Arthroscopic Treatment of an Anterior Cruciate Ligament Avulsion Fracture in a Skeletally Immature Patient

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Abstract: Anterior cruciate ligament injuries in skeletally immature patients usually involve tibial bony avulsion fractures rather than the midsubstance tears usually observed in adults. Several surgical techniques have been reported to provide stable fixation and avoid physeal injury in this pediatric population. The authors propose a novel, reproducible surgical technique using bioabsorbable anchors to obtain biomechanical stability and minimal physeal or articular cartilage damage.

Although several techniques to fix these avulsion injuries reportedly provide stability and reliable clinical outcomes, physeal damage is a major concern. This makes the surgery difficult, especially when comminuted fragments are present. The authors propose a simple surgical repair technique that can help avoid physeal damage and obviate additional procedures or procedure-related morbidity.

Case Report
A 9-year-old girl with no significant medical history sustained a right knee injury after falling from a trampoline a few days prior to presentation. Neither she nor her parents were able to recall the exact mechanism of injury, but she reported a twisting sensation of her right leg on contact with the ground. Physical examination showed a moderate knee effusion and tenderness over the anterior aspect of the knee. Lachman testing was positive; formal pivot shift testing was deferred secondary to patient guarding.

Radiographs revealed isolated avulsion and elevation of the tibial attachment of the ACL and open phyes (Figure 1). The T1-weighted magnetic resonance sequence showed displacement of the distal avulsed ACL fragment (Figure 2). No evidence of meniscal...
injury or associated chondral lesions was observed. The patient and family consented for arthroscopic fixation of the injury.

Under general anesthesia, the anterior drawer sign was positive. The patient was placed in the supine position with the right knee held in a leg holder. Initially, arthroscopic examination through anterior portals was blocked by a displaced osteochondral fragment attached to the ACL (Figure 3A). Viewing from the anterolateral portal, a probe was introduced from an anteromedial portal to attempt fragment reduction.

Once a clear visual field was obtained with appropriate reduction, a Crescent Suture Hook on a Spectrum suture delivery system (ConMed Linvatec, Largo, Florida) was introduced from the anteromedial portal to pass through the substance of the ACL proper. A #1 PDS suture (Ethicon, Inc, Somerville, New Jersey) was then passed through the ACL tissue and retrieved from the accessory anterolateral portal. This step was repeated to create a 4-strand grasping construct. The 4 strands of suture controlling the ACL were tensioned from both anterior portals and then threaded into a PushLock anchor (Arthrex, Inc, Naples, Florida) (Figures 3B, C). Figure 4 shows the 4-strand suture configuration after appropriate suture shuttling through the ACL.

The PushLock anchor was introduced from the anteromedial portal while tensioning the other side of the suture material (Figure 5A). Finally, the anchor was fixed into the intact osteochondral junction, away from the avulsion fracture site and the medial and lateral meniscus on either side, and the reduction was completed (Figure 5B). Figure 6 shows the final location of the suture fixation anchors. Gentle Lachman and pivot-shift tests were normal after fixation.

Postoperatively, a hinged knee brace was used with the knee in full extension for 6 weeks, with gradual increases in ROM. A transition from partial to full weight bearing was also initiated, and continuous passive machine and careful guided physical therapy were also started. At 12 weeks postoperatively, the brace was removed and full ROM and weight bearing were allowed. At 7-month follow-up, the patient had returned to preinjury level of sports and activity. No evidence of growth disturbance was noted on subsequent imaging at 24-month follow-up.

**TECHNICAL PEARLS AND PITFALLS**

**Pearls**

- As with all procedures in skeletally immature patients, a spinal needle inserted percutaneously may be used to confirm on static fluoroscopic imaging the precise localization of the undulating physes about the knee and to ensure all-epiphyseal fixation.
- Both anterior portals must be of sufficient height to properly visualize the fracture donor site, as well as for ease of fragment and ligament reduction.

**Pitfalls**

- Consider regional anesthesia techniques in conjunction with a trained anesthesiologist to afford adequate perioperative pain control.
- Patients’ and families’ expectations must be carefully discussed preoperatively; although minimized with this technique, the potential of physeal damage must be discussed.
- Consider slightly recessing the bony fragment in place by approximately 1 to 2 mm at the attachment site.
- It is important to visualize the ACL and fixation through the entire ROM to verify no movement at the repair site, no impingement, and precise anatomic reduction of the ACL.
that might compromise surgical outcome and postoperative ROM.
- Entrapment of the menisci, particularly the anterior horns, may hinder adequate reduction.
- Likewise, the transverse meniscal ligament may block full reduction back into the bed onto the tibial plateau and must be carefully freed from the tibial avulsion site.
- Overly aggressive reduction maneuvers or repeated attempts at grasping suture passage may further fragment the avulsed bony tissue.
- Timing of the surgical procedure, as with all forms of ACL repair, is critical; arthrofibrosis in an acute inflammatory period may necessitate lysis of adhesions or challenge postoperative ROM.
- A detailed and individualized physiotherapy program must be established and reviewed with the physical therapist and with the patient and family.

**DISCUSSION**

The treatment of ACL avulsion injuries in skeletally immature patients is controversial, and a major concern exists for potential physeal damage.\(^6\)\(^,\)\(^7\) Although reports have examined modern fixation methods, these techniques include risks to the open physeis.\(^3\)\(^,\)\(^6\) Bonin et al\(^7\) recommended that the smallest fixation device available should be chosen to avoid physeal damage; the authors suggested removal of the device once fracture consolidation occurred. Ahn et al\(^8\) described a new technique of a physeal-sparing all-inside repair. Although it has merits in terms of grasping small fragments in skeletally immature patients, it requires large suture hooks to grasp the ACL and peripheral soft tissues, and this method has concerns regarding the integrity of the transverse ligament.

Other alternative treatments exist. A trial of extension casting in an attempt to reduce the avulsed fragment through nonoperative means may be reserved for minimally displaced fragments that demonstrate acceptable reduction after cast placement. Arthroscopic reduction with crossed suture–bridge fixation of the tibial spine fracture may be performed with a cannulated drill bit and ACL targeting guide.

After establishing a tibial bone tunnel, a Prolene suture (Ethicon Inc) may be used to shuttle #2 FiberWire sutures (Arthrex, Inc) to the posterior aspect of the fracture fragment. A Scorpion suture passer device (Arthrex, Inc) may be used to then pass the suture through the ACL at its insertion point onto the avulsed fragment. A Bunnell-type suture weave across the footprint of the avulsed fragment with both suture limbs may be used to reduce the avulsed fragment into the donor site and be tied over the bone bridge at the anterior aspect of the tibial epiphysis.

Zhao et al\(^9\) used a figure-of-8 suture technique with a transpatellar tendon portal: a 45° curved cannula (ConMed Linvatec) was used to pass Ethibond suture (Ethicon, Inc) for ligament fixation. Hsu\(^9\) used an Acufex ACL drill guide (Smith & Nephew, Andover, Massachusetts) and a straight or curved Penetra-

**FIGURE 4:** Diagram of the 4-strand suture configuration after appropriate suture shuttling through the anterior cruciate ligament.

**FIGURE 5:** Arthroscopic images showing introduction of the PushLock anchor (Arthrex, Inc, Naples, Florida) from the anteromedial portal to fix the suture limbs (A) and the completely reduced avulsion fragment and attached ligament (B).

**FIGURE 6:** Diagram demonstrating final anchor placement.

Several other fixation methods have been reported with satisfactory outcomes. Generally, Kirschner wire or screw fixation can fix avulsed bony fragments.\(^10\)-\(^13\) Arthroscopic reduction and antegrade cannulated screw fixation through a high anteromedial portal or a pull-out suture via a tunnel drilled from the proximal tibia remain popular fixation strategies.\(^11\)-\(^14\)-\(^16\)

However, disadvantages include possible further comminution of fracture fragments during insertion, possible impingement of the screw head during knee extension, and the requirement of a secondary procedure for screw removal.\(^11\) Suture cerclage is also used as an alternative method.\(^6\)\(^,\)\(^9\) Eggers et al\(^7\) support this technique because, in their experience, suture fixation provides more biomechanical strength than screw fixation.

A similar technique to the current authors’ bioabsorbable
suture anchor method was reported by In et al. This study used a 2.9-mm arthroscopic drill (DePuy Mitek, Raynham, Massachusetts) followed by Bioknotless and Panaloc anchors (DePuy Mitek) to secure the PDS suture for ligament repair. The current authors’ repair technique has several advantages over those described in the study of In et al. It uses more suture strands to capture and control the ACL properly and to provide better mechanical strength of the repair site, it obviates the need for an additional portal and larger cannula for suture hook introduction, and it easily controls the tension of the ACL on each side of the tibial avulsion fracture site.

**Conclusion**

This article described a novel technique for the fixation of ACL tibial avulsions in a skeletally immature patient population. This simple suture fixation technique is easily reproducible and minimizes risks to the immature physis. It should be formally compared with other fixation strategies in future clinical studies, and it may be a viable alternative in skeletally immature patients. Further studies regarding biomechanical strength of the fixation are also needed before widespread application.

**References**


