Technical Note

Arthroscopic Suture Fixation of Comminuted Tibial Eminence Fractures: Hybrid All-Epiphyseal Bone Tunnel and Knotless Anchor Technique

Joseph C. Fox, M.D., and Michael G. Saper, D.O., A.T.C., C.S.C.S.

Abstract: Tibial eminence fractures most commonly occur in young children and adolescents with open physes. Displaced fractures are typically treated with surgical reduction and fixation. Multiple arthroscopic techniques and fixation constructs have been described. However, many of these techniques violate the physis with a risk of growth disturbance and deformity from asymmetrical physeal growth. This technical note details a surgical technique of arthroscopically assisted suture fixation of a comminuted tibial spine fracture using all-epiphyseal bone tunnels and knotless anchors. In this construct, sutures passing through the substance of the anterior cruciate ligament help to eliminate residual laxity, all-epiphyseal bone tunnels avoid growth disturbance, and suture anchors reduce persistently displaced anterior comminution.

A fracture of the tibial eminence, also called the "tibial spine" or "intercondylar eminence," is a bony avulsion of the tibial attachment of the anterior cruciate ligament (ACL). The classic clinical scenario is a child aged 8 to 14 years presenting with a knee effusion after a hyperextension or valgus and external rotation injury after falling off a bicycle.[1] Tibial eminence fractures from other mechanisms (contact sport injuries, skiing and motor vehicle accidents) and fractures in adult patients have increasingly been recognized.[2-4] The overall incidence of tibial eminence fractures is low, estimated at 3 per 100,000 persons[5] and 2% to 5% of adolescent patients with a traumatic knee effusion.[6]

Meyers and McKeever[7] first classified tibial eminence fractures as nondisplaced (type I), displaced with an intact posterior hinge (type II), or completely displaced (type III). Comminuted fractures (type IV) were later added by Zaricznyj.[8] Closed treatment is indicated for type I fractures and type II fractures that reduce after aspiration and manipulation.[9] Operative reduction and fixation are indicated for type III and IV fractures as well as persistently displaced type II fractures or those with meniscal entrapment.[9] Multiple techniques have been described to treat tibial eminence fractures including cannulated metal screws, Kirschner wires, sutures via transphyseal bone tunnels, suture anchors, bioabsorbable screws or nails, and hybrid constructs.[2-4,9] Many of these techniques cross the physis, and although rare, partial growth arrest with subsequent angular deformity has been reported.[10,11] All-epiphyseal screw fixation avoids physeal injury but may cause iatrogenic comminution of the tibial eminence fragment.[12] Likewise, screw fixation may have poor bony fixation in comminuted type IV fractures and has the highest rate of residual laxity after fixation.[3]

This technical note details a surgical technique of arthroscopically assisted suture fixation of a comminuted tibial spine fracture using a hybrid of all-epiphyseal bone tunnels and knotless anchors. In this construct, sutures passing through the substance of the ACL help to eliminate residual laxity, all-epiphyseal bone tunnels avoid growth disturbance, and suture anchors reduce persistently displaced anterior comminution. This technique can be performed safely in pediatric patients with any fracture pattern.

From the Department of Orthopedics and Sports Medicine, Seattle Children's and Department of Orthopaedics and Sports Medicine, University of Washington, Seattle, Washington, U.S.A.

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Address correspondence to Michael G. Saper, D.O., A.T.C., C.S.C.S., 4800 Sand Point Way NE, Seattle, WA 98105, U.S.A. E-mail: Michael.Saper@seattlechildrens.org

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Table 1. Advantages and Disadvantages

Advantages	
	Applicable to all fracture types
	Minimizes physeal injury and growth disturbance
	Allows reduction of comminution
	Adds tension to stretched ACL
	Additional fixation does not violate physis
	Strong fixation allows early ROM to minimize risk of postoperative stiffness or arthrofibrosis
	No need for hardware removal
Disadvantages	
	Inappropriate tunnel position may injure physis
	Requires fluoroscopy
	Implant cost
	Limited clinical outcome data

ACL, anterior cruciate ligament; ROM, range of motion.

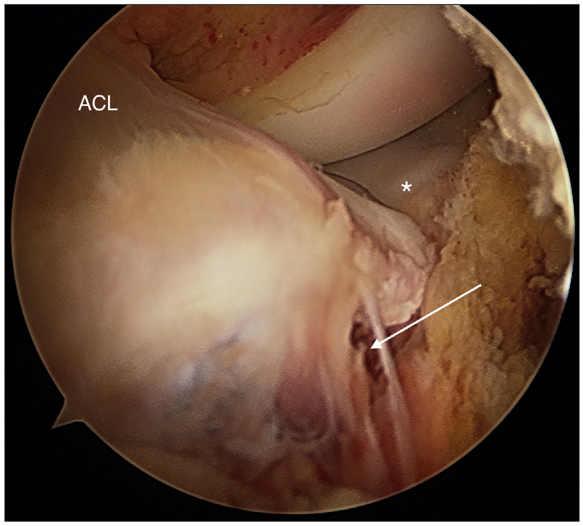

Fig 1. Right knee viewed from the inferolateral portal with a 30° arthroscope. Entrapment of the anterior horn of the medial meniscus (asterisk) is identified in the fracture site (arrow). (ACL, anterior cruciate ligament.)

Surgical Technique

A demonstration of the technique in a right knee is provided in Video 1. The advantages and disadvantages of the procedure are presented in Table 1. The indications, pearls, and pitfalls are summarized in Table 2.

Patient Positioning and Preparation

After a general anesthetic is given, the patient receives a single-shot sciatic nerve block and adductor canal nerve block with an indwelling catheter. The patient is positioned supine, and an examination under anesthesia is performed to assess knee stability and range of motion (ROM) of the operative and contralateral limbs. A single dose of antibiotic is administered for infection prophylaxis. A nonsterile tourniquet is placed high on the thigh and set at 200 to 225 mm Hg. The surgical limb is secured in an arthroscopic leg holder with the contralateral leg in a foam well-leg holder. The surgical area is prepared and draped in standard fashion.

Procedure

An Esmarch bandage is used to exsanguinate the extremity, and the tourniquet is inflated. Standard inferolateral and inferomedial arthroscopic portals are made; the fracture hematoma is evacuated, and the knee is thoroughly irrigated for optimal visualization. Routine diagnostic arthroscopy is performed, and intra-articular findings are noted. Particular attention is directed to characterizing the fracture pattern, assessing for hemorrhage or intrasubstance injury of the ACL, and identifying entrapment of the meniscus in the fracture site (Fig 1). Associated pathology such as chondral injuries and meniscus tears is treated.

The knee is allowed to hang freely in flexion. Fracture fragments are elevated, and the fracture bed is debrided using an arthroscopic shaver and curettes (Fig 2). Knee extension and probe manipulation reduce the debrided fracture (Fig 3). Kirschner wire or other provisional

Table 2. Indications, Pearls, and Pitfalls

Indications	
	Displaced tibial spine fractures (type II-IV)
	Adolescents and pediatric patients with open physes
Pearls	
	Thoroughly evacuate the fracture hematoma for visualization
	Use a cannula for suture management to avoid a soft-tissue bridge
	Use fluoroscopy to ensure an extraphyseal bone tunnel trajectory
Pitfalls	
	Physeal injury with tunnel malposition
	Inadequate spacing of bone tunnels leading to bone bridge collapse
	Leaving suture anchor proud, which may lead to hardware irritation
	Prolonged postoperative immobilization

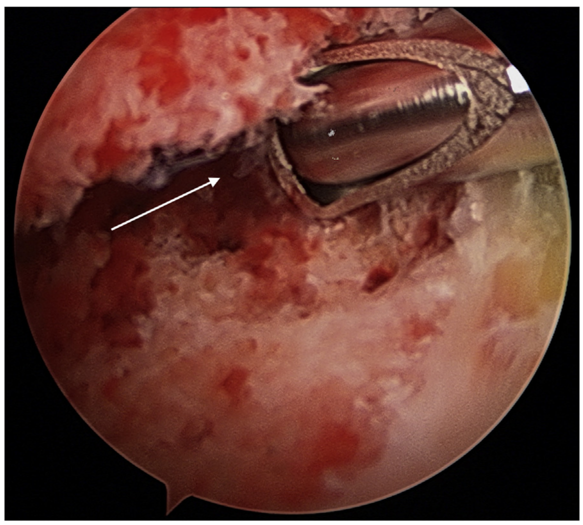

Fig 2. Right knee viewed from the inferolateral portal with a 30° arthroscope. The fracture fragments are elevated, and the fracture bed (arrow) is debrided using an arthroscopic shaver.

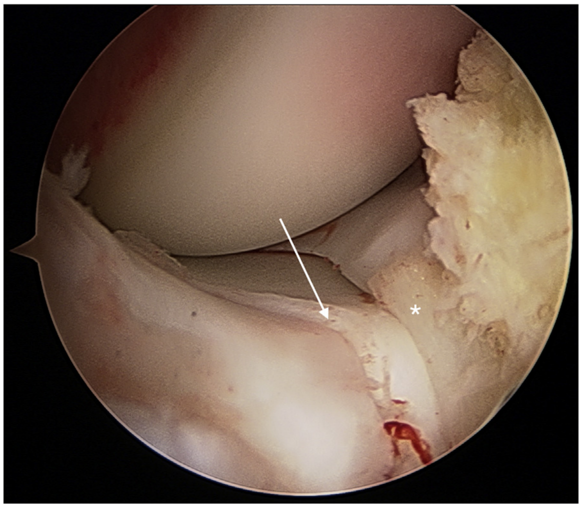

Fig 3. Right knee viewed from the inferolateral portal with a 30° arthroscope. The anterior horn of the medial meniscus (asterisk) is outside of the fracture site. The articular cartilage at the margins of the fracture should be reduced (arrow).

fixation may be necessary to reduce and hold the fragment. To aid in suture passage, a small PassPort cannula (Arthrex, Naples, FL) is introduced into the medial portal. A single 1.3-mm FiberLink with SutureTape suture (Arthrex) is passed through the base of the ACL with the Knee Scorpion (Arthrex) (Fig 4). The ACL tibial guide is set to 30° and holds the fragment reduced. A 2.4-mm cannulated drill is positioned and verified to be extraphyseal on fluoroscopy. The drill is advanced through the tibial epiphysis and the medial edge of the fragment. A nitinol suture passer shuttles the suture through the bone tunnel (Fig 5). This process is repeated on the lateral edge of the fracture (Fig 6). The sutures are tensioned and tied over a 2-hole suture button.

Anterior fracture comminution is commonly still displaced despite reduction and fixation of the main fragment (Fig 7). To address this, the Knee Scorpion passes a 1.3-mm FiberLink with SutureTape suture through the anterior bony fragment (Fig 8A). Spinal needle localization approximates the trajectory of the anchor pilot hole in the anterior tibia, and a superomedial accessory portal is made at the exit point of the needle, just medial to the inferior pole of the patella. A 5.5-mm percutaneous cannula (typically used for shoulder labral repair) is inserted into the accessory portal. The suture is retrieved through this cannula and passed through the eyelet of a 2.9-mm × 12.5-mm (short) Biocomposite PushLock anchor (Arthrex). A probe retracts the intermeniscal ligament and anterior horn of the meniscus as the pilot hole is drilled for the anchor (Fig 8B). Care is taken to avoid convergence with the previously drilled epiphyseal bone tunnels. The anchor is pushed into the drill hole until the eyelet is fully seated. With tension maintained on the sutures, the anchor is impacted into the tibia (Fig 8C). This process is repeated laterally to complete the reduction.

The knee is examined to ensure the Lachman and pivot-shift tests yield negative findings. The knee should easily be brought from full extension to full passive flexion. The arthroscope is then carefully placed back into the joint to inspect the fracture (Fig 9). The anterior horn of each meniscus and intermeniscal

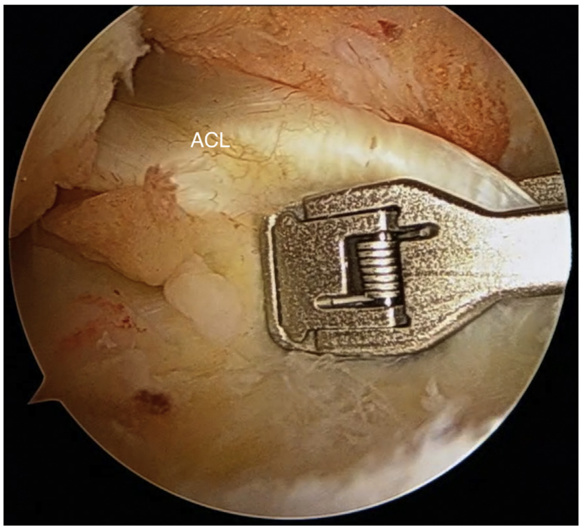

Fig 4. Right knee viewed from the inferolateral portal with a 30° arthroscope. By use of a PassPort cannula in the inferomedial portal, a single 1.3-mm FiberLink with SutureTape is passed through the base of the anterior cruciate ligament (ACL) with the Knee Scorpion.

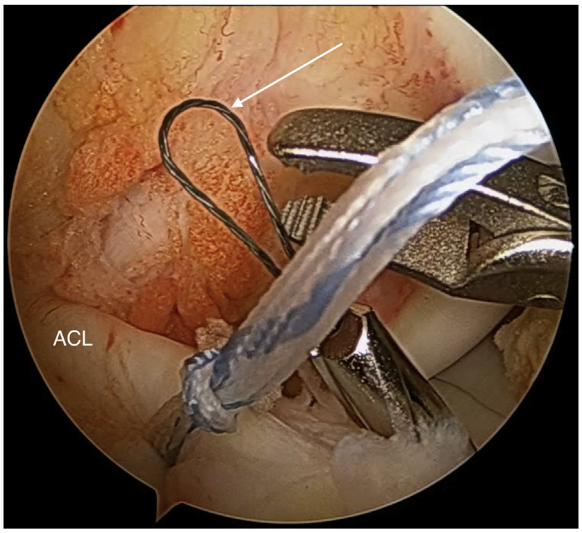

Fig 5. Right knee viewed from the inferolateral portal with a 30° arthroscope. With the pediatric anterior cruciate ligament (ACL) tibial guide set to 30°, a 2.4-mm cannulated pin is advanced through the tibial epiphysis and the medial edge of the fragment. A nitinol wire loop (arrow) is passed through the pin, pulled out through the PassPort cannula, and then used to shuttle the suture through the bone tunnel.

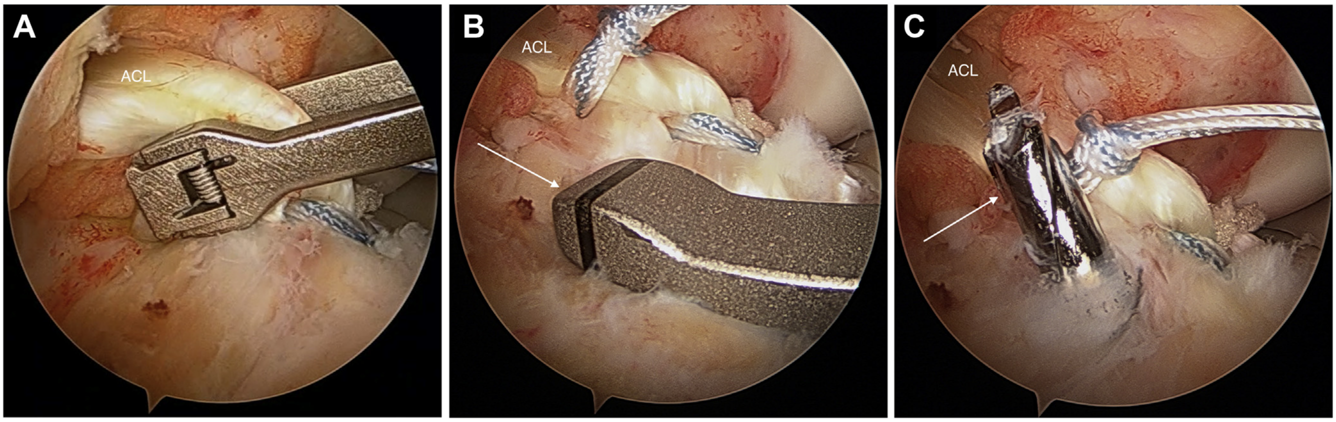

Fig 6. (A-C) Right knee viewed from the inferolateral portal with a 30° arthroscope. (A) Through the PassPort cannula in the inferomedial portal, a second 1.3-mm FiberLink with SutureTape is passed through the anterior cruciate ligament (ACL). With the pediatric ACL tibial guide (arrow) set to 30° (B), the 2.4-mm cannulated pin (arrow) is advanced through the tibial epiphysis and the lateral edge of the fragment (C).

ligament should be free and not entrapped. The articular cartilage at the margins of the fracture should be reduced and smooth.

The wounds are irrigated copiously, and the knee is cleared of any loose debris. The subcutaneous layer and skin are closed in standard fashion. Sterile dressings are applied, and the leg is placed in a hinged knee brace locked in full extension.

Postoperative Protocol

Formal postoperative rehabilitation is initiated 3 to 4 days after surgery and consists of distinct phases. Toe-touch weight bearing with crutches as tolerated is allowed immediately postoperatively in a hinged brace locked in full extension for 4 weeks. During this first phase, the patient works on quadriceps control, gait coordination with crutches, and passive ROM with a goal of 0° to 45° of knee flexion by week 2 and active ROM of 0° to 90° with the ability to perform a straight leg raise by week 4. The next phase focuses on progressive strengthening and neuromuscular control. Weight bearing is progressed, the brace is unlocked, and crutches are discontinued over a 2-week period. Bracing is discontinued after 6 weeks when healing is noted on plain radiographs. The final phase of rehabilitation starts 3 months postoperatively and focuses on advanced sport-specific training. Patients must have full ROM, quadriceps strength measuring at least 75% of that of the unaffected limb, and no pain or effusion to start this phase. Exercises include agility drills, plyometrics, and sport-specific drills with increasing intensity. At 6 months postoperatively, patients undergo functional testing to determine sport and activity readiness. Clearance for returning to sports is patient specific but typically occurs 6 to 9 months postoperatively.

Discussion

Multiple techniques have been described for surgical treatment of tibial eminence fractures with various implants including screws, sutures, staples, and anchors, as well as combinations thereof.[2-4] The overall success of surgical treatment depends on anatomic reduction with fixation strong enough to allow early motion, which decreases the risk of arthrofibrosis and hastens the return to full function.[13] Compared with cannulated screws, suture fixation over a bone bridge provides higher resistance to cyclic loading and higher ultimate strength in cadaveric knees.[14-16] Suture anchors alone have also been shown to be biomechanically stronger than screws in these studies.[14-16] Li et al.[16] found that

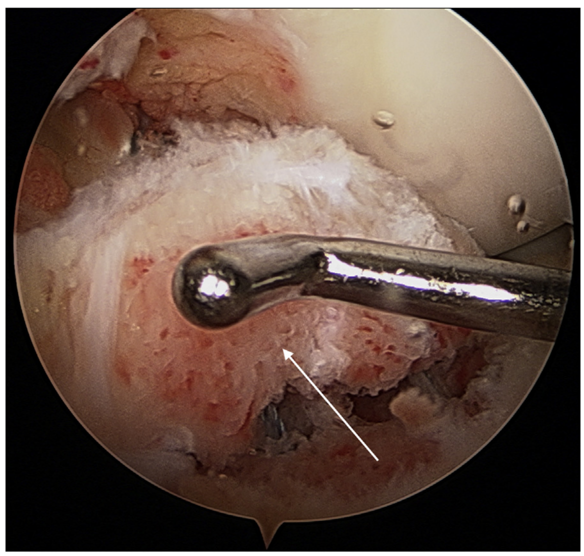

Fig 7. Right knee viewed from the inferolateral portal with a 30° arthroscope. Anterior fracture comminution (arrow) is displaced despite reduction and fixation of the main fragment.

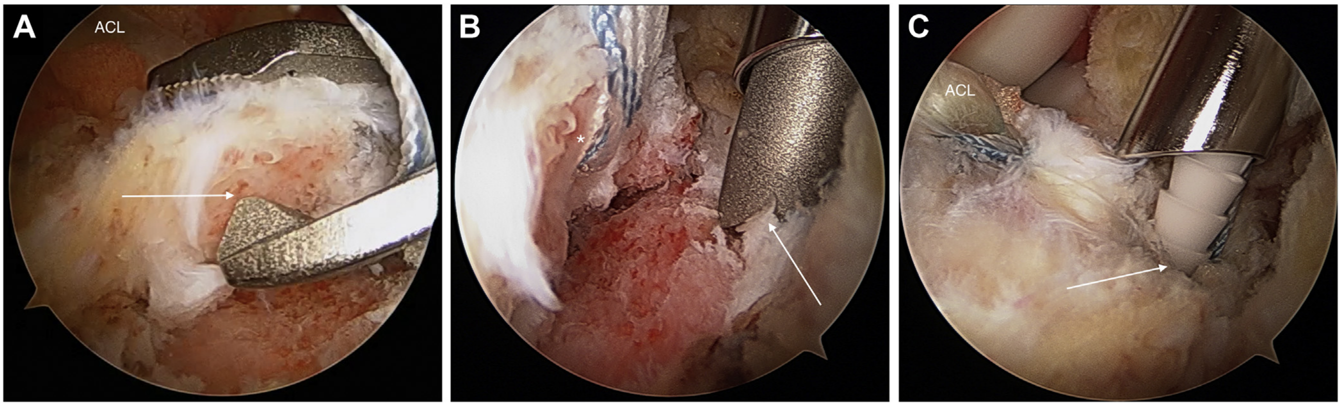

Fig 8. Right knee viewed from the inferolateral portal with a 30° arthroscope. (A) The Knee Scorpion passes a 1.3-mm FiberLink with SutureTape through the anterior bony fragment. (B) A probe retracts the intermeniscal ligament and anterior horn of the meniscus as the pilot hole is drilled for the anchor through a percutaneous cannula. The anchor is pushed into the pilot hole until the eyelet is fully seated. (C) With tension maintained on the sutures, the anchor is impacted into the tibia. (ACL, anterior cruciate ligament.)

the "necktie" or "luggage-tag" suture configuration, as in our construct, adds additional strength. These luggage-tag sutures not only work to strengthen the main fixation through the ACL footprint and tibial bone tunnels but also add peripheral fixation strength to comminuted sections fixed via suture anchors as described. Anderson et al.[17] found that, among physeal-sparing techniques, ultrahigh-molecular-weight polyethylene suture fixation over a button was the strongest both in ultimate strength and under cyclic loading. The other constructs in this study included screw fixation, polydioxanone suture (PDS) fixation, and suture anchor fixation. Suture anchors showed the highest stiffness and the second highest ultimate strength but were found to be the most variable. Suture anchors therefore may not be the best option for primary fixation but offer strength for peripheral fixation. Our technique uses the strongest fixation techniques available to allow early motion and decrease the arthrofibrosis risk.

Clinical ACL laxity after tibial eminence fracture occurs in an average of 70% of fractures treated nonoperatively and 14% treated operatively.[4] Objective instability as measured by KT arthrometry (MEDmetric, San Diego, CA), defined as 3 mm or greater compared with the contralateral side, is even more common, at 80% and 21% for nonoperative and operative treatment, respectively.[4] Subjective instability is, however, less common, at 54% and 1.2%, respectively.[4] Gans et al.[3] reviewed the available studies to compare postoperative clinical laxity for screw and suture fixation. In the screw fixation group, 82.4% had laxity on anterior drawer and Lachman tests and 11.8% had a positive pivot-shift test compared with 18.8% and 9.4%, respectively, in the suture fixation group. During a tibial eminence fracture, the ACL is known to elongate, and we theorize that suture fixation captures the ligament substance and takes up slack induced by the injury. The long-term implications of residual laxity are not yet fully understood; however, restoration of tension approximating that on the uninjured side would intuitively confer better long-term function.

Growth disturbance after fixation of a tibial eminence fracture is extremely uncommon but has been reported.[10,11] Ahn and Yoo[11] described a 6-year-old girl in whom a 10° recurvatum deformity developed after transphyseal suture fixation. They also reported on 2 patients with a 1-cm relative overgrowth of the injured leg. Although these complications are rare, our technique avoids physeal injury entirely with all-epiphyseal bone tunnels. Intraoperative fluoroscopy is imperative, however, to ensure a safe bone tunnel trajectory.

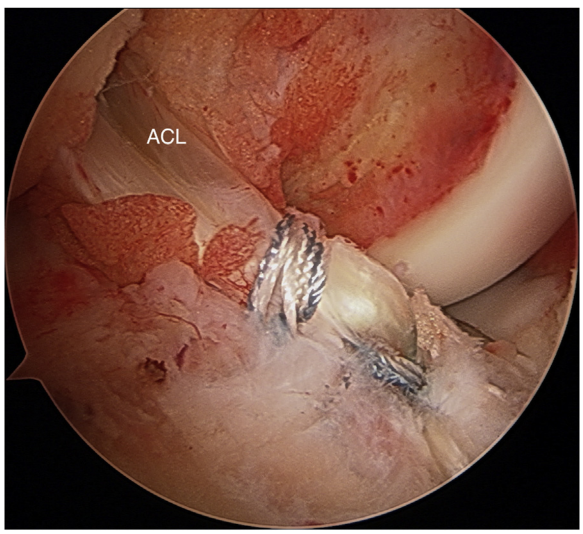

Fig 9. Right knee viewed from the inferolateral portal with a 30° arthroscope. The fracture is reduced and final fixation completed. (ACL, anterior cruciate ligament.)

This technical note details a surgical technique of arthroscopically assisted suture fixation of a comminuted tibial spine fracture using a hybrid of all-epiphyseal bone tunnels and knotless anchors. This strong construct allows early motion to avoid arthrofibrosis, high-strength sutures passing through the substance of the ACL help to eliminate residual laxity, all-epiphyseal bone tunnels avoid growth disturbance, and suture anchors reduce persistently displaced anterior comminution. This technique can be performed safely in pediatric patients with any fracture pattern.

References

1. Zionts LE, Silva M, Gamradt S. Fractures around the knee in children. In: *Green's skeletal trauma in children*. Amsterdam: Elsevier, 2015;390-436.
2. Coyle C, Jagernauth S, Ramachandran M. Tibial eminence fractures in the paediatric population: A systematic review. *J Child Orthop* 2014;8:149-159.
3. Gans I, Baldwin KD, Ganley TJ. Treatment and management outcomes of tibial eminence fractures in pediatric patients: A systematic review. *Am J Sports Med* 2014;42:1743-1750.
4. Bogunovic L, Tarabichi M, Harris D, Wright R. Treatment of tibial eminence fractures: A systematic review. *J Knee Surg* 2015;28:255-262.
5. Skak SV, Jensen TT, Poulsen TD, Stürup J. Epidemiology of knee injuries in children. *Acta Orthop Scand* 1987;58:78-81.
6. Luhmann SJ. Acute traumatic knee effusions in children and adolescents. *J Pediatr Orthop* 2003;23:199-202.
7. Meyers MH, McKeever FM. Fracture of the intercondylar eminence of the tibia. *J Bone Joint Surg Am* 1959;41:209-222.
8. Zaricznyj B. Avulsion fracture of the tibial eminence: Treatment by open reduction and pinning. *J Bone Joint Surg Am* 1977;59:1111-1114.
9. Flynn JM, Skaggs DL, Waters PM. *Rockwood and Wilkins' fractures in children*. Ed 8. Philadelphia: Lippincott Williams & Wilkins/Wolters Kluwer Health, 2014.
10. Mylle J, Mylle J, Reynders P, Reynders P, Broos P, Broos P. Transepiphysial fixation of anterior cruciate avulsion in a child—report of a complication and review of the literature. *Arch Orthop Trauma Surg* 1993;112:101-103.
11. Ahn JH, Yoo JC. Clinical outcome of arthroscopic reduction and suture for displaced acute and chronic tibial spine fractures. *Knee Surg Sports Traumatol Arthrosc* 2005;13:116-121.
12. Gans I, Babatunde OM, Ganley TJ. Hybrid fixation of tibial eminence fractures in skeletally immature patients. *Arthrosc Tech* 2013;2:e237-e242.
13. Patel NM, Park MJ, Sampson NR, Ganley TJ. Tibial eminence fractures in children: Earlier posttreatment mobilization results in improved outcomes. *J Pediatr Orthop* 2012;32:139-144.
14. Bong MR, Romero A, Kubiak E, et al. Suture versus screw fixation of displaced tibial eminence fractures: A biomechanical comparison. *Arthroscopy* 2005;21:1172-1176.
15. Eggers AK, Becker C, Weimann A, et al. Biomechanical evaluation of different fixation methods for tibial eminence fractures. *Am J Sports Med* 2007;35:404-410.
16. Li J, Yu Y, Liu C, Su X, Liao W, Li Z. Arthroscopic fixation of tibial eminence fractures: A biomechanical comparative study of screw, suture, and suture anchor. *Arthroscopy* 2018;34:1608-1616.
17. Anderson CN, Nyman JS, McCullough KA, et al. Biomechanical evaluation of physeal-sparing fixation methods in tibial eminence fractures. *Am J Sports Med* 2013;41:1586-1594.