Surgical management of fractures of the tibial plateau is evolving in response to development and application of arthroscopic techniques. Part II of this Current Concepts review of arthroscopic treatment of tibial plateau fractures specifically focuses on fractures of the tibial intercondylar eminence. As with other fractures about the knee joint, treatment was historically limited to immobilization and developed, over time, to include open surgical repair with a goal of achieving anatomic reduction and rigid internal fixation. Now, arthroscopic reduction, internal fixation (ARIF) is emerging as the state-of-the-art method of treatment.

ANATOMY

The tibia is the major weight-bearing bone of the knee joint. Proximally, the tibia widens to form the medial and lateral condyles. Between the condyles, the intercondylar eminence serves as the point of attachment for portions of the menisci and the anterior and posterior cruciate ligaments. Specifically, the anterior cruciate ligament (ACL) distal attachment is the midpoint of the tibial intercondylar eminence. In addition to disrupting ACL continuity, intercondylar eminence avulsion fractures, depending on size, may affect weight-bearing aspects of the articular surface of the tibia.

EPIDEMIOLOGY

Avulsion fractures of the tibial intercondylar eminence most commonly occur in children and adolescents, and are equivalent to rupture of the ACL in adults. This fracture usually occurs in individuals between the ages of 8 and 14 years, and almost one half result from a fall from a bicycle. However, it is sometimes misunderstood that this condition occurs only in the younger population. While less common, tibial intercondylar eminence fractures also occur in adults. In older patients, tibial eminence fractures are often combined with lesions of the menisci, capsule, or collateral ligaments.
MECHANISM OF INJURY

A fracture of the tibial intercondylar eminence is a consequence of ACL avulsion at its insertion. Mechanisms of injury are similar to those associated with ACL rupture, but instead of tearing of the ligament fibers, the ACL is pulled from the tibia with a piece of the bony plateau. It is believed that this condition is most common in children because children manifest relative weakness of the incompletely ossified tibial eminence as compared with the fibers of the ACL. This may also be related to the greater elasticity of ligaments in young people.

EVALUATION

As in patients with other fractures about the knee joint, patients with fractures involving the tibial intercondylar eminence present with a painful swollen knee and complain of difficulties in bearing weight. Signs of ACL insufficiency are positive, although pain may make thorough examination of the ligaments difficult. A complete neurologic and vascular examination must be performed.

IMAGING

Standard anteroposterior, lateral, and oblique radiographic views are usually diagnostic. Computed tomographic (CT) scanning allows precise definition of the fracture anatomy and magnetic resonance imaging (MRI) provides the added benefit of diagnostic imaging of associated meniscal, ligamentous, or chondral pathology. If pulses are abnormal or dislocation is suspected, arteriography must be considered.

ROLE OF ARTHROSCOPY

In addition to the option of ARIF (as discussed later), diagnostic arthroscopy allows direct visualization of the menisci, cruciate ligaments, chondral surfaces, and the articular portion of the fracture site. Diagnostic arthroscopy may provide a valuable adjunct in cases of open treatment of ACL avulsion fractures.

CLASSIFICATION

Meyers and McKeever describe 3 different fracture patterns specific to tibial intercondylar eminence fractures (Fig 1): Type I fractures are nondisplaced or associated with minimal displacement of the anterior margin; Type II fractures have superior displacement of their anterior aspect with an intact posterior hinge, resembling a bird’s beak; Type III fractures are completely displaced. Type III fractures have been subclassified: Type IIIA involves the ACL insertion only; Type IIIB includes the entire intercondylar eminence. Some have labeled comminuted fractures as type IV.

ASSOCIATED INJURIES

Meniscus tears are the injuries most commonly associated with fractures of the tibial intercondylar eminence. Intercondylar eminence fractures may include or be associated with any combination of bone, chondral, meniscal, or ligamentous injuries. In the authors’ experience, intercondylar eminence avulsion is commonly associated with more complex tibial fractures.

FIGURE 1. The Meyers and McKeever classification of tibial intercondylar eminence fractures.
plateau fracture patterns, especially Schatzker type V and VI patterns.\textsuperscript{18,19}

**MANAGEMENT**

The goal of treatment of tibial intercondylar eminence avulsion is anatomic reduction. Theoretically, over-reduction must be avoided to prevent excessive tightening of the ACL and limitation of knee motion.\textsuperscript{7} On the other hand, some believe that permanent intersubstance stretching of the ACL occurs before the fracture,\textsuperscript{15} and in such cases, over-reduction could be considered. Although further clinical or in vitro research is required to address this controversy, excessive tightening has not been observed to result in poor outcomes in the experience of the authors; slight over-reduction, while difficult to achieve, may be of benefit. In further support of slight over-reduction, long-term evaluation of well-reduced tibial eminence fractures reveals subtle increases in anteroposterior knee laxity, albeit without functional deficit.\textsuperscript{3,14,20-22}

In general, treatment of intercondylar eminence fractures is based on the Meyers and McKeever classification: type I fractures may be immobilized at or near full extension.\textsuperscript{4,5} Should the patient present with a tense hemarthrosis, aspiration may result in substantial pain relief.\textsuperscript{23} The treatment of type II fractures is controversial. In all cases, closed reduction may be attempted by aspiration of the hemarthrosis and knee extension or hyperextension (allowing the femoral condyles to reduce the fracture). A lateral radiograph is required to assess the reduction, and a CT scan may be considered if the radiograph is difficult to interpret. In cases of persistent superior displacement of the anterior aspect of the fragment, some authors recommend nonoperative management and cast immobilization.\textsuperscript{3,5,24} However, we believe that in cases of persistent superior displacement of the anterior aspect of the fragment, arthroscopic evaluation and treatment are required. Often, in such cases, the anterior horn of the medial (or occasionally, the lateral) meniscus will be trapped in the fracture site.\textsuperscript{9,10,11,17}

Closed reduction may also be attempted for type III injuries. In cases of persistent displacement, reduction and internal fixation is the standard-of-care.\textsuperscript{3-6,9,10,17,25,26} In the opinion of the authors, ARIF has supplanted open reduction and internal fixation as the state-of-the-art.

**SURGICAL TECHNIQUE**

ARIF of ACL avulsions with a retrograde lag screw technique was described in 1991,\textsuperscript{6} and ARIF using antegrade cannulated lag screws via a high anteromedial portal was described in 1993.\textsuperscript{7} Self-drilling, self-tapping screws facilitate the techniques. Disadvantages include risks of comminution of the fracture fragment, posterior neurovascular injury, and the need for hardware removal. Because of these risks, ARIF using nonabsorbable suture(s) passed through drill holes and tied over the tibial tubercle is now preferred. The technique described is based on the work of previous investigators.\textsuperscript{12,27-34}

The patient is placed in a circumferential leg holder with the knee off the end of the table. A tourniquet facilitates visualization, and a fluoroscopy unit (C-arm) may be placed such that the flat (image acquiring) plate is used as an operating table beneath the proximal tibia. Fluoroscopic imaging, however, is not required. In all cases, the calf compartments must be continually palpated to assure that fluid extravasation does not result in compartment syndrome. While intercondylar eminence avulsion fractures are contained injuries, they may be associated with capsular disruption.

Standard anterolateral and anteromedial portals are used. Cannulas are required when passing sutures to prevent inadvertent interposition of soft tissue. The technique may be performed using only 2 portals, while an accessory portal, particularly a central, transpatellar tendon portal, may facilitate the technique.

Thorough lavage is required to remove hemarthrosis or loose chondral or osteochondral fragments. Treatment of the avulsion fracture is recommended before treatment of associated pathology to prevent iatrogenic fracture displacement. Fibrous tissue or clot must sometimes be removed or debrided from the fracture bed while, again, avoiding iatrogenic displacement of the fragment.

A standard probe or double-hooked meniscal retractor (Arthrex, Naples, FL) may be used to retract the anterior horn of the medial (or lateral) meniscus or the transverse meniscal ligament, which is frequently trapped within the fracture site. In some cases, the entrapment may recur unless the fracture is simultaneously reduced. Should this be the case, definitive removal of the entrapped meniscus is performed after the reduction sutures are in place; once the fracture is reduced and fixed, the entrapment will not recur.

A 90° suture lasso (Arthrex) is placed percutaneously (or via an accessory portal) through the fibers of
the ACL in its midcoronal plane and as close to the bony fragment (distal) as possible. The wire loop within the lasso is secured with an arthroscopic grasper (Fig 2) and pulled via a cannula through either of the portals and loaded with a No. 2 Fiberwire suture (Arthrex). With one end of the suture secured, the lasso is then retrieved, pulling the other end of the Fiberwire back through the ligament fibers and out through the skin (or accessory portal).

Medial and lateral drill holes must next be established to pull the ends of the suture (and ultimately the fragment) down into the fracture bed. A short longitudinal incision is centered over the tibial tubercle; the medial pin will enter the tibia just medial to the tubercle, and the lateral pin will enter just lateral to the tubercle. A cruciate ligament guide with a custom marking hook (Arthrex) is used to place, respectively, two 2.4 mm drill-tipped guide pins (Arthrex) at the medial and the lateral edges of the fracture bed in its midcoronal plane, under direct arthroscopic visualization. Because the risk of growth disturbance due to transepiphyseal drilling has not been completely evaluated,35 in patients with wide open epiphyses, transepiphyseal tunnel placement may be considered as an alternative to transepiphyseal tunnels.

A specially designed, narrow shaft grasper (Arthrex) or a loop of wire is passed up through each drill hole to pull down the respective ends of the reduction suture. Planning is required to select the order of steps based on the pattern of the fracture. The surgeon and an assistant must work as a team because it is necessary, when removing the guide pin, to immediately place the grasper so that the small (2.4-mm) entrance hole for the grasper does not become obscured by soft tissue and difficult to locate.

The grasper is so narrow that it is rarely possible to grasp the entire No. 2 multifilament suture, but it is effective in affixing at least some of the filaments, and this proves adequate to secure the respective (medial and lateral) ends of the suture and pull the ends down through the respective (medial and lateral) tunnels. In addition, as the grasper can only slide superiorly or inferiorly within the tibial tunnel, a standard arthroscopic grasper must be placed through one of the portals in order to “hand” the respective ends of the suture to the narrow shafted grasper. Finally, it is challenging to visualize the tip of the grasper owing to its proximity to the fracture fragment and the respective femoral condyles. Because of these technical challenges, a surgical assistant skilled in knee arthroscopy is required.

Once the respective ends of the suture have been passed through the tunnels, the fracture is reduced by pulling down on the suture ends while removing any entrapped soft tissue. Treatment of associated intra-articular pathology may be performed before tying the suture, while provisional reduction is held by the assistant. Finally, the suture is tied over the tibial tubercle while an assistant performs a reverse Lachman maneuver. With the use of Fiberwire, only 1 suture is required in most cases (Fig 3).

Postoperative radiographs may suggest a few millimeters of superior displacement of the fracture fragment. This is usually not seen on the arthroscopic view, and so long as the surgeon is certain that the meniscus is not entrapped, this should not be considered a failure of surgical treatment. In the experience of the authors, excellent functional outcome and knee stability result despite this common, subtle radiographic finding. However, the goal of treatment is anatomic reduction. Residual displacement may result in loss of extension, and some recommend excision of the anterior bony portion of the fracture fragment to allow full extension if anatomic reduction is not achieved (D. H. Johnson, personal communication, January 2004).

ARIF of ACL avulsion may be performed on an outpatient basis. Crutches are optional and recommended at first, and patients are permitted to bear full weight with the knee locked in a brace in full extension. The brace is unlocked or removed for continuous passive motion, which is prescribed for 6 to 10 hours a day for 3 weeks. Formal physical therapy may be
required to achieve the goals of 90° of knee flexion at 2 weeks and full range of motion by 6 weeks. Isometric quadriceps and hamstring and abductor and adductor strengthening with the knee locked in the brace is permitted during the first 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° to 90°. Terminal resisted extension is not performed until 3 months.

**CLINICAL OUTCOME STUDIES**

The earliest published series describing ARIF of tibial intercondylar eminence avulsion fractures is also the largest. In 1982, McLennan\(^\text{10}\) described treatment of 20 type IIIA fractures and 15 type IIIB fractures with arthroscopic reduction followed by either extension and immobilization in a cast or retrograde crossed percutaneous pin fixation. Separate incisions were performed for collateral ligament or meniscus repair when required. The author concluded that arthroscopic reduction and percutaneous pin fixation provided an effective treatment for tibial eminence fractures and significantly decreased both morbidity and length of hospital stay compared with alternative treatments.\(^\text{10}\)

In a 1995 case report, Prince and Moyer\(^\text{36}\) recommended arthroscopic reduction and casting of an intercondylar eminence fracture. However, in an earlier report of 2 cases of arthroscopic suture repair and cast immobilization of comminuted tibial eminence fractures, Berger\(^\text{12}\) described the complication of arthrofibrosis. More vigorous and accelerated rehabilitation was recommended.

In a report of 6 cases of ARIF using multiple sutures followed by early rehabilitation, Matthews and Geissler\(^\text{29}\) described stable fixation with minimal morbidity in all cases. Osti et al.\(^\text{32}\) described a series of 10 type III fractures in adults. ARIF using metallic pull-out sutures resulted in no cases of symptomatic clinical instability despite 2 patients with KT-1000 results of greater than 3 mm side-to-side difference. All patients regained full extension and at least 125° of flexion.

Falstie-Jensen and Sondergard Petersen\(^\text{11}\) reported a series of 4 cases of type II or III fractures. Arthroscopy revealed entrapment of the medial meniscus in the fracture site. The fractures could not be reduced until the meniscus had been retracted. The authors recommended operation for all type II and III fractures.\(^\text{11}\) In a unique case of a type II eminence fracture, Chandler and Miller\(^\text{2}\) described that hyperextension of the knee joint resulted in radiographic evidence of adequate fracture reduction. However, arthroscopy revealed incomplete fracture reduction and entrapment of the anterior horn of the medial meniscus beneath the fracture fragment. These authors recommended arthroscopic evaluation for all displaced fractures of the tibial eminence.\(^\text{2}\) Kocher et al.\(^\text{37}\) described the prevalence of meniscal entrapment in displaced tibial eminence fractures in children to be 26% (6 of 23) in type II fractures and 65% (37 of 57) in type III fractures.

Lowe et al.\(^\text{20}\) found at arthroscopy that failure of closed reduction of 12 type III fractures was not a result of soft tissue interposition in any case. Rather, tethering of the fragment by an attached anterior horn of the lateral meniscus prevented reduction. ARIF was performed, using either screws or suture, in combina-

![Figure 3](image-url). The fracture is reduced by pulling down on the suture ends, which are tied over the tibial tubercle. Used with permission.
tion with meniscus repair. “Although all patients had functional stability and were satisfied with the result at the time of follow-up, positive anterior drawer and Lachman tests were commonly found.”

Kobayashi and Terayama described a single case of ARIF using a staple that allowed early motion and resulted in a good outcome.

Reynders et al. reported a series of 16 type II fractures and 10 type III fractures in children and adolescents were treated with ARIF using cannulated screws and washers. While complete restoration of anteroposterior knee stability was seldom seen, the results were uniformly good. No patients had stiffness, although 2 had extension lag. Two patients required revision in the form of ACL reconstructive surgery.

Senekovic and Veselko retrospectively reviewed a series of 32 cases (8 type II fractures, 18 type III, and 6 type IV) after ARIF of intercondylar eminence fractures using 1 or 2 cannulated screws or screws and washers. Soft tissue interposition was noted in all cases. Hardware was removed in 27 of 28 patients. At the 5-year follow-up, the mean Lysholm score was 98.9, mean KT-1000 side-to-side difference was 1.04 mm, and subjective outcomes were normal in 27 patients and nearly normal in 1 patient. The authors describe their technique as simple, safe, reproducible, and effective, and emphasize that postoperative immobilization is not required.

Binnet et al. reported a retrospective review of 21 cases of ARIF of intercondylar eminence avulsion repaired with suture in 8 adolescents and screws in 13 adults. All patients had satisfactory outcomes except 1 patient who had the complication of arthrofibrosis. The complication was attributed to lack of participation in rehabilitation due to vascular insufficiency, whereas all other patients underwent early range-of-motion exercise.

Hunter and Willis retrospectively reviewed 8 type II and 9 type III fractures treated with either suture or screw fixation. At 32.6 months’ follow-up, the mean Tegner score was 6.35 and mean Lysholm score was 94.2. The best outcomes were seen in younger patients. No significant differences were seen in outcomes with regard to type of fixation.

**SUMMARY**

ARIF of intercondylar eminence avulsion is recommended for all displaced type III fractures and should be considered in all cases of displaced type II fractures. Fractures without displacement after closed reduction require careful evaluation to rule out meniscal entrapment. Subjective results of ARIF using either cannulated screws or suture are uniformly excellent, despite many reports of objective anteroposterior laxity. Early range-of-motion exercises are essential to prevent loss of extension. Repair using nonabsorbable suture fixation, when of adequate strength to allow early range of motion, has the advantages of eliminating the risks of comminution of the fracture fragment, posterior neurovascular injury, and the need for hardware removal as compared with ARIF using screws.

**REFERENCES**


19. Schatzker J, McBroom R, Bruce D. The tibial plateau fracture:


