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Avulsion fractures of the tibial tuberosity in adolescent athletes treated by internal fixation and tension band wiring

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Abstract Avulsion of the tibial tuberosity is a rarely reported fracture. It is mainly considered as an athletic injury accounting for less than 3% of all epiphyseal lesions. In this study, we hypothesized that the use of tension band wiring as a supplement of the internal fixation for the avulsion fractures of the tibial tuberosity would lead the adolescent athletes to a more effective rehabilitation program and an earlier resumption of their previous activity level. Ten patients were treated in our department over a period of 11 years (1985–1995). Operative treatment was thought necessary for all our cases due to tibial tuberosity displacement. Open reduction and internal fixation in combination with tension band wiring was used. The result in all cases was that the reduction was maintained intact and the fracture united. The functional results were excellent, and all patients returned to their previous athletic activities. Our conclusion is that the combination of internal fixation and tension band wiring for avulsion fractures of the tibial tuberosity seems to be more effective and advantageous than conservative or other surgical methods. Avoiding the need of external support and allowing early joint motion, the method described prevents serious quadriceps atrophy, allowing the young athletes to return earlier to their previous sport activities.

Keywords Tibial tuberosity · Avulsion fracture · Internal fixation · Tension band wiring

Introduction

An acute avulsion fracture of the tibial tuberosity is a dramatic but fortunately uncommon injury, which usually occurs during sport activities. In adolescents this type of fracture accounts for less than 3% of all epiphyseal plate injuries [5, 14, 19, 26]. Up to 1986, 150 fractures had been reported in 145 patients [7].

Avulsion fracture of the tibial tuberosity is often the result of one of four actions: (a) springing off for a jump, (b) bad landing on one foot after a jump, (c) impeded extension; or (d) forced flexion [1]. The mechanism of injury is related to the tensile forces exerted by the quadriceps and transmitted to the anterior tibial tuberosity through the patellar tendon. When these forces are greater than the combined strength of: (a) cohesive forces within the apophyseal cartilage, (b) the surrounded perichondrium, and (c) the adjacent periosteum, an avulsion fracture of the tibial tuberosity may occur [9, 22].

In this type of fracture there has been some concern about potential disturbance of growth and development of arthritic changes after the injury, since the fracture involves a growth plate and occasionally involves an articular surface [7]. Furthermore, this fracture usually occurs in adolescent athletes for whom the main goal is an early resumption of the previous activity level. If the fracture is non-displaced, conservative treatment is proposed, including cylinder cast immobilization for three to four weeks. In patients with displaced fractures, open reduction and internal fixation are required for anatomic alignment and restoration of isometry to the quadriceps – patellar

Table 1 Patients' demographic data. *M* Male, *TB + S* tension band wiring and 6.5 mm cancellous screw fixation, *TB + 2S* tension band wiring and two 6.5 mm cancellous screws fixation

No.	Sex	Age (years)	History of O-S disease[a]	Fracture type[b]	Mechanism of injury	Treatment
1	M	16	(-)	1b	Football	TB + S
2	M	16	(+)	2b	Basketball	TB + 2S
3	M	16	(-)	2a	Basketball	TB + S
4	M	14.5	(-)	2a	Jump	TB + S
5	M	16.5	(+)	1b	Basketball	TB + S
6	M	15	(+)	2a	Football	TB + S
7	M	17	(-)	2b	Football	TB + S
8	M	15	(-)	2b	Basketball	TB + S
9	M	14.5	(-)	2b	Football	TB + S
10	M	15	(-)	3a	Football	TB + 2S

[a]Osgood-Schlatter's disease
[b]Ogden's classification [19]

mechanism. In this study we considered open reduction and internal fixation supplemented by tension band wiring as the treatment of choice. We hypothesized that our technique would allow early mobilization and prevent quadriceps waste, in order to achieve a better rehabilitation and an earlier return to sport activities. We demonstrated the outcome of our technique and compared it with other techniques, reviewing the pertinent orthopaedic literature.

Patients and methods

Over a period of 11 years (1985–1995), ten patients with avulsion fracture of the tibial tuberosity were treated surgically in our department (Table 1). They were all boys, between 14.5 and 17 years old (average 15.5 years). Six of them had the left knee injured and the other four had the right one injured. All injuries were the result of a vigorous athletic activity. In particular, in four patients the injury happened at a bad landing after a high jump and in another one during a springing off a flexed knee. In the remaining five cases, the exact mechanism of injury was not clear, but all these fractures happened during a football game. All patients complained of acute pain at the anterior aspect of the knee. Physical examination revealed swelling on the proximal anterior aspect of the tibia, tenderness over the tibial tuberosity, and functional disability with complete loss of active extension of the affected knee. In three patients, a history of Osgood-Schlatter's disease was reported. Plain radiographs confirmed the clinical diagnosis.

Several classifications have been proposed for the avulsion fracture of the tibial tuberosity (Salter and Harris [24], Watson-Jones [27], Hand and coauthors [12]). We used the classification of Ogden and associates [19], which has the merit of considering both the different lines of fracture and the displacement of the avulsed fragments (Fig. 1). According to this classification, two cases were of type 1b, three cases of type 2a, four cases of type 2b and one case of type 3a. The three type 2a fractures remained irreducible after closed manipulation and could not be treated conservatively. Since all patients had a displaced fracture they were treated surgically by open reduction, internal fixation and tension band wiring.

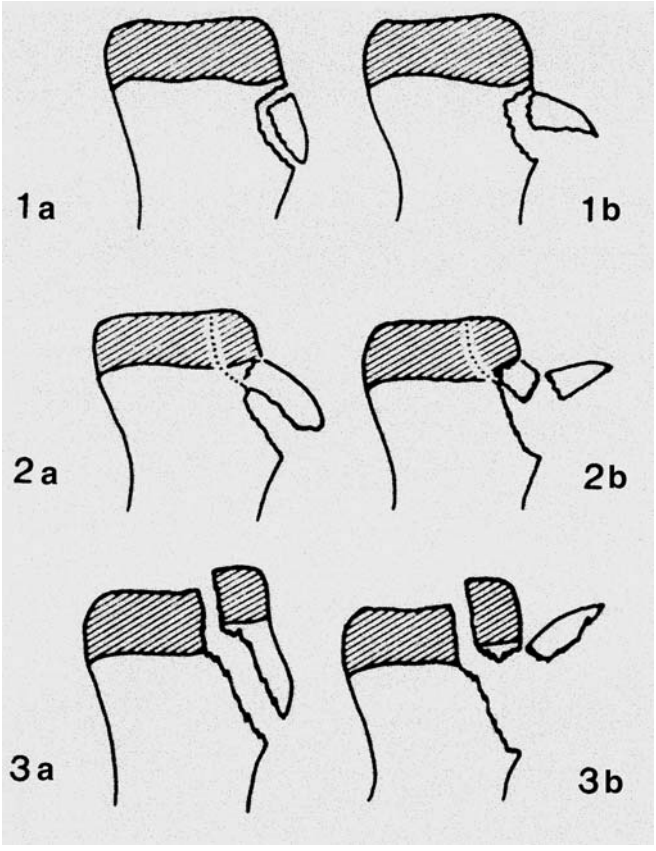

Fig. 1 Classification of tibial tuberosity fractures according to Ogden [19]. *Type 1* fracture across the secondary ossification center at level with the posterior border of the inserting patellar ligament. *Type 2* fracture at the junction of the primary and secondary ossification centers of the proximal tibial epiphysis. *Type 3* fracture propagates across the primary ossification center of the proximal tibial epiphysis into the knee joint. Each type is divided into two subtypes, *a* and *b*, depending upon the severity of displacement and comminution

Technique

The lateral parapatellar approach via a midline incision was preferred. The fracture bed was carefully cleared of debris. The periosteal flap was usually found folded under the avulsed fragment, and it was extracted. The fracture was then reduced and the patellar tendon was examined. Fixation was achieved by one 6.5 mm cancellous screw. Internal fixation was supplemented by tension band wiring in a "figure of eight" fashion (Fig. 2). The wire was driven proximally around the patella, and distally around a cortical screw fixed in the upper tibial diaphysis. In two cases, fixation of the avulsion was completed by two 6.5 mm cancellous screws (Fig. 3).

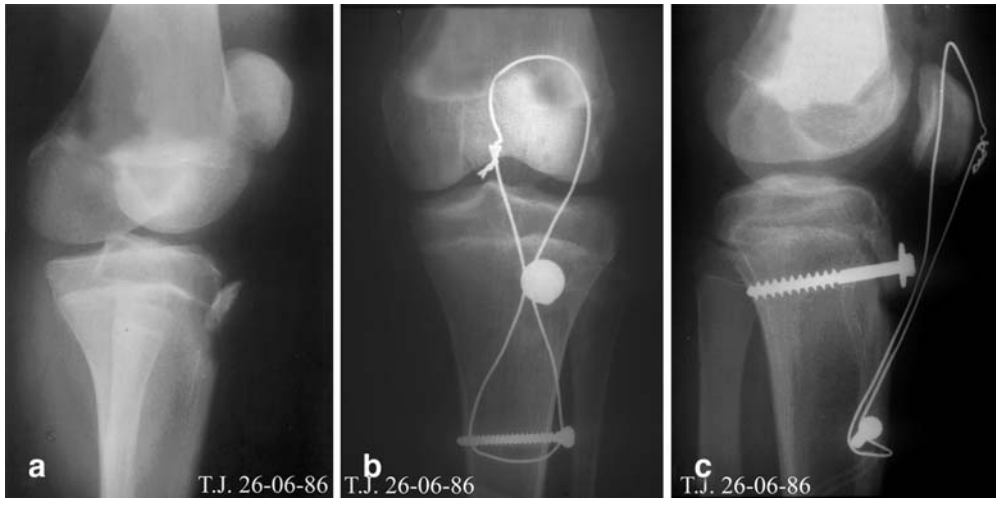

Fig. 2a–c Type 2b fracture of the tibial tuberosity of a 15-year-old basketball player (**a**). The fracture was treated by internal fixation with a 6.5 mm cancellous screw supplemented by tension band wiring (**b, c**)

Fig. 3a–d Type 2b fracture of the tibial tuberosity of a 16-year-old basketball player (**a**). In this fracture two screws were needed (**b, c**). Six weeks after surgery, the wire and the cortical screw were removed (**d**)

Fig. 4a, b Type 3a fracture of the tibial tuberosity of a 15-year-old football player with no history of Osgood-Schlatter's disease (**a**). Four years after surgery the epiphyseal plates were closed, and no complications associated with growth disturbance were observed (**b**)

Compression was always parallel to the growth plate. The periosteum was sutured and the skin was closed with separate stitches on a suction drainage. Before closure, a flexion-extension test of the knee was always performed. No cast immobilization was applied, and guarded physiotherapy was started early in the first postoperative days. The boys were walking on two crutches without weight bearing for six weeks. The wires were removed at six weeks and weight bearing was allowed (Fig. 3d).

Results

Follow-up was carried out at an average of five years. Reduction was maintained and the fracture united in all cases

(Fig. 4). Full range of motion was regained between the fourth and the eighth week post-operatively. Quadriceps wasting was present in all patients, but they regained full muscle mass within three months post surgery. All patients resumed their previous sports activities three months after surgery.

We did not observe any patella baja (infera) or alta or genu recurvatum and the line of epiphysis of the proximal tibia was closed without deformity of the bone. Neither growth disturbance nor leg length discrepancy was observed (Fig. 4). Only minor complications such as a prominent and uncomfortable tibial tubercle were noticed in two cases.

Discussion

The tibial tuberosity is a well-defined cartilaginous structure by the end of embryonic life [19, 20]. The secondary ossification center is seen between the age of 7 and 9 years. Enlargement of this center is followed by its extension towards the ossification center of the proximal epiphyseal end. The physeal cartilage of the tibial tuberosity presents a particular fibrocartilaginous histological structure. This is thought to be a functional modification for this apophysis to withstand the normal high tensile stresses applied through the patellar tendon. Fusion of this physis is completed at the age of 13–15 years in female adolescents, and 15–19 years in male adolescents. During the pre-closure period the above-mentioned fibrocartilage tissue underlying the tuberosity is gradually replaced in a proximal to distal direction by columnar cartilage cells [19]. This tissue cannot withstand high tensile forces and under certain circumstances could mechanically fail, leading to the avulsion of the apophysis.

From a biomechanical aspect, the type of fracture seems closely related to the degree of flexion of the knee during the accident [16]. When injury occurs near complete extension of the knee or flexion up to 30°, there is an avulsion of the anterior tuberosity without fracture of the proximal tibial epiphysis. In this position, the tensile forces exerted on the anterior tibial tuberosity by the patellar tendon are directed proximally and anteriorly due to the thickness of the patella [13]. When injury occurs in further flexion, biomechanical conditions result in an avulsion involving both the anterior tibial tuberosity and the proximal epiphysis. In this case, forces applied by the extensor mechanism are exerted across the tibial epiphysis and usually cause a fragmented fracture of the apophysis extended into the upper tibial epiphysis [25]. According to Mirbey and coworkers [16], the latter is usually the result of a bad landing on one foot after high jump or of the springing off from a hyperflexed knee.

In our study, all the patients were between 14.5 and 17 years old. All cases reported in the literature, including our own, occurred in 12- to 17-year-old adolescents. The age was not closely related to the type of the avulsion fracture. Considering the fact that the proximal tibial epiphysis and the tibial tuberosity are developed from two separate ossification centers which fuse at the end of adolescence, one might think that early in adolescence, and prior to fusion of these two centers, avulsion fractures would involve only the tibial tuberosity. Furthermore, by the end of adolescence avulsion would be more extensive, involving the proximal tibial epiphysis as well. However, our own study showed that the type of injury is not closely related to the age at which it occurs. In addition, biomechanical factors as described above play a major role in determining the type and nature of the avulsion fracture.

In our series, all patients were boys. In the literature, this type of fracture seems to occur predominantly in male adolescents. The male to female ratio of tibial tuberosity avulsion fracture is 5:1 as noted in a study by Mirbey and coworkers [16]. Bolesta and Fitch reported a series of sixteen patients who were all boys [2]. This higher incidence in male adolescents is due to various factors, such as a comparatively more intensive activity by them, the participation in violent sports, a more powerful quadriceps, and possibly hormonal factors, as well as the earlier fusion in females than males [3, 20].

Simultaneous bilateral fractures are rare but have been reported [14, 15, 17]. Also, these fractures may be combined with ligament or meniscal tears [6, 10, 23]. In our study, all fractures were unilateral and no other coexisted injuries were diagnosed. Despite that, one must always examine both knees and look for other coexisting injuries.

Certain predisposing factors such as patella infera, tight hamstrings, or pre-existing Osgood-Schlatter's disease may be associated with fracture of the tibial tubercle [8, 9, 12, 14, 18, 19, 22]. These factors have not been found in our series. Gebhur and Lyndrup [11] conclude

Table 2 Comparison of the clinical features of acute traumatic avulsion of the tibial tubercle and Osgood-Schlatter's disease

	Acute traumatic avulsion of the tibial tubercle	Osgood-Schlatter's disease
Onset	Acute injury	Insidious
Symptoms	Immediate marked pain and swelling	Mild intermittent symptoms
Disability	Often unable to stand or walk	Partial disability
Treatment	Often open reduction and internal fixation	Symptomatic and supportive
Prognosis	Rapid healing and return to full activities	Fairly good and occasionally long-term symptoms with ununited ossicle

that there is an increased incidence of pre-existing Osgood-Schlatter's disease in patients with this type of injury. Ogden and Southwick [20] believe that the structural modifications of the physeal cartilage in Osgood-Schlatter's disease are responsible for alterations in the biomechanical response of this cartilage during strains transmitted by the patellar tendon. Ogden and associates [19] suggest that possible alteration of the columnar *cartilage / fibrocartilage ratio* – the latter being the weaker – in patients with Osgood-Schlatter's disease may predispose to tensile failure. Bowers [4] goes even further to conclude that avulsion fracture of the tibial tuberosity is a complication of Osgood-Schlatter's disease. Deliyannis [8] is the only one in the literature proposing familial predisposition for avulsion of the tibial tuberosity. He reported such fracture occurring in two brothers at the same age, both of whom had suffered from Osgood-Schlatter's disease. We advocate the theory that Osgood-Schlatter's disease is a predisposing factor, but should be considered separately from acute traumatic avulsion of the tibial tubercle because clinical presentation, treatment, and outcome are different (Table 2).

Considering the treatment of the avulsion fractures of the tibial tuberosity, non-displaced fractures are treated by cylinder cast immobilization for 3–4 weeks with the knee in extension. Minimally displaced avulsions (types 1a, 2a) may be treated like non-displaced ones if the displacement can be reduced by closed manipulation. In our series, three patients had type 2a avulsion fracture irreducible by closed methods. In these cases we preferred open reduction to repeated manipulations because of the great risk of damaging the delicate blood supply to the epiphysis. In patients with displaced fractures (type 1b, 2b or 3) open reduction and internal fixation are required for anatomic alignment and restoration of isometry to the quadriceps-patellar mechanism. Some authors believe that open reduction provokes a cartilaginous fusion of the tibial apophysis, thus reducing the risk of recurrence [1].

Considering the surgical approach, many authors recommend a midline vertical incision to facilitate any possible knee surgery in the future [9]. In our study, we preferred the lateral parapatellar approach via a midline incision for two reasons: (a) the direct approach to the fracture and (b) the avoidance of injuring the infrapatellar branch of the saphenous nerve [18].

Fixation of the avulsion fracture of the tibial tuberosity can be achieved by transfixing pins or screws, staples, bone pegs, tension bands or even direct suture. In our study, we preferred fixation with one or two screws and tension band wiring. The tension band wire assisted both in neutralizing tensile forces and in compressing the fractured apophysis to its bed, where it was fixed by the cancellous screw. Finally, we reinforced the fixation by repairing the torn periosteum.

The early complications after avulsion fractures of the tibial tuberosity include compartment syndrome, meniscal tears and infection [6, 10, 21]. The late complications include genu recurvatum, loss of knee flexion, patella alta, patella baja (infera) and refracture. In our cases we did not observe such complications. Genu recurvatum is a rare complication after avulsion fracture of the tibial tuberosity, despite that healing actually occurs by epiphysiodesis. This is because avulsions of the tibial tubercle almost always occur in patients whose age is close to skeletal maturity.

Regardless of the treatment (surgical or conservative), sport activities are prohibited for three months. Considering this, one might choose conservative treatment avoiding the possible complications of surgery. Having in mind that the patients are adolescent athletes, we strongly prefer internal fixation supplemented by tension band wiring. This combined internal fixation is more effective in stabilizing the fracture, avoiding the need for external support and allowing early joint motion. Furthermore, early joint motion prevents serious quadriceps wasting and avoids the need for heavy rehabilitation protocols. Comparing our technique to the simple internal fixation of the fracture, one might say that we use more hardware which might lead to complications such as infection. However, we did not notice any additional complications to those observed in cases where simple internal fixation is used. Furthermore, tension band wire was easily removed under local anesthesia six weeks after surgery.

There were some limitations to our study. Firstly, no control group was used. However, we compared our results to those of other studies that advocated different surgical techniques. Secondly, we did not utilize a subjective scoring system. We thought that the use of a scoring system or standardized knee follow variables could not provide any useful conclusions if applied in such a small and unusual set of patients.

We recommend treatment of displaced or irreducible avulsion fractures of the tibial tuberosity by open reduction and internal fixation supplemented by tension band wiring. Such fixation will allow earlier and easier rehabilitation which is very important, particularly for young athletes who need to resume their previous activity levels as soon as possible.

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