Technical Note

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 McKeever[2] 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. Zaricznyj[3] 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

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approaches have gradually supplanted open approaches, no gold-standard technique has emerged.[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,[7,8] as well as lower rates of complications and reoperation than with rigid fixation.[6] However, modern suture-based techniques vary in suture configuration, fixation, and technical details that limit critical comparison.[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

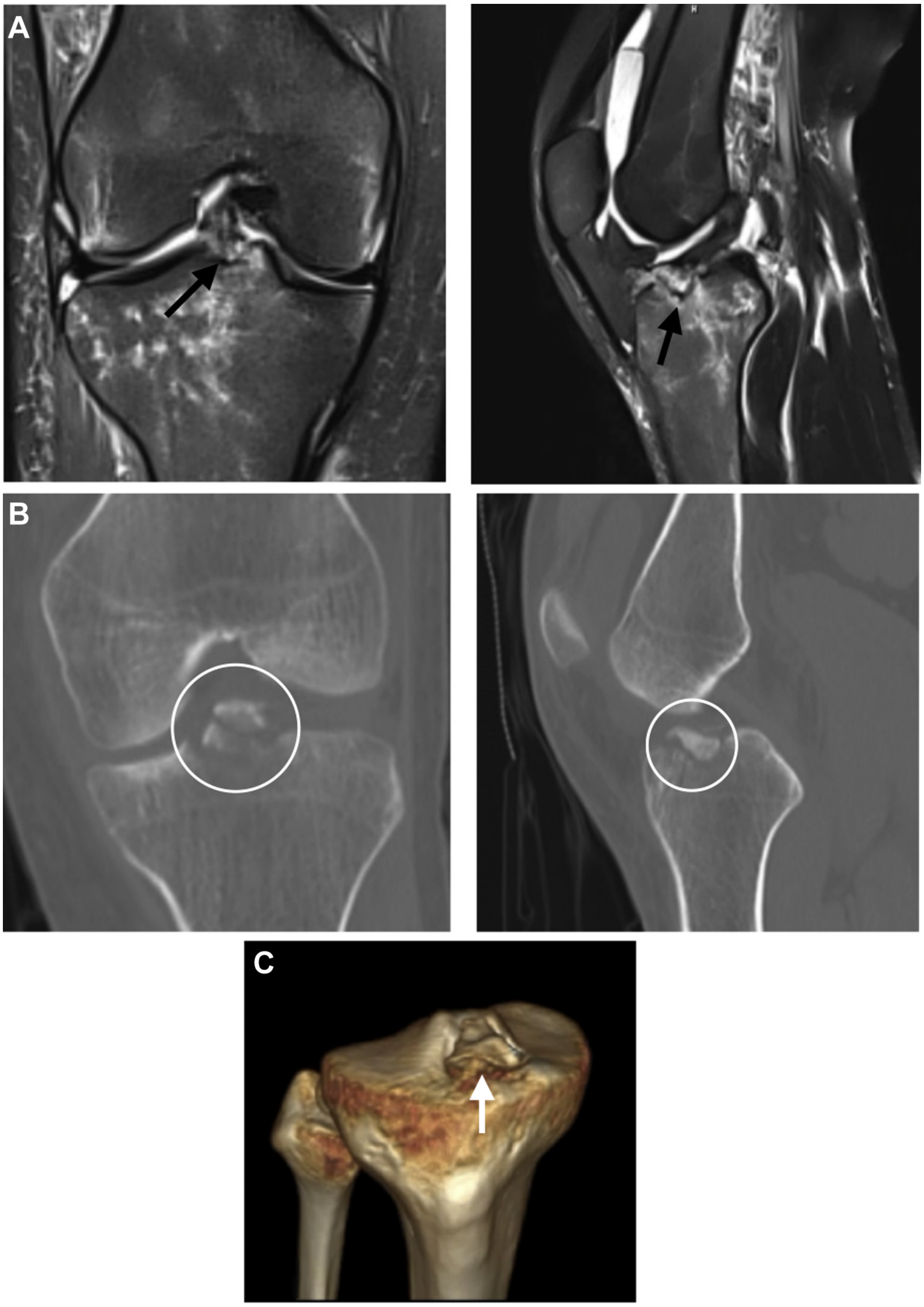

Fig 1. (A) Coronal and Sagittal T2 weighted MRI cuts of the right knee (a) confirm the integrity of the ACL (black arrow). Coronal and Sagittal CT images (b) best demonstrate the tibial eminence fracture (white circle) with adjunct three dimensional CT reconstruction (c) further representing the fracture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

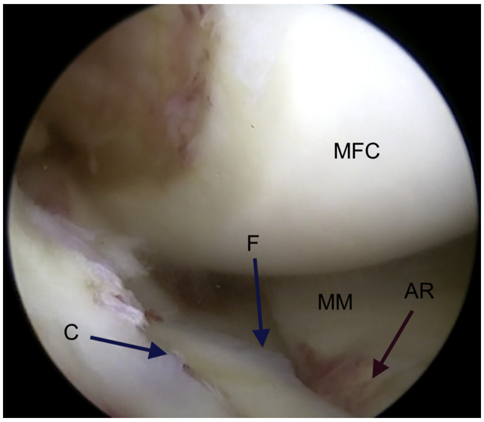

Fig 2. Arthroscopic view of the right knee from the anterolateral portal showing displaced tibial eminence fracture with primary fracture line (F) resulting in incongruity of tibial articular cartilage along with comminution (C). The anterior root (AR) attachment of the medial meniscus (MM) can be seen in the foreground interposed in the anterior aspect of the fracture site, inhibiting anatomic reduction. (MFC, medial femoral condyle.)

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).[16] 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).

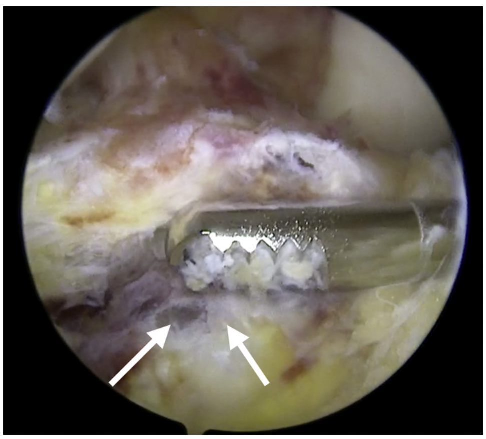

Fig 3. Viewing from the anterolateral portal of the right knee, a shaver is used through the anteromedial working portal to debride hematoma and fibrous soft tissue to expose a bleeding cancellous fracture bed (arrows).

Fig 4. A longitudinal incision approximately 3 cm in length is made over the flat area of the anteromedial tibial plateau approximately 3 cm distal to the joint line and centered between the tibial tubercle and posterior cortex of the right knee.

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

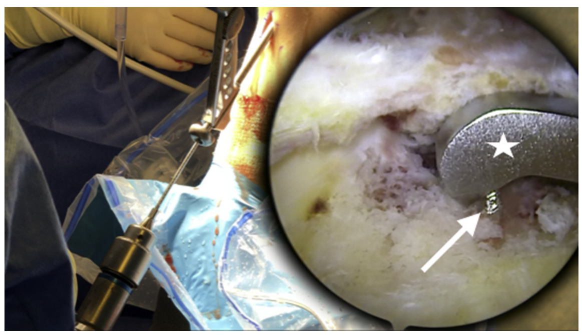

Fig 5. The 2.8 mm 2-piece drill set consisting of a guide pin and sheath (arrow) is advanced into the joint using a curved offset drill guide (Curved Aimer Guide [star]). This is arthroscopically viewed through the anterolateral portal to guide the drill through the right knee.

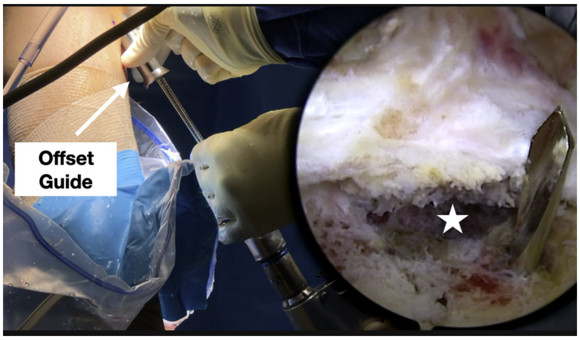

Fig 6. An offset guide (Offset Guide Device) with options ranging from 5 to 7 mm is used to facilitate placement of a second parallel pin and sheath at the anteromedial margin of the fracture bed (star). This is arthroscopically viewed through the anterolateral portal to guide the drill through the right knee.

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. Comminution may

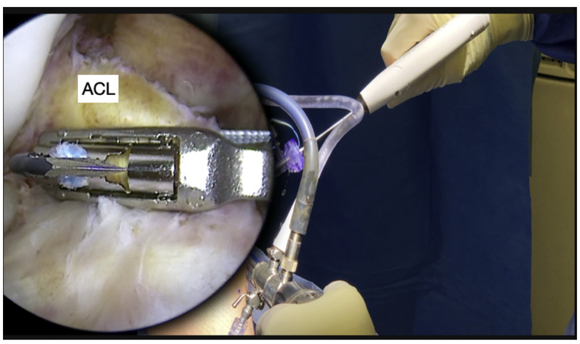

Fig 7. Viewing from the anterolateral portal of the right knee, a low-profile disposable suture-passing device (FirstPass Mini Suture Passer) with straight and curved tip options is used to pass nonabsorbable suture tape (Ultratape) through the substance of the anterior cruciate ligament (ACL).

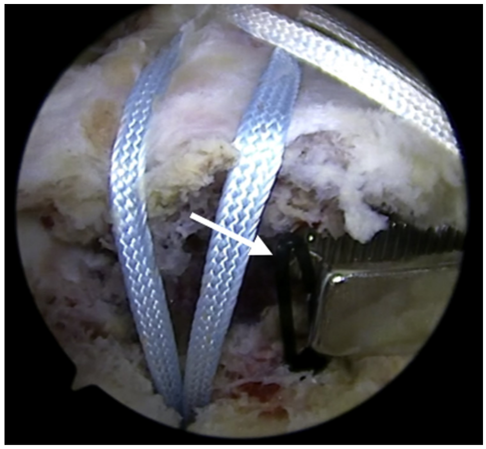

Fig 8. Viewing from the anterolateral portal in the right knee, a monofilament suture loop (arrow) is passed up through the first sheath and retrieved through the cannula along with both suture tape tails. The loop is then pulled down to shuttle the suture tape tails through the tunnel.

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

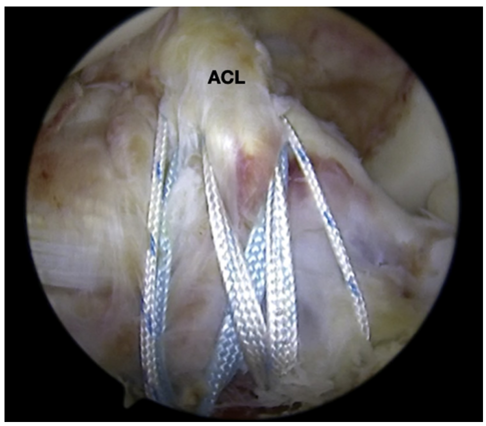

Fig 9. Manual tensioning of the sutures limbs reduces the fracture and compresses the tibial eminence against the fracture bed such that the anterior cruciate ligament (ACL) and its footprint are anatomically reduced; this is viewed through the anterolateral portal of the right knee.

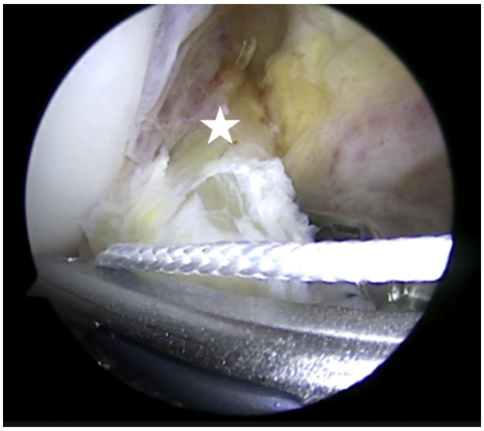

Fig 10. Additional fixation can be obtained with another suture tape placed through the substance of the anterior cruciate ligament (star) and shuttled down an accessory tunnel using a monofilament loop; this is viewed from the anterolateral portal in the right knee.

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)

Fig 11. The suture limbs through the anterior cruciate ligament are brought down through cortical tunnels and tied over the anteromedial tibia using a cortical button (EndoButton) with the right knee in full extension.

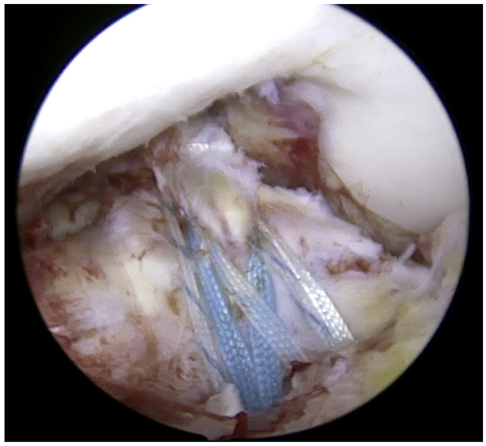

Fig 12. Arthroscopic view of the final construct from the anterolateral portal in the right knee shows adequate reduction and fixation of the tibial eminence fracture.

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

Table 1. Postoperative Rehabilitation Protocol

Phase I	Phase II	Phase III	Phase IV
Timing			
Weeks 0-6	Weeks 7-12	Weeks 12-18	Months 5-6
Exercises			
AAROM proceeding to AROM	Initiation of stationary bicycle	Initiation of straight-ahead treadmill running	Initiation of plyometric program
Maintenance of full extension	Continued ROM and flexibility	Progressive core, hip, quadriceps, hamstring, and calf strengthening	Agility progression
Progressive knee flexion	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
Patellar and/or scar mobilization	Toe raises	Aerobic exercise on bicycle, elliptical, and stair-climber	Advancement of running and endurance program
Quadriceps sets, hamstring curls, and heel slides	Initiation of proprioception regimen		
Straight-leg raise in brace until no extension lag			

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

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 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.
Disadvantages	
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.

Table 3. Pearls and Pitfalls

Pearls
Obtain advanced imaging preoperatively, including CT and 3D CT reconstructions, to characterize the fracture pattern and plan tunnel and suture configuration.
Evacuate fracture hemarthrosis and hematoma, debride the fracture site, and retract interposed structures (e.g., anterior horn of the medial meniscus or intermeniscal ligament) for optimal visualization.
Plan tunnel placement at the anteromedial and anterolateral margins of the fracture bed for anatomic fracture reduction and optimization of the suture tension-band construct for fracture compression.
Consider peripheral tunnel placement to reduce the fracture margins in the presence of medial or lateral extension.
Pitfalls
Aggressive fracture manipulation or debridement may comminute or disrupt the primary fragment, complicating reduction and inhibiting fixation.
Aberrant tunnel placement or suture passage through the ACL may result in over-reduction or over-tensioning.
Soft-tissue interposition (i.e., soft-tissue bridge) can occur during suture shuttling if a cannula is not used for suture management.
Tensioning and fixation in flexion may over-reduce or over-tension the construct.

ACL, anterior cruciate ligament; CT, computed tomography; 3D, 3-dimensional.

popularity over the past 2 decades. Although a wide array of arthroscopic techniques have been described, a gold standard remains elusive.[1,4,5]

This article describes an arthroscopic technique for reduction and fixation of displaced tibial eminence fractures using a transosseous suture bridge construct with cortical button fixation. Several key features and advantages of this technique are summarized in Table 2, and pearls and pitfalls are presented in Table 3. Of note, this technique uses small (2.8-mm) drill tunnels for suture fixation over a bone bridge. In addition, the primary construct avoids drill tunnels in the tibial eminence, minimizing the risk of comminution and fracture displacement. Suture passage is performed with a commercially available low-profile device with a curved needle to avoid the femoral condyles during passage. Parallel tunnel placement is facilitated by use of a meniscal root repair system. The associated guides permit reliable, precise tunnel positioning and maintenance of bony bridge integrity. The final crossing suture bridge configuration over the anterior tibial eminence creates a tension-band construct for optimal biomechanical strength and compression. Peripheral fixation points can be added for reinforcement once reduction is performed. Finally, cortical button fixation permits tensioning without the risk of suture cut through or loosening.

Although the described technique shares similarities with other suture-based techniques,[9-15] it is the first to use a commercially available meniscal root repair system along with a disposable suture-passage device to facilitate accurate, reliable suture passage and tunnel creation. Boutsiadis et al.[10] describe a similar technique using thoracic drain needles for tunnel creation for 4-point suture fixation. However, the simple crossing suture configuration fails to take advantage of the tension-band suture bridge configuration of the construct in our study. Biomechanical studies have shown superior strength with a suture bridge construct over simple suture configurations.[7,8]

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.[1,5] 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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