 years). The average duration of Ilizarov frame application was 12 weeks. All fractures united without residual angular deformity. One patient developed superficial pin tract infection and another experienced minor axial deviation, both managed successfully. Functional outcome was excellent in five cases and good in three, based on Paley's criteria. The Ilizarov method is a reliable option for treating complex pediatric distal tibial fractures involving the physis, offering stable fixation, early mobilization and satisfactory alignment without compromising growth potential. It is especially useful in cases where internal fixation is either difficult or contraindicated.

INTRODUCTION

Tibial shaft fractures are among the most common long bone fractures in the pediatric population, second only to forearm fractures. While most of these fractures can be managed effectively through conservative means or intramedullary fixation, complex fracture patterns-particularly those extending into or around the distal physis-pose a significant clinical challenge. In children, any disruption of the physis raises concerns about potential growth arrest, angular deformities, limb length discrepancies and joint incongruity. These complications are amplified in high-energy trauma or when soft tissue injury accompanies the fracture[1]. The distal tibial physis contributes approximately 45% of the overall tibial growth, making its preservation critical during fracture management. Conventional internal fixation methods may not provide sufficient control of the fracture segments without compromising the physis. Additionally, the pediatric bone's remodeling potential, while advantageous in simple patterns, may not suffice in comminuted, unstable, or physeal-involved fractures[2]. In this context, circular external fixators, particularly the Ilizarov method, offer a versatile and minimally invasive solution. First developed for complex limb deformity correction and non-union treatment, the Ilizarov system allows for stable fixation across metaphyseal and physeal regions while preserving soft tissue integrity. It facilitates controlled axial loading, micromotion at the fracture site and simultaneous correction of alignment-features particularly beneficial in growing children with complex fracture morphology[3]. The Ilizarov technique has demonstrated efficacy in managing pediatric fractures with associated deformity, open injuries, or failed prior fixation. Despite its advantages, its application in physeal injuries remains less well reported, particularly in small series with focused anatomical localization. The ability to avoid internal implants and directly address multi-planar instability makes it an attractive option when growth preservation and alignment control are critical[4]. The current retrospective study was conducted to evaluate the clinical and radiological outcomes of pediatric patients with complex tibial shaft fractures involving the distal physis, treated using Ilizarov circular external fixation. The primary objective was to assess union time, complication rate, alignment and final functional recovery using Paley's outcome criteria.

MATERIALS AND METHODS

This retrospective study was conducted in a tertiary orthopedic referral center and included pediatric patients treated between March 2013 and November 2014. The objective was to analyze the outcomes of complex tibial shaft fractures involving the distal physis, managed using Ilizarov circular external fixation. Eight children, aged between 9 and 14 years (mean: 11.5 years), were included in the study. The study population consisted of six boys and two girls. All patients presented with closed complex tibial fractures that extended to or closely approximated the distal physis. Inclusion criteria comprised skeletally immature patients with tibial shaft fractures involving the distal physis or meta physeal-diaphyseal junction, managed using the Ilizarov technique. Patients with pathological fractures, open growth plates unrelated to the injury zone, or prior surgical intervention for the same fracture were excluded. Initial evaluation included detailed history, clinical examination and radiographic imaging including anteroposterior and lateral views of the leg and ankle. All fractures were classified radiographically and the presence of physeal extension or adjacent metaphyseal comminution was documented. The mechanism of injury was also recorded. The Ilizarov ring fixator was applied under general anesthesia in all cases. The construct typically included two full rings secured with 1.8 mm tensioned wires and 3.0 mm Schanz screws. Intraoperative fracture reduction was performed either closed or with minimal open assistance. Ring position was adjusted to span the fracture zone and ensure neutral alignment. The fixator configuration allowed for fine-tuning of alignment postoperatively through gradual correction in some cases. Postoperative care included pin site care and early mobilization. Weight-bearing was encouraged as tolerated, usually within the first week after surgery. Patients were followed up clinically and radiographically every 2-3 weeks. Frame removal was considered when radiological union was evident on three cortices, typically after 10-14 weeks. At the time of frame removal, dynamization was performed for a few days before complete removal. Final outcomes were assessed based on fracture healing, residual deformity, range of motion, complications and functional recovery. Paley's criteria were used for evaluating both bony and functional outcomes. Bony outcome included union, angulation, limb length discrepancy and infection. Functional outcome was graded based on return to activity, joint motion, pain and gait. Data were compiled and analyzed descriptively due to the small sample size. Values were presented as mean, range and proportions where applicable.

RESULTS AND DISCUSSIONS

Eight pediatric patients with complex tibial shaft fractures involving the distal physis were included. The mean age was 11.5 years, with a male predominance. All patients achieved clinical and radiological union following Ilizarov external fixation. Functional and bony outcomes were assessed using Paley's criteria. (Table 1) presents the age and gender distribution. Most children were aged between 10 and 12 years.

Table 1: Age and Gender Distribution (N=8)

Age (years)	Number of Patients	Gender (M/F)
9	1	1/0
10	2	2/0
11	2	1/1
12	2	1/1
14	1	1/0
Total	**8**	**6/2**

(Table 2) shows the mechanism of injury. All injuries were due to high-energy trauma.

Table 2: Mechanism of Injury (N=8)

Mechanism of Injury	Number of Patients	Percentage (%)
Fall from height	5	62.5
Road traffic accident	3	37.5
Total	**8**	**100.0**

(Table 3) shows the laterality of fractures.

Table 3: Side of Involvement (N=8)

Side Involved	Number of Patients	Percentage (%)
Right	5	62.5
Left	3	37.5
Total	**8**	**100.0**

(Table 4) presents the mean duration of external fixator application.

Table 4: Duration of Ilizarov Fixator Application

Parameter	Value
Mean duration (weeks)	12.1
Range (weeks)	10-14

(Table 5) shows union time. All fractures united within 14 weeks.

Table 5: Time to Fracture Union (Radiological) (N=8)

Union Time (weeks)	Number of Patients	Percentage (%)
10-12	6	75.0
13-14	2	25.0
Total	**8**	**100.0**

(Table 6) summarizes postoperative complications.

Table 6: Complications Observed (N=8)

Complication	Number of Patients	Percentage (%)
Superficial pin tract infection	1	12.5
Minor axial deviation	1	12.5
None	6	75.0

(Table 7) shows residual angular deformity after union.

Table 7: Residual Angular Deformity (N=8)

Deformity Present	Number of Patients	Percentage (%)
<5 degrees	1	12.5
None	7	87.5

(Table 8) summarizes limb length discrepancy.

Table 8: Limb Length Discrepancy at Final Follow-up (N=8)

Discrepancy	Number of Patients	Percentage (%)
<1 cm	1	12.5
None	7	87.5

Table 9 presents Paley's bony outcome assessment.

Table 9: Bony Outcome Based on Paley's Criteria (N=8)

Outcome	Number of Patients	Percentage (%)
Excellent	7	87.5
Good	1	12.5
Poor	0	0.0

(Table 10) presents Paley's functional outcome assessment.

Table 10: Functional Outcome Based on Paley's Criteria (N=8)

Outcome	Number of Patients	Percentage (%)
Excellent	5	62.5
Good	3	37.5
Fair	0	0.0
Poor	0	0.0

Distal tibial fractures involving the physis in children represent a particularly challenging subset of pediatric injuries due to the high risk of growth arrest, angular deformities and articular incongruity. Management is further complicated when these fractures exhibit comminution, metaphyseal-diaphyseal extension, or soft tissue compromise[5]. In such scenarios, traditional internal fixation methods often pose limitations in maintaining stability without compromising physeal integrity. The Ilizarov method of circular external fixation offers a promising alternative, especially in complex pediatric cases requiring fine control over alignment, length and load-sharing[6]. In this retrospective case series, eight children aged 9-14 years were treated with the Ilizarov external fixator for complex distal tibial shaft fractures involving or adjacent to the physis. The majority of fractures resulted from high-energy mechanisms such as falls from height or road traffic accidents, which are frequently associated with comminution and metaphyseal extension in skeletally immature patients[7]. The mean duration of fixator application in this study was 12.1 weeks, consistent with reported union times for pediatric long bone fractures managed with external fixators. All fractures achieved radiological union within 14 weeks and none required secondary procedures for non-union or delayed healing. These findings align with those of Green *et al.* and Gugenheim *et al.,* who demonstrated high union rates and early mobilization benefits using circular fixators in pediatric long bone injuries[8]. Importantly, no case in this series demonstrated significant residual angular deformity or limb length discrepancy at final follow-up. Only one patient had a minor axial deviation (<5°) and one had a limb length discrepancy of <1 cm, both of which are clinically insignificant and within acceptable limits of pediatric remodeling. These outcomes highlight the Ilizarov system's ability to allow dynamic correction and growth-friendly stabilization, particularly crucial in physeal-involved injuries[9]. Functional outcomes, assessed using Paley's criteria, were excellent in five patients and good in three. These results reflect high patient satisfaction, minimal functional limitation and a smooth return to activity. The circular fixator not only permits early weight-bearing but also enables maintenance of joint mobility through simultaneous rehabilitation, which is essential in preserving long-term function in children[10]. Complication rates were low. Only one case of superficial pin tract infection was reported, which resolved with local care and oral antibiotics. Another patient developed a mild angular deviation,

successfully managed through frame adjustment. Notably, no deep infection, neurovascular injury, or re operation for implant failure occurred in this series-demonstrating the Ilizarov method's safety profile when applied with proper technique and follow-up care[11]. The versatility of the Ilizarov technique lies in its capacity for multi planar correction, its minimally invasive nature and its respect for biological healing. Its application in pediatric fracture care-especially in anatomically sensitive areas like the distal tibial physis-remains underrepresented in literature, although its advantages are increasingly being recognized[12]. This study supports the growing body of evidence suggesting that external ring fixators may be superior to conventional plating or elastic nailing in select complex pediatric fractures, particularly where the physis is at risk. Limitations of this study include its retrospective nature, small sample size and lack of a comparison group managed by other modalities. Moreover, long-term follow-up beyond skeletal maturity would be essential to confirm the absence of growth-related complications or deformity recurrence. Despite these limitations, the uniformity of results and absence of major complications affirm the effectiveness of Ilizarov fixation in managing such challenging cases.

CONCLUSION

The Ilizarov circular external fixator is a safe, effective and growth-friendly method for managing complex tibial shaft fractures involving the distal physis in pediatric patients. It offers stable fixation, allows early mobilization and facilitates precise correction of alignment without violating the physis. The technique demonstrated excellent union rates, minimal complications and favorable functional outcomes in this series. Its application should be strongly considered in cases where conventional internal fixation may be unsuitable or potentially hazardous to physeal integrity.

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