

Classification and management of tibial tubercle avulsion fractures in children

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Abstract

Fractures of the tibial tubercle are an uncommon injury, constituting 0.4–2.7% of all epiphyseal injuries. They occur in the adolescent age group, often during sports such as basketball and football. They are often classified using the modified Ogden classification. Understanding the anatomy and pathophysiology is essential in the management of these fractures, to predict complications and counsel patients and families on care. Tibial tubercle fractures generally have favourable overall outcomes when the correct treatment modality is chosen, with a high rate of union and a 98% return to preinjury activities. This article provides a guide for doctors on the classification and management of these injuries, to ensure that appropriate treatment is given according to current literature and best practice.

Key words: Children; Classification; Fractures; Investigation; Management; Tibial; Tubercle

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Introduction

Tibial tubercle avulsion fractures are an uncommon injury, with reported incidence rates of 0.4% to 2.7% of all epiphyseal injuries, and less than 1% of all physal injuries (Mosier and Stanitski, 2004). They are more commonly seen in adolescents, a period where the tubercle apophysis is mechanically most vulnerable to avulsion injury. The average age at presentation is 14.6 years, ranging from 13 to 16, with most patients being male (Pretell-Mazzini et al, 2016).

These injuries can often be associated with complications such as compartment syndrome, associated injuries to the knee, as well as post-operative stiffness and symptomatic metalware following surgical fixation.

The primary goals of management are a restoration of the knee extensor mechanism and proximal tibial articular surface (Frey et al, 2008). This article provides a guide to ensure that avulsion fractures of the tibial tubercle are managed appropriately according to current literature and best practices.

Anatomy

The epiphyseal ossification centre of the proximal tibia is usually present within the first few months after birth. Subsequent ossification contributes to elongation of the tibia and forms the shape of the tibial plateau.

The tibial tubercle apophysis appears as a separate ossification centre from the ages of 9 to 11. This apophysis then goes on to fuse with the tibial epiphysis, and by the age of 18, both the tibial epiphysis and apophysis are fused to the rest of the tibia (Figure 1).

Physal closure occurs from posterior to anterior and proximal to distal, with the tibial tubercle being the last to fuse (Ogden and Southwick, 1976). During the period before fusion of the physes, the fibrocartilage of the tubercle is sequentially replaced with columnar cartilage cells. These are less able to withstand high tensile forces (Formiconi et al, 2020). The extensor mechanism of the knee exerts large forces at the tibial tubercle, predisposing to greater risk of injury in adolescents in this transition period.

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Figure 1. Diagram illustrating the process of ossification of the proximal tibial epiphysis and the tibial tubercle.

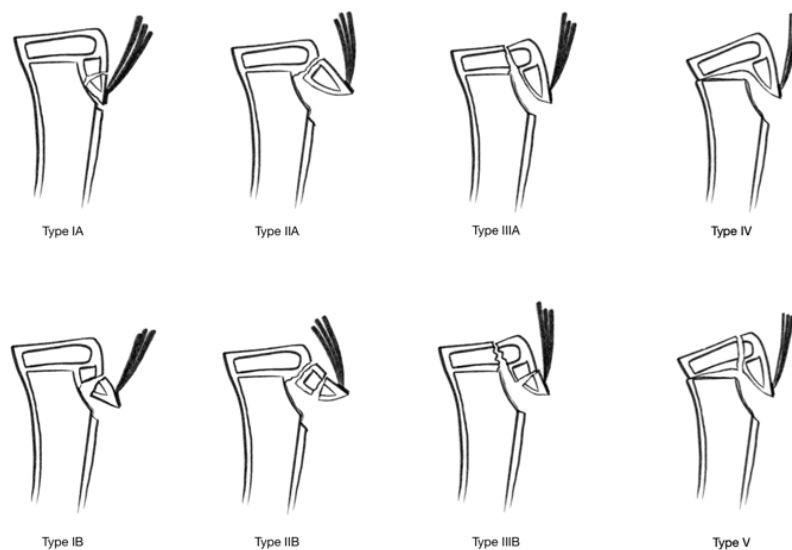


Figure 2. Diagram showing the modified Ogden classification (IA, IB, IIA, IIB, IIIA, IIIB) as well as the Ryu-Debenham type IV and McKoy-Stanitski type V modifications.

Vascular supply is derived from several arteries, forming a dense arterial network. As a result, the risk of non-union or avascular necrosis after a fracture is low (Nelson et al, 1960; Hamel et al, 2011; Rodriguez et al, 2020). This arterial network however has implications in associated compartment syndrome.

Mechanism of injury

The mechanism of injury is typically a flexion-avulsion type injury.

The two commonly cited actions are when the patient initiates a jump, and there is strong eccentric muscular contraction of the quadriceps. This contraction avulses the tibial tubercle. The second is during acute passive flexion of the knee against a contracting quadriceps (landing after a jump) (Mosier and Stanitski, 2004).

The common mechanism for both actions is the eccentric contraction of the quadriceps tendon.

These injuries often occur during sporting activity, the most common being in basketball, football and running (Frey et al, 2008; Pandya et al, 2012; Formiconi et al, 2020).

Classifications

The original classification system by Watson-Jones and Wilson (1982) outlined 3 fracture types. This was amended by Ogden et al (1980), who added modifiers for non-displaced

and displaced or comminuted fractures. This remains the most popular classification system in use.

There have been subsequent modifications to the Ogden classification (Figure 2). Ryu and Debenham (1985) proposed a type IV injury that involves the tibial tubercle as well as the entire proximal tibial epiphysis.

McKoy and Stanitski (2003) later proposed a type V fracture. This can be described as a combination of a type IV fracture and type IIIB fracture, resulting in a 'Y' configuration.

Type III fractures are the most common, accounting for more than 50% of cases (Pretell-Mazzini et al, 2016).

Pandya et al (2012) proposed a classification system based on the level of development and physal closure of the proximal tibia epiphysis and tibial tubercle. Fractures, where the tibial epiphysis and tubercle come off together (Type IV), occur when there is incomplete closure of the tibial epiphysis and tubercle. Intra-articular injuries occur when there has been partial closure of the proximal tibia epiphysis (Types IIIA and IIIB). Injuries to the distal part of the tubercle (Type IA and IB) occur when there has been closure of the proximal tibial epiphysis and proximal tubercle.

Assessment

Patients typically present with these injuries after athletic activity, with an acute onset of pain on the affected side.

There is usually no history of direct impact on the knee, as the mechanism is a flexion-avulsion type injury (Beaty and Kumar, 1994; Little and Milewski, 2016). As a result, these injuries are usually closed, with minimal damage to the overlying skin.

Examination findings may vary depending on the degree of injury. Often patients will be unable to ambulate, with associated swelling and effusion to the affected knee. In significantly displaced fractures, the skin overlying the tibial tuberosity is at risk of necrosis.

There may be an extensor lag or complete loss of extensor mechanism. In certain cases, intact retinacular fibres may allow for some active knee extension (Pandya et al, 2012; Pretell-Mazzini et al, 2016).

The anterior tibial recurrent artery lies close to the tibial tubercle. Damage to this can lead to the development of compartment syndrome. It is important to assess for firmness over the anterior compartment, worsening pain as well as pain out of proportion on passive plantarflexion of the foot. Furthermore, fractures which extend to the posterior proximal tibia should raise concern for popliteal artery injury.

Several studies have shown an association with Osgood-Schlatter, a type of traction apophysitis (Polakoff et al, 1986).

Initial management in the acute setting involves immobilisation with an above knee backslab, held in extension. This reduces the deforming forces acting at the fracture site.

Imaging

The initial imaging modality is plain radiographs of the knee (anterior to posterior [AP] and lateral). The injury is usually most clearly visualised on the lateral projection. A further optional view is an internal rotation or oblique view which will bring the tibial tubercle into profile (Dupuis et al, 2009). For isolated tibial tubercle fractures not involving the proximal tibia epiphysis, plain radiographs are often sufficient, without a need for advanced imaging (Pandya et al, 2012).

However, recent studies have suggested that the extent of injury may be underestimated on plain radiographs and have advocated for further cross-sectional imaging. Pandya et al (2012) propose that further cross-sectional imaging should be mandatory for intra-articular fractures to assess fracture pattern (Pandya type C, Ogden type IIIA, IIIB and V).

Furthermore, computed tomography (CT) scans are recommended for pre-operative planning in type B fractures (Pandya classification) or type IV fractures (Ogden classification).

The use of magnetic resonance imaging (MRI) has also been suggested for imaging these fracture subtypes, with the advantage of imaging intra-articular soft tissues, and reduced radiation exposure in the paediatric population. However, CT scans are generally more readily available, and provide greater bony detail (Pandya et al, 2012).

If there is any concern regarding popliteal artery injury, an arteriogram may be indicated.

Management

The goals of treatment are to restore the extensor mechanism of the knee, as well as the articular joint surface. Furthermore, damage to the meniscus and soft tissues may mandate further repair (Ogden et al, 1980; Pandya et al, 2012). Further injury to the physis should be minimised to reduce the risk of growth arrest (Rodriguez et al, 2020).

In addition to bony union, rehabilitation for range of motion, strength and function are important considerations.

It is essential to assess for compartment syndrome. If there is evidence of this, the patient should be taken for a fasciotomy and subsequent surgical fixation of the fracture (Frey et al, 2008).

There is no clear consensus regarding which fractures require surgical fixation, and different centres have had successful outcomes with different approaches (Frey et al, 2008; Formiconi et al, 2020).

Type IA, IB and IIA fractures with minimal displacement (<2 mm), may be treated non-operatively in an above-knee cast. If the reduction is maintained, then immobilisation is continued for a total period of 4–6 weeks. Thereafter patients may begin range of motion activities, with a return to full function from 8–12 weeks (Frey et al, 2008; Rodriguez et al, 2020).

For type IIB, IIIA, IIIB, IV, V fractures, surgical management is preferred. An example of a type IIIB fracture treated operatively is shown below (Figures 3,4). This involves anatomical reduction of the displaced fragment and internal fixation. The techniques depend on the nature of the fracture, however, a commonly used method is lag screw fixation with 4.0 mm partially threaded cancellous screws (Figure 4) (Rodriguez et al, 2020). Countersinking may reduce the prominence of the screw and subsequent development of symptomatic metalware. The popliteal artery is at risk when using bicortical fixation, so unicortical fixation is recommended, with use of fluoroscopy (Biolatto et al, 2023). The use of cerclage compression wiring, or tension band wiring has also been described (Figure 4) (Polakoff et al, 1986).

For fractures involving the articular surface, concurrent arthrotomy or arthroscopy can be used to directly visualise the joint for further injuries, and to aid anatomical fixation. This can also help to identify and repair injuries to the meniscus.

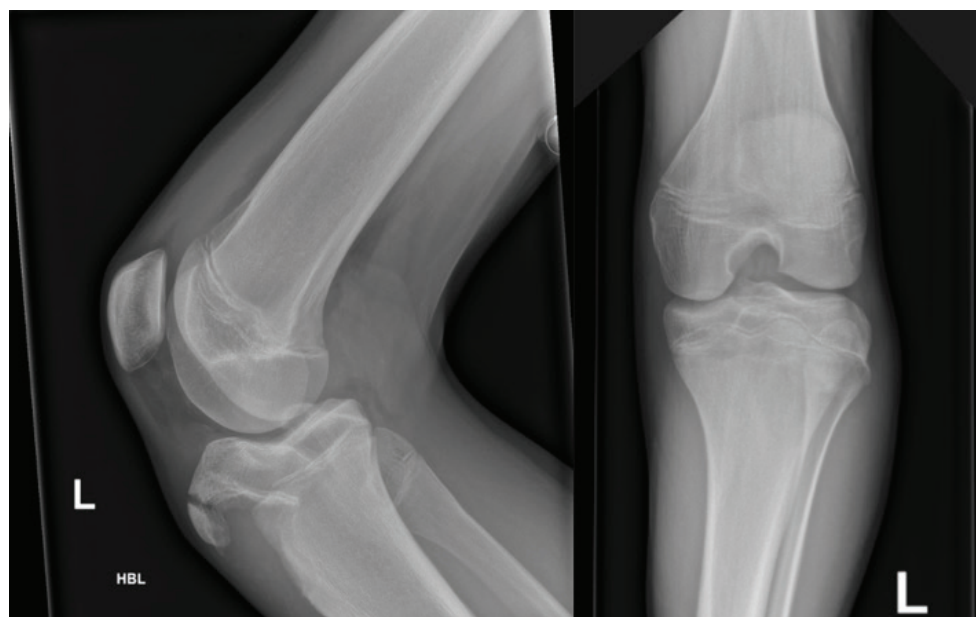


Figure 3. An anterior to posterior (AP) and lateral radiograph of a patient with an Ogden IIIB fracture. L, left; HBL, horizontal beam lateral.

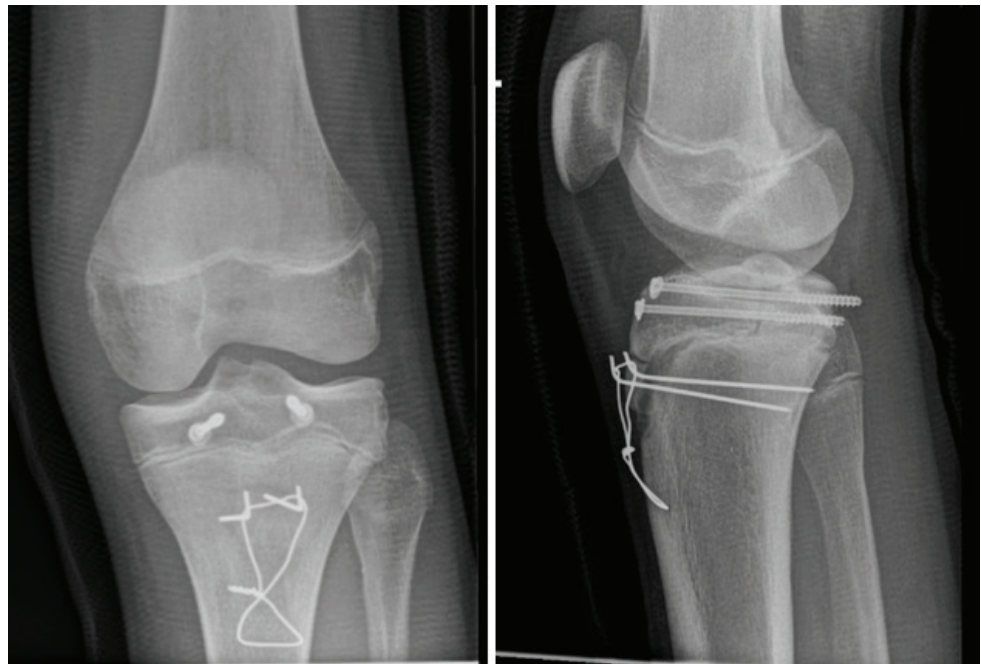


Figure 4. Post-operative radiographs were taken 2 weeks after surgery illustrating fixation using a combination of two partially threaded cancellous screws and cerclage compression wiring.

After surgery, a period of immobilisation is commonly used, followed by rehabilitation in a hinged knee brace. Post-operative care can vary depending on fracture pattern, security of fixation, associated injuries as well as surgeon preference. Patients are kept non-weight bearing in a cast or hinged knee brace for 6 weeks.

Outcomes are generally good, with 98% of patients achieving full range of motion (Pretell-Mazzini et al, 2016).

Complications

The prognosis of tibial tubercle fractures is generally good, with a high rate of union and return to sports. However, there are some notable complications.

Pretell-Mazzini et al (2016) reported that painful bursitis was the most common due to irritation from metalwork, requiring removal of hardware in 53% of cases.

Compartment syndrome is an important complication. Frey et al (2008) reported a 20% incidence, however a systematic review by Pretell-Mazzini et al (2016) found a 4% rate pre-operatively.

Damage to the physis both at the time of injury and surgery can occur, leading to growth arrest, limb length discrepancy or genu recurvatum. This is rare, as these injuries typically occur close to the time of normal physis closure. It occurs more frequently in younger patients with a greater degree of skeletal immaturity, with rates of 4% for genu recurvatum, and 5% limb length discrepancy in patients under 13 (Beaty and Kumar, 1994; Pretell-Mazzini et al, 2016).

Other complications such as stiffness, malunion, non-union and re-fracture have also been described although thankfully these are generally rare (Ogden et al, 1980; Little and Milewski, 2016; Pretell-Mazzini et al, 2016).

Conclusion

Fractures of the tibial tubercle are a relatively uncommon injury and generally have favourable outcomes if managed appropriately.

It is important not to underestimate the extent of these injuries, and further cross-sectional imaging may be required to establish the fracture pattern and management choice, and associated soft tissue damage must be considered.

Tibial tubercle fractures have good overall outcomes but treating clinicians must be aware of both early and late complications. The methods of fixation used are variable, and the differences between techniques used are beyond the scope of this paper and need further work.

Key points

- Tibial tubercle avulsion fractures are uncommon injuries seen mostly in adolescents. The mechanism is usually a flexion-avulsion type injury.
- There have been several modifications to the classification of these injuries, to help direct management strategies.
- Recent studies have advocated for further cross-sectional imaging to estimate the extent of injury.
- Treatment goals are to restore the extensor mechanism, as well as the articular surface of the knee joint.
- The prognosis of tibial tubercle fractures is generally favourable, however, there are some common complications to be aware of.

Curriculum checklist

This article addresses the following requirements of the trauma & orthopaedics curriculum:

- Anatomy of bones and joints in the growing child and its application to growth and deformity.
- Fractures in children and growth plate injuries.
- History and examination of the child.
- Indications for and interpretation of plain X-ray, CT, and MRI in children.
- Compartment syndrome.
- Neurovascular injury.
- Rehabilitation of the child.

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Availability of data and materials

All data and materials of this study are included in this article.

Author contributions

VK, CP, AS, AH and SNMS designed the research. VK drafted the manuscript. All authors contributed to important editorial changes in the manuscript. All authors read and approved the final manuscript. All authors have participated sufficiently in the work and agreed to be accountable for all aspects of the work.

Ethics approval and consent to participate

Not applicable.

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Conflict of interest

The authors declare no conflict of interest.

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