ORIGINAL ARTICLE

Complex Tibial Shaft Fractures in Children Involving the Distal Physis Managed with the Ilizarov Method

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Abstract

Introduction: Segmental fractures in the juvenile distal tibia with physeal involvement present specific challenges. Injury to the growth plate may be overlooked, potentially resulting in late sequelae. Fracture stabilization can be complex. Previous reports of management of such an injury are by open reduction and internal fixation. This study reviews the management and outcome of a group of such patients treated with Ilizarov external fixators.

Materials and methods: Patients aged 16 or younger treated in our unit between March 2013 and November 2014 by Ilizarov circular fine wire fixation for tibial fractures with ipsilateral physeal injuries were identified. Retrospective collection of patient demographics, fracture classification, treatment pathways, fixation methods, postoperative follow-up, outcomes, and complications was undertaken.

Results: Eight patients were identified; two had Gustilo and Anderson grade IIIA open injuries. All were managed definitively using an Ilizarov external fixator in combination with percutaneous screw fixation of the physeal component as required. All patients were ambulant during treatment and were allowed unrestricted weight-bearing immediately postoperative. All but one attended school. All fractures united. In follow-up, one patient had a distal tibial physeal growth arrest, but there were no other complications.

Conclusion: Pediatric patients with complex distal tibial fractures should be scrutinized for concomitant physeal injury. Where identified treatment, using a combination of internal fixation and an Ilizarov fixator can be considered.

Keywords: Distal tibial physis, Ilizarov frame, Pediatric, Salter Harris, Tibial diaphysis.

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Introduction

A segmental fracture of the tibial diaphysis with the involvement of the distal physis is a rare injury pattern in children with a specific set of challenges. High complication rates are associated with both the segmental nature and high energy physeal injury. Treatment decision-making can be difficult. Furthermore, an obvious tibial shaft fracture can distract attention away from identifying a physeal injury, which is more subtle with subsequent growth arrest and late sequelae.

A review of the literature has provided a single reported case of the management of a tibial shaft fracture with an ipsilateral distal tibia triplane injury in a 14-year-old male. Open reduction and internal fixation were used.[1] In this particular case, the tibial shaft fracture was stabilized with a plate and a single cannulated lag screw used for the physeal injury. Weight-bearing was restricted for the first 6 weeks following which weight-bearing, as tolerated, was permitted in a removable below knee splint. The fracture was deemed radiologically united at 12 weeks with no complications noted and no evidence of damage to the growth plate observed at this point. No further follow-up information is provided.

We undertook a retrospective case review to examine our experience of treating these injuries using the Ilizarov method of fine wire external fixation. Our aim was to determine whether such an approach is a valid and safe option for managing these fractures and look for the incidence of late sequelae.

Materials and Methods

All patients aged 16 years or under at the time of injury and treated for a tibial fracture in our department utilizing the Ilizarov method between March 2013 and November 2014 (21 months) were identified from our prospective database. This included patients presenting primarily to our department and those referred in for specialist treatment from other units. Patient records and radiographs were reviewed. Patients with a combination of distal tibial physeal and ipsilateral tibial shaft injury were included.

From the patient records and radiographs, the following information was retrieved: demographics, the fracture description, AO fracture classification, Salter–Harris fracture classification, the initial fracture management, definitive fixation method, time between injury and frame application, time to union, the patient-reported outcomes, complications, and any additional treatment.

Adverse events were classified according to Paley as problems (not requiring operative treatment, resolved by the time of frame removal), obstacles (requiring operative treatment, resolved by the time of frame removal), and complications. Complications were classified as minor (when not compromising the goals of treatment) and major (compromising the goals of treatment).[2]

Clinical, Operative and Postoperative Management

The degree of fracture displacement and soft-tissue injury determined whether limbs were immobilized initially with plaster back-slabs or a

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Table 1: Patients details and outcome

Age	Fracture classification	Physeal injury	Mechanism of injury	Initial treatment	Definitive treatment	Time to full weight bearing	Time in frame	Complications
11	Segmental tibial fracture involving physis	II	Sport injury	Spanning ex-fix	Ilizarov frame	<59 days	100 days	Pin-site infection treated with antibiotics
11	IIIa open segmental tibial fracture involving physis	II/V	RTC	Debridement, closure and cast	Ilizarov frame and skin graft following loss of position	<57 days	72 days	Medial growth arrest—completion epiphysiodesis
15	Segmental tibial fracture involving midshaft and physis	Triplane	Fall from height	Spanning ex-fix	Ilizarov frame and cannulated screw fixation	<34 days	80 days	None
14	Segmental tibial fracture with separate distal physeal injury	II	Sport injury	Spanning ex-fix	Ilizarov frame and cannulated screw fixation	<66 days	123 days	Pin-site infection treated with antibiotics
15	IIIa open tibial fracture with ipsilateral triplane fracture	Triplane	Fall from pedal bike	Acute definitive care	Debridement, primary closure, cannulated screws to physeal injury and Ilizarov frame	<55 days	133 days	Pin-site infection treated with antibiotics
14	Segmental tibial shaft fracture with separate distal physeal injury	II	Fall from skateboard	Cast	Ilizarov frame and cannulated screw fixation	<57 days	107 days	None
13	Distal tibial spiral fracture extending into the distal physis, ipsilateral midfoot injury	II	Fall from push scooter	Spanning ex-fix	Ilizarov frame	<66 days	109 days	None
15	Segmental tibial fracture involving physis	42A1	Fall from height	Spanning ex-fix	Ilizarov frame and cannulated screw fixation	<50 days	138 days	None

temporary mono-lateral external fixator. Open fractures were treated in accordance with BOAST 4 guidelines.[3] Definitive external fixation was undertaken by one of the senior authors. Fluoroscopy was used throughout the procedure. Standard Ilizarov ring fixtures were applied, utilizing 1.8 mm wires throughout. The standard operative approach followed this sequence: (1) the physeal injury was stabilized using either olive wires or cannulated lag screws; (2) a stable proximal ring block was then applied aligned with the long axis in coronal and sagittal planes; (3) wire-to-ring reduction techniques were used to reduce the diaphyseal fracture and this stabilized; (4) where necessary wires stabilizing the physeal injury were then attached and tensioned; (5) additional tensioned wires were inserted to secure the initial physeal fixation as needed. This sequence is illustrated in Figure 1. Where possible, four fixation elements were applied to each main fracture fragment by using two rings.

All patients were encouraged an unrestricted range of ankle and knee motion and to weight-bear, as tolerated on day one postoperatively. Physiotherapy was commenced at this point and maintained through treatment. Patients were discharged as soon as comfortable and were encouraged to attend school as soon as practical. The initial follow-up was 2 weeks after frame application and then every 4–6 weeks until fracture union. Serial plain radiographs in at least two planes were used to judge progression to union. Evidence of union was based on clinical (pain-free weight-bearing without crutches) and radiological (callus formation on all sides) criteria. Frames were removed under a brief general anesthetic as a day-case procedure.

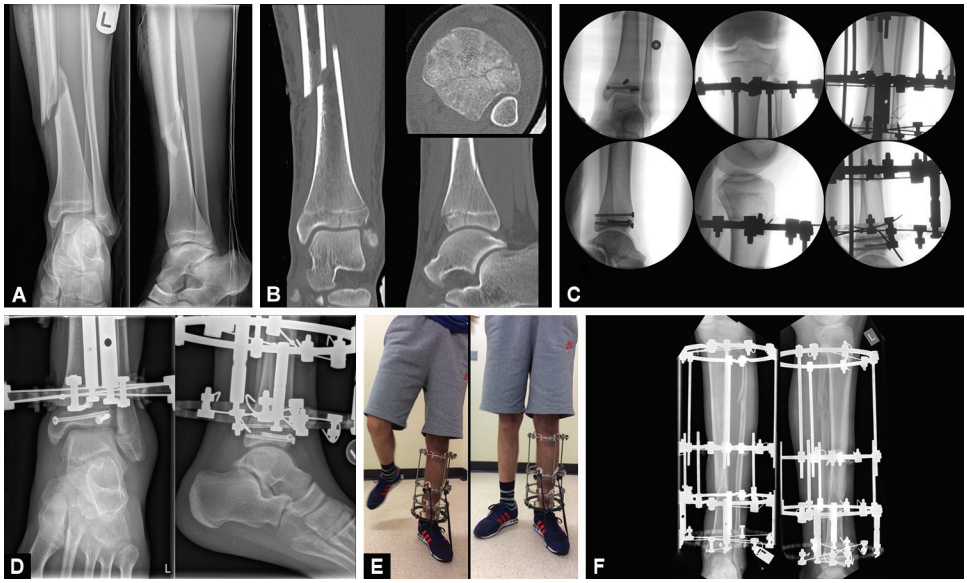
No splints were used, after frame removal and unrestricted movement and physiotherapy encouraged. Patients were advised to not engage in any sporting activity for a further 6 weeks. Patients were followed up for at least 1 year following frame removal in a specialist outpatient clinic with one of the senior authors.

Results

Eight patients were found to meet the inclusion criteria (Table 1). All fractures were segmental, and all involved the growth plate; two were open injuries. Five patients presented to another hospital initially before being transferred for specialist care in our Major Trauma Centre (secondary presentation). The remaining three patients presented directly to our emergency department (primary presentation). Five patients were managed using a mono-lateral external fixator initially, and two were treated with a back slab plaster cast. One patient who presented with a Gustilio and Anderson grade IIIA open fracture was treated definitively with an Ilizarov frame without any initial form of stabilization. The median delay from time-of-injury to time of definitive treatment for those who presented directly to our unit was 4 days. This was longer for secondary presentation patients (mean time of 10.7 days).

All eight patients were ambulant throughout treatment. At discharge from hospital, all were at least partially weight-bearing with crutches. All patients had a documented range of knee motion from full extension to flexion limited only by the position of the most proximal ring. The median documented time from frame on to full weight-bearing without crutches was 57 days (range 34–66). Seven patients attended school during their treatment (87.5%). The other patient was encouraged to attend school by the senior author and was deemed safe to do so but was prohibited by the school despite advice to the contrary. The patient had an education at home arranged.

All fractures united without the need for further intervention. The fixators were removed at a median of 108 days (range 72–138).



Figs 1A to F: Patient with closed segmental injury to tibia including a triplane fracture of the distal tibial physis; (A) Initial radiographs; (B) CT scan of distal tibia demonstrating the physeal injury; (C) Intraoperative radiographs; (D) Initial postoperative radiographs of the ankle; (E) Patient ambulatory in clinic at 2 months post injury; (F) Radiographs at union prior to frame removal

No patient had a refracture or loss of alignment subsequent to frame removal. The overall limb alignment was restored; this was measured radiographically, giving a mean mLDTA within 3° of 90 (range 0–9), and all had leg lengths within 5 mm. Figure 1 illustrates the case shown in Figure 2.

Adverse Events and Complications

Problems and Obstacles

Four patients had superficial pin-site infections treated successfully with oral antibiotics (flucloxacillin for 1 week or with oral clarithromycin if the patient was allergic to penicillin). No patients required unexpected reoperations, and there were no unexpected readmissions to hospital.

Complications

There were no significant complications during treatment. However, after frame removal, one patient went on to develop a partial physeal growth arrest. This was identified early on CT after frame removal (Fig. 3). This patient had presented initially to another unit with an open diaphyseal fracture. A Salter–Harris type V crush injury to the physis was identified subsequently, this having been overlooked initially. The physeal injury was identified on subsequent radiographs, and only then, the patient referred to our unit for specialist treatment. Review of the patient's radiographs and records revealed that at no point was the physis instrumented or injured iatrogenically. To control and prevent significant deformity, the patient underwent percutaneous completion epiphysiodesis of the ankle (Fig. 3). At the last outpatient review appointment, the patient, aged 14 and very close to full skeletal maturity, had acceptable mechanical alignment (mLDTA 99) and equal leg lengths. There should not be a requirement for further surgical procedures.

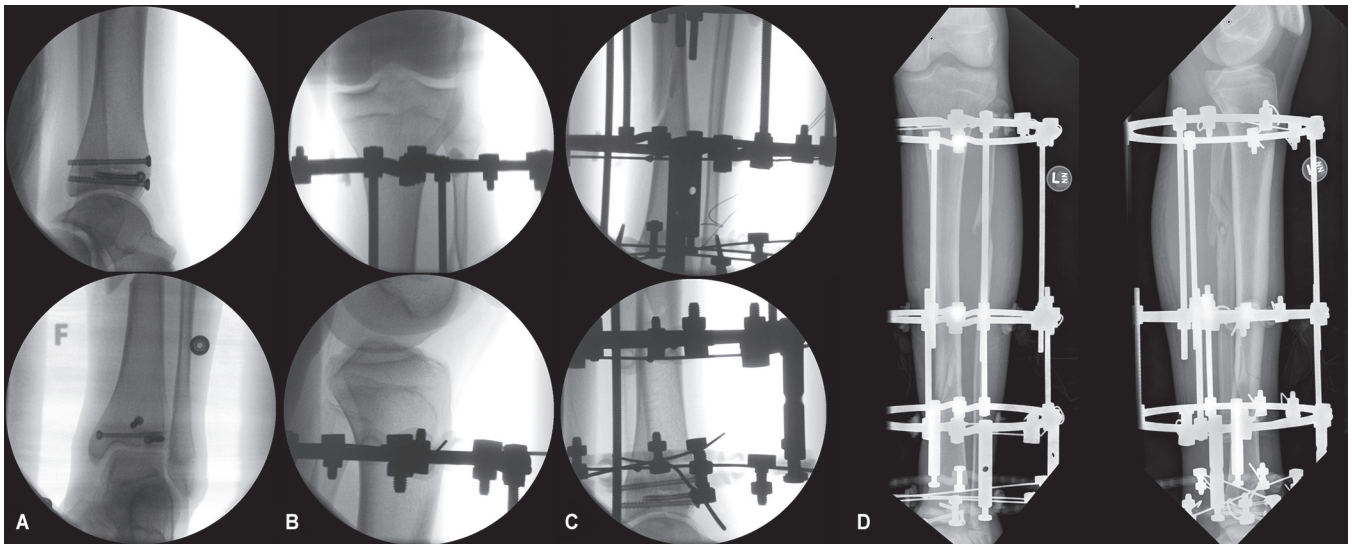
Discussion

This case series demonstrates successful management of complex high-energy injuries with 100% union and restoration of mechanical alignment and with no deep infection. The single complication was the likely consequence of the injury itself. Half of our patients had minor pin-site infections, which were all treated by short courses of oral antibiotics without significant sequelae.

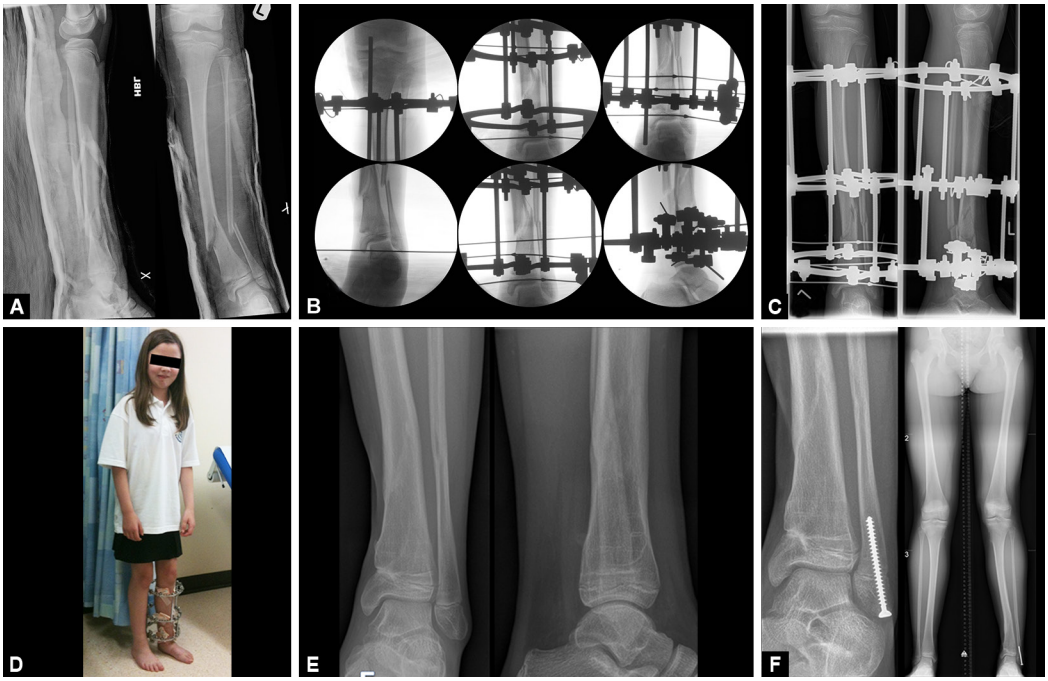
There are several specific advantages to the utilization of the Ilizarov method for such injuries. The tibia has a relatively poor soft tissue envelope and a variable blood supply. This may have been affected by the initial trauma. Further disturbance to the surrounding soft tissues by internal fixation methods has the potential to reduce tissue viability further. This can potentially impair fracture healing and lead to complications.

Fine wire external fixation is carried out percutaneously. The insertion of cannulated screws or olive wires, to treat the physeal injury required little or no exposure of the fracture site or further violation of the zone of injury. This advantage of preserving biology in the injured limb can minimize the risk of wound complications. Good clinical results with low complication rates have been documented in adults with complex and segmental tibial fractures treated by fine wire external fixation.[4]

Patients with such fractures when treated by open reduction and internal fixation are immobilized in a cast and instructed to restrict weight-bearing usually for a minimum of 6 weeks postoperatively. Two patients in this cohort weighed more than 100 kg; this meant weight-bearing with internal fixation would have risked failure of fixation. Flexible nailing in older patients, particularly in the tibia, is difficult and seldom achieves convincing stability without additional splinting. Its use is contraindicated in those weighing more than 50 kg, as was the case for three patients in this cohort. Fine wire external fixation allows unrestricted early ankle motion and weight-bearing. This is pertinent for this patient group as mobility influences whether a patient can attend school during treatment. Whilst the Ilizarov method does facilitate mobility and allow a return to education and tasks associated with daily living, the fixators are cumbersome and difficult to live with. It has been our experience that these are well tolerated in patients in this age range, but there is interference with certain tasks, particularly washing, sleeping, and dressing.[5] Small numbers of patients find living with the fixators psychologically distressing, and



Figs 2A to D: Radiographs demonstrating surgical technique: (A) Physeal injury has been stabilized using cannulated screws; (B) A stable ring block has been applied to the proximal segment aligned with the axis of the limb; (C) Diaphyseal fracture has been reduced using wire to ring techniques and stabilized. In this case, fixation of the metaphyseal component of the physeal injury has been augmented with wires; (D) Final construct



Figs 3A to F: Patient with open segmental injury to tibia including the physis. Initially managed in another unit with plaster immobilization. Physeal injury was initially overlooked: (A) Radiographs at presentation; (B) Intraoperative radiographs; (C) Immediate postoperative radiographs; (D) Patient ambulatory in clinic; (E) Partial growth arrest with developing varus deformity; (F) Patient has undergone completion epiphysiodesis of the distal fibula and long leg alignment views show symmetrical leg length and mechanical axes. This remained the case until skeletal maturity

this should be considered when assessing for different treatment options.[6]

Once united, internal fixation implants are removed, in a pediatric population usually, particularly in the lower limb. Surgery for removal of metalwork carries risks. In a recent study reviewing such surgery in pediatric orthopedic trauma patients over a 1-year period, complications occurred in 21% of patients. The complications included refractures, hypertrophic wound scarring, abscess formation, skin reactions, wound breakdown, and excessive bruising and discomfort.[7] A significant advantage of definitive external fixation is that once treatment is complete, all major metalwork is removed. Single percutaneous lag screws may usually be left *in situ*. If they do require removal, this is easily achieved by small percutaneous approaches with extremely low potential for complication, in contrast to the removal of larger nails and plates.

Seven of the eight patients in this series had a spiral type pattern to the shaft fracture (42A1 or 42B1). This is consistent with a twisting mechanism of the injury, which can produce a distal

physeal injury. The paucity of literature about this combination of injuries may be explained that the distal component is often overlooked. A CT scan was used in several of our cases to accurately confirm and define the physeal injury before definitive treatment.

Conclusion

This case series demonstrates that the Ilizarov technique can provide safe and effective management for pediatric patients with ipsilateral physeal and diaphyseal tibial injuries. This treatment has allowed early functional rehabilitation and the potential for school attendance throughout treatment. It highlights an injury pattern that might go unrecognized, and that should be screened for when treating children with tibial fractures. If identified, we recommend that the Ilizarov method of treatment is considered or, if not available locally, for a referral to a specialist unit.

Ethical Approval

This article does not contain any studies with human participants performed by any of the authors.

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