Arthroscopic Reduction and Internal Fixation of Tibial Eminence Fractures With Transosseous Suture Bridge Fixation

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Abstract: Arthroscopic reduction—internal fixation (ARIF) is an increasingly popular option for surgical management of displaced tibial eminence fractures. Although a variety of ARIF techniques have been described, anatomic reduction and stable fixation remain challenging. As a result, complications such as malunion, nonunion, anterior instability, arthrofibrosis, and hardware issues persist. In an effort to reduce complications and improve outcomes, modern suture-based ARIF techniques have been developed. However, the optimal technique and construct remain elusive. This article presents a technique for ARIF of tibial eminence fractures using a transosseous suture bridge construct with extracortical fixation. This technique uses a commercially available suture-passage device and meniscal root repair system for accurate tunnel placement, efficient suture management, and reliable fixation.

Tibial eminence fractures are bony avulsions of the anterior cruciate ligament (ACL) from its insertion on the intercondylar eminence of the tibia. Although these injuries are most common in skeletally immature patients, the incidence of tibial eminence fractures in adults is higher than previously thought.1

Tibial eminence fractures were originally classified by Meyers and McKeever2 as type I, II, or III, in which type I fractures are nondisplaced; type II, displaced anteriorly with an intact posterior hinge; and type III, completely displaced. Zaricznyj3 subsequently introduced type IV fractures as those with comminution. In general, on the basis of current evidence and expert consensus, type I fractures are managed conservatively whereas type III and IV fractures are managed operatively. Although the treatment of type II fractures remains controversial, most are managed surgically if closed reduction fails.1,4,5

Regardless of the fracture pattern, anatomic reduction and stable internal fixation are essential for fracture healing, early motion, and restoration of normal knee biomechanics. Numerous techniques have been described for reduction and fixation of tibial eminence fractures.2,6 Although arthroscopic
approaches have gradually supplanted open approaches, no gold-standard technique has emerged.\textsuperscript{1,4,5} Fixation constructs vary from rigid implants (e.g., screws, pins, and staples) to suture-based constructs. Recent biomechanical studies have shown improved strength with suture-based constructs,\textsuperscript{7,8} as well as lower rates of complications and reoperation than with rigid fixation.\textsuperscript{6} However, modern suture-based techniques vary in suture configuration, fixation, and technical details that limit critical comparison.\textsuperscript{9-15}

This Technical Note describes arthroscopic reduction–internal fixation (ARIF) of tibial eminence fractures using a transosseous suture bridge construct with extracortical fixation. This technique uses a commercially available suture-passage device and meniscal root repair system to create a tension-band

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**Fig 1.** (A) Coronal and Sagittal T2 weighted MRI cuts of the right knee (a) confirm the integrity of the ACL (black arrow). Coronal and Sagittal CT images (b) best demonstrate the tibial eminence fracture (white circle) with adjunct three dimensional CT reconstruction (c) further representing the fracture (white arrow) and used to assist in surgical planning.
suture bridge construct for anatomic reduction and robust fixation.

**Surgical Technique**

**Preoperative Evaluation and Surgical Indications**

Tibial eminence fractures can usually be diagnosed and classified on the basis of plain radiographs. However, magnetic resonance imaging is recommended to assess the integrity of the ACL and rule out concomitant intra-articular injury, which is common, particularly in adults (Fig 1A). In addition, computed tomography is invaluable to characterize the fracture pattern (Fig 1B). Three-dimensional computed tomography reconstruction provides sensitive details to understand the fracture location, orientation, comminution, and displacement to facilitate surgical planning (Fig 1C).

Indications for ARIF of tibial eminence fractures include type III and IV fractures, as well as type II fractures that remain displaced after attempted closed reduction. Concomitant intra-articular injury necessitating surgical management is a relative indication for ARIF. Intrasubstance rupture or insufficiency of the ACL is a relative contraindication and may warrant fragment excision and primary ACL reconstruction.

**Setup and Positioning**

After induction of anesthesia, standard knee examination under anesthesia is performed. Special attention is paid to the findings of the Lachman test and pivot-shift maneuver to assess anterior instability. We compare the knee range of motion with that on the contralateral side, noting any asymmetrical loss of extension or block to motion.

Once the examination is complete, the patient is positioned supine on the operating room table with the operative lower extremity placed in a standard leg holder and the contralateral leg in an abduction stirrup.
to permit unimpeded motion of the operative leg. A high thigh tourniquet is placed and inflated for the duration of the procedure. Fluoroscopy should be available but is not routinely used.

**Arthroscopic Evaluation**

High standard anterolateral and anteromedial portals are established to optimize perspective and visualization. A hemarthrosis is typically present and evacuated with lavage for exposure. Standard diagnostic arthroscopy is performed. The integrity of the ACL is confirmed, and the tibial eminence fracture site is identified.

The fracture is interrogated, and the pattern is characterized. Tibial eminence fractures often hinge posteriorly with displacement and gapping anteriorly. Interposition of the transverse (intermeniscal) ligament and/or anterior horn of the medial (or occasionally lateral) meniscus may obscure the fracture and inhibit reduction (Fig 2). Retraction of these structures with a probe or traction suture is critical for visualization and reduction. Limited debridement of the retropatellar fat pad may further facilitate exposure. Commination may be present, and care must be taken to avoid disturbing or displacing the fragments during manipulation. Once the fracture bed is exposed, careful debridement of hematoma and fibrous tissue is performed with an arthroscopic shaver to expose the entire cancellous bed (Fig 3, Video 1).

A longitudinal incision measuring approximately 3 cm is made over the flat area of the anteromedial tibial plateau, 3 cm distal to the joint line, and centered between the tibial tubercle and posterior cortex (Fig 4, Video 1). The incision is carried down through subcutaneous tissue, and the periosteum is elevated with care to avoid the pes anserinus and medial collateral ligament insertions.

A meniscal root repair system (Meniscal Root Repair System; Smith & Nephew, Andover, MA) is used for...
tunnel creation and suture shuttling. A curved offset aimer drill guide (Curved Aimer Guide; Smith & Nephew) is set to the appropriate angle, introduced into the joint, and positioned with the tip at the anterolateral margin of the fracture bed. The bullet is advanced flush against the cortex, and the 2.8-mm 2-piece drill set consisting of a guide pin and sheath is advanced into the joint (Fig 5, Video 1). The pin is removed, and the sheath is adjusted until it is at the level of the surrounding bone to minimize the risk of cutting the monofilament loop during suture retrieval.

An offset guide (Offset Guide Device; Smith & Nephew) with offsets ranging from 5 to 7 mm is then used to facilitate placement of a second parallel pin and sheath at the anteromedial margin of the fracture bed (Fig 6, Video 1). Again, the inner pin is removed and the sheath is positioned flush with the surrounding bone.

Attention is now turned to suture passage through the native ACL. A low-profile disposable suture-passage device (FirstPass Mini Suture Passer; Smith & Nephew) with straight and curved tip options is used to pass nonabsorbable suture tape (Ultratape; Smith & Nephew) obliquely through the substance of the ACL (Fig 7, Video 1). The curved needle of the suture passer helps avoid contact with the femoral condyles during suture passage, particularly in the presence of a narrow intercondylar notch. A threaded cannula (5.5 × 72–mm ClearTrac Cannula; Smith & Nephew) is placed in the anteromedial portal to facilitate suture management. A monofilament suture loop is passed up through the first sheath and retrieved through the cannula along with both suture tape tails. The sheath is then removed with pliers, the tails are threaded through the loop, and finally, the monofilament loop is pulled down to shuttle the suture tape tails through the tunnel (Fig 8, Video 1). This process is repeated for the second tunnel with an alternatively colored suture tape to avoid confusion. Sutures are oriented in the ACL to create a crossing pattern to balance tension. A separate No. 2 nonabsorbable suture (Ultrabraid; Smith & Nephew) is passed through the posterior aspect of the distal ACL behind the suture tapes, and 1 limb is shuttled down each tunnel for reinforcement. Ultimately, each tunnel contains 3 limbs: 2 suture tape limbs and 1 suture limb. Manual tensioning of suture limbs reduces the fracture and compresses the tibial eminence against the fracture bed (Fig 9, Video 1). Minor adjustment of suture position can be performed with a probe during suture tensioning.

Depending on the fracture pattern and degree of extension into the medial or lateral compartment, addition peripheral fixation may be desirable. The fracture is anatomically reduced by tensioning the sutures and provisionally fixed with a 1.6-mm K-wire. An accessory tunnel is created in similar fashion using the pin and sheath combination advanced through the reduced tibial eminence. Another suture tape is passed from posterior to anterior through the substance of the
ACL and shuttled down the accessory tunnel with the monofilament loop (Fig 10, Video 1).

Once suture passage and retrieval are complete, the suture limbs are threaded through a cortical button (EndoButton; Smith & Nephew) and tied over the anteromedial tibial cortex with the knee in full extension (Fig 11, Video 1). A second cortical button may be necessary depending on the number of suture limbs. Final arthroscopic evaluation shows anatomic reduction with suture limbs crossing over the anterior tibial eminence (Fig 12, Video 1). The ACL and fracture site are probed to confirm integrity and stability.

Arthroscopic fluid is drained from the knee, and the incisions are closed in standard fashion. Dressings are applied, and the operative lower extremity is placed in a hinged knee brace locked in extension.

**Postoperative Rehabilitation**

Postoperative rehabilitation is dictated by a staged protocol guiding the patient through 4 distinct phases (Table 1). Weight bearing is advanced gradually from toe-touch weight bearing during weeks 0 to 2 to partial weight bearing during weeks 3 to 4 and, finally, to weight bearing as tolerated during weeks 5 to 6. Crutches are required for ambulation for the first 4 weeks and gradually weaned by 6 weeks. The use of the hinged knee brace is continued for 8 weeks total and locked in extension during ambulation. The timing of return to sport without restrictions is patient dependent but usually is considered at 6 months. Functional sports assessment may be performed if residual deficits or concerns remain.

**Discussion**

The goals of surgical management of displaced tibial eminence fractures are anatomic reduction to restore the native biomechanics and robust fixation to permit early range of motion and a rapid return of function. In an effort to achieve these objectives while minimizing morbidity, arthroscopic approaches have grown in

| Table 1. Postoperative Rehabilitation Protocol |
|-----------------------------------------------|
| **Phase I** | **Phase II** | **Phase III** | **Phase IV** |
| **Timing** | **Weeks 7-12** | **Weeks 12-18** | **Months 5-6** |
| **Exercises** | Initiation of stationary bicycle | Initiation of straight-ahead treadmill running | Initiation of plyometric program |
| AAROM proceeding to AROM | Continued ROM and flexibility | Progressive core, hip, quadriceps, hamstring, and call strengthening | Agility progression |
| Maintenance of full extension | Closed-chain extension exercises | Mini-wall squats (0°–60°), short-arc leg press, lateral lunges, and step-ups | Side steps, crossovers, figure-8 and shuttling running, 1- and 2-leg jumping, and ladder drills |
| Progressive knee flexion | Toe raises | Acrobic exercise on bicycle, elliptical, and stair-climber | Advancement of running and endurance program |
| Patellar and/or scar mobilization | Initiation of proprioception regimen | | |
| Quadriceps sets, hamstring curls, and heel slides | | | |
| Straight-leg raise in brace until no extension lag | | | |

AAROM, active-assisted range of motion; AROM, active range of motion; ROM, range of motion.

**Table 2. Advantages and Disadvantages**

| Advantages | Benefits or Risks |
|------------|------------------|
| All-arthroscopic technique | Arthrofibrosis is minimized; there is potential to manage concomitant intra-articular pathology. |
| No intra-articular hardware | Hardware-associated complications are minimized: impingement, loosening, migration, and removal. |
| Minimal tunnel diameter | The risk of physeal injury, disturbing the fracture bed, and tunnel convergence is limited. |
| Tunnel sparing | Avoiding drilling through the tibial eminence limits the risk of comminution or displacement. |
| Suture passage | Use of a low-profile device facilitates suture passage without additional portals or instruments. |
| All-suture fixation construct | Biomechanical strength is optimized; hardware prominence or complications are minimized. |
| Tension-band configuration | Anatomic footprint compression is performed, with restoration of ACL length and tension. |
| Multifocal suture construct | Balanced, bridged fracture reduction and compression are performed across the tibial eminence. |
| Extracortical fixation | Robust ultimate fixation is achieved, minimizing the risk of suture cut through or loosening. |
| Reduction dependent on tunnel position | Inaccurate tunnel placement may interfere with anatomic reduction. |
| Suture passage, management, and shuttling | Suture passage, management, and shuttling are technique dependent and require familiarity with the system and devices. |
| Expense of suture-passage device and implants | The cost-effectiveness of value-based outcomes remains theoretical. |

ACL, anterior cruciate ligament.
To facilitate accurate, reliable suture passage and tunnel creation, Boutsiaidis et al. describe a similar technique using thoracic drain needles for tunnel creation for point suture fixation. However, the simple crossing suture configuration fails to take advantage of the tension-band suture bridge configuration of the in our study. Biomechanical studies have shown superior strength with a suture bridge construct over simple suture configurations.

Adherence to a patient-specific postoperative protocol is vital to achieve good functional outcomes. A generalized summary of the rehabilitation timeline is summarized in Table 1. Studies reporting the outcomes of arthroscopic techniques for reduction and internal fixation of displaced tibial eminence fractures are limited to case reports and small series. Recent systematic reviews have concluded that although operative treatment of displaced tibial eminence fractures results in higher union rates and superior outcomes compared with nonoperative treatment, there is insufficient evidence to support one superior surgical technique. Although our study describes a technique for surgical management of displaced tibial eminence fractures, further studies are needed to compare the biomechanical properties and clinical outcomes with other available techniques.

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