Original Article

Arthroscopic Operative Treatment of Type 2 and 3 Displaced Tibial Eminence Fractures in Children and Adolescents Using Absorbable Sutures for Stabilisation: Case Series of Short-term Results

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Abstract

Background: Tibial eminence fractures (TEFs) are prevalent amongst paediatric and adolescent demographics. Surgical intervention becomes imperative in cases of significant displacement, with various approaches proposed. This study aims to present the outcomes of treating type 2 and 3 displaced TEFs utilising an arthroscopic operative technique employing absorbable sutures for fixation. **Materials and Methods:** A retrospective case series analysed the outcomes of 18 paediatric and adolescent patients (15 males and 3 females) treated for type 2 and 3 displaced TEFs between 2017 and 2022. Absorbable sutures were threaded through the anterior cruciate ligament just above the fractured tibial eminence, passing beneath the intermeniscal ligament to reposition the fracture adequately. Sutures were tightened at a transversal cortical tibial tunnel. Post-operative management included a knee brace in extension for 5 weeks, followed by physical therapy. Clinical and radiological assessments were conducted, with patient-reported outcomes evaluated using the Single Assessment Numeric Evaluation (SANE) question. Favourable results were determined by subjective knee stability, negative Lachman test and successful return to play. **Results:** Nearly 9 months post-surgery, 14 patients achieved complete range of motion and resumed regular activities. At the latest follow-up, 94% demonstrated satisfactory knee stability and gradual return to sports. The SANE question yielded a rating of 91. **Conclusion:** Fixation of type 2 and 3 displaced TEFs using absorbable sutures, and a distal bone bridge presents a reliable operative technique for achieving bone consolidation and knee stability in paediatric and adolescent patients within a short-term period. In addition, it offers a minimally invasive and cost-effective solution without necessitating hardware removal.

Keywords: Absorbable suture fixation, arthroscopy, skeletally immature, tibial eminence fracture

Introduction

Tibial eminence fractures (TEFs) are more prevalent amongst the paediatric and adolescent population. The mechanism of injury mirrors that of anterior cruciate ligament (ACL) injuries. In children, hyperextension or a direct blow to a flexed knee leads to a fracture of the tibial spine, rather than the ligamentous mid-substance rupture seen in adults. This phenomenon is attributed to the weakness of the subchondral bone, which fails before the ACL due to incomplete ossification of the tibial eminence.[1] Consequently, TEF commonly occurs in skeletally immature patients aged 8–14 years, often during sporting activities such as cycling, skiing or football. Associated knee injuries are present in 40% of cases, including soft-tissue interposition, ruptured menisci, collateral ligament or capsular injuries.[1,2]

When a paediatric patient presents with knee effusion and pain following significant trauma, a TEF must be considered. Radiographic evaluation, particularly lateral knee radiography, aids in diagnosis and classification according to the modified

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Meyers and McKeever system. Conservative treatment is suitable for non-displaced (type 1) fractures, while surgical fixation is necessary for type 2–4 fractures.[3] Advanced radiological imaging, such as computed tomography and magnetic resonance imaging (MRI) scans, are useful for pre-operative evaluation, as they can be used to assess the amount of TEF displacement and comminution, as well as possible soft-tissue involvement.[4]

Various operative techniques have been described for treating displaced TEF, with arthroscopic fixation emerging as the preferred method.[5] Screws, K-wires, staples and non-absorbable sutures have all been proven as effective fixation methods for displaced TEF treatment.[6-11] Despite the effectiveness of the described techniques, complications such as non-union, loss of motion, growth disturbance, arthrofibrosis, pain and hardware-related issues may arise.[1,3,12,13] To mitigate these risks, a modified minimally invasive arthroscopic extraphyseal operative technique employing absorbable sutures has shown promising results by Brunner *et al*.[14]

This retrospective case series aimed to assess short-term clinical and subjective outcomes following the reduction and fixation of displaced type 2 and 3 TEFs using an arthroscopic extraphyseal operative technique with absorbable sutures.

Materials and Methods

All subjects in this study were managed and followed at Children's Hospital Zagreb from May 2017 to May 2022. The study was conducted in accordance with the Ethics Committee of Children's Hospital Zagreb and with the Helsinki Declaration. This study was conducted as a retrospective case series, thus analysed data were collected from medical records and other diagnostic tools; medical history was taken from patients and their parents. The patients' parents provided informed consent for publication. Patients' characteristics are outlined in Table 1. At the initial presentation at the outpatient clinic, all the patients complained of knee pain and swelling. Positive Lachman and anterior drawer tests were also noticed in all patients. TEF was confirmed preoperatively by radiograms taken in lateral and frontal views. According to the Meyers and McKeever classification,[15] 18 (18 knees) patients with displaced type 2 and 3 TEFs were enrolled in this study [Figure 1]. Based on the World Health Organization's definition of adolescence, our study included 5 paediatric and 13 adolescent patients.[16] All patients were treated by arthroscopic extraphyseal operative technique using absorbable sutures (Vicryl, Number 2, Ethicon, Johnson and Johnson Medical, Norderstedt, Germany) and distal fixation over a transverse tibial bone bridge,[14] performed by two independent orthopaedic surgeons. After surgery, a knee brace was applied in full extension for 5 weeks. At the final follow-up visit, functional and clinical evaluation of 17 knees was done by orthopaedic surgeons involved in surgery. Knee range of motion (ROM), Lachman test and patients' subjective knee stability were observed, while patient satisfaction was assessed using the Single Assessment Numeric Evaluation (SANE) question.[17]

Surgical technique

The surgery was performed under general anaesthesia with prophylactic antibiotics administered. Patients were placed in a supine position with the knee in 90° of flexion, and a thigh tourniquet was applied. Standard anterolateral and anteromedial portals were established, and a complete diagnostic arthroscopy was performed searching for concomitant injuries. The TEF site was debrided with a shaver, taking care not to damage the intermeniscal ligament (IML). Through the distal part of the ACL, two threads of absorbable Vicryl 2 sutures were placed using a Knee Scorpion™ suture passer and a retriever (Arthrex, Naples, FL, USA).[18] Suture loop placed in a needle was passed inside the knee, below the IML, penetrating the skin medially to the patellar tendon. Absorbable sutures were retrieved and pulled out under the IML [Figure 2a]. A vertical skin incision was made 2 cm medial and inferior to the tibial tubercle, and a transverse transcortical tibial bone tunnel was created with a 2.5 mm drill. Then, sutures were captured with a suture loop placed in a needle through the transverse transcortical tibial bone tunnel and pulled out laterally. A curved clamp was used to bring sutures in front of the transverse transcortical tibial bone tunnel through a previously made tibial skin incision. The displaced TEF was then reduced with an arthroscopic probe and by tensioning the sutures in a distal direction. Sutures were finally tied over the tibial bone bridge in knee extension [Figure 2b].

Post-operative protocol

After surgery, a knee brace was applied in full-knee extension. Patients were instructed to use crutches for support, but gradual weight-bearing was permitted. After 5 weeks, gradual flexion and full weight-bearing were allowed to regain complete ROM. Muscle strengthening was encouraged, and bicycle riding was advised. Walking without a brace and crutches was not allowed for 8 weeks after surgery. Progressive return to sports and everyday activities was allowed judging on physical examination.

Follow-up

All patients were postoperatively assessed at the outpatient clinic. Clinical assessment and ROM of the operated knee were measured, and the SANE question had been filled out by parents. Bone healing was assessed on two-plane radiographs [Figure 3].

Results

Eighteen (18 knees) patients with a mean age of 11.11 years (age range = 3–16 years) were included in the study. Male predominance was 83%, with the right knee slightly more affected (ratio = 10:8). Five operated paediatric patients had a mean age of 6.8 years (3 males and 2 females), and 13 operated adolescent patients had a mean age of 12.8 years (13 males). According to the Meyers and McKeever classification, 14 knees were type 2 injury. The mean length of follow-up was 8.22 months (range = 4–22 months). Four months after surgery,

Table 1: Details of our patients included in this report

Patient	Sex (male/ female)	Age at surgery	Side of TEF (right/ left)	Meyers and McKeever classification type	Mechanism of knee injury	Concomitant injury	Follow-up (months)	ROM at the last follow-up	SANE question
1	Male	10	Right	2	Skiing accident	None	13	0/120	100
2	Male	14	Right	2	Football injury	None	7	0/120	70
3	Male	11	Left	3	Traffic accident	None	22	5/120	80
4	Male	13	Right	2	Fall from bicycle	None	4	0/120	70
5	Female	9	Right	2	Fall from hoverboard	None	4	0/120	70
6	Male	11	Left	2	Fall from bicycle	Lateral meniscus posterior horn rupture	2	0/90	100
7	Male	14	Right	2	Fall while jumping	Interposition of medial meniscus and IML	22	0/120	100
8	Male	13	Left	2	Fall from bicycle	Interposition of IML	9	0/120	100
9	Male	10	Right	2	Fall from bicycle	None	4	18/110	100
10	Female	3	Left	3	Hard object fell on the knee	None	12	0/120	100
11	Male	8	Right	2	Fall from bicycle	Lateral meniscus anterior horn lesion	5	0/120	100
12	Male	13	Left	2	Football injury	None	8	0/110	Lost to follow up
13	Female	7	Left	2	Fall while jumping	Interposition of medial meniscus	17	0/120	100
14	Male	14	Right	3	Fall while jumping	None	2	0/120	100
15	Male	13	Right	2	Fall from scooter	None	4	5/110	90
16	Male	14	Right	2	Football injury	None	4	0/110	70
17	Male	7	Left	2	Fall while jumping (trampoline)	Interposition of medial meniscus	5	0/110	100
18	Male	16	Left	3	Basketball injury	Interposition of medial meniscus	4	5/110	100
Average	15 male/3 female	11.11	10 right/8 left	14 type 2/4 type 3			8.22	8/115	91.18

SANE: Single Assessment Numeric Evaluation, TEF: Tibial eminence fracture, IML: Intermeniscal ligament, ROM: Range of motion



Figure 1: Lateral knee radiograph image of a 14-year-old adolescent with type 2 displaced tibial eminence fracture according to the Meyers and McKeever classification. White arrow points to the type 2 displaced tibial eminence fracture

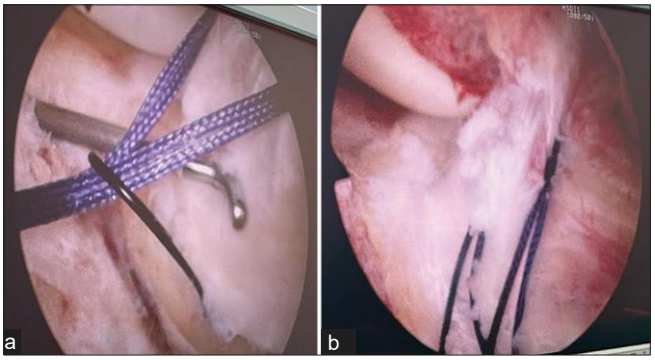


Figure 2: (a) Intraoperative arthroscopic view of the left knee with a tibial eminence fracture. Absorbable Vicryl 2 sutures are placed using a knee scorpion through anterior cruciate ligament just above the tibial eminence. A suture loop is passed below intermeniscal ligament, and sutures are caught, ready to be pulled out. (b) Intraoperative arthroscopic view of the left knee after absorbable Vicryl 2 sutures are tensioned and fixed at the transcortical tibial bone bridge. Complete tibial eminence fracture reduction is achieved, and anterior cruciate ligament is tight

ROM was >90° in all patients while TEFs were radiographically consolidated in 17 patients. In one female patient, a sclerotic 'arch' above the previously properly stabilised TEF was noticed. Six months after surgery, 14 patients had full ROM and had returned to their regular sporting activities. However, four patients reported slight knee pain and did not return to



Figure 3: Anterior-posterior and lateral view radiograph images of the left knee. (a) A displaced tibial eminence fracture, type 2. (b) After extraphyseal tibial eminence fracture repair with absorbable sutures and a distal bone bridge fixation, the tibial eminence is reduced. A distal bone bridge is present on the frontal cortex of the tibia. (c) Nine months postoperatively, a complete healing of the tibial eminence is present

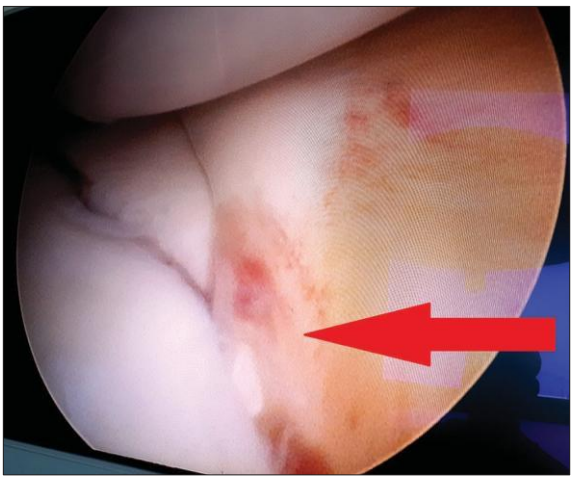


Figure 4: Intraoperative arthroscopic view of the right knee with the tibial eminence fracture from the anterolateral portal. Red arrow points to the anterior horn of the medial meniscus entrapped into the tibial eminence fracture

full ROM at 1-year follow-up [Table 1]. One patient sustained new knee trauma during physical therapy, and partial ACL rupture was confirmed by MRI. At the last follow-up, anterior drawer test, Lachman test, and pivot shift tests were negative in 17 patients. No knee stiffness or arthrofibrosis was reported in any of the patients. The mean results of the SANE question in 17 patients were 91 (range = 70–100) [Table 1].

Discussion

The main finding of this case series is that the arthroscopic extraphyseal operative technique used for the reduction and fixation of displaced type 2 and 3 TEFs with absorbable sutures provides proper bone consolidation. Moreover, good-to-excellent knee stability results in paediatric and adolescent patients are achieved in short-term follow-up. Therefore, application of this technique should be encouraged amongst orthopaedic surgeons dealing with children's knees.

TEFs are relatively uncommon injuries in adults but are quite common in skeletally immature patients from 8 to 14 years, as seen in our cohort where 78% of patients were within this age frame. Overall, TEFs represent 2%–5% of all paediatric knee injuries accompanied with effusion. Following the results of our study, fall from bicycle, skiing and motor vehicle accidents were reported as the most common causes of type 2 and 3 TEFs.[19-21] However, the second most common cause of type 2 and 3 TEFs in our cohort was a fall caused by jumping or due to football injury [Table 1].

In displaced TEF, conservative treatment could be applied; however, it can lead to a higher percentage of knee instability.[22] Furthermore, Pailhé *et al*. reported better functional outcomes in patients treated surgically for displaced TEF, with an average post-operative Lysholm score of 84.6.[23]

Various methods and techniques in reducing and fixing displaced TEF were described in literature, with no consensus regarding the best option.[3,6,8,9-13] However, nowadays, it is considered that methods using an arthroscopic approach are less invasive, while most popular fixation methods for displaced TEFs include fixation of fracture site by K-wires, compression screws and sutures.[3] Considering that the main characteristic of a good TEF fixation technique is to resist a cyclic load of 300–450 N, sutures are the method of choice. They have sufficient tensile strength and are inexpensive compared to K-wires and, especially, compression screws.[24,25]

When comparing absorbable and non-absorbable sutures for displaced TEF fixation, Hirschmann *et al*. and Brunner *et al*. both had good clinical results in 6 and 15 paediatric and adolescent knees, respectively.[8,14]

Nonetheless, the benefits of using absorbable sutures, besides lower costs, are lower risk of complications caused by hardware, avoiding possible pain and irritation at the fixation site and no need for secondary operation in case of hardware removal.[14] On the other hand, Sharma *et al*. reported a median increase in knee laxity gap of 2 mm in group of paediatric patients treated using absorbable-suture fixation, compared to 1 mm laxity gap fixed with non-absorbable materials such as screws or stainless steel wire loop. However, the same study did not show a significant statistical difference in Lysholm knee scoring system between the two groups of patients.[26]

Since the usage of absorbable sutures for reduction and fixation of displaced TEF in children and adolescents has been recently highlighted as a feasible alternative to standard hardware usage, literature lacks long-term results. Brunner *et al*. operated on 14 children and adolescents' knees with displaced TEFs using absorbable sutures and reported more than 90% satisfied patients in terms of subjective knee stability.[14] Our study had more than 90% of satisfied patients from 17 children and adolescents that were evaluated based

on Lachman and pivot shift tests. These patients reported satisfactory knee stability and were able to return to their usual activities in short-term follow-up. However, we did not use subjective knee measure with a Rolimeter. The SANE outcome question rated excellent for most patients, what seems to be encouraging, since no poor patient's satisfaction results were recorded [Table 1]. Interestingly, there was no significant difference in post-operative ROM or patients' satisfaction between displaced type 2 and 3 TEFs. Although the paediatric group of patients had a female predominance, there was no significant difference in any of the observed post-operative parameters between paediatric and adolescent patients. Therefore, surgical approach in treatment of displaced type 2 and 3 TEFs should always be applied, as reported previously.[23]

Intraoperative complications of displaced TEF treatment include meniscal injuries and interposition of soft tissue in the fracture site. This can prevent fracture reduction and healing, as well as lead to impingement of the malreduced fracture; therefore, knee arthroscopy is obligatory to deal with additional possible pathologies found.[23] In our study, four patients had interposed IML and/or medial meniscus, and two patients had lateral meniscal lesions, which were all addressed properly [Table 1 and Figure 4].

The main post-operative complications of displaced TEF treatment described include arthrofibrosis, non-union, malunion, pain and severe laxity.[1]

Nevertheless, during our short-term follow-up period, no significant knee arthrofibrosis was noted – a complication reported up to 20% in a study where this operative technique was used.[14] Instead, we had four patients with a decreased ROM who needed prolonged physical therapy and one patient who sustained a new knee trauma and torn his ACL partially. We can speculate that during initial trauma when TEF occurs, an ACL mid-substance also sustains injury, and it is therefore weakened and susceptible to a complete rupture; however, further studies will be needed to elucidate this issue.

The major limitation of this study is a relatively small number of non-randomised patients; therefore, solid interpretation of the results is not permitted. Other limitations are short time of follow-up with the outcomes presented through subjective tests and strong male predominance in the adolescent group of patients, meaning that the results for female patients may not be representative. However, this study is relevant because it reports the successful application of a relatively new, feasible and cost-redundant operative technique for the treatment of displaced type 2 and 3 TEFs in paediatric and adolescent patients.

Conclusion

We concluded that extraphyseal displaced type 2 and 3 TEF fixation with absorbable sutures and transversal distal bone bridge fixation is a safe and minimally invasive technique in children and adolescents, providing bone consolidation and knee stability. However, long-term evaluation until the end of bone growth is essential to ascertain the technique's superiority comprehensively.

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Conflicts of interest

There are no conflicts of interest.

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