

Tibial Tuberosity Avulsion Fracture in an Adolescent and its Anatomical and Clinical Relationships: Case Report

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ABSTRACT

Introduction: tibial tuberosity avulsion fractures (TTAF) occur are rare in children and adolescents, predominantly in males and typically during sports activities. The injury mechanism involves a sudden knee flexion associated with an eccentric contraction of the quadriceps femoris muscle. The treatment of choice follows classification criteria and involves either closed reduction or open reduction with fixation. The prognosis is excellent, and most patients return to sports activities without complications.

Objective: To report a case of TTAF in a female adolescent during a soccer match and discuss the associated anatomical and clinical correlations.

Case Report: a 13-year-old female adolescent presented an injury during a school soccer match and was referred to the emergency department with severe knee pain, edema, and an inability to extend the leg or bear weight. Radiography and computed tomography confirmed TTAF with anterior metaphyseal involvement. Treatment involved closed reduction of the fracture, immobilization with a long leg cast encompassing the entire lower limb, and physiotherapy. Subsequently, the patient-initiated strength training and returned to sports activities. However, she developed pes anserinus tendinitis and was referred to physiotherapeutic treatment, resulting in significant improvement.

Conclusion: the patient has currently resumed sports activities without any complications related to the fracture. Appropriate treatment based on fracture type and physiotherapeutic rehabilitation were key factors in achieving full recovery.

Keywords: Tibia; Fracture; Avulsion; Tibial tuberosity.

Introduction

Physal fractures, also known as Salter-Harris fractures, are characterized by injuries to the epiphyseal plate and, therefore, occur exclusively in children and adolescents during their growth phase^{1,2}. These fractures are more common in the upper limbs and predominantly affect males since they engage more frequently in high-risk activities predisposing to injury^{3,4}.

Tibial tuberosity avulsion fracture (TTAF) is a less common type, accounting for approximately 3% of physal fractures in individuals aged 12 to 14 years⁵⁻⁷, and it typically occurs during sports activities⁸.

The TTAF were first classified in 1955 by Watson-Jones⁹. In 1980, Ogden *et al.* expanded Watson-Jones' classification by introducing subtypes¹⁰, followed by additional subtypes proposed by Ryu & Debenham¹¹ in 1985, and Mackoy¹² in 2003. As a result, these fractures can be categorized into types I to V, with types I to III further subdivided into two subtypes each. This classification is based on the location of the fracture line and the presence or absence of displacement of the bone fragment.

Considering that tibial tuberosity fractures can involve the epiphyseal plate, they can also be classified according to the Salter-Harris criteria¹³, which provides

a classification system for fractures affecting this structure. Consequently, when the epiphyseal plate is compromised, there is a risk of impaired bone growth and the development of deformities such as genu recurvatum^{14,15}. Although rare, other complications may also occur, including compartment syndrome, bursitis, and anterior cruciate ligament injury^{4,15,16}.

The treatment of TTAF depends on the classification type and involves immobilization, closed reduction or open reduction with fixation^{6,10,12}. The prognosis is excellent, with most patients returning to sports within 3 to 4 months post-fracture without complications^{4,6,15}.

This study aims to present a case report of a 13-year-old female adolescent who presented a tibial tuberosity avulsion fracture during a soccer match, analyze the associated anatomical and clinical correlations, and describe the conservative treatment approach.

This research was approved by the Human Research Ethics Committee of the Health Sciences Center (CAAE: 82704024.0.0000.5060 / Decision number: 7.126.030).

Case Report

A 13-year-old female patient experienced sudden and intense pain in her right knee after forcefully kicking a soccer ball during a match. In addition to

pain, she presented with an inability to extend the leg or bear weight, along with significant edema in the proximal anterior region of the leg. She was taken to the hospital emergency department, where intravenous analgesia was administered, followed

by imaging studies, including radiography and computed tomography (CT) of the affected knee. The imaging confirmed a tibial tuberosity avulsion fracture with anterior metaphyseal involvement (Figures 1-2).

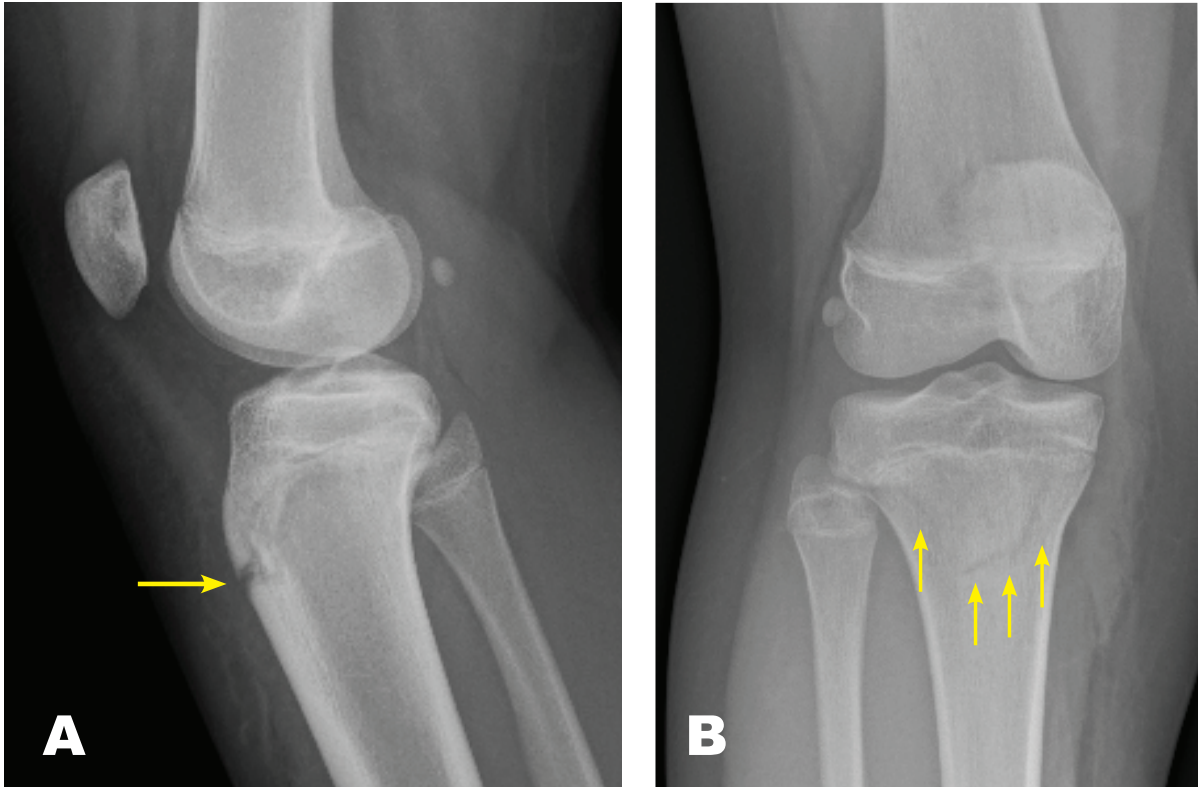


Figure 1. Lateral (A) and anteroposterior (B) radiographs of the right knee showing a fracture (arrows) of the tibial tuberosity extending to the tibial condyles. Images were obtained on the day of the fracture occurrence.

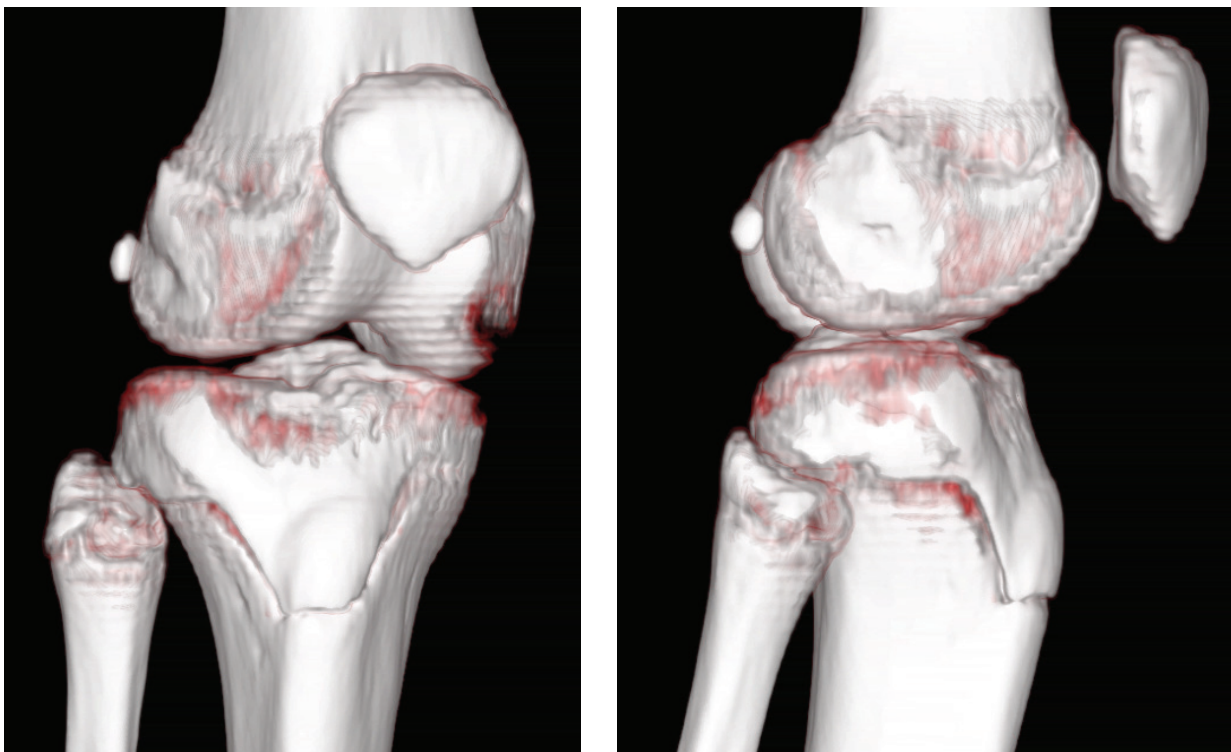


Figure 2. Computed tomography (CT) images of the right knee showing a fracture of the tibial tuberosity extending to the tibial condyles. Images of the right knee obtained on the day of the fracture.

Initial management included immobilization of the leg in a semi-flexed position using a semi-rigid splint encompassing the entire lower limb. Two days later, a closed reduction of the fracture was performed under sedation in the operating room, followed by immobilization with a long-leg cast covering the thigh, leg, and foot. After three weeks, follow-up radiography showed signals of the partial consolidation with maintenance of the reduction. The cast was then removed and replaced with a long rigid splint covering the thigh and leg, allowing the foot to remain free, enabling the patient to walk and remove the splint for short periods during the day. This immobilizing splint was used for two weeks, after which another radiograph was performed (Figure 3), confirming fracture consolidation.

The patient was then referred to physiotherapy, where she submitted passive mobilization exercises, stretching of the leg and thigh muscles, gait training, knee and foot flexion-extension exercises against gravity only, light proprioception exercises, and hydrotherapy. After two weeks, resistance exercises with elastic bands were introduced to strengthen the gluteal, thigh, and leg muscles. Subsequently, the patient progressed to strength training at a gym for 4 weeks and right away resumed sports activities, including soccer concomitantly to strength training.

Concurrently, she began experiencing moderate pain in the proximal medial tibia during movement and was diagnosed with pes anserinus tendinitis. As a result, all exercises were discontinued, and a new

four-week cycle of physiotherapeutic treatment was initiated. At the end of this rehabilitation period, the patient resumed sports and recreational physical activities without any limitations. This was the single complication observed following the fracture.

Discussion

The knee is a complex synovial joint composed of the femur, tibia, and patella, stabilized by ligaments, tendons, and surrounding musculature. Functionally, it plays a crucial role in weight-bearing and movement, allowing flexion, extension, and limited rotation. The tibial tuberosity serves as the distal attachment site for the patellar ligament, which transmits the force generated by the quadriceps femoris muscle to extend the leg. Due to the close anatomical relationship between the tibial tuberosity and adjacent structures, fractures in this region can potentially compromise the growth plate, patellar tendon, and surrounding soft tissues. This may lead to complications such as genu recurvatum, patellar instability, compartment syndrome, and, less commonly, anterior cruciate ligament injury⁴.

The most severe complication arising from TTAF is compartment syndrome, which may occur due to injury to the anterior tibial recurrent artery (ATRA)¹⁷. After the anterior tibial artery (ATA) traverses the interosseous membrane of the leg, the ATRA branches off and follows an ascending course, passing anterior to the tibial tuberosity (TT) before terminating in an anastomosis with the patellar arterial network¹⁸. In TT

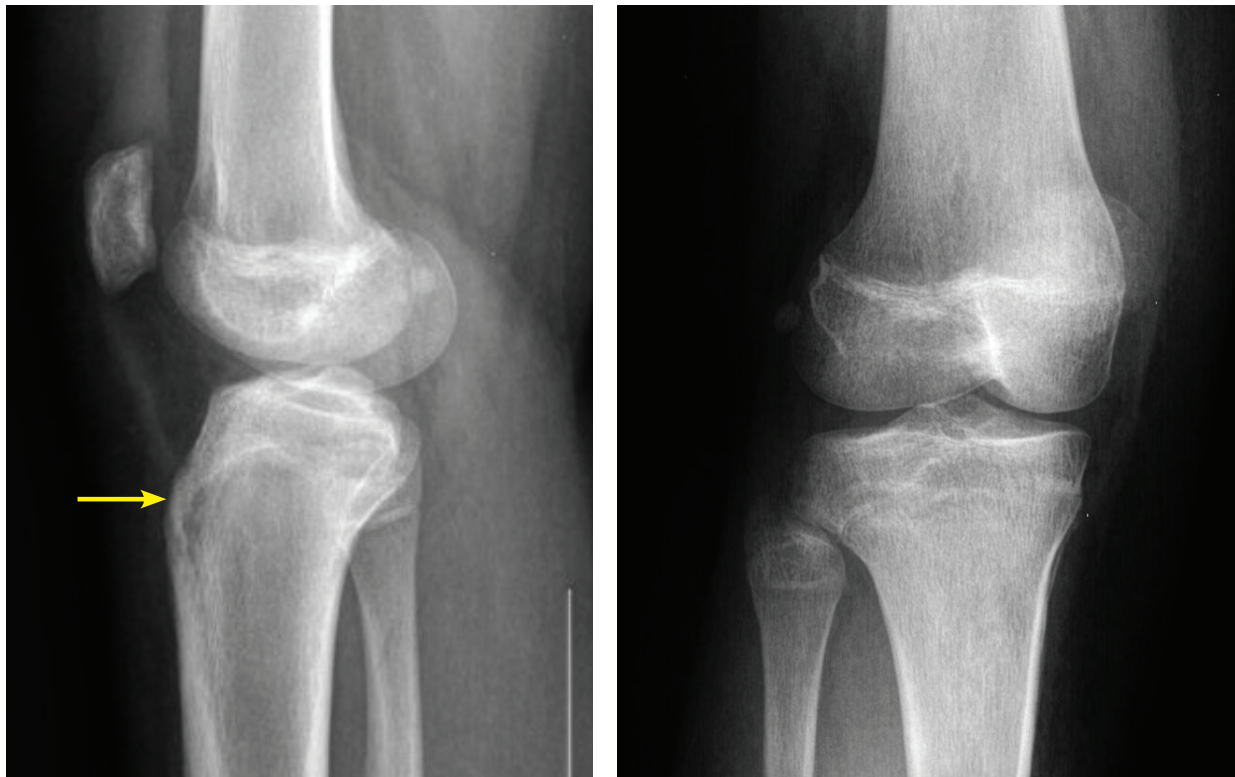


Figure 3. Lateral (A) and anteroposterior (B) radiographs of the right knee showing the healing process of the tibial tuberosity. Image obtained 10 weeks after the fracture.

fractures, anterior and/or superior displacement of the entire TT or a bone fragment may result in ATRA rupture. Consequently, blood accumulates within the anterior fascial compartment of the leg, leading to compression of the regional muscles, vessels, and nerves, ultimately causing tissue necrosis^{17,19}. In such cases, an urgent surgical approach is required to decompress the affected anatomical structures¹⁹. In the present case, the risk of compartment syndrome was low, as there was no significant displacement of the TT or bone fragments (Figure 1).

Tibial tuberosity fractures in adolescents are frequently associated with sports involving jumping, such as soccer, volleyball, basketball, handball, running, and gymnastics⁸. The injury mechanism typically involves the abrupt concentric contraction of the quadriceps femoris muscle to extend the leg, generating propulsion at the initiation of a jump. The injury can also occur during landing, when the quadriceps undergoes eccentric contraction to control knee flexion^{3,4}.

Although rarely mentioned in the literature, another trauma mechanism that can trigger TTAF is the abrupt and forceful concentric contraction during leg extension, as seen in kicking movements³. This information aligns with the injury mechanism described in this case report. Such movements may also be associated with knee rotation, which can further contribute to the injury mechanism⁷.

The tibial tuberosity serves as the insertion site for the quadriceps femoris muscle via the patellar tendon. Consequently, this structure experiences significant tensile forces generated by the quadriceps during leg extension, such as during a kicking motion. These forces are particularly amplified in sports activities, where movements tend to be more abrupt and forceful²⁰.

In the present case, radiographic imaging of the contralateral leg (not shown) confirmed that the patient's tibial tuberosity was fully ossified. However, its fusion to the metaphysis usually occurs between 13 and 16 years in females. This transition phase can create a biomechanical weakness, making the region more susceptible to avulsion fractures under high tensile forces. This is clearly observed in the fracture pattern (Figures 1 and 2), which closely resembles the contours of the epiphyseal plate seen in growing adolescents²¹.

Although no visible epiphyseal plate was present in the contralateral leg, and the literature suggests that ossification of the tibial tuberosity is generally complete by 12 years of age in females, the ossification process in this case appears to be relatively recent. This suggests that the epiphyseal

line was still undergoing its final maturation, making it more susceptible to avulsion at the time of the injury.

The TTAF are often mistaken for Osgood-Schlatter disease, as both conditions affect the tibial tuberosity in adolescents undergoing growth and are commonly associated with sports activities. Although Osgood-Schlatter disease may play a role in the pathogenesis of the fracture, it typically involves an avulsion limited to the apex of the tibial tuberosity rather than the entire structure, as seen in avulsion fractures²². Additionally, Osgood-Schlatter disease tends to follow a chronic course and may be asymptomatic or present with mild symptoms³.

Considering that the fracture pattern in the present case presented a small deviation and was exhibited intermediate characteristics between type IA and IB (Figure 1) according to Ogden *et al.* (1980), a non-surgical reduction was performed before immobilization to realign the bone fragments and promote optimal healing. Surgical reduction with fixation is recommended when there is displacement of one or more tibial tuberosity fragments or when the fracture extends through the epiphyseal plate and reaches the articular surface¹⁰. Therefore, surgical fixation is indicated for type IB fractures, all type II and III fractures, as well as type IV and V fractures^{10-12,23}.

As a complication of the fracture, the patient developed tendinitis of the tendons inserting at the proximal anteromedial tibia, precisely in the region of the fracture. This condition, clinically known as pes anserinus tendinitis, involves the tendons of the semitendinosus, gracilis, and sartorius muscles. No reports of this specific complication were found in the literature. The development of tendinitis may be attributed to potential adhesion of these tendons at the fracture site due to fibrotic healing tissue. This complication may also be explained by muscular imbalance caused by muscular inhibition resulting of fracture as well by muscular hypotrophy arising immobilization.

Physiotherapeutic treatment was implemented, leading to a reduction in fibrotic adhesions, improved mobility, and pain relief, ultimately allowing the patient to return to sports activities.

Currently, the patient exhibits no complications from the injury and engages in all physical and sports activities without limitations. We believe that the choice of an appropriate treatment strategy based on the fracture type, along with a well-structured physiotherapeutic rehabilitation program according to the clinical condition, were key factors in achieving full recovery.

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