ORIGINAL ARTICLE • KNEE - PAEDIATRIC

Management of pediatric tibial tubercle fractures: Is surgical treatment really necessary?

P. Checa Betegón[1] · C. Arvinius[1] · M. I. Cabadas González[1] · A. Martínez García[1] · R. Del Pozo Martín[1] ·
F. Marco Martínez[1]

Abstract
Fractures of the anterior tibial tubercle are infrequent lesions. They often occur in male adolescent athletes, usually in relation with sports involving powerful jumps. We present a retrospective study of 10 patients, with an average age of 15.1 years, all of them males, and a total of 11 acute avulsions of the anterior tibial tubercle. We analyzed the etiology of the lesion, the type of treatment used as well as non-weight bearing period, protected immobilization period, and time until sports reincorporation. We obtained 11 acute avulsions: one case of type I; three cases of type II; four cases of type III; and three cases of type IV. Five cases were treated conservatively, including the three cases of type IV, and surgery was only performed in six cases since an anatomical reduction was not obtained with closed reduction. The results were satisfactory in all cases, with 100% percentage of sport reincorporation in less de 25 weeks. We registered only one complication, intolerance of material, which did not require additional surgeries. These fractures, although rare, have an excellent prognosis. Even if they are often treated surgically, we have obtained good results with the conservative treatment in patterns previously reported as surgical.

Keywords Anterior tibial tubercle avulsion · Anterior tibial tubercle fracture · ATT fracture · Proximal tibia fractures · Pediatric fractures of the tibia

Introduction

The anterior tibial tuberosity (ATT) serves as the insertion to the leg's extensor apparatus. Its ossification center appears in ages between 11 and 14 years and ossifies approximately at ages between 14 and 18 years [1, 4]. Acute avulsions at this level are rare, representing 0.4–2.7% of pediatric fractures and less than 1% of the physeal lesions [9]. It is a lesion typically seen in teenagers, with an average age, according to the literature of 14.6 years [1, 9]. It occurs more frequently in males, 97%, and usually in the left leg, given that it is usually the propulsive leg in right-handed patients.

Watson and Jones described the original classification with three types of fractures, which was later completed by Ogden adding subtypes A and B. Then, finally, Ryu and Debenham added type IV pattern, consisting of an avulsion of the ATT whose fracture line continues from the proximal anterior physis of the tibia posteriorly as if it were a type I or II epiphysiolysis of the Salter and Harris' classification system [2, 6]. See Table 1.

There are two proposed causal mechanisms, both related to sports that involve jumping. In the anglo-saxon literature, this lesion is often related to basketball [3, 14]. The first one of these mechanisms is a powerful contraction of the quadriceps, to push-off for a jump, on a bent knee. The second one consists of a passive knee flexion, with a contracted quadriceps, during landing after a jump. The degree of knee flexion determines the fracture pattern and whether or not the articular surface will be involved [9].

Most of the published papers regarding this lesion consist of isolated clinical cases [5, 6, 8, 10, 13]. Our aim is to present our series of 11 avulsions of the ATT and to analyze whether the treatment applied influenced the results.

✉ P. Checa Betegón
  pachebet@gmail.com

1 Department of Traumatology and Orthopaedic Surgery,
   Hospital Clínico Universitario San Carlos, Madrid, Madrid,
   Spain

Table 1 Ogden classification

Classification of tibial tubercle avulsion fractures	
IA	Fracture distal to junction of ossification center of proximal tibial epiphysis and tuberosity
IB	Same as IA, but with fragment comminution
IIA	Fracture extension to junction of proximal tibial physis
IIB	Same as IIA, but with fragment comminution
IIIA	Fracture extends into joint through proximal tibial epiphysis with displacement of fracture fragment
IIIB	Same as IIIA, but with fragment comminution
IV	Fracture extension transversely through proximal tibial physis with displacement of fracture fragment

Materials and methods

Using our database, we conducted a retrospective descriptive study, between the years 2011 and 2017, of patients who presented this type of injury and who had a minimum follow-up of 12 months. Patients with other injuries of the proximal tibia or with the lesion described but whose follow-up time was shorter were excluded, as we considered the information these cases could provide would not be definitive enough, such as sports reincorporation and level of activity or pain or other long term complications, such as growth disturbance. We obtained a sample of 10 patients and 11 avulsion fractures of the ATT, the patient who injured both his tuberosities did not do so simultaneously. The average age was 15.1 years (12–16 years), and the average time of final follow-up was 56.3 months (12–82.4). Sport was the cause of the injury in 8 of the 11 avulsions, football being the most common (4 cases). Other sports registered in this series were basketball (2 cases), handball (1 case), and a case of vaulting horse jumping (1 case). The demographic data are described in Table 2.

X-rays were taken on arrival at the emergency department, which were afterward used to classify the lesions according to the modified Ogden classification. When needed CT or MR was used to confirm the fracture. Serial radiographs were taken later during follow-up. According to the classification previously described, in our series, we found a case of fracture I, three cases of fracture type II, four cases of type III pattern, and three cases of type IV (see Table 2).

These injuries were treated by the on call team the day of reception or the day afterward. Therefore, the treatment decision was based mainly by the chief surgeon. Normally, we would try a close reduction and immobilization, no matter the type of pattern. However, if closed reduction is not achievable or reduction unsatisfactory, or there is a loss of active extension, an open reduction and internal fixation would be performed.

We analyzed the type of treatment used, conservative versus surgical, and in the case of the later, the time of surgery, type of osteosynthesis, and whether or not there was any associated action during surgery. The times of immobilization without weight bearing and protected immobilization with an articulated orthosis were registered, as well as the time until the sport reincorporation and whether this was at the same level as the one that the patient had before the injury. Normally, the conservative cases were immobilized with a cast 4–5 weeks and then an articulated orthosis the following 2 weeks (flexion limited to 50° the first week and then 90° the second week). The surgical patients were immobilized with a cast 4 weeks and another 3 weeks with orthosis (1 week with flexion limited at 50° and 2 weeks at 90°). When changing to the orthosis, protected weight bearing was initiated in both groups as well as active flexo-extension and quadricep-strengthening exercises.

We then compared the results and timings obtained in both surgical and conservative groups using the Mann–Whitney U test.

Results

In our series, five cases were treated conservatively, corresponding to one case of type I, one case of type II, and three cases of type IV (see Fig. 1); compared to six cases that were treated surgically, being these two cases of type II and four cases of type III (see Fig. 2). The conservative treatment consisted of splint immobilization in full extension in the emergency room, with exception of two of the three type IV cases, which required closed reduction in the operating room under sedation before immobilization due to pain. As for the surgical treatment, the standard treatment in our center was open reduction and osteosynthesis with cannulated screws, one, two, or three depending on the size of the fragment (one case with one screw; two cases with two screws and three cases with three screws). The average time of surgery was 75.5 (ranging from 45 to 90 min approximately) minutes, and there were no major incidences in any of them. Three of the cases presented associated actions during surgery: one prophylactic fasciotomy (in a type IIIA) and two cases

Table 2 Epidemiologic, demographic, and etiologic data. Treatment and times of loading and sport reincorporation

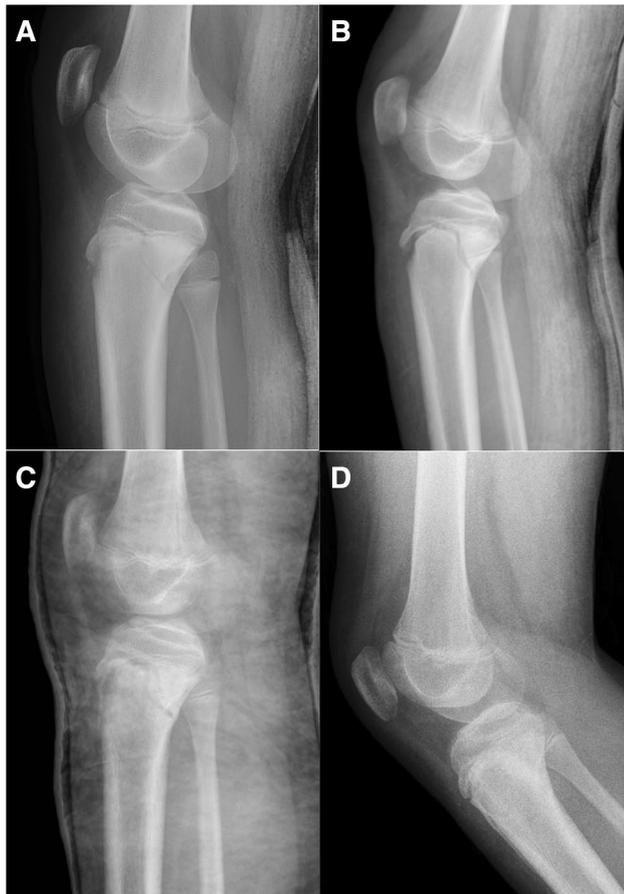| Lesion	Patient	Age	Side	Sex	Sports	Mechanism	Sport	Dominance	Ogden	Treatment	Type of surgery	Associated action	Which	No weight bearing (weeks)	Time until sports reincorporation
1	1	15	Left	Male	Yes	Sport	Soccer	Right handed	IIIB	Surgical	Screws	Yes	Tendon reattachment	4.43	26.29
2	2	13	Left	Male	Yes	Sport	Soccer	Right handed	IIIA	Surgical	Screws	No	–	4.28	36.71
3	3	14	Left	Male	Yes	Sport	Basketball	Right handed	IIB	Surgical	Screws	No	–	3.71	18.86
4	4	14	Left	Male	Yes	Sport	Gymnastics	Right handed	IIB	Surgical	Screws	Yes	Tendon reattachment	4.16	11.14
5	5	13	Right	Male	Yes	Traumatism	–	Right handed	IV	Conservative	Closed reduction	–	–	4.86	20.71
6	6	16	Left	Male	No	Traumatism	–	Right handed	IIIB	Surgical	Screws	No	–	3.86	29.43
7	7	13	Left	Male	No	Traumatism	–	Left handed	IV	Conservative	–	–	–	4.14	21.14
8	8	13	Left	Male	Yes	Sport	Basketball	Right handed	IIIA	Surgical	Screws	Yes	Fasciotomy	3.86	25.86
9	9	12	Left	Male	Yes	Sport	Soccer	Right handed	IIA	Conservative	–	–	–	4.57	13.71
10	10	14	Right	Male	Yes	Sport	Soccer	Right handed	IA	Conservative	–	–	–	4.43	12.29
11	10	14	Left	Male	Yes	Sport	Handball	Right handed	IV	Conservative	Closed reduction	–	–	4.28	21.57
Media														4.23	21.61
SD														0.34	7.72
Median														4.28	21.14

Fig. 1 A 13-year-old male with a type IV ATT avulsion of the right leg after a forced passive leg flexion from an improper jump reception (non-sports-related). The patient was treated with a cast in the emergency room which was removed after 34 days and changed for an articulated orthosis for 19 days (flexion limited to 50° the first week approximately and then 90°) and active flexo-extension exercises were explained. The patient did not required extra rehabilitation. It took the patient approximately 21 weeks to recover and practice sports at the same level prior to the lesion. The images show AP and lateral radiographs at **a** 1 day after reception; **b** 1 week; **c** 1 month and **d** 3 months)

Fig. 2 Type IIIA treated surgically with cannulated screws. This 13-year-old male injured his right leg after an hyperextension mechanism while playing soccer. There was no active extension of the knee and the x-rays showed a type IIIA ATT lesion. Surgical treatment was performed with open reduction and three cannulated screws and a cast was applied for 30 days. An articulated orthosis was used for another 20 days (flexion limited to 50º for one week and then 90º) allowing weight bearing, and explaining active flexo-extension exercises. He did not required extra rehabilitation. It took the patient approximately 36 weeks to recover sports ability at the same level prior the lesion.**a** X-ray at emergency room; **b** first day after surgery; **c** one month; **d** one year

of reinsertion of the patellar tendon (IIB/IIIB) (see Table 2). The fasciotomy was performed due to the intense swelling of the injured limb in order to prevent the development of a compartmental syndrome. The patients who required surgery were hospitalized one night and were discharged the day after. Patients treated conservatively, however, did not required hospitalization and were only kept in emergency for some hours for observation and for administration of analgesic treatment. All the information related to fracture pattern and treatment applied is summarized in Table 2.

Plaster immobilization and no weight bearing time on average was 4.23 weeks, showing no difference among both groups of treatment ($p = 0.40$). Global immobilization was 6.86 weeks in the conservative group compared
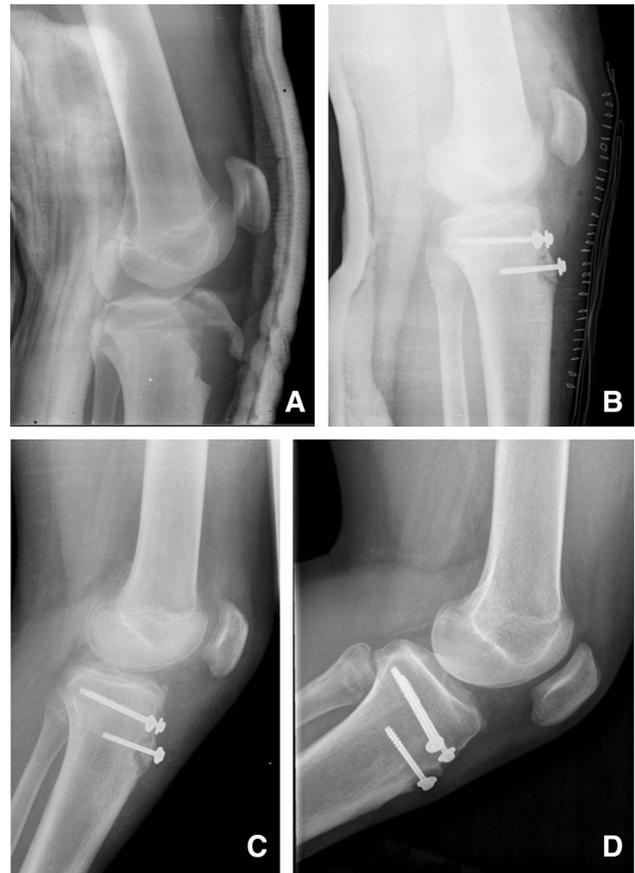
to 6.93 in the surgical group, no statistical differences were found ($p = 0.25$). Finally, sports reincorporation to previous level was achieved in all the patients that previously practiced any sport. The time until sports reincorporation was shorter in the group treated conservatively (17.86 weeks on average compared to 24.71 weeks in the group treated surgically). However, no statistical significance was found ($p = 0.26$).

We registered no cases of compartmental syndrome or of growth alterations such as genu recurvatum. We only recorded one case of discomfort related to the osteosynthesis material that did not require surgical removal nor affected the patient's sports reincorporation. Other complications described in the literature, such as surgical injury infection,

prominent tuberosity, or patella height disturbance, were not registered in this series.

Discussion

The avulsion fractures of the ATT are uncommon lesions and there are no large series to be found in the literature [4, 9, 12–15]. There are, however, systematic reviews of the literature that provide more information about these fractures and their management, such as the article published by Pretell-Mazzini [9].

These lesions occur frequently in adolescence due to the sequence and particular ossification process of this tuberosity, as described by Ehrenborg in 1962 [6]. This tubercle has four stages: the cartilaginous phase, the apophyseal phase, the epiphyseal (approximately 10–15 years in women and 11–17 in males; it is the moment of weakness in which these fractures appear, since fibrocartilage is modified histologically, arranged in cell columns from the proximal physis of the tibia to the tuberosity and is therefore less resistant to the tension of the extensor apparatus), and finally, the bone stage [6]. The average age in our review was 15.1 years, which is similar to other works in the literature [12, 14, 15].

There is a consensus in the literature that these injuries usually occur during sports practices and the most related sport is basketball [3, 14]. In our series, 8 of the 11 patients were injured while performing sports, but soccer was the responsible sport in half of those cases, probably since it is practiced more often than basketball in the Spanish society. We only had three cases in which the sport was not involved and the patients referred a casual trauma instead. It is, however, possible that it was not caused by a direct trauma itself since the mechanism described in the literature is a powerful quadricipital contraction and these patients might, in order to prevent the fall, have performed a sudden quadricipital contraction as a defense mechanism that would tear off the tuberosity [3, 14].

There is controversy in the literature on whether the traction apophysitis of the tibial tuberosity, named Osgood–Schlatter, may be a risk factor or not of these lesions. According to other works, the previous incidence of Osgood–Schlatter is 12–60% [1, 10, 14]. Due to the retrospective character of our study, it is difficult to find any possible relationship; however, when reinterrogating the patients, one of them described symptoms compatible with an Osgood–Schlatter lesion.

It has usually been considered that these lesions are predominantly surgical, other studies report 85–90% of the patients treated surgically [1, 8, 9, 14]. In general, it is recommended to treat the fractures that are undisplaced and that preserve the active extension conservatively. According to the modified Ogden classification, such fractures

are usually types IA, IB, and IIA [2, 7, 14]. Surgical treatment should be applied in displaced, comminuted or intra-articular fractures or when there is loss of extension ability (types IB, III and IV of the modified Ogden classification; see Table 1) [1, 11, 14]. Even though cannulated screws are the most widespread treatment, different surgical therapeutic alternatives have been proposed, such as reduction with fixation from Kirschner wires to compression plates (in type IV). Regardless of surgical treatment, immobilization and non-weight bearing are necessary. There are currently no conclusions about whether there is benefit in performing an arthroscopy in intra-articular fracture patterns [2]. Comparing to other studies so far we have treated conservatively a higher percentage of these injuries, including patterns that in other review papers are considered surgical, such as type IV. The choice on either conservative or surgical treatment depended fundamentally on the degree of reduction achieved by the emergency team or whether the patient was unable to extend the knee. In case of lesser displacements, a cast was applied in the emergency room, if this was considered unsatisfactory the patient was sedated in order to perform a closed reduction in the OR under fluoroscopy. When fixation was needed in order to maintain the reduction, cannulated screws were used, one, two, or three depending on the size of the fragment. Associated surgical actions were needed in three of the six surgical cases, including two reanchored patellar tendons due to an associated tendon avulsion (Table 3).

The literature recommends an immobilization and no weight bearing of about 6 weeks [9, 12, 14]. After this period, deambulation begins and other immobilizations are eliminated. However, our patients were allowed to start weight bearing earlier (at 4.23 weeks on average) with an articulated orthosis whose degrees of flexion were progressively augmented. Therefore, although the patient began weight bearing earlier, global immobilization (adding plaster and orthosis) almost doubled the time without weight bearing, being approximately 7 weeks overall. Despite this, the result was satisfactory in all cases, since all fractures consolidated, the range of movement of the joint was recovered without needing rehabilitation and all patients were able to rejoin their previous sport activity at the same level they had prior the lesion. The times to said reincorporation were shorter in the conservative treatment (17.86 weeks) compared to the surgical treatment (24.71 weeks), probably due to a tendency to be more protective in patients who underwent surgery. We have obtained excellent results, despite the conservative treatment of previously reported surgical patterns which suggests that the most important factor is to obtain a good reduction of the fracture that can be maintained either with a cast or cannulated screws, when the prior is not sufficient. We agree with the literature; these fractures have a good prognosis with percentages close to 100% of

Table 3 Comparative data with other similar studies

	Wiss et al. [12]	Mosier et al. [14]	Pace et al. [15]	Pretell-Mazzini et al. [9]	Checa et al. (2019, this study)
N knees (patients)	15 (15)	19 (18)	24 (23)	336 (325)	11 (10)
Age	15.2	13.9	14.8	14.6	15.1
Conservative/surgery	0/15	4/15	0/24	41/293	5/6
No loading (weeks)	6	4.5	–	5.2	4.2
Immobilization (weeks)	6	4.5	–	5.2	6.9
Sports reincorporation	14/15	18/18	–	248/325	(10/10)
Complications	1 compartmental syndrome	11 material intolerance	1 compartmental syndrome	1 vascular compromise	1 material intolerance
	1 non-union		1 DVT	3 superficial infection	
	1 refracture		7 material intolerance	4 genu recurvatum	
	1 superficial infection			6 refractures	
	5 material intolerance			53 material intolerance	

sport reincorporation and consolidation [7, 9, 12, 14]. (See Table 2 for comparative data with other papers.)

The percentage of complications depends on the series that we analyze, but in general, it ranges from 0 to 28% [9, 14]. The most important complications are growth disturbances and genu recurvatum and compartment syndrome, due to injury to the recurrent anterior tibial artery [5, 7, 11, 16]. In fact, in one of our patients, due to swelling and pain, a prophylactic fasciotomy was performed. This patient had no more complications afterward. However, the most frequent complication described is intolerance to the osteosynthesis material, accounting for approximately 56% of the complications which often requires material removal [9, 16]. Other complications are refracture (approximately 6%), esthetic alterations such as the prominence of the tuberosity, rigidity or high patella if there is a poor reduction [9, 16]. In our series, we had only one case of discomfort and intolerance to the osteosynthesis material that did not require additional surgeries.

Conclusions

These types of lesions are rare and often cause intra-articular compromise being therefore treated mainly surgically. However, we have treated conservatively a higher percentage of these fractures than what literature recommends, obtaining excellent results. Our work suggest at least as good results with the conservative treatment, avoiding complications such as material intolerance, which could need a second surgery. We therefore conclude that the results and prognosis of these fractures are excellent, despite the fracture pattern or treatment used as long as an anatomical reduction is obtained.

References

1. Schiller J, DeFroda S, Blood T (2017) Lower extremity avulsion fractures in the pediatric and adolescent athlete. J Am Acad Orthop Surg 25(4):251–259
2. Howarth WR, Gottschalk HP, Hosalkar HS (2011) Tibial tubercle fractures in children with intra-articular involvement: surgical tips for technical ease. J Child Orthop 5(6):465–470
3. Mubarak SJ, Kim JR, Edmonds EW, Pring ME, Bastrom TP (2009) Classification of proximal tibial fractures in children. J Child Orthop 3(3):191–197. https://doi.org/10.1007/s11832-009-0167-8
4. Khoriati AA, Guo S, Thakrar R, Deol RS, Shah KY (2015) Bilateral atraumatic tibial tubercle avulsion fractures: case report and review of the literature. Injury 46(4):767–769
5. Pape JM, Goulet JA, Hensinger RN (1993) Compartment syndrome complicating tibial tubercle avulsion. Clin Orthop Relat Res 295:201–204
6. Mata SG (1991) Fractura-avulsión de la tuberosidad tibial anterior en adolescentes. A propósito de dos casos. Revisión de la literatura. Rev Esp de Cir Ost 4:211–217
7. Medvecky M, Noonan B (2009) Fractures about the knee in children and adolescents. Tech Orthop 24(3):204–210
8. Subbu R, Nandra R, Jordan R, Krikler S (2013) Lessons learnt from managing an avulsion fracture of the tibial tubercle extending into the tibial physis. BMJ Case Rep 2031:bcr2013200551. https://doi.org/10.1136/bcr-2013-200551
9. Pretell-Mazzini J, Kelly DM, Sawyer JR, Esteban EMA, Spence DD, Warner WC, Beaty JH (2016) Outcomes and complications of tibial tubercle fractures in pediatric patients: a systematic review of the literature. J Pediatr Orthop 36(5):440–446

10. Narayana Gowda BS, Mohan Kumar J (1903) Simultaneous bilateral tibial tubercle avulsion fracture in a case of pre-existing osgood-schlatter disease (OSD). J Orthop Case Rep 2(1):24–27

11. Brey JM, Conoley J, Canale ST, Beaty JH, Warner WC, Kelly DM, Sawyer JR (2012) Tibial tuberosity fractures in adolescents: is a posterior metaphyseal fracture component a predictor of complications? J Pediatr Orthop 32(6):561–566

12. Wiss DA, Schilz JL, Zionts L (1991) Type III fractures of the tibial tubercle in adolescents. J Orthop Trauma 5(4):475–479

13. Kaneko K, Matsuda T, Mogami A, Obayashi O, Iwase H, Kurosawa H (2004) Type III fracture of the tibial tubercle with avulsion of the tibialis anterior muscle in the adolescent male athlete. Injury 35(9):919–921

14. Mosier SM, Stanitski CL (2004) Acute tibial tubercle avulsion fractures. J Pediatr Orthop 24(2):181–184

15. Pace JL, McCulloch PC, Momoh EO, Nasreddine AY, Kocher MS (2013) Operatively treated type IV tibial tubercle apophyseal fractures. J Pediatr Orthop 33(8):791–796

16. Skaggs DL (2006) Chapter 23, Extra-articular injuries of the knee. In: Beaty J, Kasser J (eds) Rockwood & Wilkins' Fractures in children, 6th edn. Lippincott Williams & Wilkins, Philadelphia, pp 938–984