A 16-year-old male student football (soccer) player was participating in a training session when he was tackled directly from in front while taking a shot at the goal. He immediately experienced excruciating pain in his right knee and fell to the ground. He was unable to ambulate after the event. He was assisted from the field of play to the sidelines, where he noticed swelling of the knee. He was subsequently transported to the authors’ institution for medical care. On examination approximately 1 hour later, he was seen holding the knee in flexion and had global swelling to the knee. A bony fragment was palpated in close proximity to the tibial tuberosity. The patient was unable to do a straight leg raise. There were no neurovascular deficits.

Radiographs revealed a completely displaced avulsion fracture to the tibial tuberosity. He was diagnosed as having a tibial tuberosity avulsion fracture. Operative intervention was undertaken. The initial attempt at percutaneous fixation failed and open reduction was undertaken via an anterior midline incision. Operative findings included a completely avulsed tibial tubercle with complete separation of the patella tendon at the enthesis (Figures 1-2).

An intraoperative diagnosis of an Ogden Type IIC tibial tuberosity fracture was made. The fracture was fixed with three 4-mm diameter lag screws placed in a triangular configuration. The patellar tendon was then reattached using a #2 polydioxanone suture passed as a continuous Krakow darn through the distal patellar tendon to oblique drill holes passed through the reattached fragment and the proximal tibial bed inferolaterally. The
The construct was then protected by the passage of a cerclage wire through the patella and proximal tibia to limit effective quadriceps pull (Figures 3-5).

Postoperatively, he was allowed a range of motion of 0° to 50°. This was
gradually increased by 20° every 3 weeks. Cerclage wires were removed at 2 months and the patient returned to full activity at 5 months postoperatively. He had no extension lag with a range of motion of 0° to 140° and follow-up continues in the authors’ outpatient department.

**DISCUSSION**

The tibial tubercle is a traction apophysis of the proximal tibia. This tubercle develops as a traction apophysis under tension. It is composed initially of fibrocartilage, which is replaced gradually by columnar hypertrophic physal cartilage around the time of physiodesis. Physiological physiodesis at this center takes place in the posterior to anterior and superior to inferior directions. Whereas fibrocartilage is resistant to tensile forces, the hypertrophic columnar physal cartilage that replaces it during physiological physiodesis is not. During the transitional period to physeal closure, the most inferior aspect of the extensor mechanism of the knee (ie, the tibial tubercle) becomes susceptible to injury from the tensile forces to which it is constantly exposed. The mechanism of injury is thought to involve active quadriceps contraction with a flexed knee. This combined with a muscular imbalance is thought to produce avulsion type injuries. Patients with this pathology tend to have well-developed quadriceps muscles capable of exerting tremendous forces across the extensor mechanism of the knee. The fracture pattern that results has many possible combinations, and the classification of these fractures has evolved. The first classification of tibial tubercle fractures was formulated by Sir Reginald Watson-Jones, who originally described 3 types. Type I was described as an avulsion of the distal part of the tibial tubercle, distal to the proximal tibial physe. Type II extended across the physe but did not enter the knee joint. Type III was an avulsion that extended proximal to the physe into the knee.

Ogden et al further modified this classification system by looking at other parameters that impacted management, including displacement and comminution, adding a type A and B if any of these parameters were met. In the Type I pattern, if there was mild anterior displacement, then it was designated a Type IA. Type IB was used to describe those in which the fractured segment was separated from the metaphysis. A Type II injury without comminution was designated as Type IIA, while one with comminution was designated as Type IIB. Likewise, a Type III injury with a single fragment was designated as Type IIIA, while one with comminution was designated as Type IIIB.

The addition of a Type IV was suggested by Ryu and Debenham to describe tibial tuberosity fractures that extended along the proximal tibial physe posteriorly (ie, an avulsion of the entire proximal epiphysis).

Frankl et al then proposed a Type C for fractures with associated patella ligament avulsions, as in the current case. A Type V was later proposed by McKoy and Stanitski, which consists of a Type IIIB fracture with an associated Type IV fracture creating a “Y” configuration. Of all these possible fracture patterns and combination of injury, the Frankl Type C fractures remain a rare entity.

The reported frequency of Type C fractures varies in the literature. Bauer et al found a Type C injury pattern in 5 of the 22 patients in their series. Other series subsequent to this found lower ratios. The injury pattern is more common in Type II and III injuries. However, association with Type I has been reported.
The mechanism responsible for this synchronous injury (ie, avulsion of both the tuberosity and the patella tendon), as in this case, has not been clearly defined. Apart from Mayba, who postulated that continued contraction of the quadriceps after avulsion of the tuberosity was responsible for the injury pattern, there is sparse mention of possible mechanisms in the literature. The possibility of associated injuries is, however, well documented in the literature, and a high index of suspicion must be maintained. These include injury to the meniscus, cruciate and collateral ligamentous injury, and injury to the patella ligament as seen in the current case.

The presence of a patellar tendon avulsion (ie, Frankl Type C injuries) has significant management implications, and therefore clinical detection is of utmost importance. Clinical diagnosis of this double-hit phenomenon may prove challenging. There are, however, some clues that may heighten one’s suspicion. A palpable patella ligament gap and the patient’s inability to actively extend the knee against gravity are clinical clues. These, however, may be difficult to appreciate because of swelling or severe pain. Radiographic parameters may also assist in making a preoperative diagnosis. The presence of patella alta on lateral radiographs of the knee done at 30° and the presence of multiple calcified fragments below the patella on radiographs are diagnostic clues. The calcified fragments are thought to represent the avulsed flap of the tubial tubercle periosteum still attached to the distal aspect of the patellar ligament.

Frankl et al observed increased distance in the patella to tubial tuberosity distance in flexion extension views and suggested this as a radiographic diagnostic clue. Diagnostic arthroscopy and magnetic resonance imaging have been used by some to identify associated lesions because of the rate of concomitant chondral, meniscal, and cruciate ligament injuries. The use of magnetic resonance imaging would surely increase diagnostic accuracy but may not prove to be cost-effective for such a rare phenomenon.

Current treatment paradigms of tubial tubercle fractures include both percutaneous and open fixation. Type C injuries mandate repair of the patella tendon; therefore, an open approach is indicated. Preoperative clinical diagnosis is often difficult, but due to the rarity of this double-hit phenomenon, routine magnetic resonance imaging is not justified. It is the authors’ belief that displaced tubial tuberosity fractures should only be treated with closed reduction and internal fixation if advanced imaging (ie, ultrasound or magnetic resonance imaging) is done and identifies no associated injuries. In cases in which it is not practical to do advanced imaging, then routine open reduction and internal fixation should be done in which the insertion of the patella tendon is visualized.

REFERENCES