Arthroscopic treatment of type III tibial intercondylar imminence avulsion fracture with pullout sutures in skeletally immature patients

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Study design
This was a retrospective study.
Objective of the study
The objective of this study was to evaluate the results of arthroscopic reduction and internal fixation of type III tibial intercondylar imminence avulsion fracture by pullout nonabsorbable suture technique in skeletally immature patients.
Background
Tibial intercondylar eminence fracture is an intraarticular avulsion fracture of the anterior cruciate ligament (ACL) insertion. Traditionally, they can be seen between 8 and 14 years of age, and they are rare among those under the age of 8 years. The reported incidence is three per 100 000 children each year. The best functioning results are obtained after arthroscopic reduction and internal fixation by pullout sutures technique.
Patients and methods
Between March 2010 and March 2012, we received 14 patients referred from the emergency department. There were 10 males and four female patients. The right knee was involved in nine cases and the left knee in five cases. The median age of the patients was 14 years (13–15 years). The time between injury and surgery was 6 days (4–12 days). The inclusion criteria were displaced tibial eminence fractures (type III) in skeletally immature patients. Tibial eminence fractures were defined according to the classification of Meyers and McKeever modified by Zaricznyj. An arthroscopic standard anterolateral portal, an anteromedial portal, and a viewing accessory high anterolateral portal were utilized. The fracture bed is cleared of debris and the fracture fragment is reduced. The ACL tibial guide is utilized to drill two 5-mm tunnels on both sides of the fracture fragment to the upper anteromedial tibia. Two no. 5 Ethibond sutures were passed through the ACL substance close to the bone fragment by suture passing instrument. The sutures were the tied at the anteromedial tibia.
Results
The median follow-up was 24 months. The mean IKDC score was 91 (range, 87–100). The IKDC grades were A (normal) in 10 (72%) patients and B (nearly normal) in four (28%) patients. The mean preinjury Tegner score was 5 (range, 3–7), and at follow-up evaluation, the mean Tegner score was 4 (range, 3–6). The mean preoperative Lysholm score was 42 (range, 32–56); the mean postoperative Lysholm score was 92 (range, 88–100).
Conclusion
Arthroscopic reduction and internal fixation of tibial imminence avulsion fracture by pullout nonabsorbable suture technique in skeletally immature patients is a safe and effective method to treat this lesion.

Keywords:
arthroscopic, avulsion fracture, intercondylar imminence, pullout sutures

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Introduction

Tibial intercondylar eminence fracture is an intraarticular avulsion fracture of the anterior cruciate ligament (ACL) insertion, which was first reported by Ochiai in 1875 [1]. Skak *et al.* [2] reported an incidence of three per 100 000 children each year.

Midsubstance tears are the main mode of ACL failure in adults and adolescents with closed physis. On the opposite, in skeletally immature patients, chondroepiphyseal bone avulsions of the tibial ACL insertion do frequently occur. Traditionally, they can be seen between 8 and 14 years of age, and they are rare in those under the age of 8 years. In younger children, the chondroepiphyseal avulsion may be more frequently cartilaginous rather than osseous [3].

In children, a lesion of the ACL often occurs in combination with an avulsion fracture of the anterior part of the intercondylar eminence of the tibia, usually as an isolated lesion. By contrast, in adults, this lesion is often combined with lesions of menisci, capsule, or collateral ligament [4].

Mechanism of injury

Traditionally, falling off of a bicycle has been thought to be the main mode of injury. More recently, increasing modes of injury for tibial eminence fractures have been reported, including sport, motor vehicle accidents, and skiing. With stress, the incompletely ossified tibial eminence in the child fails before the ligament through the cancellous bone beneath the subchondral plate [5].

Classification

Meyers and McKeever classified these injuries in 1959 as nondisplaced (type I), partially displaced or hinged (type II), and completely displaced (type III) fractures [6]. Type III fractures were further subdivided into 'not rotated' and 'rotated.' This classification was modified by Zaricznyj [7] to include comminuted avulsion fractures (type IV).

Pathophysiology

Lower-limb growth in children mostly centers on the knee. Residual growth needs to be determined in case of fracture with growth plate involvement or of surgery liable to traumatize the growth plate (cruciate ligament reconstruction and osteosynthesis). Residual growth is about 10 mm per year in the distal femur and 6 mm per year in the proximal tibia, up to the age of 13 and a half years in girls and 15 and a half years in boys. Tibial tuberosity growth plate fusion is achieved late (at 16 years of age in girls and 18 in boys) and represents final lower-limb bone maturity [8].

The drilling of transphyseal tunnels in cruciate ligament reconstruction incurs a risk of iatrogenic growth disturbance. Tunnels should avoid the periphery of the physis and the Ranvier zone. Kercher *et al*. [9]recently developed an MRI-based 3D reconstruction software to calculate the damaged physeal volume from tunnel diameter and angle: for an 8-mm tunnel, damaged physeal volume is a mean 2.4% of total volume at the distal femur and 2.5% at the proximal tibia, diminishing with patient age.

Avulsion fractures mainly occur after a low-energy injury mechanism. The diagnosis of cartilaginous tibial eminence fractures can be easily missed on initial presentation. Acute knee joint effusion in children makes the physical examination difficult and often inaccurate. In the presence of an acute traumatic knee hemarthrosis, an intraarticular structural damage should be suspected and MRI examination should be mandatory [10].

Arthroscopic reduction and fixation of the avulsed fragment is gaining popularity over the traditional open methods. Lubowitz *et al*. [11], described a technique of arthroscopic reduction internal fixation (ARIF) of ACL avulsions using nonabsorbable sutures passed through drill holes and tied over the tibial tubercle. In this study, we followed that surgical principle with some modification of the technique.

Patients and methods

Between March 2010 and March 2012, we received 14 patients referred from the Emergency Department, Zagazig University. This prospective study was conducted after approval of the Ethics Committee of the University Hospital. There were 10 males and four female patients. The right knee was involved in nine cases and the left knee in five cases. Overall, four cases reported a history of fall from height around 1–2 m, seven cases reported injury during a football game, and three cases reported a bicycle accident. The median age of the patients was 14 years (13–15 years). The time between injury and surgery was 6 days (4–12 days). The inclusion criteria were displaced tibial eminence fractures (type III) in skeletally immature patients. Tibial eminence fractures were defined according to the classification of Meyers and McKeever modified by Zaricznyj.

A careful clinical examination of the knee was performed. All cases presented with hemarthrosis. Anterior instability was confirmed by recording the anterior drawer test and the Lachman test. Pain usually limits the accuracy of this step, so we relied completely on radiologic examination for proper diagnosis.

Plain radiographs in anteroposterior and lateral views were taken and were diagnostic in 10 cases. Plain radiographs were carefully scrutinized by looking for thin ossifications at the tibial ACL insertion site on the lateral view. MRI was valuable in cases of pure chondral avulsions (four cases) and to diagnose concomitant lesions. In four cases, the clinical examination showed anterior laxity with Lachman test, but the plain radiographic examination was not conclusive because the avulsed fragment was mainly chondral. MRI examination was performed and it confirmed the diagnosis.

MRI allowed for an improved differentiation of the type of cartilaginous tibial eminence fractures, especially to define its anteroposterior extension. The large cartilaginous fragment simulated a double-posterior cruciate ligament (PCL) sign, and a fluid signal underneath the cartilaginous fragment and proximal to the ossified epiphysis on T2 sequences may orient the diagnosis further. Computed tomographic scans were not performed owing to the radiation risk (Figs 1–10).

Surgical technique

Surgery was performed under spinal anesthesia, supine position, upper thigh tourniquet, and arthroscopic pump. Standard anterolateral, anteromedial, and a viewing accessory high anterolateral portals were used. Thorough lavage was performed to evacuate hemarthrosis or loose chondral or osteochondral fragments to improve visualization. The joint was then thoroughly inspected for associated injuries.

Treatment of the avulsion fracture is recommended before treatment of associated pathology to prevent iatrogenic fracture displacement. Fibrous tissue and blood clots were removed or debrided from the fracture bed avoiding iatrogenic displacement of the fragment.

A standard probe is used to retract the anterior horn of the medial (or lateral) meniscus or the transverse meniscal ligament, which are frequently trapped within the fracture site preventing accurate reduction. Trial reduction was performed with a probe or blunt trocar. If the intermeniscal ligament or anterior horn of the medial or lateral meniscus, as was often the case, was trapped in the fracture site and thereby preventing the reduction, a probe was used to free the interposed soft tissue with the knee in 90° of flexion. The fracture was then reduced by slowly extending the knee.

A suture hook (Linvatec, Largo, Florida, USA) loaded with no. 2-0 polydioxanone suture (PDS; Ethicon, Somerville, New Jersey, USA) was introduced through the anteromedial portal through the fibers of the ACL posterior to its midcoronal plane and as close to the bony fragment (distal) as possible. The PDS was then advanced into the joint while the suture hook was removed and a grasper forceps is used to deliver the PDS suture end through the anterolateral portal. The PDS was used to shuttle a no.5 Ethibond nonabsorbable suture (Ethicon) through the ACL fibers. The two ends of the suture limbs were gathered with a hemostat for future identification. The same step was repeated to place another set of Ethibond No. 5 suture through the ACL fibers anterior to its midcoronal plane.

A 3-cm longitudinal incision was made over the midproximal anteromedial tibia at the level of the tibial tuberosity. A cruciate ligament guide (Smith & Nephew Endoscopy, Andover, Massachusetts, USA) is used to place, respectively, two 2.4-mm drill-tipped guide pins at the medial and the lateral edges of the fracture bed in its midcoronal plane, under direct arthroscopic visualization. A 5-mm drill bit is introduced over the guide pin and two 5-mm bone tunnels were drilled toward the fracture site. Care was taken to leave a bony bridge of at least 2 cm between the two tunnels over the external cortex of the proximal tibia.

An arthroscopic hook is introduced through each bone tunnel and is used to retrieve the medial and the lateral Ethibond sutures through the corresponding bone tunnel. While the scope is inside the knee, the fracture reduction is checked especially for entrapment of the intermeniscal ligament and if anatomical reduction is achieved, the assistant holds the reduction firmly by a blunt probe.

The sutures were then tied over the bony bridge with the knee in 30° of flexion while the assistant performs a reverse Lachman maneuver. Then, we re-examined the reduced fragment with the probe, checking the reduction and stability of the fragment throughout knee flexion and extension. ACL tension was also checked with the probe.

Rehabilitation

The knee was put in a brace locked in full extension for 4 weeks. Isometric quadriceps, hamstring, abductor, and adductor strengthening with the knee locked in the brace is permitted during the first 6 weeks. Patients are permitted to bear full weight with crutches with the knee locked in a brace in full extension. Overall, 90° of knee flexion was allowed at 4 weeks and full range of motion by 6 weeks. After 6 weeks, the brace is discontinued, resisted flexion is permitted through a full range of motion, and resisted extension is permitted through a range of 30°–90°. Terminal resisted extension is not performed until 3 months. Return to sports was permitted at 6 months.

Results

Arthroscopic findings

Interposition of the intermeniscal ligament or anterior horn of the medial or lateral meniscus, which required mobilization or partial resection to obtain anatomic reduction, was found in seven (50%) patients. Medial meniscus tear was found in two (14%) patients, lateral meniscus tear was found in two (14%) patients, and grade I medial collateral ligament injury in one (7%). Meniscal tears were not amenable to repair and were treated with partial meniscectomy. Medial collateral ligament injuries were treated conservatively (Figs 11–21).

Patients were followed up for 24 months, both clinically and radiologically. The patients' visits were scheduled at 3, 6, 12, and 24 months.

Clinical evaluation at 6 months

All patients reported no symptoms of instability, such as giving-way episodes.

Regarding range of motion, knee range of motion was evaluated actively and passively with a goniometer. Measurement to the nearest 5° with a goniometer showed a mean extension deficit of 2° (range, 0°–5°) and a mean flexion deficit of 2.5° (range, 0°–5°) compared with the unaffected side. No cases of arthrofibrosis were recorded at the final evaluation.

Regarding anteroposterior laxity, Lachman 1+ was found in one case of a 15-year-old girl. KT-1000 arthrometer measurements (MEDmetric, San Diego, California, USA) at 134N two patients showed side-to-side difference of 3 and 5 mm.

Regarding rotatory laxity, positive pivot-shift test 1+ was found in one patient who had undergone medial meniscectomy.

Regarding thigh muscle circumference, two patients showed 10 mm less than the normal side.

Regarding one-leg hop test at 6-month evaluation, all cases were able to perform the one-leg hop test at three repetitions. No one failed jump. A total of 10 (72%) patients were able to hop 90% of the distance or greater using their operated limb compared with the contralateral healthy limb, and four (28%) were able to hop 76–89% of the distance.

Radiologic evaluation

Anteroposterior and lateral plain radiographs were examined to assess fragment healing in all cases except for four cases with mainly chondral and a small bony fragment, in which MRI examination was needed to assess healing. The median range of fracture healing was 12 weeks.

MRI examination was performed for four cases at final evaluation to assess fragment healing. The MRI showed complete fragment healing at 12 weeks postoperatively.

Clinical outcome

In the IKDC subjective knee score, a score of 100 is interpreted to mean no limitation with activities of daily living or sports activities and the absence of symptoms. The mean IKDC score was 91 (range, 87–100).

The IKDC grades were A (normal) in 10 (72%) patients and B (nearly normal) in four (28%) patients.

Tegner activity score

The rating system scores a person's activity level between 0 and 10, where 0 is 'sick leave or disability pension because of knee problems' and 10 is 'participation in competitive sports such as soccer at a national or international elite level.' The mean preinjury Tegner score was 5 (range, 3–7), and at follow-up evaluation, the mean Tegner score was 4 (range, 3–6). The highest level of preinjury athletic activity was recreational and occasional participation. At final evaluation, two patients reduced their activity level to occasional that resulted in reduction in the overall score.

Lysholm knee score

The rating system consists of eight different items on a 100-point scale, with 25 of the points attributed to instability and 25 to pain. The mean preoperative Lysholm score was 42 (range, 32–56), and the mean postoperative Lysholm score was 92 (range, 88–100).

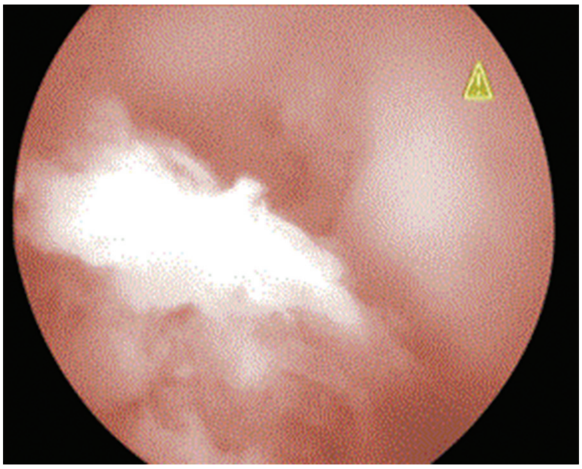
Complications

One patient had rerupture of the healed fragment 12 months after healing. The patient injured his knee while jumping from a truck. A revision surgery was performed. Fragment healing was achieved after 16 weeks, but this case was considered as a clinical failure. This case was not included in the study, because it is a revision case, and it did not match the inclusion criteria of the study, as all the cases were acute primary fractures (Tables 1 and 2).

Discussion

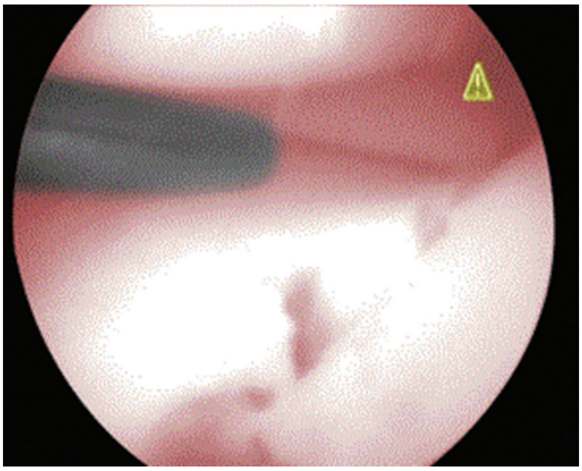
Fractures of the tibial eminence represent avulsion fractures of the ACL insertion. They are uncommon, with an age peak in children and adolescents [5]. Nonoperative treatment of type I tibial eminence fractures is recommended by most

Figure 1



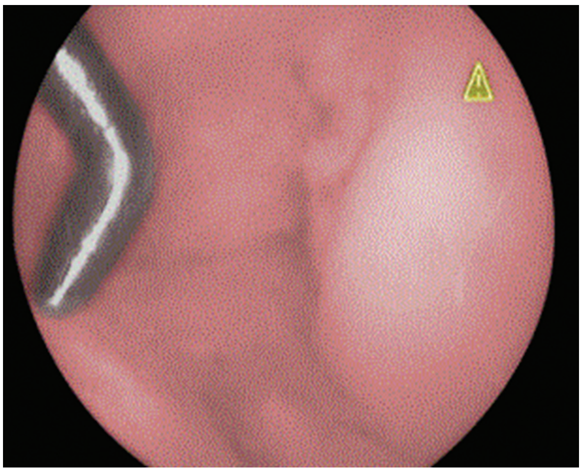
Avulsed ACL tibial footprint. ACL, anterior cruciate ligament.

Figure 2



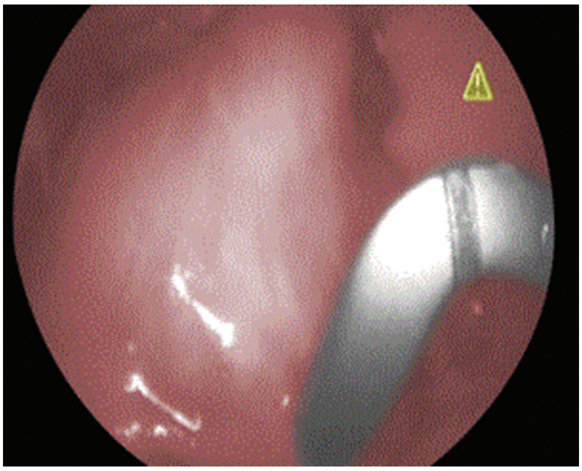
Reduction of the chondral fracture with a blunt probe.

Figure 3



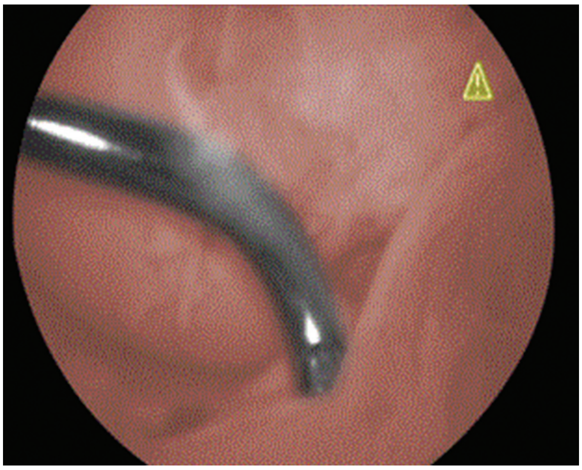
Trial reduction restored the ACL tension. ACL, anterior cruciate ligament.

Figure 4



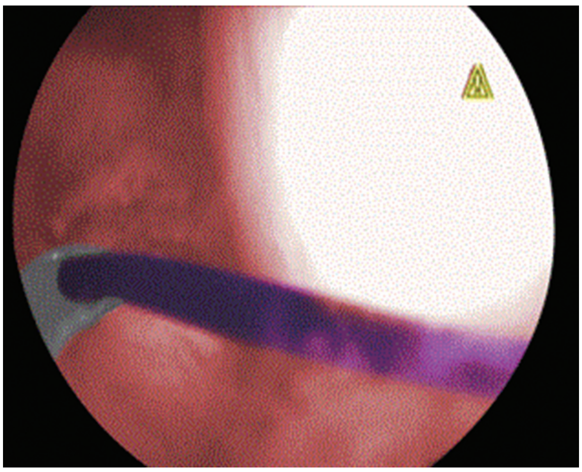
ACL tibial guide is used to create medial tibial tunnel. ACL, anterior cruciate ligament.

Figure 5



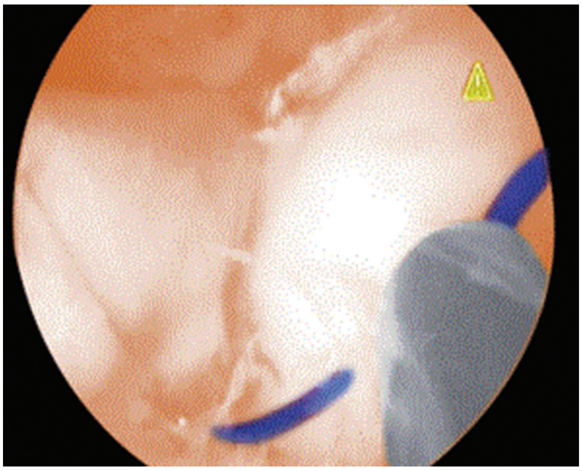
A suture hook penetrating the ACL base to deliver no. 2 PDS. ACL, anterior cruciate ligament; PDS, polydioxanone suture.

Figure 6



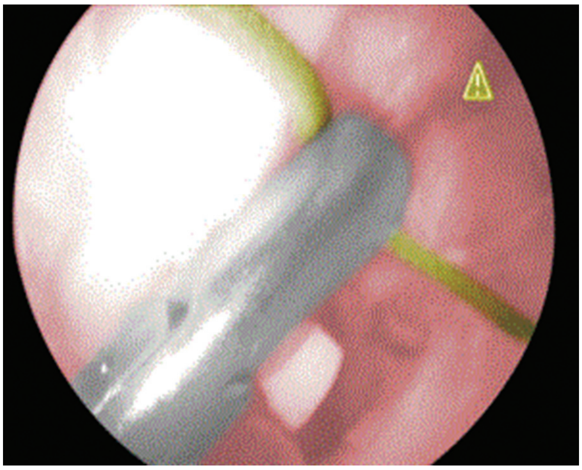
PDS suture delivered through the ACL base. ACL, anterior cruciate ligament; PDS, polydioxanone suture.

Figure 7



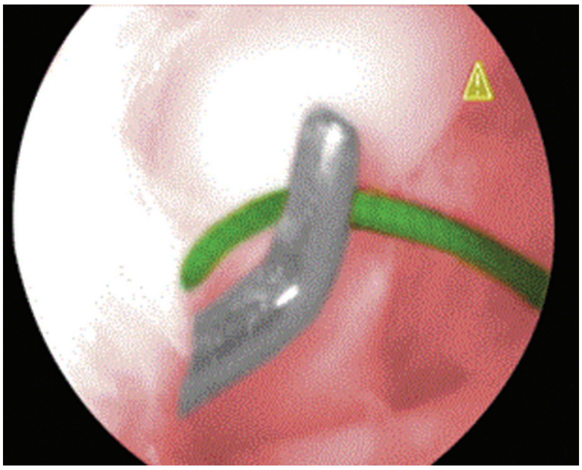
PDS suture retrieved by a grasping instrument. PDS, polydioxanone suture.

Figure 8



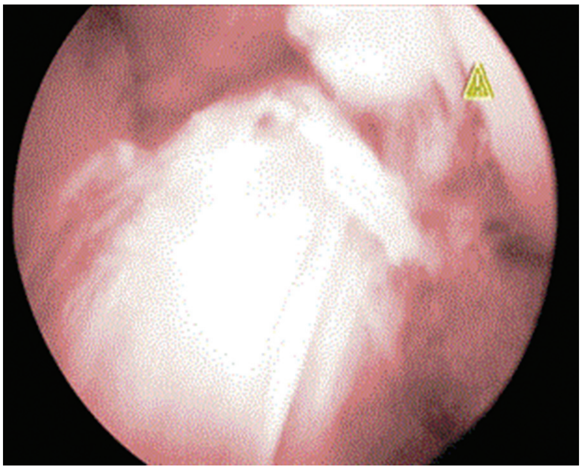
PDS suture is used to shuttle no. 5 Ethibond suture through the ACL base. ACL, anterior cruciate ligament; PDS, polydioxanone suture.

Figure 9



Ethibond suture retrieved through the tibial tunnel with an arthroscopic hook.

Figure 10



ACL tension is restored after suture tightening over the anteromedial tibia. ACL, anterior cruciate ligament.

Figure 11

Postoperative clinical photograph showing postoperative full flexion range of motion.

Figure 12

Postoperative clinical photograph showing full flexion with squat.

Figure 13

Postoperative clinical photograph showing full extension with single-leg stance.

Figure 14

Clinical photograph showing postoperative negative Lachman test result.

authors. The management of types II, III, and IV fractures, however, remains controversial. There is no consensus in the literature regarding closed versus open treatment, type of internal fixation, and postoperative management [12].

Wilfinger *et al*. [12], in a case series, showed that the nonunion of type III fracture treated in plaster cast was attributed to soft tissue interposition. The authors concluded that closed methods are not the best line to treat type III fractures. Several papers have reported worse results for type III fractures treated nonoperatively [13].

In type III fracture, the literature is increasingly supporting surgical reduction. Kocher *et al*. [14] reviewed 80 fracture cases that underwent arthroscopic or open reduction for type II or III fractures that did not reduce in extension. They demonstrated entrapment of the anterior horn of the medial meniscus in 36 patients, the anterior horn of the lateral meniscus in one patient, and the transverse ligament in six patients. In the remaining 37 patients, adequate reduction was not obtained despite hemarthrosis aspiration.

The advantage of surgery over closed methods includes restoring the stabilizing function of the ACL, retrieving interposed soft tissue from within the fracture site, eliminating any mechanical obstruction to motion, and decreasing the period of immobilization to minimize stiffness [15].

There is an increasing popularity of arthroscopic fixation in modern times. Before the regular use of arthroscopy, open reduction for displaced tibial eminence fractures was advocated. Arthroscopic treatment has been reported to result in decreased morbidity, earlier mobilization, and shorter hospital stay [11].

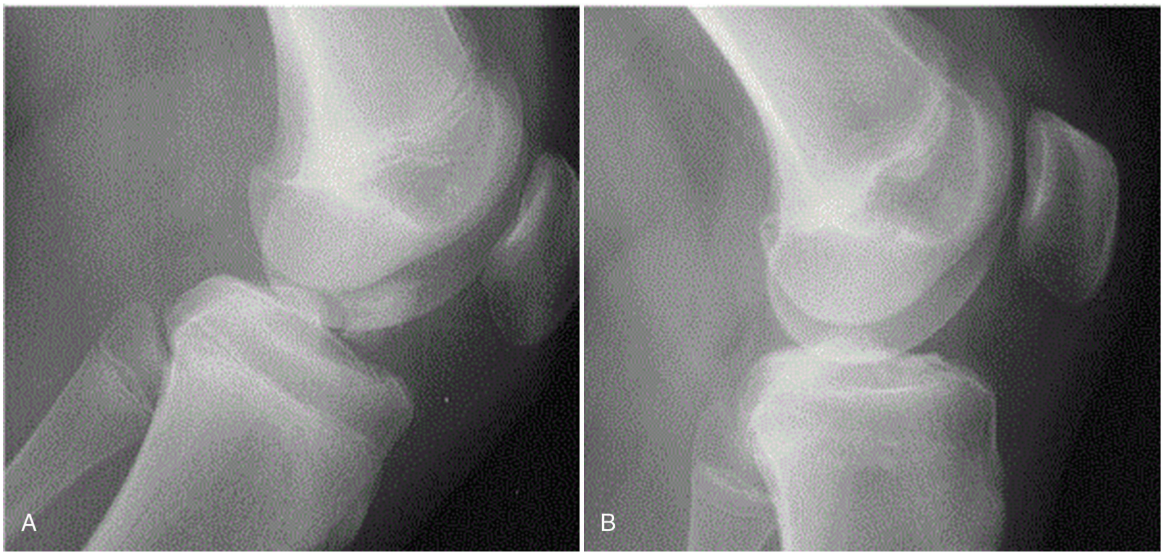
There is no consensus in the body of literature regarding the best type of fixation as there are no randomized controlled trials comparing any of these methods. The most popular fixation devices in the literature are sutures, K-wires, and screws [5].

Investigators using K-wire fixation have had successful results, with patients having no pain or instability at 12 months. This technique can also be physeal sparing, which is safer for the pediatric population. If left proud, K-wires can be removed in the outpatients department, but there may be an infection risk [16].

Cannulated partially threaded cancellous screws have been used to fix larger fragments. However, these screws are often removed owing to the risk of anterior impingement and potential damage to the articular surface. In addition, this technique is not effective for cases in which a small or a comminuted tibial spine fragment occurs [17].

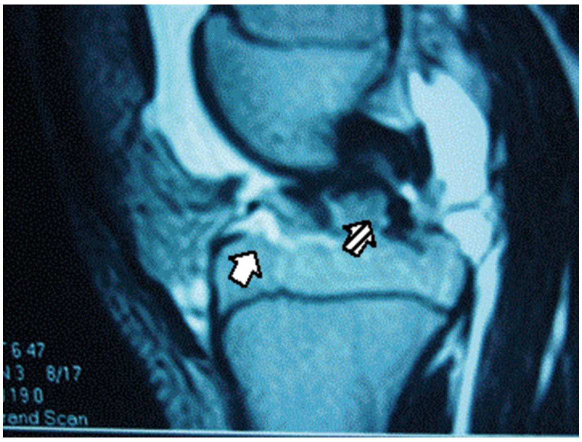
Advocates for suture fixation [15] report that screws and K-wire fixation are not suitable for comminuted fractures and can even cause comminution of the fracture fragment plus there is no need for a second surgery to remove the hardware. Investigators have reported full function and return to sport for all

Figure 15



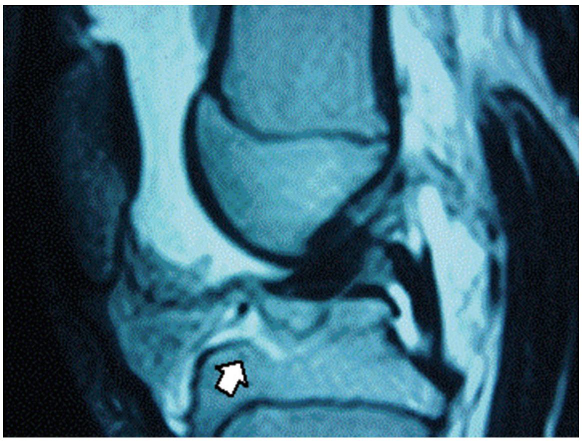
(a) Preoperative plain radiograph showing the avulsed tibial imminence fracture. (b) Postoperative plain radiograph at 6 months showing fracture healing.

Figure 16



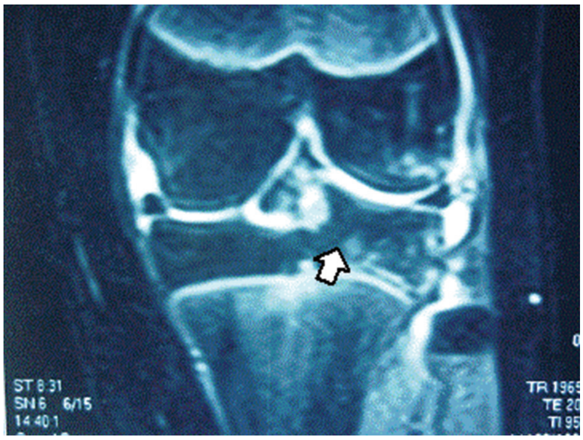
Preoperative MRI showing fluid signal under the avulsed fragment (white arrow) and a double-PCL sign (strapped arrow).

Figure 17



Preoperative MRI showing fluid signal under the avulsed fragment (white arrow).

Figure 18



Preoperative STIR MRI showing fluid signal under the avulsed fragment (white arrow). STIR, Short TI Inversion Recovery.

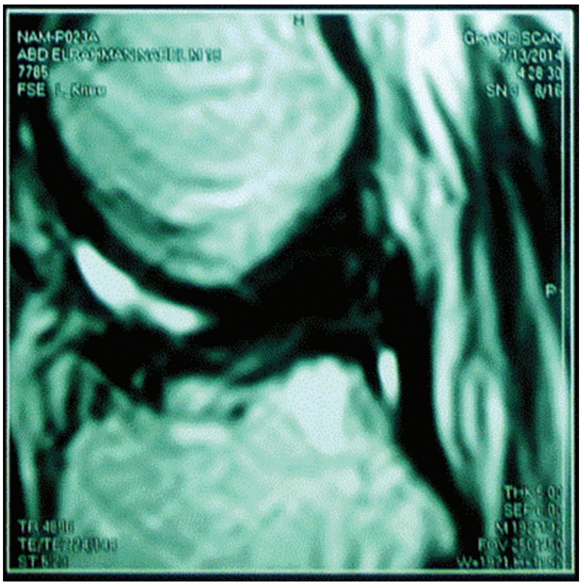
patients treated by arthroscopic suturing, with early mobilization and full range of motion.

Bong *et al.* [18] in a cadaveric biomechanical study compared surgical outcomes of two techniques in seven matched pairs of fresh–frozen human cadaveric knees with type III tibial eminence fractures. A fixation technique was performed using a single 4-mm cannulated cancellous screw with a washer, and an arthroscopic suture technique was performed using three no. 2 fiber wire sutures (Arthrex, Naples, Florida, USA) passed through the tibial base of the ACL and tied over bone tunnels on the anterior tibial cortex. The fiber wire fixation of eminence fractures provides biomechanical advantages over cannulated screw fixation.

Figure 19

Postoperative STIR MRI showing fragment fusion under the avulsed fragment (white arrow). STIR, Short TI Inversion Recovery.

Figure 20



Postoperative MRI showing fragment fusion and restoration of ACL tension. ACL, anterior cruciate ligament.

Eggers *et al.* [19], in a porcine model, found that under cyclic loading, suture fixation provides greater strength than screw fixation does. Matthews and Geissler [20] used multiple no. 2 PDS sutures through arthroscopic techniques in six patients with tibial eminence fractures. No patients had subjective complaints of instability at 1 year, and only one patient lost 2° of terminal extension at latest follow-up.

In our study, we followed the surgical principles described by Lubowitz *et al.* [11], in which they

Figure 21

Postoperative MRI showing anteromedial bone tunnels.

used nonabsorbable sutures passed through drill holes and tied over the tibial tubercle to treat ACL avulsion fractures. The technique described is based on the work of previous investigators [21]. Medial and lateral drill holes were created through a short longitudinal incision centered over the tibial tubercle. In our study, we modified this step in which we created the bone tunnels at the proximal anteromedial tibia to avoid drilling near the tibial tubercle. That was based on the fact that tibial tuberosity growth plate fusion is achieved late (at 16 years of age in girls and 18 in boys) and represents final lower-limb bone maturity [4]. We were also keen not to create large tunnels to avoid inflicting iatrogenic damage to the growth plate. Our follow-up radiographs did not show any growth arrests.

Wiley and Baxter [22] reported increased laxity in types II and III fractures of 3.5 mm when compared with the uninjured knee, regardless of closed reduction or open and internal fixation. It is thought that the ACL fibers are elongated at the moment of trauma. Perugia *et al.* [23], in a case series of 10 patients, showed that increase of KT-1000 measurements of 6 mm compared with the contralateral healthy side was associated with a positive pivot glide test result (three patients). None of these patients had symptoms of instability at follow-up, and all patients returned to their preinjury sports activity. Perugia and colleagues confirmed this observation that the lack of clinical instability is postulated to be owing to the integrity of the nerve fibers along the ACL and neuromuscular feedback.

Table 1 Patients' demography and postoperative functional deficits

Patient number	Sex	Age	Concomitant injuries	Soft tissue interposition	Extension deficit (°)	Flexion deficit (°)
1	M	15	LM	Y	2	0
2	M	16		N	0	0
3	F	15	MM	Y	5	10
4	M	14		N	0	0
5	M	16		Y	0	0
6	M	15		N	0	0
7	F	14	MM	Y	2	5
8	M	16		N	0	0
9	F	13		Y	0	0
10	F	15		N	0	0
11	M	14	LM	Y	2	2
12	M	16		N	0	0
13	M	15	MCL	Y	2	2
14	M	14		N	0	0

F, female; LM, lateral meniscus; M, male, MCL, medial collateral ligament; MM, medial meniscus; N, no; Y, yes.

Table 2 Postoperative functional scores

Patient number	Tegner score (preoperative–postoperative)	Lysholm score	IKDC score	IKDC grade
1	7–6	90	89	B
2	6–6	100	100	A
3	5–3	88	87	B
4	5–5	100	100	A
5	6–6	96	95	A
6	6–6	100	100	A
7	5–3	88	87	B
8	4–4	98	97	A
9	5–5	92	93	A
10	5–5	94	94	A
11	6–5	92	93	A
12	6–6	95	94	A
13	7–6	88	89	B
14	7–7	100	100	A

Our results confirmed the observation of Wiley and Baxter and Perugia and colleagues, in which we had two cases of increased anterior laxity of 3 and 5 mm after fracture healing compared with the other normal knee, but still the patients did not complain of instability episodes. A possible cause responsible for the residual laxity is ACL lengthening, and plastic deformation of the ligament before ultimate avulsion fracture and the fact that the ACL does not have the ability to remodel.

Loss of motion and arthrofibrosis are concerns after tibial eminence fracture. Aderinto *et al*. [24], reported that stiffness may occur in as many as 60% of knees that were treated surgically for tibial eminence fracture. Vander Have *et al*. [25], in a series of 32 patients, reported that 24 patients required reoperation for loss of flexion (n=9), loss of extension (n=4), or both (n=11). Manipulation under anesthesia resulted in distal femoral fractures and subsequent growth arrest in three patients. Twenty-nine patients were able to achieve near full knee motion at final follow-up.

Patel *et al*. [13] in a retrospective review investigated 40 tibial eminence fractures treated with closed reduction. Those who started range of motion rehabilitation later than 4 weeks of treatment were 12 times more likely to develop arthrofibrosis than those who started before 4 weeks. Early range of motion would, therefore, seem to be a factor in the prevention of arthrofibrosis.

Montgomery *et al*. [26], despite the use of an unrestricted rehabilitation regimen, found that 53% of the patients treated with arthroscopic suture fixation had severe difficulty regaining motion postoperatively. They applied an accelerated program with passive and active motion 0–2 weeks after surgery, to avoid arthrofibrosis. In our study, we found that this may interfere with fragment healing, so we decided to follow a more conservative regimen and followed the recommendations of Patel *et al*. [13], and we started the mobilization program at 4 weeks.

In our study, we had no case of arthrofibrosis. At final evaluation, the mean extension deficit was 2° (range, 0°–5°) and the mean flexion deficit was 2.5° (range, 0°–10°) compared with the unaffected side. This result contradicts the results of Aderinto *et al*. [24] and Vander Have *et al*. [25]. A possible explanation for this is that we used arthroscopic techniques (rather than open techniques) and our patients started range of motion within 4 weeks after surgery.

Avoiding damage to the growth plate is a main concern in open reduction internal fixation (ORIF) of pediatric intercondylar fractures. There were no reports of growth arrest in the current literature, except after fracture during manipulation under anaesthesia (MUA) for postoperative arthrofibrosis [12]. In our study, we had no case growth arrests at final evaluation. Chotel *et al*. [27] emphasized the role of early MRI analysis if a cartilaginous tibial eminence fracture is suspected in young patients presented with acute hemarthrosis. MRI allows to establish the correct diagnosis, to evaluate potential associated injuries, to classify the lesion, and to help define the best management.

The authors [27] gave valuable guidelines to help diagnosis, for example, a thin ossification visible on the lateral plain radiograph close to the tibial ACL insertion can be affirmative for tibial eminence avulsion fracture. MRI is the examination of choice, but its interpretation may be difficult because of the absence of the traditional primary and secondary findings after ACL injury. A fluid signal underneath the cartilaginous fragment and proximal to the ossified epiphysis on T2 sequences or a double-PCL sign may orient the diagnosis further [27].

In our study, we had four adolescents who presented with hemarthrosis and anterior knee laxity, but the plain radiography were not conclusive for diagnosis. The MRI examination was extraordinarily helpful to delineate the fracture line and to take the decision for surgery. Without the help of MRI, missing the diagnosis would have been inevitable. Missing the diagnosis of ACL tibial imminence avulsion fracture carries the risk of persistent knee anterior instability and limits terminal extension in children and adolescents. Any patient in this age group who presents to the emergency department with hemarthrosis should be carefully examined for tibial imminence avulsion fracture. Plain radiography can miss the diagnosis owing to the chondral nature of the lesion. Our study confirmed the observations of Chotel *et al*. [27] that MRI examination is the modality of choice to diagnose this lesion.

All patients were satisfied with surgery and returned back to their preinjury activity level, except for two patients who had to modify their sport activity.

Our results are comparable to other studies using pullout nonabsorbable sutures to fix the avulsed bony fragment. This study showed that arthroscopic pullout nonabsorbable suture technique is simple, effective, and nontraumatizing method to treat this lesion.

The main limitations of this study are the relatively small number of patients included, as tibial eminence fracture is a rare injury, and the absence of a control group.

Conclusion

Arthroscopic reduction and internal fixation of tibial imminence avulsion fracture by pullout nonabsorbable suture technique in skeletally immature patients is safe, effective method to treat this lesion.

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Conflicts of interest

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