Clinical Outcome of Arthroscopic Suture Fixation for Tibial Eminence Fractures in Adults

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Purpose: The purpose of this study was to evaluate the clinical outcome of arthroscopic suture fixation for tibial eminence fractures in adults. **Methods:** Twelve patients with a mean age of 29.9 years (range, 18 to 45 years) were prospectively followed up after arthroscopic suture fixation for tibial eminence fractures. Along with clinical examination, Lysholm, Tegner, and International Knee Documentation Committee (IKDC) rating scales were used to evaluate the patients. Anteroposterior knee laxity was measured with a Rolimeter (Aircast, Vista, CA), and range of motion was measured with a goniometer. **Results:** Patients were followed up for a mean of 50 months (range, 25 to 69 months). There were no detectable signs or symptoms of instability postoperatively. The mean preinjury Tegner score was 6.1 (range, 3 to 9), and at follow-up, the mean Tegner score was 5.8 (range, 3 to 9). No Lysholm or IKDC scores were obtained and no range-of-motion measurements were performed preoperatively because all injuries were acute. The mean Lysholm score was 98 (range, 94 to 100), and the mean IKDC score was 94.7 (range, 89.1 to 100). Anterior translation of the tibia, measured with the Rolimeter, was 0.58 mm on average (range, 0 to 3 mm) compared with the healthy side. Postoperatively, the mean extension deficit was 1° (range, 0° to 5°) and the mean flexion deficit was 2.7° (range, 0° to 10°) compared with the unaffected side. Overall, knees were graded as normal or nearly normal in 11 patients and abnormal in 1. **Conclusions:** Tibial eminence fractures in adults can be effectively treated with arthroscopic suture fixation. **Level of Evidence:** Level IV, therapeutic case series.

Tibial eminence fractures were first described in 1959 by Meyers and McKeever[1] and classified into 3 types. Type I fractures are nondisplaced; in type II fractures, the anterior margin is displaced; and type III fractures are completely displaced. Zaricznyj[2] added a type IV fracture, where the fragment is comminuted.

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Tibial eminence fractures are more commonly seen in children and adolescents.[3,4] Consequently, there are only a few reports of this injury in adults, and therefore the clinical outcome has not been extensively evaluated.

Surgical reduction and fixation are usually required for displaced fractures. The goal of the operative treatment is to restore full range of motion and knee stability.[3,4] Fixation can be accomplished with either sutures or hardware.

Interestingly, the outcome of arthroscopic fixation in children and adolescents is usually satisfactory, but the results in adults are less predictable. Hunter and Willis[5] found that the younger the patient is, the better the outcome after arthroscopic fixation for tibial eminence fractures.

Moreover, some authors have reported high rates of postoperative complications, such as motion impairment and instability, in both skeletally immature and skeletally mature patients, raising concerns about the efficacy of arthroscopic fixation. Berg[6] reported on 2 cases in which postoperative arthrofibrosis developed, and Montgomery et al.[7] reported that 9 of 17 patients (53%) had severe difficulty in regaining motion postoperatively. Osti et al.[8] studied 10 patients and found no extension deficit but reported a rate of laxity of 30% (3 of 10 patients) with fair or poor results. On the other hand, Zhao and Huangfu[9] treated 18 patients with nonunited anterior cruciate ligament (ACL) tibial avulsion fractures with arthroscopic suture fixation and reported no case of arthrofibrosis or instability. Similar results were reported by other authors as well.[10,11]

The purposes of this study were to evaluate the clinical outcome of arthroscopic suture fixation for tibial eminence fractures in skeletally mature adults and particularly to assess knee stability and range of motion. We hypothesized that arthroscopic suture fixation for tibial eminence fractures in adults could restore knee stability and range of motion.

METHODS

Between January 2006 and October 2009, 15 patients with tibial eminence fractures were treated at our institution. The inclusion criteria were displaced tibial eminence fractures (types II, III, and IV) in skeletally mature patients. Tibial eminence fractures were defined according to the classification of Meyers and McKeever[1] modified by Zaricznyj.[2]

Clinical and radiographic examinations were used to evaluate the injury on admission (Fig 1). Three patients had type I fractures (nondisplaced) and were treated conservatively with a long cast. The nondisplaced fractures were excluded from the study; thus 12 patients were included in the final results.

Surgical Technique

All patients were operated on by the same surgeon within 5 days after injury. The surgical technique used the fundamental principles of suture fixation for avulsion fractures that were first described by Lee[12] in 1937 using an open technique. Under general or epidural anesthesia, the patient was placed in the supine position and standard knee arthroscopy was performed under tourniquet control. A fluid pump was set in the range of 60 to 90 mm Hg to control bleeding and improve visualization. Because all cases were acute, the first stage of the procedure was evacuation of the hematoma. The joint was then thoroughly inspected for associated injuries, which were addressed appropriately before tibial spine fracture reduction was attempted. The soft tissue was debrided with a motorized shaver to enhance visualization (Fig 2). Fibrin clots and small fracture fragments were removed underneath the main fragment and from the tibial crater if needed. Trial reduction was performed with a probe or blunt trocar in cases of comminuted fractures. 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 prevented 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. If that maneu-

Figure 1. Anteroposterior and lateral radiographs of type III tibial eminence fracture.

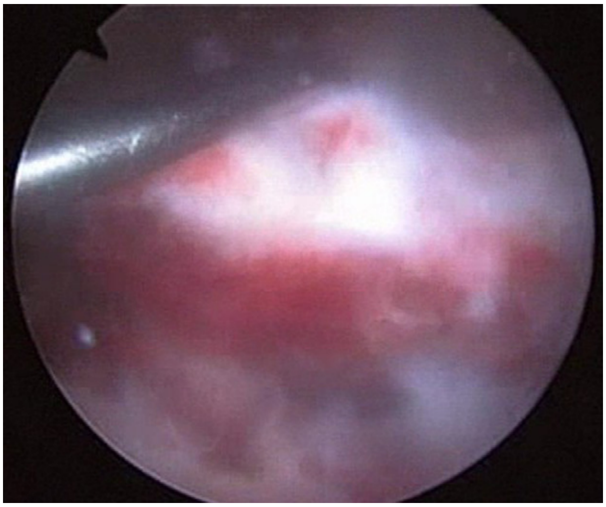

Figure 2. Arthroscopic view of fracture shown in Fig 1.

ver was not successful, we resected the part of the soft tissue that interfered with the reduction. After the trial reduction, a suture hook (Linvatec, Largo, FL) loaded with No. 2-0 polydioxanone suture (PDS; Ethicon, Somerville, NJ) was introduced through the anteromedial portal and pierced the fibers of the ACL as far anteriorly as possible. The PDS was then advanced into the joint while the suture hook was removed. A suture grasper was used to retrieve the end of the PDS out of the joint through the anteromedial portal. The PDS was used as a guide suture to deliver a No. 2 Ethibond nonabsorbable suture (Ethicon) through the

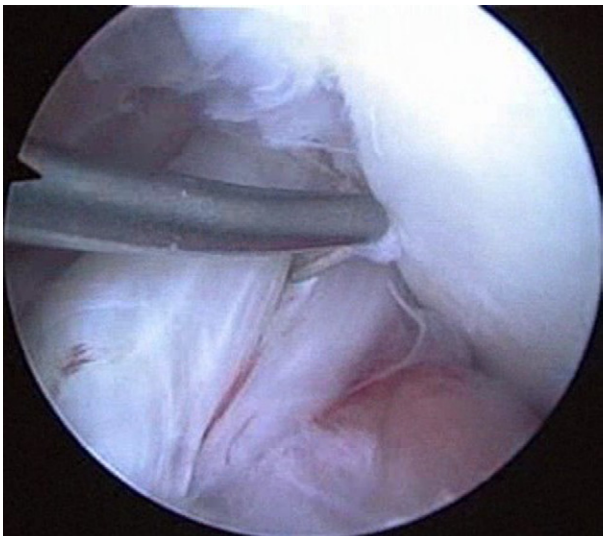

Figure 3. Checking ACL tension after fragment fixation.

Figure 4. Postoperative lateral radiograph of fracture shown in Fig 1.

base of the ACL. The 2 ends of the suture limbs were gathered with a hemostat for future identification. An additional 2 sutures were passed in the same fashion through the ACL slightly posterior to the initial sutures. A 3-cm longitudinal incision was made over the proximal anteromedial tibia, and by use of the ACL tibial guide, 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 2 tunnels over the external cortex of the proximal tibia. The exit of the medial and lateral tunnels in the joint was positioned at the anteromedial and anterolateral margins of the fracture site, respectively. The medial and lateral limbs of the sutures were then brought out of the medial and lateral bone tunnels, respectively. This was accomplished using a suture grasper through the anteromedial portal to deliver the suture limbs to the suture retriever that was introduced through the tunnels. The sutures were then tied over the bony bridge with the knee in 30° of flexion. The fragment was held reduced with the probe or blunt trocar, and the sutures were kept under tension until all sutures were tied. The surgeon then 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 (Fig 3). Postoperative radiographs were used to confirm anatomic reduction of the fragment (Fig 4).

Rehabilitation

A long leg splint was applied for 2 weeks. The knee was then placed in a hinged knee brace locked in extension for another 2 weeks. Patellar mobilization exercises were performed while the patients wore the brace. The brace was then adjusted to allow increased range of motion of the knee. Patients were initially allowed partial weight bearing with crutches, and at 4 weeks, full weight bearing was allowed. Isometric quadriceps muscle exercises were performed throughout the immobilization period to minimize disuse atrophy. Return to sports was permitted at 6 months postoperatively, after knee stability, range of motion, muscle strength, and proprioception were restored.

Clinical Evaluation

The patients were followed up at 1.5 months, 3 months, 6 months, and 12 months and then yearly. Anteroposterior and lateral radiographs were obtained 1.5 and 3 months postoperatively to assess fracture healing. A fracture was considered united if no fracture line was visible radiographically at 3 months. Proximal migration of the fragment was assessed and measured using an object (a coin) of a known size projected onto the film to determine the magnification. At final follow-up, all patients were reviewed by an independent orthopaedic surgeon uninvolved with their care. Patients were evaluated both subjectively and objectively. A comprehensive clinical examination was performed. Anteroposterior laxity was assessed with the Lachman-Noulis, pivot-shift, and anterior drawer tests. A Rolimeter knee tester (Aircast, Vista, CA) was used for quantification of anterior tibial translation. Knee range of motion was evaluated actively and passively with a goniometer. Knee function was evaluated by the Lysholm and International Knee Documentation Committee (IKDC) scores, and the activity level before injury and at follow-up was rated by the Tegner scale. Patients were also evaluated according to the IKDC knee examination form, and their knees were graded as normal (grade A), nearly normal (grade B), abnormal (grade C), or severely abnormal (grade D). Knee radiographs in standing anteroposterior, standing lateral, and Merchant views were examined for alignment, joint space narrowing, and degenerative knee changes.

Statistical Analyses

All statistical analyses were performed with IBM SPSS Statistics software (version 20.0; IBM, Armonk, NY). Descriptive statistics were presented for all continuous variables (e.g., age, Rolimeter measurement, extension deficit, flexion deficit, Tegner score difference, Lysholm score, and IKDC score). Frequencies were used to obtain descriptive statistics for all categorical variables (e.g., sex, cause of injury, type of fracture, and IKDC grade). A paired t test was conducted to test for differences in Tegner score between preoperative and postoperative measurements. The criterion level for significant differences was set at $P < .05$.

RESULTS

The study population consisted of 9 male (75%) and 3 female (25%) patients. The mean patient age at the

TABLE 1. *Demographic and Injury Data of Patient Population*

Patient No.	Sex	Age (yr)	Cause of Injury	Type of Fracture	Time to Surgery (d)	Concomitant Injuries	Soft-Tissue Interposition
1	M	41	Skiing	II	2	LM	Y
2	M	22	Motorcycle	IV	2	—	Y
3	M	18	Motorcycle	III	1	LM	Y
4	F	24	Skiing	III	3	MM, MCL	Y
5	M	28	Handball	II	3	—	N
6	M	21	Soccer	II	1	LM	N
7	F	38	Skiing	III	5	—	Y
8	F	45	Fall	IV	4	MCL	Y
9	M	34	Soccer	III	1	—	N
10	M	32	Motorcycle	II	2	—	Y
11	M	34	Motorcycle	IV	2	MM	N
12	M	22	Skiing	III	1	—	Y

Abbreviations: F, female; LM, lateral meniscus tear; M, male; MCL, medial collateral ligament injury; MM, medial meniscus tear.

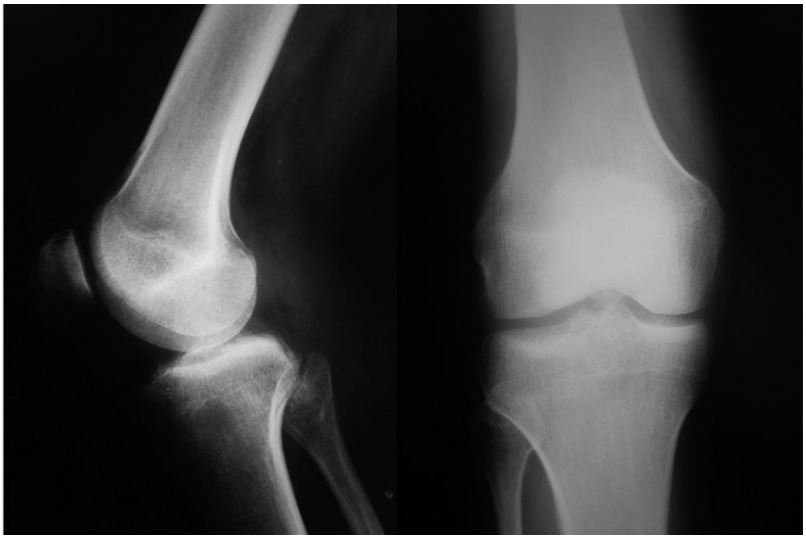

Figure 5. Anteroposterior and lateral radiographs showing healing of tibial eminence fracture shown in Fig 1.

time of surgery was 29.9 years (range, 18 to 45 years). The cause of injury was related to sports in 7 patients (58%), a motorcycle accident in 4 (33%), and a simple fall in 1 (8%). The modified Meyers and McKeever classification identified 4 type II fractures (33%), 5 type III (42%), and 3 type IV (25%). The mean time from injury to surgery was 2.25 days (range, 1 to 5 days). No Lysholm or IKDC scores were obtained and no range-of-motion measurements were performed preoperatively because all injuries were acute. Concomitant injuries were found in 6 patients (50%). Lateral meniscus tears were found in 3 patients (25%), a medial meniscus tear in 1 (8%), grade I medial collateral ligament injury in 1 (8%), and grade II medial collateral ligament injury and a medial meniscus tear in 1 (8%). All meniscal tears were not amenable to repair and were treated with partial meniscectomy, whereas medial collateral ligament injuries were treated conservatively. 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 8 patients (67%). The demographic and injury data of the patient population are analytically presented in Table 1. The mean follow-up period was 50 months (range, 25 to 69 months).

Radiographs showed that all fractures healed anatomically within 3 months after surgery (Fig 5), with the exception of 1 patient (8%) (patient 9) in whom the fragment healed slightly superiorly (Fig 6). At the latest follow-up, no radiographs showed joint space narrowing or degenerative changes.

One patient (patient 3) was initially lost to follow-up and did not follow the suggested rehabilitation

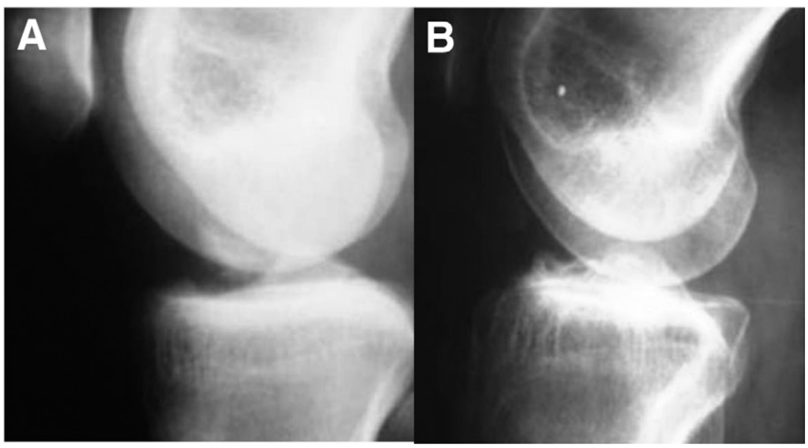

Figure 6. (A) Preoperative lateral radiograph of tibial eminence fracture. (B) Lateral radiograph showing that the fragment has healed slightly superiorly.

TABLE 2. *Statistical Analysis*

	N	Minimum Statistic	Maximum Statistic	Mean	SE	SD
Rolimeter measurement (mm)	12	0	3	0.58	0.260	0.900
Extension deficit (°)	12	0	5	1.00	0.444	1.537
Flexion deficit (°)	12	0	10	2.67	0.882	3.055
Preoperative Tegner score	12	3	9	6.08	0.514	1.782
Postoperative Tegner score	12	3	9	5.83	0.505	1.749
Tegner score difference	12	0	2	0.25	0.179	0.622
Lysholm score	12	94	100	98.08	0.773	2.678
IKDC score	12	86.7	100.0	94.725	1.4369	4.9776
Valid N (list-wise)	12					

regimen, and on his return to the clinic 4 months postoperatively, he showed a range of motion of 15° to 75°. Intense physiotherapy for 2 months was not effective, and the patient underwent arthroscopic lysis of the adhesions that, along with physiotherapy, resulted in a satisfactory result (range of motion of 0° to 125°). Second-look arthroscopy showed a healed fracture with normal ACL tension. With the exception of this case of arthrofibrosis, no other major complication, such as infection, deep venous thrombosis, or neurovascular deficit, was encountered. At the final follow-up, all patients reported no symptoms of instability, such as giving-way episodes; moreover, clinical signs of ACL deficiency (Lachman-Noulis, pivot-shift, and anterior drawer tests) were negative. Physical examination did not show any other pathologic findings. The mean preinjury Tegner score was 6.1 (range, 3 to 9), and at follow-up evaluation, the mean Tegner score was 5.8 (range, 3 to 9); however, this decrease was not found to be statistically significant (t_{11} = 1.39, $P > .05$). The mean Lysholm score was 98 (range, 94 to 100), and the mean IKDC score was 94.7 (range, 89.1 to 100). Anterior translation of the tibia, measured with the Rolimeter, was 0.58 mm on average (range, 0 to 3 mm) compared with the uninjured side. Range-of-motion measurement with the goniometer showed a mean extension deficit of 1° (range, 0° to 5°) and a mean flexion deficit of 2.7° (range, 0° to 10°) compared with the unaffected side. The descriptive data for Rolimeter measurement, extension deficit, flexion deficit, preoperative Tegner score, postoperative Tegner score, Tegner score difference, Lysholm score, and IKDC score are summarized in Table 2. Overall, the IKDC grade was A (normal) in 7 patients (58%), B (nearly normal) in 4 (33%), and C (abnormal) in 1 (8%). The analytic results of knee subjective and objective evaluation are presented in Table 3.

TABLE 3. *Analytic Results of Knee Subjective and Objective Evaluation*

Patient No.	Follow-up (mo)	Rolimeter Measurement (mm)	Extension Deficit (°)	Flexion Deficit (°)	Tegner Score (Preoperative-Postoperative)	Lysholm Score	IKDC Score	IKDC Grade
1	69	0	2	5	8-6	94	89.1	B
2	38	1	0	0	6-6	100	100	A
3	25	1	0	10	7-7	94	90	C
4	57	0	2	2	7-7	100	100	A
5	57	0	0	0	5-5	100	100	A
6	32	0	0	0	9-9	95	89.1	A
7	45	0	0	4	6-6	100	100	B
8	63	1	1	1	3-3	100	96.3	A
9	57	3	5	5	4-4	99	94	B
10	61	1	0	0	5-4	95	86.7	A
11	52	0	2	1	5-5	100	94	A
12	44	0	0	4	8-8	100	97.5	B

DISCUSSION

Tibial eminence fractures commonly occur in children and adolescents and are less common in skeletally mature individuals.[3,4] In adults the treatment options for displaced tibial eminence fractures are suture or hardware fixation of the avulsed fragment and ACL reconstruction. We preferred to retain the native ACL to maintain the proprioceptive function and neuromuscular control provided by the presence of mechanoreceptors in the ACL.[13] Both suture and hardware fixation techniques have been studied in cadavers. Tsukada et al.[14] found that there was significantly greater anterior translation after cyclic loading in fractures stabilized with pullout suture fixation compared with antegrade screw fixation. On the other hand, Bong et al.[15] reported that the initial ultimate strength was higher with 3 No. 2 FiberWire sutures (Arthrex, Naples, FL) than with a 4 × 40–mm partially threaded cannulated screw with a washer, whereas Eggers et al.,[16] in a porcine model, found that under cyclic loading, suture fixation provides greater strength than screw fixation does. These 2 techniques have also been directly compared clinically. Hunter and Willis[5] found no significant differences in outcomes with regard to type of fixation, whereas Seon et al.[17] reported that both the screw and suture fixation techniques produced relatively good results in terms of functional outcomes and stability, without any significant differences. Consequently, the current literature supports that, in terms of biomechanical properties and clinical outcome, suture fixation and screw fixation are comparable and effective techniques in tibial eminence fracture treatment. In our department we prefer the arthroscopic suture fixation technique because of the advantage of its applicability in all types of fractures whereas screw fixation cannot be applied in comminuted fractures.[3,4] Moreover, with the suture fixation technique, there is no need for hardware removal later.[3,4]

Concomitant injuries of the menisci, capsule, collateral ligaments, and cartilage have been found in nearly 40% of cases with tibial eminence fractures in children and adolescents.[3] In our study in adults, in total, we found 6 patients (50%) with isolated fractures of the tibial spine and 5 patients (41%) with meniscal injury, which is in accordance with the studies of Montgomery et al.[7] and Huang et al.,[11] who reported rates of 41% for isolated injuries and 25% for meniscal injuries, respectively.

We did not evaluate our patients with magnetic resonance imaging to look for bone bruises that often accompany acute ACL tears.

Interposition of the anterior horn of the medial meniscus, anterior horn of the lateral meniscus, or intermeniscal ligament has been reported in skeletally immature patients. Kocher et al.,[18] in a series of 80 skeletally immature patients with tibial eminence fractures, found that meniscal entrapment obstructed anatomic reduction in 54% of cases. This phenomenon has not been studied in adults. In our case series, soft-tissue interposition was found in 8 patients (67%). Debridement of the portion of the entrapped meniscus or intermeniscal ligament that prevented anatomic reduction did not cause any clinical symptoms. Nevertheless, care should be taken to remove only the necessary part of the intermeniscal ligament, because this provides stability to the anterior horn of the menisci in patients without a bony attachment.[3]

Postoperatively, our patients were advised to follow a conservative rehabilitation regimen. We allowed immediate partial weight bearing but no motion at all for 4 weeks, with the intention to secure the fixation. In contrast, other authors who treated tibial eminence fractures in adults applied an accelerated program with passive and active motion 0 to 2 weeks after surgery, to avoid arthrofibrosis.[7-11] Nevertheless, we applied early (after 2 weeks) passive mobilization of the patellofemoral joint for the same purpose. Our results in terms of knee motion were satisfactory. We had 1 case of arthrofibrosis (range of motion of 15° to 75°) that required arthroscopic lysis of the adhesions, along with intense physiotherapy, to obtain full extension and a 10° flexion deficit. This patient was temporarily lost to follow-up after surgery, and the rehabilitation regimen followed is unspecific. All other patients had no difficulties in regaining satisfactory knee motion, and at final follow-up, range-of-motion measurement was satisfactory. Loss of motion and arthrofibrosis are concerns after tibial eminence fracture. It has been reported that stiffness may occur in as many as 60% of knees that are treated surgically for tibial eminence fracture.[19] Berg[6] reported 2 cases of arthrofibrosis, whereas Montgomery et al.,[7] 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. Loss of motion may occur because of mechanical impingement of the displaced fracture or arthrofibrosis. We had 1 case of a 2-mm superior fracture displacement in a patient who, at final follow-up, showed a 5° extension deficit. We believe that, in most of our patients, full extension was achieved because we immobilized and braced the knee in this position. Theoretically, full extension also allows the femoral condyles to compress and anatomically reduce the fracture.[4] In addition, we believe that early patella–femoral joint mobilization is of great importance in ultimately achieving full flexion.

The main goal of tibial eminence fracture treatment is to restore ACL competence. Nevertheless, continued laxity and instability have been reported in 10% of skeletally mature patients treated surgically and in 22% managed nonsurgically.[19] Moreover, positive anterior drawer and Lachman tests were commonly found in patients who were satisfied with the clinical result and had functional stability.[20] Two factors are likely responsible for the residual laxity and instability. Imperfect reduction may result in malunion and ACL lengthening, and plastic deformation of the ligament before ultimate avulsion fracture may also be responsible for ACL incompetence. The ACL does not have the ability to remodel. Despite the fact that skeletal growth has been shown to compensate for some laxity of the ACL in an animal model,[21] this hypothetically protective mechanism has no effect in skeletally mature patients. Osti et al.[8] reported that 30% of their patients had a positive Lachman test and side-to-side difference greater than 3 mm (4.5 mm, 7 mm, and 8.5 mm) recorded with the KT-1000 manual maximum test (MEDmetric, San Diego, CA). These patients had fair/poor clinical outcomes. Interestingly, a partial ACL tear (<50% of fibers) was detected intraoperatively in these cases. Montgomery et al.[7] had 1 patient with instability (7%) and 3 patients (20%) with knee laxity (side-to-side difference >3 mm). In our study no signs or symptoms of instability were detected. Objective measurement of knee laxity showed 1 case with a 3-mm side-to-side difference; this occurred in the patient with the superiorly healed fracture. Our results are in accordance with other authors who found normal laxity and stability in their series.[9-11,22]

In total, the final outcome was satisfactory, with 11 of 12 patients' knees being graded as normal or nearly normal and 1 patient's knee as abnormal because of a 10° flexion deficit. IKDC grading was used only in 2 other studies with similar results.[9,11]

The main limitations of this study are the relatively small number of patients included and the absence of a control group. Tibial eminence fracture is a rare injury, however, with only a few reports of arthroscopic suture fixation in adults[6-9,11,22] or mixed populations.[5,10] This study is a consecutive case series with no patient lost to long-term follow-up. All procedures were performed by the same surgeon using the same surgical technique, and patients were evaluated at the final follow-up by an independent examiner.

CONCLUSIONS

Tibial eminence fractures in adults can be effectively treated with arthroscopic suture fixation.

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