Arthroscopic Suture Fixation of Tibial Eminence Fractures

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Abstract

Tibial eminence avulsion fractures are relatively rare injuries, most frequently occurring in skeletally immature patients. Screws or suture fixation can be used, with each offering different potential advantages. The purpose of this retrospective study was to evaluate the clinical outcomes of a suture fixation technique for displaced tibial eminence avulsion fractures using the Rotator Cuff Guide (RCG; Acufex Microsurgical, Mansfield, Massachusetts). In a 12-year period from 1998 to 2010, a total of 17 tibial avulsion fractures were treated using the RCG for suture fixation. Outcomes evaluated included pain at final assessment and findings from Lachman, drawer, pivot shift, flexion, extension, and varus/valgus stress tests. Demographic data, fracture type, mechanism of injury, and postoperative activity were obtained for 17 patients (16 males and 1 female) who underwent surgery during the study period. Average patient age was 16.8 years (range, 13-37 years). Average follow-up was 25 months (range, 2 months to 13 years). Postoperatively, all fractures in all patients were radiographically healed, and all patients had stable Lachman and negative pivot shift tests. Two patients had 3° of extension loss, and 1 patient lost greater than 10° of knee flexion. The length of follow-up was broad. Further limitations include a small sample size and suture versus T-Fix (Acufex Microsurgical, Mansfield, Massachusetts) fixation methods. This technique offers a simplified, reliable method of suture fixation that provides few long-term complications and predictable results. Patients can expect to return to preinjury levels of activity, with the majority of patients achieving full range of motion.
Displaced tibial eminence avulsion fractures can be difficult to treat. These fractures occur most often in children and adolescents aged 8 to 14 years; however, such fractures can also occur in adults. Although the anterior cruciate ligament (ACL) undergoes strain and attenuation during these injuries, the bone avulses because the tibial eminence is not completely ossified in children, and the cancellous bone beneath the subchondral plate fails before the ligament ruptures. These fractures are classified as types I through IV based on their degree of avulsion and presence of displacement and comminution.

Despite anatomic reduction and secure fixation, patients with this injury can exhibit residual anterior knee laxity as well as decreased extension. If surgical reduction and fixation is performed and the fracture heals in good position, the majority of patients are able to return to their preinjury activity levels.

Multiple surgical methods of reduction and fixation for displaced tibial eminence avulsion fractures have been described. Open reduction and internal fixation techniques have a higher incidence of postoperative stiffness. Currently, this type of injury is generally treated with arthroscopic reduction and internal fixation. Screw or suture fixation are the 2 most common methods of fixation. Use of a screw technique provides stable fixation and allows for early range of motion. However, arthroscopic fixation with a screw can be difficult. Hyperflexion of the knee is generally required to allow an angle for placement of the screw, and often the resulting angle of the screw is suboptimal (ie, not perpendicular to the fracture line). In addition, achieving purchase with a screw can be difficult with smaller fracture fragments. Finally, screw fixation leaves hardware in the joint with the potential for joint injury, and the hardware may require removal if additional surgery, such as ACL reconstruction, is required.

Suture fixation of tibial eminence fractures can also be technically demanding. The sutures must be passed through drill holes in the tibia, through or around the reduced fracture fragment. The purpose of this study was to evaluate the outcomes of a suture fixation technique for displaced tibial eminence avulsion fractures using the Rotator Cuff Guide (RCG; Acufex Microsurgical, Mansfield, Massachusetts).

**Materials and Methods**

After obtaining internal review board approval, data from the trauma registry and clinic notes were obtained and reviewed. All of the patients in this retrospective study underwent arthroscopic reduction and internal fixation at the University of Kentucky orthopedics and sports medicine department between 1998 and 2010. When possible, patients were contacted to answer follow-up questions and to schedule a physical examination. For patients who could not be contacted, their most recent clinical evaluation was used. Inclusion criteria were tibial eminence fractures treated operatively with the RCG device/suture or the RCG device/T-Fix (Acufex) methods of fixation. Exclusion criteria were screw fixation, damage to the ACL exceeding 50% of substance, and previous knee surgery. A total of 30 patients were initially identified based on injury, and 13 were excluded based on method of fixation or concomitant injuries. Thus, 17 patients composed the patient population of this study.

Initial injury data concerning mechanism, avulsion type, time to operation, comorbidities, and concomitant injuries were recorded. Postoperative clinical evaluation parameters included range of motion, Lachman stability and endpoint, varus/valgus stress test, pain, anterior and posterior drawer tests, resumption of preinjury activity levels, and integrity of the ACL at latest follow-up. Pain was quantified as constant, intermittent with light activity, intermittent with strenuous activity, and none.

**Surgical Technique**

Patients are positioned in a standard leg holder placed around the proximal thigh. Three arthroscopic portals are used: a standard lateral portal, an anteromedial portal just medial to the patellar tendon, and a far medial portal. A diagnostic arthroscopy is performed, and the hemarthrosis is evacuated from the joint. The fracture is visualized (Figure 1), and the fracture bed on the underlying tibial cancellous bone is cleaned with a shaver and slightly deepened, allowing for a slight overreduction of the fracture.
The RCG guide (Figure 2) is placed within the joint, and the fracture is reduced. A blunt probe often is placed through the far medial portal to hold the fracture fragment in position. The double-barreled RCG guide then is clamped into position, much like a standard ACL tibial guide, after making a small incision over the anteromedial tibia. A disposable guide pin with an overlying metal sheath has been designed for the RCG guide. Two of these guide pins then are sequentially drilled through the RCG guide, each crossing the fracture line and exiting into the joint, 1 just medial and 1 just lateral to the guide itself, under direct arthroscopic visualization.

The guide pins are removed, leaving the 2 sheaths in the joint, crossing the fracture into the tibial eminence fragment with the fracture reduced (Figure 3). A #2 FiberWire suture (Arthrex, Naples, Florida) is then passed up 1 sheath. A small cannula is placed through the far medial portal. A Shuttle Relay (Conmed Linvatec, Largo, Florida) is then passed up the second sheath and pulled out of the cannula along with the FiberWire suture. The FiberWire suture is placed within the Shuttle Relay, which is pulled back through the sheath, through the bone, and out the incision in the proximal tibia (Figure 4).

The sheaths and RCG guide are removed, and the sutures are tied through the incision in the proximal medial tibia. If desired, 1 sheath can be left in place, the RCG guide moved slightly, and a third sheath drilled into position to form a triangle type of configuration. A second FiberWire suture then is passed in a similar manner. After tying the sutures, the knee is taken through a range of motion under arthroscopic visualization to confirm a stable anatomic reduction (Figure 5).

Currently, the authors use this same technique with FiberWire sutures. In the early cases performed with the RCG guide, a T-Fix implant made for the RCG guide was used instead of the FiberWire suture. This T-Fix was deployed through the sheath and then pulled distally after removing the sheath (Figure 6). The sutures on the T-Fix implants were then tied to each other through the incision over the anteromedial tibia. All other steps of the procedure were the same.

**Postoperative Protocol**

Patients were fitted in a brace locked in extension for weight bearing. At 2 weeks postoperatively, patients began physical therapy for range of motion and quadriceps activation. Early emphasis was placed on regaining terminal extension, with flexion limited to 90° for the first 6 weeks. Full range of motion and weight bearing with the brace unlocked were then allowed. If anatomic fracture healing was confirmed radiographically at 3 months, the brace was discontinued, and return to sports was allowed at 4 months.

**Statistical Analysis**

Data were analyzed using SPSS version 16.0 software (SPSS Inc, Chicago, Illinois). Independent-sample *t* tests were performed to evaluate potential association between injury variables and postoperative flexion. Significance was set at *P* = .05.

**RESULTS**

A total of 17 patients (16 males and 1 female) composed the study population. The right knee was affected in 10 patients and the left knee was affected in 7 patients. Mean patient age at the time of trauma was 16.8 years (range, 13-37 years). Average follow-up was 25.3 months (range, 2 months to 13 years). Six patients were injured in a fall from a single-rider motor vehicle (eg, dirt bike, motorcycle, all-terrain vehicle). Less common methods of injury included football (4 patients), basketball (1 patient), cheerleading (1 patient), bicycle (1 patient), and stepping in a hole (1 patient). Fifteen (88%) of the 17 fractures were type III according to the Meyers and McKeever rubric. One patient sustained a type II fracture, and 1 patient sustained a type IV (comminuted fracture).

All of the fractures were treated using the RCG device. Average time from injury to surgery was 14 days (range, 5-150). The T-Fix device was used in the first 11...
patients, and FiberWire suture fixation was used in the remaining 6 patients. Average number of T-Fix deployments in the 11 patients was 2.5.

Preoperatively, all 17 patients demonstrated a positive Lachman with instability and no firm endpoint. At their latest follow-up, all patients had a negative Lachman, good stability was achieved, and a firm endpoint was identified. All patients also demonstrated negative anterior and posterior drawer tests. All patients had a stable to varus/valgus stress test, and all had resumed their preoperative level of activity. Two patients subsequently reinjured their knee and tore the ACL (1 patient at 2 years postoperatively and 1 patient at 4 years postoperatively).

Physical examination demonstrated full extension in all but 2 (88%) patients (Table 1). The 2 patients without full extension lacked 3° of extension compared to their uninjured knee. Sixteen patients achieved greater than 130° of flexion; the remaining 1 patient had 122° of flexion. On average, patients lost 5.5° of flexion, but this varied as a function of age at time of surgery. To examine the relationship between skeletal maturity at injury and eventual flexion achieved, patients were divided into those aged older than 16 years and those aged younger than 16 years, as others have reported. Six patients were in the older group and 11 patients were in the younger group. Mean age was 23 years (range, 17-37 years) in the older group and 13.5 years (range, 13-14 years) in the younger group. Postoperative flexion of the repaired knee varied as a function of age ($P=.011$), with the younger group achieving 144°±4.5° and the older group regaining 132°±7.5°.

To examine whether delay in treatment had any effect on eventual range of motion, patients were divided into those who underwent surgery in 7 days or less and those who waited longer than a week for surgery. No statistical difference in flexion or extension existed between the groups.

Nine (53%) of 17 patients reported no pain at follow-up. The remaining 8 patients reported mild intermittent pain associated with strenuous activity. None of the patients reported constant pain. Patients who reported intermittent pain achieved average flexion of 137°, whereas those who reported no pain demonstrated a mean flexion of 142°; this difference was not statistically significant ($P=.25$).

**DISCUSSION**

Pediatric tibial eminence avulsion injuries generally involve a low-energy mechanism, with falls from bicycles and motorbikes, sporting activities, and pedestrian/motor vehicle collisions being the most common causes. Adult fractures often result from high-energy mechanisms and are more commonly associated with concomitant injuries to other ligaments or the menisci.

Meyers and McKeever initially classified these injuries as types I, II, and III. Type I is nondisplaced or minimally displaced with good bone apposition, type II has displacement of the anterior third to half of the avulsed fragment, and type III is a complete separation of the avulsed fragment. Type IV, which is a displaced and comminuted fragment, was later added by Zaricznyj. Treatment of these injuries is dictated by the classification.
Type I and II injuries usually are treated nonoperatively in a long leg cast in either full extension\textsuperscript{1,2} or in 20° of flexion.\textsuperscript{3} A closed reduction, with the knee placed in full extension thereby compressing the fragment with the condyles, may be attempted in type II and III injuries.\textsuperscript{2} Interposition of the anterior horn of the medial meniscus, anterior horn of the lateral meniscus, or the intermeniscal ligament may block reduction.\textsuperscript{2} Type III and IV injuries are treated operatively with reduction and fixation,\textsuperscript{4} with some advocates recommending operative treatment for type II injuries.\textsuperscript{5}

Although the overall treatment algorithm has remained largely unchanged since it was first described in 1959,\textsuperscript{2} the surgical techniques have evolved. Arthroscopic reduction and internal fixation, as opposed to open reduction and internal fixation, has become increasingly popular.\textsuperscript{2} This shift may be attributed to the proposed associated decreased morbidity,\textsuperscript{6} as well as to advances in arthroscopic techniques and devices.\textsuperscript{2} Two modes of fixation, screws or sutures drilled through bone tunnels, have emerged as the preferred means of fixation and have been compared in biomechanical studies. Postoperative mobilization is necessary to prevent knee stiffness and is largely dependent on the strength of fixation at the fracture site.

Much has been published on the diverse surgical options available in the management of tibial eminence fractures. The use of cannulated screws can achieve a rigid fixation of the avulsed fragment and ACL as well as potentially earlier weight bearing. However, this technique may require a second procedure to remove the hardware and is of limited usefulness when fragments are small or comminuted.\textsuperscript{2,9} In addition, when a patient has open physes, the screw must be short to avoid crossing the growth plate. Screw placement also is complicated by the challenge of achieving a satisfactory angle of placement, which can be difficult given the confines of the arthroscopic approach. Suture placement avoids a future operation for hardware removal and serves to minimize damage to the growth plate. FiberWire sutures have been shown to have higher fixation strength compared with screws.\textsuperscript{10,11} In addition, Eggers et al\textsuperscript{10} found that in comparing screw and suture cyclic weight loading, suture fixation provided support for higher maximum load as well as longer fixation without failure.

The primary problem with suture fixation of tibial eminence fractures has been the difficulty in reproducibly performing the arthroscopic procedure. The current study demonstrates that the use of the RCG method of fixation is an excellent option for surgical management of this injury in children and adults. It is a simple, uncomplicated method for achieving rigid fixation of the avulsed fragment, even if the avulsion is small or comminuted. It allows the surgeon a stable approach and provides a consistent, standardized bone tunnel through which sutures can be passed.

The presence of residual anterior laxity, which has been reported in some cases to occur in more than 10% of patients managed surgically, is a demonstrated complication of this injury.\textsuperscript{2,3,12} The patients in the current study showed good stability on examination, with all of the patients showing negative results on all of clinical laxity/instability tests. A positive Lachman is an occasional finding among suture fixation studies\textsuperscript{13,14}; however, this did not apply to the current study. In addition, other studies have shown that diminished range of motion in the long term is a concern.\textsuperscript{2,3} The results obtained in the current study were encouraging for range of motion; at their latest follow-up, 2 patients had lost 3° of extension, and 1 patient had lost more than 10° of flexion.

Limitations of this study include the small sample size of 17 patients, the use of T-Fix devices in early study patients, and a broad follow-up period.

**CONCLUSION**

Multiple options are available for the surgical management of the fractured tibial eminence. The current authors believe the RCG method of suture fixation is an excellent choice with limited long-term complications and predictable results. The primary advantages of this technique are its simplicity and reproducibility. Patient outcomes after this technique are generally good.

**REFERENCES**

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