Technical Note

Tibial Spine Avulsion Fracture Fixation Using a Re-tensionable All-Suture Construct

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Abstract: Tibial spine avulsion injuries, including fractures, are a variant of anterior cruciate ligament injuries. Treatment historically consisted of open reduction and internal fixation of the avulsion fracture, with anterior cruciate ligament reconstruction considered in cases of failed open reduction and internal fixation or residual laxity. However, improved instrumentation has led to the advancement of various arthroscopic techniques for addressing these injuries. The emergence of newer implants designed for all-suture fixation has also overcome the limitations associated with screw fixation, such as hardware-related complications, challenges in treating comminuted fractures, and potential physeal injury. The purpose of this article is to describe a technique consisting of arthroscopic-assisted reduction and internal fixation of a tibial spine avulsion fracture with a re-tensionable all-suture—based construct using multiple looped cinch stitches and a cortical suspensory suture button device.

Avulsion fractures of the tibial spine, which is the bony attachment of the anterior cruciate ligament (ACL) on the tibia, most commonly occur in pediatric patients; however, they are also observed in young adult populations. Although relatively uncommon compared with midsubstance ACL injuries, tibial spine avulsions represent 2% to 5% of all pediatric knee injuries and up to 3% of all adult ACL injuries.[1] Classically, tibial spine avulsions were classified as described by Meyers and McKeever[2] in 1959, including minimal displacement (type I), elevation of the anterior edge with an intact posterior hinge (type II), and complete displacement (type III). Type IV, defined as a displaced and comminuted variation, was later added as a modification in 1977.[3] In pediatric patients, type I and reducible type II patterns (reduced in extension) are typically amenable to treatment with cast immobilization. In contrast, surgical treatment is indicated for type III and IV patterns, as well as adult patients.[4,5]

Historically, surgical procedures were performed through open reduction and internal fixation. However, arthroscopically assisted approaches have dated back to the 1980s and have become the primary method of treatment, with open reduction only being used in instances of failed arthroscopic approaches.[5-8] Since then, many methods of fixation have been described, including Kirschner wires, metal screws, all-suture constructs, anchors, and various bioabsorbable implants (screws, nails, etc.).[9-11] Given the significant variety of fixation techniques, each with advantages and disadvantages, there is no current gold standard for the surgical treatment of these injuries. Therefore, the purpose of this article is to describe arthroscopically assisted reduction and internal fixation of a displaced and comminuted tibial spine avulsion fracture using multiple looped cinch stitches (FiberRing; Arthrex, Naples, FL) and a cortical suspensory suture button device (ACL TightRope RT; Arthrex).

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Surgical Technique

Patient Evaluation, Imaging, and Indications

All patients undergoing tibial spine avulsion fixation of the knee require a complete preoperative evaluation.

This includes a complete history, physical examination, and imaging workup, typically including plain radiographs, magnetic resonance imaging (MRI), and computed tomography. On examination, these patients present with acute knee pain and an effusion that restricts motion and weight bearing.[12] Anterior drawer testing and Lachman testing are limited owing to guarding in the acute setting, but laxity is often appreciated after pain and swelling are controlled. Persistent lack of motion or the inability to reach full knee extension is concerning for a mechanical block resulting from soft-tissue entrapment or a displaced fracture fragment.[13] A tibial spine fracture is typically evident on standard knee radiographs. The lateral and oblique views are beneficial in determining the fracture displacement and extent of tibial plateau involvement, respectively (Fig 1). Because of radiation exposure concerns in the pediatric population, we do not routinely use computed tomography scans as the advanced imaging modality of choice despite their utility for preoperative planning. However, such imaging can be used for improved resolution of the bony fragment, particularly in the setting of significant comminution. Instead, MRI has become the examination of choice for assessing fracture characteristics. MRI also has the advantage of determining the presence of intermeniscal ligament entrapment and concomitant injuries, including meniscal pathology, ligament injury, or osteochondral fracture.[13] Surgery is mainly indicated for type III and IV patterns or after failed nonsurgical treatment.[14]

Surgical Positioning and Diagnostic Arthroscopy

The surgical procedure is performed with the administration of either general or regional anesthesia, depending on the preference of the surgical team, with the patient in the supine position. After the patient is positioned on the operating table, a well-padded tourniquet is placed on the operative thigh, and an examination under anesthesia is performed. The leg is then elevated and exsanguinated, and the tourniquet is inflated. Standard anterolateral and anteromedial portals are created, and a PassPort cannula (Arthrex) is inserted into each portal to facilitate subsequent suture passage. A standard diagnostic knee arthroscopy is performed to identify and address associated intra-articular pathology, as well as inspect and prepare the fracture bed (Fig 2, Video 1). In some cases, especially chronic cases, removal of bone and callus with the arthroscopic shaver is necessary to allow for anatomic reduction of the avulsed fragment (Table 1). Soft tissue, such as the intermeniscal ligament, may also be entrapped between the fracture bed and the avulsed fragment; this requires manipulation or resection before reduction is attempted.

Tibial Spine Avulsion Reduction and Fixation

After preparation of the fracture bed, a tibial ACL guide (Arthrex) is inserted through the anteromedial portal to reduce the ACL footprint to its anatomic position using the aiming arm (Fig 3). This maneuver ensures that the subsequently passed cannulated pin will enter the joint through the fracture bed, capture the avulsed tibial spine fragment, and preliminarily reduce it to the tibia. The bullet from the ACL guide is now used to mark the skin just medial to the tibial tubercle and then moved aside. A No. 15 blade is used to incise the skin over the mark, straight down to the bone. The ACL guide is repositioned, and a 2.4-mm cannulated drill (Arthrex) is advanced through the reduced tibial spine fragment. After the ACL guide is removed, a lasso wire is advanced up the 2.4-mm cannulated drill. The water to the arthroscope is shut off during this step to facilitate passage of the lasso

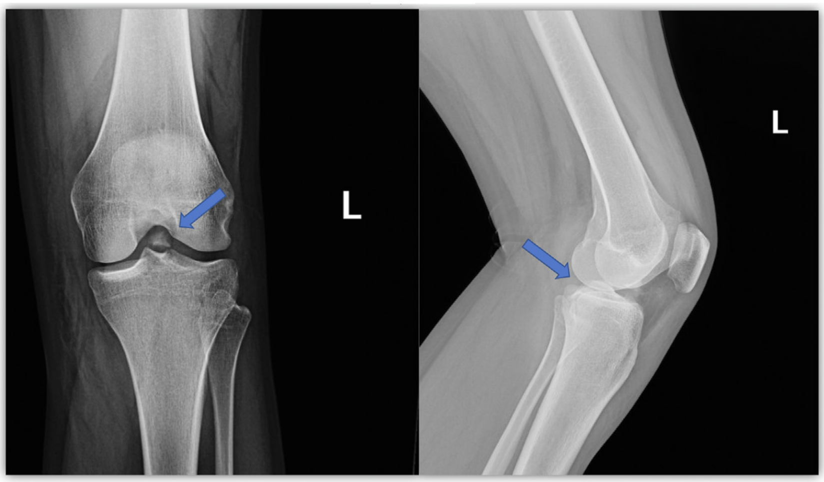

Fig 1. Anteroposterior (left) and lateral (right) radiographs of left (L) knee showing tibial spine avulsion fracture (arrows).

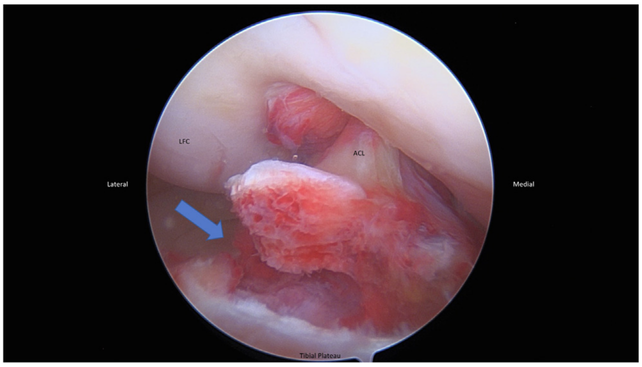

Fig 2. Arthroscopic view from anterolateral portal in left knee identifying tibial spine avulsion fracture bed (arrow). Assessment of the fragment shows anterior cruciate ligament (ACL) slack and redundancy with an intact femoral attachment. (LFC, lateral femoral condyle.)

wire. The wire is subsequently retrieved through the anteromedial portal using a loop grasper. The free end of a knotless FiberRing suture is loaded into the jaws of a Scorpion suture passer (Arthrex), and the barrel of the Scorpion device is placed through the large loop of the suture to create a luggage-tag suture once passed. The suture passer is introduced through the anteromedial portal, and the suture is passed through the base of the ACL (Fig 4A). Another FiberRing suture is loaded onto the passer in the same fashion. After the arthroscope is switched into the anteromedial portal, the Scorpion device is introduced through the anterolateral portal. The suture is passed through the ACL, just proximal to the previous FiberRing suture (Fig 4B). The arthroscope is switched back into the anterolateral portal, and a loop grasper is used to retrieve the previously passed FiberRing sutures through the anteromedial portal. At this point of

Table 1. Pearls and Pitfalls of Tibial Spine Avulsion Fracture Fixation Using ACL Repair TightRope and FiberRing Suture Construct

Pearls
In chronic cases, arthroscopic debridement of the fracture bed and callus may be necessary to achieve anatomic reduction of the avulsed fragment.
The knee should be extended to aid with fracture reduction and button tensioning.
The tails of the TightRope implant should be marked to ensure equal and adequate tensioning.
Pitfalls
Soft-tissue entrapment or callous formation between the fracture bed and the avulsed fragment will prevent complete reduction if manipulation or resection is not performed.
Tissue bridges or twisted sutures will result with improper FiberRing suture management.
Failure to cycle the knee with subsequent re-tensioning may result in gapping and roof impingement if not recognized at the time of surgery.

ACL, anterior cruciate ligament.

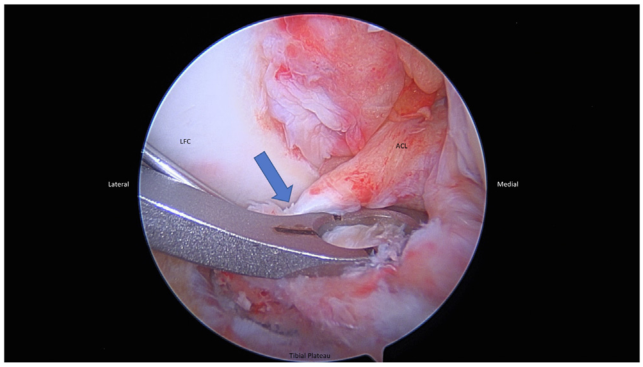

Fig 3. Arthroscopic view from anterolateral portal in left knee showing reduction of fragment back to anterior cruciate ligament (ACL) footprint on tibia using ACL guide (arrow). (LFC, lateral femoral condyle.)

the procedure, both FiberRing sutures should be passed through the ACL fibers in a luggage-tag fashion and out of the anteromedial portal. For suture management, the most proximal FiberRing suture is retrieved using a loop grasper and docked outside the anteromedial PassPort cannula. Two No. 0 FiberLink sutures (Arthrex) of different colors and opposite ends (1 looped and 1 free end) are then loaded through the

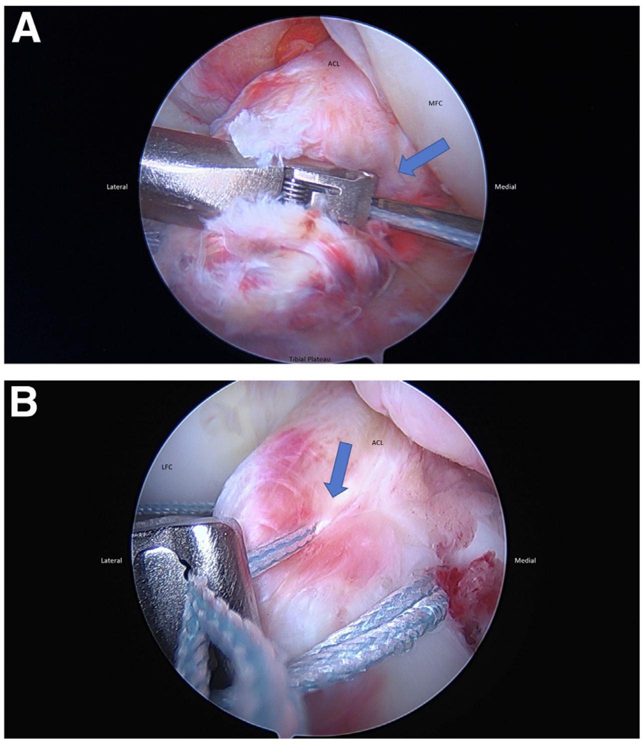

Fig 4. Arthroscopic view from anteromedial portal in left knee. (A) The first FiberRing suture is passed through the anterior cruciate ligament (ACL) (arrow), working through the anteromedial portal. (B) The second FiberRing suture is passed just proximal to the first (arrow). (LFC, lateral femoral condyle; MFC, medial femoral condyle.)

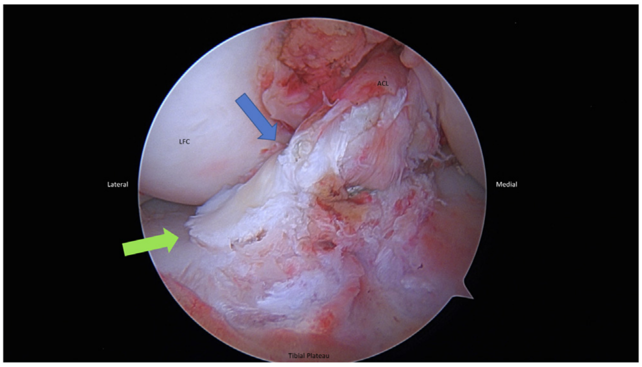

Fig 5. Arthroscopic view from anteromedial portal in left knee visualizing final ACL (anterior cruciate ligament) Repair TightRope and FiberRing suture construct (blue arrow), revealing sufficient fragment reduction without gapping (green arrow) after knee cycling and TightRope re-tensioning. (LFC, lateral femoral condyle.)

Table 2. Advantages and Disadvantages of Tibial Spine Avulsion Fracture Fixation Using ACL Repair TightRope and FiberRing Suture Construct

Advantages
Performed arthroscopically
No requirement for subsequent hardware removal
Improved fixation through ACL fibers in type IV comminuted fractures
Prevention of gapping in flexion and impingement in extension owing to ability to re-tension under direct visualization after knee cycling
Anatomic repair that restores native ACL tension and biomechanics
Disadvantages
Technically demanding

ACL, anterior cruciate ligament.

lasso wire and shuttled down through the avulsed fragment and out of the tibial tunnel. The looped end of the No. 0 FiberLink suture with the free end exiting the tibial tunnel is docked outside the anterolateral PassPort cannula for suture management. The leader suture from an ACL Repair TightRope RT implant (Arthrex) is then loaded through the No. 0 FiberLink suture with the looped end exiting the tibial tunnel and shuttled so that the leader suture exits the anteromedial portal. The distal FiberRing suture, still within the cannula, is cut at the swedged portion to create 2 suture tails for shuttling the TightRope device through the FiberRing construct. The leader suture is passed through the eyelet of the FiberRing suture and shuttled back out of the anteromedial portal. The second, more proximal FiberRing suture, previously docked outside the anteromedial cannula, is retrieved through the anteromedial cannula using a lopped grasper. The same process is repeated, and the 2 FiberRing sutures are now linked to the TightRope RT implant. By use of a looped grasper, the looped end of the other No. 0 FiberLink suture, which had been previously docked outside the anterolateral portal, is now retrieved through the anteromedial portal. The leader suture from the TightRope is passed through the FiberLink suture and shuttled down through the avulsed fragment and out of the tibial tunnel. The loop of the leader suture is cut, and the ACL TightRope is assembled. The included FiberTape suture (Arthrex) for the InternalBrace technique (Arthrex) can either be discarded at this time or left intact for augmentation of the repair, depending on surgeon preference. The knee is then extended to aid with fracture reduction (Table 1), and the button is reduced to the tibia and tensioned with the TightRope suture limbs. To allow for equal tensioning of each free limb, it is recommended to mark the suture tails with a sterile marking pen to help maintain their lengths as the button is being tensioned to the tibia. After the achievement of sufficient fragment reduction with the desired tension, the knee is cycled under direct visualization to evaluate for fracture gapping and roof impingement (Table 1). The TightRope can then be re-tensioned, and a probe is used to confirm appropriate tension under direct visualization (Fig 5, Video 1). Finally, the arthroscope is removed, and knee stability is evaluated with the Lachman test before the remaining sutures are cut.

Closure

The knee is cleared of loose debris, and the subcutaneous and skin layers are closed in standard fashion. Sterile dressings are applied, followed by the application of a hinged knee brace locked in full extension.

Rehabilitation Protocol

Postoperatively, the knee remains locked in full extension, and 50% toe-touch weight bearing is implemented for the first 2 weeks. Early range of motion (ROM) is encouraged to improve pain and stiffness using a continuous passive motion device starting at 2 weeks postoperatively. Proprioceptive and neuromuscular training is essential during the initial phase and continues throughout the recovery process. Physical therapy is also initiated at 2 weeks postoperatively, focusing on muscle activation and strengthening. During weeks 4 to 6, exercises progress to restore full knee flexion. The use of a stationary bicycle is introduced to promote ROM and muscle activation. The use of the hinged knee brace is discontinued once full ROM is achieved with no evidence of extension lag, typically around 6 weeks postoperatively. Muscle strengthening is achieved through the implementation of closed kinetic chain exercises. At 12 weeks postoperatively, straight-line running is permitted. Plyometric exercises begin with jumping at 16 weeks and cutting and/or pivoting at 20 weeks postoperatively and are advanced to include sport-specific movements. A functional return-to-sport performance test is recommended to ensure readiness and safety for physical performance.

Discussion

Tibial spine avulsion fractures are uncommon and represent 2% to 5% of all pediatric knee injuries and up to 3% of all adult ACL injuries.[1] These injuries can cause knee instability and mechanical symptoms. Therefore, treatment goals are the restoration of stability and elimination of mechanical obstruction via anatomic reduction and stable internal fixation.[15,16] Open reduction and internal fixation had been the traditional treatment approach until 1982, when McLennan[6] introduced a less invasive arthroscopic technique, which led to a more rapid recovery. Subsequently, arthroscopic fixation has become the more prevalent method. Several fixation devices have been used to treat tibial spine avulsion fractures, including Kirschner wires, metal screws, sutures, and suture anchors. Although various arthroscopic reduction and internal fixation techniques have been developed, no universally recognized gold standard exists.[17] Among the techniques described, suture fixation and screw fixation are most commonly used, and both have produced satisfactory results.[18,19] Moreover, several studies comparing the efficacy of absorbable sutures versus nonabsorbable suture anchors and comparing suture fixation versus screw fixation have not shown any significant differences in radiographic healing, patient-reported outcome metrics, and instability testing.[19,20]

In patients with tibial spine avulsion fractures, an intact ACL is typically retained. Even with adequate fixation, underlying structural damage or attenuation of the ACL fibers may result in residual laxity.[5] Functional instability is a rare complication of this surgical procedure, even with measurable laxity on examination or KT-1000 testing (MEDmetric, San Diego, CA).[21,22] However, conversion to ACL reconstruction (ACLR) should be considered in patients with symptomatic laxity. The rate of conversion of tibial spine fracture fixation to ACLR exceeds 20%.[23] Additionally, arthrofibrosis occurs in as many as 60% of knees that are managed surgically.[24,25] In a study looking at outcomes and subsequent injury rates, Quinlan et al.[26] reported that 21% of patients with fracture fixation required an additional procedure. Despite the potential for undergoing conversion to ACLR or undergoing another procedure, 92% of patients in their study reported satisfactory outcomes and would have elected to undergo tibial spine avulsion fixation again.[26] Nonetheless, this finding signifies the importance of counseling patients preoperatively on the risks associated with this operation.

This article describes a technique for arthroscopic tibial spine avulsion fracture reduction and internal fixation using a re-tensionable all-suture construct. This technique has many advantages, including decreased morbidity and a faster recovery associated with performing the procedure arthroscopically compared with open. Moreover, in contrast to fixation with screws and wires, this technique uses suture fixation, eliminating the need for a potential secondary procedure to remove the hardware. In addition, this technique allows for re-tensioning of the construct after cycling, improving the stability of the repair and minimizing creep. Furthermore, it eliminates the potential for physeal injury, as well as irritation and impingement, from malpositioned hardware. This technique also has an advantage when treating type IV (comminuted) fractures because the sutures provide secure fixation through the base of the ACL itself rather than the bony fragment, reducing the risk of further comminution and fracture displacement (Table 2). The potential disadvantages of this technique include technical difficulties associated with suture management (Table 2). In the appropriately indicated patient, our technique for arthroscopic tibial spine avulsion fracture reduction and internal fixation using a re-tensionable all-suture construct provides a practical and reproducible construct for fixation of displaced tibial spine avulsion fractures in both pediatric and adult patients.

Disclosures

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