Surgical management of proximal tibial epiphyseal fracture in children

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Background

Fractures of the proximal tibial physis require a significant amount of force, and therefore, these injuries account for less than 1% of all physeal separations. The proximal tibial physis has intrinsic varus–valgus and side-to-side translational stability because of the collateral ligaments and the lateral fibular buttress.

Purpose

The aim was to evaluate operative treatment of children who have proximal tibial epiphyseal fracture (indications, techniques, advantage, disadvantages, complications, and results).

Patients and methods

From December 2015 to February 2018, a prospective case series study was performed at Al Mataria Teaching Hospital and Al-Hussein University Hospital. A total of 20 patients with proximal epiphyseal fractures were admitted and treated.

Results

The mean operative time was 54±22.45 min (range: 25–90 min), with average intraoperative blood loss of 25 ml (range: 20–30 ml). The method of fixation changes according to the type of fixation. K-wire accounts for ∼75%, whereas cannulated screw 4.5 accounts for ∼25% in the physeal group. In the tubercle group, cannulated screw 4.5 accounts for ∼50%, cannulated 4.5+ tension band accounts for ∼25%, and K-wire accounts for ∼25%.

Conclusion

Fractures of the proximal tibial epiphysis are rare, and the potential complications in this young population are limb threatening. Constant monitoring of neurovascular status is essential to identify acute and delayed compromise. A low tolerance should be taken in to account to use supplementary fixation, such as K-wires, in view of the difficulty in maintaining the reduction and the potential for poor outcomes should this be lost.

Keywords:
fracture, Kirschner wire, proximal tibial epiphysis

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Introduction

Fractures of the proximal tibial physis require a significant amount of force, and therefore, these injuries account for less than 1% of all physeal separations. The proximal tibial physis has intrinsic varus–valgus and side-to-side translational stability because of the collateral ligaments and the lateral fibular buttress [1].

Although potentially problematic regarding an apophyseal fracture of the tibial tubercle, the metaphyseal overhang of the tubercle can provide anterior–posterior translational support. An avulsion fracture of the tibial tuberosity is uncommon, accounting for less than 1% of all epiphyseal injuries and ∼3% of all proximal tibial fractures [2].

Most fractures concerning the proximal tibial physis result in anterior, anterolateral, and anteromedial epiphysis displacement relative to the metaphysis caused by the anatomic stability: In the rare fracture with posterior displacement, the epiphysis and tubercle apophysis are displaced as a single unit [1].

The tibial tuberosity acts as an effective block, making posterior displacement rare. In such injuries, the fracture usually propagates along the physeal extension beneath the tibial tuberosity, so that the proximal tibial epiphysis and tuberosity are displaced as a single unit [3].

Fractures of the proximal tibial metaphysis usually occur in children aged 3–6 years and may be complete or greenstick. In contrast, the tibial tubercle fracture is most commonly sustained by adolescents; the most critical features of proximal tibial physeal fractures are proximity to the popliteal artery and possible development of compartment syndrome [4].

Patients and methods

From December 2015 to February 2018, a prospective case series study was performed at Al Mataria Teaching Hospital and Al-Hussein University Hospital. The study was approved by the institutional ethics committee in the Orthopedic Department of Orthopaedic Surgery, El Azhar University, Cairo, Egypt. A total of 20 patients with proximal epiphyseal fractures were admitted and treated.

Inclusion criteria were as follows:

(1) Patients who are skeletally immature.
(2) Open fractures.
(3) Presence of neurovascular compromise from the initial trauma

Exclusion criteria were as follows:

(1) Age more than 18 years.
(2) Fractures more than 3 weeks between the injury and the operation.
(3) Pathologic fractures (Table 1).

(1) Patient criteria

A total of 20 patients (12 men and six women) with tibial epiphyseal fractures were classified into two groups: physeal group (12 patients, 60%) and tubercle group (eight patients, 40%). Salter–Harris (S.H) type 1 accounts for ~25%, S.H type 3 accounts for ~25% S. H type 2 accounts for ~25%, and S.H type 4 accounts for ~25% in the physeal group.

In the tubercle group, type III A accounts for ~50%, F type III B accounts for ~25%, and type II C accounts for ~25%.

The mean age was 13±2.7 years for the physeal group and 14.6±0.5 years for the tubercle group. The injuries mostly occurred during jumping and sport activities. At initial presentation, no patient with compartment syndrome occurred. Sequalae following acute tibial tubercle avulsion fractures are rare in the reported series. There were only five patients (25%) with pre-existing osteochondritis desican (OSD) from the 20 acute injury cases.

(1) Operative management
  (a) Anesthesia
    (1) General anesthesia was used in all patients.
    (2) Prophylactic antibiotic was taken with induction of anesthesia.
    (3) OR table: Radiolucent, preferably without metallic side bars.
    (4) Position/positioning aids: assistant for counter traction.
    (5) Fluoroscopy location: opposite to surgeon and back table.
    (6) Equipment: C-arm, smooth pins, unopened trays for open reduction, and trays for open reduction including a cannulated compression screw system (4.0–6.5 mm sizes available).
    (7) Tourniquet (nonsterile): may not need to inflate, unless surgery converted to open reduction.
  (b) Operative technique
    (1) Closed reduction and percutaneous pinning of proximal tibial epiphyseal fractures.

Surgical steps

(1) Closed reduction of the fracture with C-arm guidance.

The technique of reduction varied depending on the direction of the displacement of the proximal fracture fragment. Reduction of the fracture is best done under image intensifier control. The surgeon applies longitudinal traction to the leg, whereas an assistant stabilizes the thigh. For hyperextension injuries, traction followed by flexion of the distal fragment usually achieves reduction.

Salter–Harris types I and II valgus injuries are reduced by longitudinal traction followed by application of a

Table 1 Indication of operative treatment for epiphyseal fracture of proximal tibia

Physeal group	Tubercle group
Irreducible type I and II fractures	Types IIB, IIIA, IIIB, and IV tibial tuberosity avulsion fractures
Fractures associated with vascular injury	Associated quadriceps or patellar tendon avulsions
Displaced type III or IV fracture	

gentle varus stress. If the fracture is deemed stable, a long-leg cast is applied with the knee in extension, and varus molding is used. If the fracture is unstable, smooth, crossed transphyseal pins can be used to stabilize the reduction.

In type II fractures with a large lateral fragment, the fracture may be stabilized with the use of pins or screws across the metaphyseal portion of the fracture,

Types I and II varus injuries are managed in a similar manner, except that after closed reduction, valgus molding is applied to the long-leg cast (Fig. 1).

(1) Option 1: smooth cross-pinning pin placement (SH type 1 and 2).
(2) Option 2: guide pin placement that does not cross physis in the metaphyseal fragment (SH type 2) drill proximal cortex with cannulated system compression screw placement.
(3) Option 3: smooth pin placement that does not cross physis but crosses apophysis in tibial tubercle fragment.
(4) Can use this smooth pin as a guide pin for compression screw placement, if desired.
(5) For smooth pin placement, bend and cut pins to be pulled at 4–6 weeks postoperatively.
(6) For cannulated screws, close stab incisions with suture.
(7) Place dressing and apply long-leg cast in 30° of knee flexion.

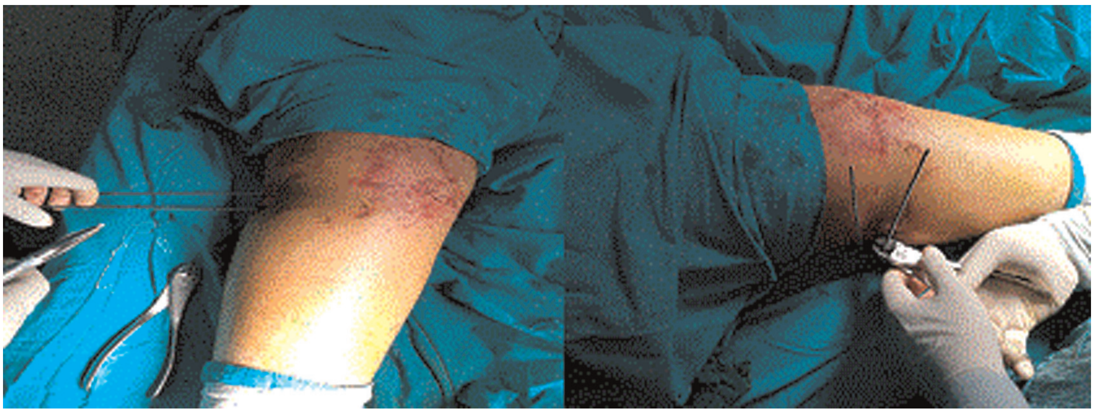
(c) Open reduction internal fixation (ORIF) of proximal tibial epiphyseal fractures:

(1) The preoperative plan for open reduction and internal fixation of these fractures follows the course outlined in the closed reduction and percutaneous pinning section with two exceptions: for the Salter–Harris III and IV physeal injuries plus types IIB, IIIA, IIIB, and IV tibial tuberosity avulsion fractures. In addition, associated quadriceps or patellar tendon avulsions should be repaired to restore the extensor mechanism.
(2) A long medial or lateral parapatellar incision was made depending on the location of the fracture.
(3) Soft tissues were dissected down to the fracture and the fracture was exposed widely both medially and laterally into the joint until the epiphyseal fracture was seen.
(4) The epiphyseal fragment was elevated.
(5) Debris was washed out and interposed periosteum was removed from between the fragments.
(6) Then, the fracture was reduced anatomically.
(7) Joint congruity was checked as well as apposition of the fragments at the peripheral extra-articular margins.
(8) Smooth K-wires were inserted though the reduced fragment from medial and lateral aspects to the metaphysis, crossing each other distal to the growth plate.
(9) If there was a long metaphyseal fragment, it was fixed by cancellous screws.
(10) Tension band was applied after tendon repair (Fig. 2).
(11) The wound was closed in layers with suction drain, and above-the-knee cast was applied.

(3) Postoperative care:

Patients are made non-weight bearing and generally immobilized in a long-leg or cylinder cast for 4–6 weeks. Rehabilitation focused on range-of-motion and progressive extensor mechanism strengthening. Full motion and quadriceps strength are required for return to sports, usually not sooner than 12 weeks.

Figure 1



Closed reduction with K-wire fixation guided by C-arm.

Case presentation

A 9-year-old girl with a history fall from a bike was unable to elevate her right lower limb. Physical examination showed that there was local tenderness along the left proximal tibial and a palpable gap, and associated joint effusion absent distal pulsation with decrease capillary filling urgent closed reduction. This was achieved with forward traction over the proximal tibia distal to the epiphysis, with the knee flexed to 100°, followed by above-knee slap with checkup of the distal pulsation, which returns after reduction.

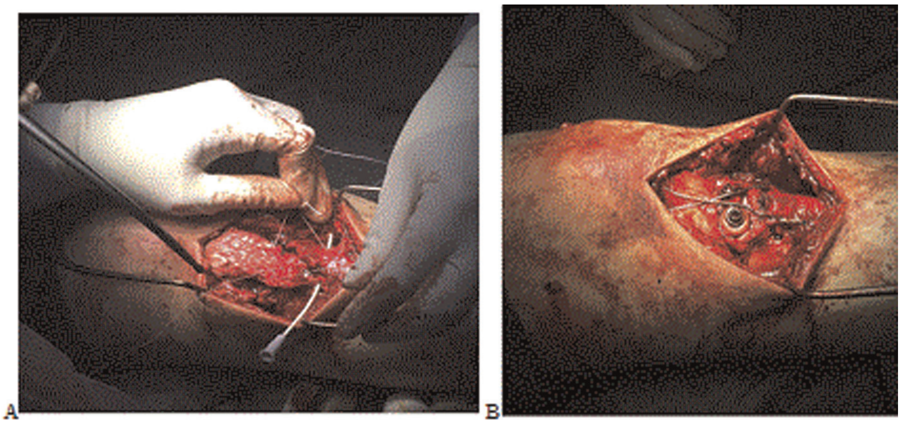
Radiographs show proximal physeal fraction S.H type I (Fig. 3).

Intraoperatively, the fracture was unstable, so was fixed by two K-wires associated with back slap. The K-wire and the slap were removed at 1.5 months postoperatively. Physiotherapy was started immediately after removal of the wire for a vigorous, active range-of-motion exercises and quadriceps strengthening exercises. The fracture healed, and the patient regained his full range of movement of the knee at 3 months after the operation.

Results

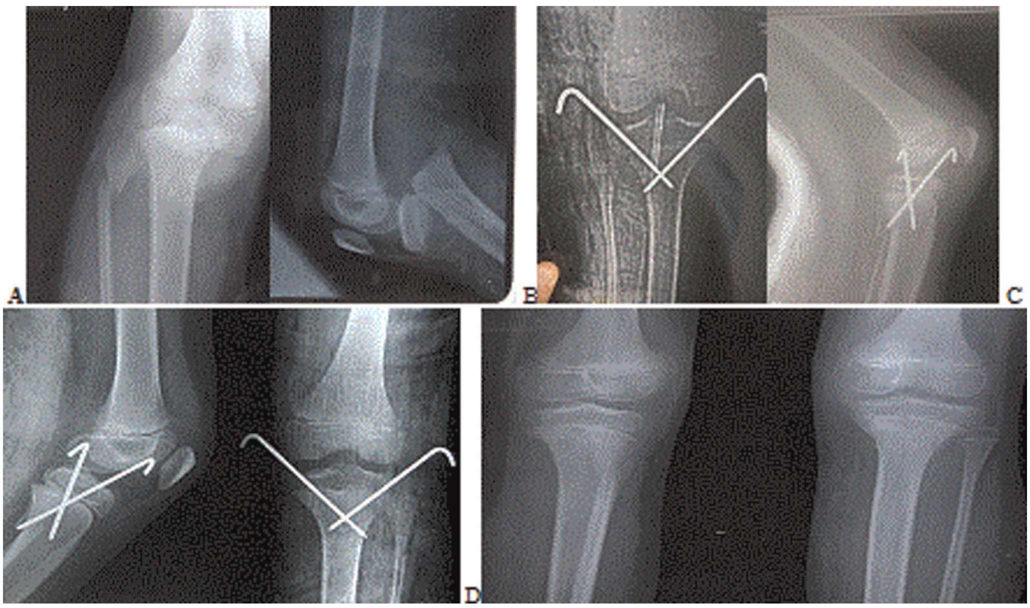
The mean operative time was 54 min (range: 25–90 min) (SD 22.45) with average intraoperative blood loss of 25 ml (range: 20–30 ml). The method

Figure 2



(a) Patellar tendon sutured and tension adjusted. (b) Fracture fixed and protective wire loop inserted.

Figure 3



(a) Preoperative radiography of case 1. (b) Postoperative. (c) 1.5 months postoperative AP of case 1. (d) Three months postoperative AP of case 1. AP, anteroposterior view.

of fixation was changed according to the type of fixation. K-wire accounted for ~75%, whereas cannulated screw 4.5 accounted for ~25% in the physeal group. In the tubercle group, cannulated screw 4.5 accounted for ~50%, cannulated 4.5+tension band accounted for ~25%, and K-wire accounted for ~25%.

Arthrotomy was done in 25% of patients of the physeal group, whereas patellar tendon repair was done in 25% of the patients of the tubercle group.

Follow-up for the patients after the operation ranged from 3 to 24 months, with a mean of 11.06±7.80 months. Fracture union was obtained in all patients at a mean of 5±1 weeks (range: 4–6 weeks). Clinical manifestation of union consisted of absence of tenderness and good knee joint function such as range-of-motion.

We recorded two complications in four patients of the 20 patients. Two patients with prominent hardware needed removal. Two patients (10%) with pin-tract infection needed antibiotics and daily dressing with saline, giving good results.

Other sequelae reported in the literature include malunion, nonunion, fracture through a fixation device, saphenous nerve neuroma, prominent tubercle, pain on squatting, numbness below tuberosity or posterior cruciate laxity, leg-length discrepancy, or deep venous, which were not reported in our patients (Tables 2–5).

Table 2 Type of fixation in studied patients

Physeal group (*N*=12) [*n* (%)]		Tubercle group (*N*=8) [*n* (%)]	
K-wire	9 (75)	Cannulated screw 4.5	4 (50)
Cannulated screw 4.5	3 (25)	Cannulated 4. 5+tension band	2 (25)
–	–	K-wire	2 (25)

Table 3 Additional intervention in studied patients

Physeal group (*N*=12) [*n* (%)]		Tubercle group (*N*=8) [*n* (%)]	
Non	9 (75)	Non	6 (75)
Arthrotomy	3 (25)	Patellar tendon repair	2 (25)

Discussion

Avulsion fractures of the tibial tubercle and their expansion to the tibial epiphysis are rare. These injuries can damage the vascular supply of the limb, making close monitoring of limb perfusion crucial. An avulsion force, while the quadriceps femoris is contracted, usually separates the anterior portion of the proximal tibial epiphysis (tibial tubercle) [5].

Closure of the proximal tibial physis starts posteriorly and the anterior part fuses lastly. This characteristic explains why this type of fracture affects mainly adolescents and young people between 14 and 18 years of age whose anterior portion of the proximal tibial epiphysis is more vulnerable and is predisposed to type 1 or type 2 Salter–Harris injuries [4,6,7].

The Ogden's classification, which is a modification of the former Watson–Jones' classification, is mostly used for classifying these injuries. Ryu and Debenham [8] added a type 4 to describe an avulsion fracture of the entire proximal tibial epiphysis. We do not consider this type of injury as a tibial tubercle injury but as a separation of the entire proximal tibial epiphysis [9].

McKoy and Stanitski [10] proposed to add a type 5. According to them, type 5 is the Ogden type 3B combined with a type Salter–Harris IV fracture of the proximal tibia, forming a 'Y' configuration.

OSD WAS suggested by Gowda and colleagues to be a possible predisposing cause of the acute tibial tubercle injury. They presented nine patients with pre-existing OSD from a series of 14 acute injuries. Seven of them involved the contralateral knee, and there was no evidence of similar involvement of the side of an acute injury [11].

Table 5 The duration for hardware removal after operation

	Groups	
Variables	Physeal group	Tubercle group
K-wire (months)		
N	9	2
Mean	1.5	2
Cannulated screw 4.5 (months)		
N	3	6
Mean	6.0	6.0

Table 4 Comparison between studied groups regarding return to sports (months)

	Groups (mean±SD)		
Variables	Physeal group (*N*=12)	Tubercle group (*N*=8)	*P* value
Return to sports (months)	3.0±0.0	3.7±0.5	<0.001*

*$P<0.001$ is considered highly significant.

All of the excerpted authors recommend ORIF as the only method to manage the displaced form of the tibial tubercle injury; the method of osteosynthesis varies from tension band in younger children to screws in older cases [4,12].

The accurate positioning of the fragments with fully articular surface congruence was established. In these cases, the fragments were stabilized by two cannulated screws inserted in parallel percutaneously. this method was fully sufficient for fracture management.

In general, fracture pattern and degree of displacement determine the need for surgical intervention and the overall outcome. Although a variety of fixation techniques or constructs may be used, because of the importance of restoring physeal and articular anatomy for avoidance of growth disturbance and degenerative joint disease, respectively, achieving anatomic, rigid fixation is of greater importance than with many other fracture locations in the growing skeleton [13].

Tibial tubercle fractures represent high-energy injuries with potentially devastating complications such as compartment syndrome and/or vascular compromise. Intra-articular involvement is often missed with the use of plain radiography and drastically underestimates injury severity [14].

Conclusion

This study demonstrated operative management of children with proximal tibial epiphyseal fractures. Satisfactory clinical and radiologic outcomes were obtained without serious complications.

Fractures of the proximal tibial epiphysis are rare, and the potential complications in this young population are limb threatening. Constant monitoring of neurovascular status is essential to identify acute and delayed compromise. A low tolerance should be taken to use supplementary fixation, such as K-wires, in view of the difficulty in maintaining the reduction and the potential for poor outcomes should this be lost.

The main goal of surgical treatment of tibial tubercle fracture is restoring the extensor mechanism and the joint surface with all its associated components. Early recognition and treatment usually produce good results.

The limitations of this study were the small number of the patients and the absence of a control group treated with open plating. A randomized controlled trial with a larger sample size is required in the future to confirm the outcome achieved in our study.

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Nil.

Conflicts of interest
There are no conflicts of interest.

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