

Arthroscopic Single-Tunnel Pullout Suture Fixation for Tibial Eminence Avulsion Fracture



Ahmed Nady Saleh Elsaid, M.D., Assem Mohamed Nouredin Zein, M.D., Mohamed ElShafie, M.D., F.R.C.S.(Orth), Nady Saleh El Said, M.D., and Alaa Zenhom Mahmoud, M.D.

Abstract: Various arthroscopic techniques have been devised for fixation of tibial eminence avulsions, namely percutaneous K-wires, arthroscopy-guided screw fixation, staples, TightRope (Arthrex)—suture button fixation, and transosseous suture fixation. Such techniques provide well-pronounced advantages including less postoperative pain, a reduced hospital stay, and minimal scar with resultant earlier and more compliant rehabilitation. As for transosseous suture fixation, the standard technique comprises the creation of 2 tibial tunnels exiting on both sides of the footprint of the avulsion fracture using an anterior cruciate ligament tibial guide with the angle set at 45°. Our technique entails the creation of a single tibial tunnel directed from the proximal anteromedial tibia to the center of the tibial eminence. The technique uses Ethibond suture (No. 5) and/or FiberWire suture (Arthrex) to fix the tibial eminence by pulling the anterior cruciate ligament fibers and tightening the pullout suture at the tibial exit of the tunnel with a 4-hole button. This modified single-tunnel pullout suture technique is an appealing option that has proved to be effective and economical with a shorter operative time. Moreover, it provides a less invasive option for skeletally immature patients.

Avulsion of the tibial eminence was first described by Poncet¹ in 1875. This injury represents 2% to 5% of knee and 14% of anterior cruciate ligament (ACL) injuries in skeletally immature patients,²⁻⁴ with a higher prevalence in those aged 8 to 14 years.⁵ This injury in this age group was first described by Pringle et al.⁶ in 1907.⁷ The high incidence of occurrence among children could be explained by the weaker incompletely ossified tibial plateau compared with the ACL, which makes it easier for avulsion of the footprint of the ACL to occur than for ACL rupture to occur.^{5,8} However, in fact, the fibers of the ACL become

stretched before the onset of the avulsion, resulting in ACL laxity even after anatomic reduction of the fracture.⁹⁻¹¹

A widely used system for classification of this type of fracture was published by Meyers and McKeever¹² in 1959. Recently, the incidence of this injury within the adult population has seemed higher than previously thought.¹³ However, in such a population, tibial eminence avulsion is usually associated with meniscal, capsular, or collateral ligament injuries. This represents a different mode of injury than in the pediatric group, which exhibits a higher incidence of isolated injuries.¹⁴

The epiphyseal growth plates around the knee dominantly participate in the growth of the lower limb, with annual distal femoral growth of about 10 mm and proximal tibial growth of 6 mm until the age of 13 years. Tibial tuberosity growth plate fusion is achieved later, at 16 years of age in girls and 18 years in boys, and represents final lower-limb bone maturity.¹⁵

With the progress and recent advances and refinements in arthroscopic techniques, various techniques have been advocated for the management of such injuries, including Kirschner wires,¹⁶ metal screws,^{17,18} stainless steel wires,¹⁹ sutures,^{14,20} suture anchors,^{21,22} and TightRope (Arthrex)—suture button fixation.²³ Of course, each method has its merits and demerits, but the clear fact is that many studies have

From the Orthopedic Surgery and Traumatology Department, Minia University, Minia, Egypt.

The authors report that they have no conflicts of interest in the authorship and publication of this article. Full ICMJE author disclosure forms are available for this article online, as [supplementary material](#).

Received September 26, 2017; accepted November 1, 2017.

Address correspondence to Ahmed Nady Saleh Elsaid, M.D., Department of Orthopedic Surgery and Traumatology, Minia University, Abrag Elgmaa Borg (G), Third Floor, Flat No. 9 Ard Sltan Taha Hessen Street, Minia, Egypt. E-mail: ahshwakh@yahoo.com

© 2018 by the Arthroscopy Association of North America. Published by Elsevier. This is an open access article under the CC BY-NC-ND license (<http://creativecommons.org/licenses/by-nc-nd/4.0/>).

2212-6287/171185

<https://doi.org/10.1016/j.eats.2017.11.004>

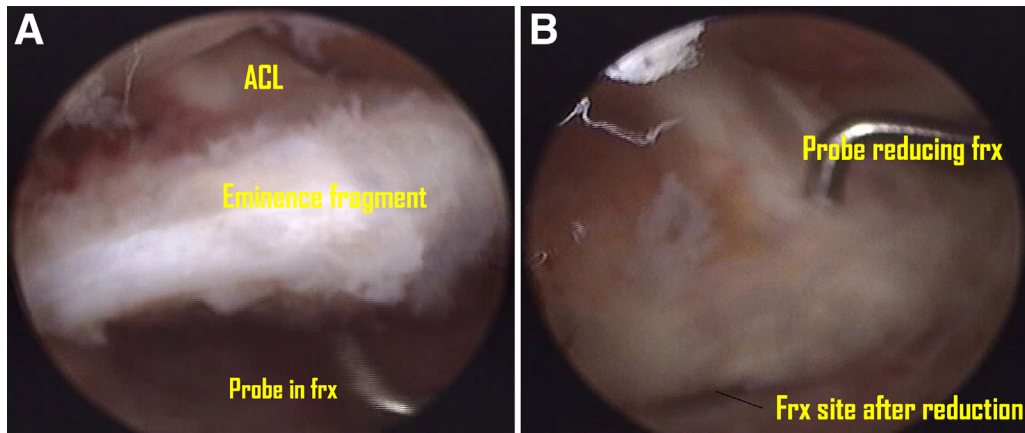


Fig 1. Right knee in 90° of flexion viewed from anterolateral portal. (A) Lavage is performed to evacuate any hemarthrosis or loose chondral or osteochondral fragments with debridement of the fat pad to improve visualization. A probe is introduced from the anteromedial portal and under the eminence fragment. (ACL, anterior cruciate ligament; frx, fracture.) (B) Trial reduction is performed with the probe with the knee in 90° of flexion; the fracture (frx) is then reduced by slowly extending the knee until reaching 40°.

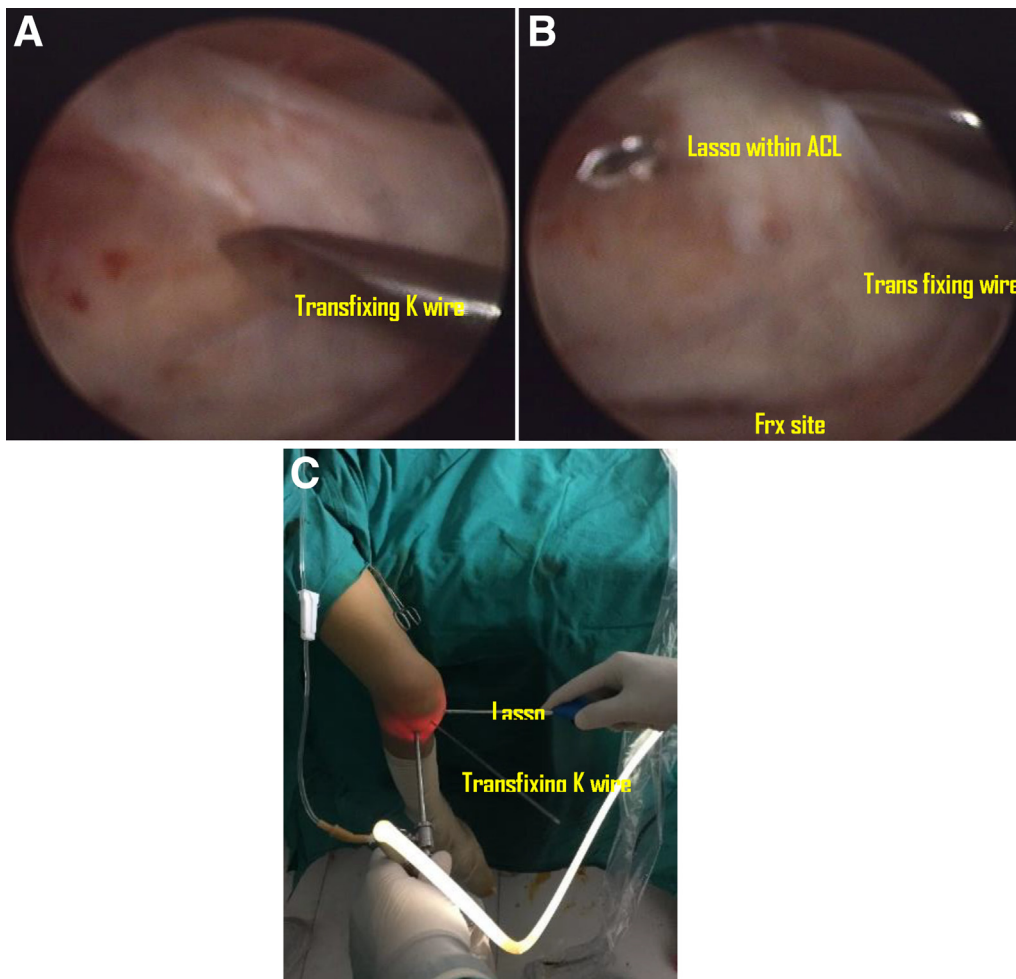


Fig 2. (A) Right knee viewed from anterolateral portal. A K-wire is used to temporarily fix the avulsed fragment in its bed. (B) Right knee viewed from anterolateral portal. A suture hook (45° SutureLasso) loaded with a closed steel wire is introduced through the anteromedial portal and then through the fibers of the anterior cruciate ligament (ACL), close to its tibial bony insertion, posterior to its mid-coronal plane, from medial to lateral. (C) The right knee is shown with introduction of the arthroscope from the lateral portal, transfixing the K-wire just lateral to the patellar tendon; a suture hook (45° SutureLasso) is introduced from the medial portal. (Frx, fracture.)

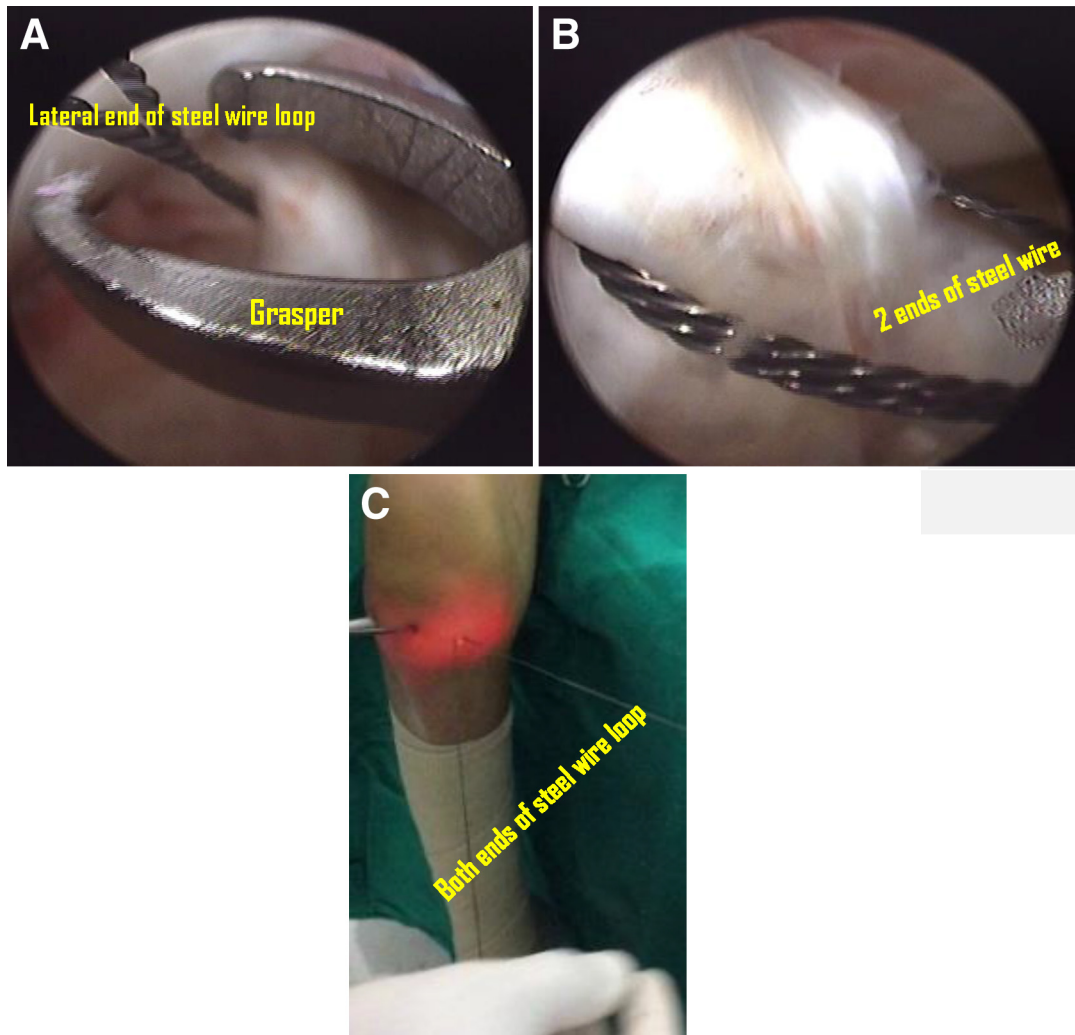


Fig 3. Right knee viewed from anterolateral portal. (A) The closed steel wire is advanced while the suture hook is simultaneously withdrawn; a grasper forceps is then used to deliver the steel wire through the anteromedial portal. (B) Both ends of the steel wire, which have already captured the anterior cruciate ligament fibers, are now going outside the knee through the anteromedial portal. (C) Both ends of the steel wire are outside of the knee from the anteromedial portal.

emphasized the clear advantages of arthroscopic techniques.^{24,25} The aim of this work is to describe a modified arthroscopic single-tunnel pullout suture technique for fixation of tibial eminence avulsions.

Surgical Technique

All patients receive spinal anesthesia except those younger than 12 years and those who are agitated or refuse this type of anesthesia, in which case they receive a general form of anesthesia. The first step after anesthesia is to thoroughly examine the involved knee. Most of the cases show anterior knee instability with Lachman grade II or III. Patients are positioned supine with thigh support, and a nonsterile pneumatic tourniquet is applied at the mid thigh. After scrubbing and draping, the pressure of the tourniquet is elevated to 100 mm Hg above patients' systolic blood pressure.

Standard anterolateral and anteromedial portals are used. Thorough lavage is performed to evacuate any hemarthrosis or loose chondral or osteochondral fragments with debridement of the fat pad to improve visualization. Routine knee arthroscopic examination is performed for assessment of associated injuries. Treatment of the avulsion fracture is recommended first, before treatment of associated pathology.

An ACL tibial tunnel C-guide is adjusted to 55° and applied through the anteromedial portal with its tip lying on the tibial eminence. In our technique, we do not use a 4-mm guidewire. Alternatively, we use an ACL TightRope 4-mm drill pin wire (Arthrex). This has 2 benefits: a shorter surgical time and minimization of physeal morbidity through a single penetration. A probe is used to retract the anterior horn of the medial or lateral meniscus or the transverse meniscal ligament, which is frequently entrapped within the fracture site,

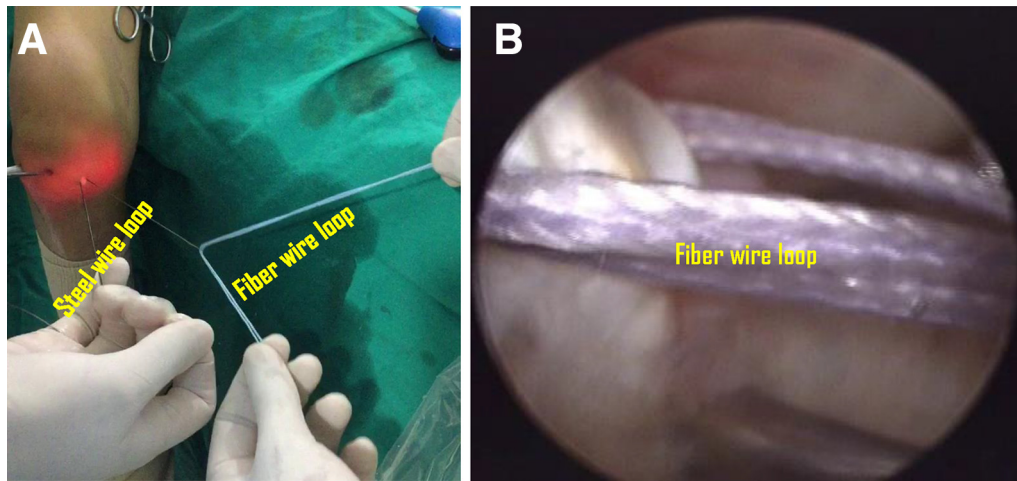


Fig 4. (A) The right knee is shown with introduction of the arthroscope from the lateral portal. A nonabsorbable FiberWire suture loop is shuttled through the anterior cruciate ligament fibers from the anteromedial portal. (B) Right knee viewed from anterolateral portal. Passage of the FiberWire loop is performed through the anterior cruciate ligament from the anteromedial portal.

preventing accurate reduction. Trial reduction is performed with the probe with the knee in 90° of flexion; the fracture is then reduced by slowly extending the knee until reaching 40° (Fig 1).

After confirmation of reduction, a K-wire is used to temporarily fix the avulsed fragment in its bed.

Thereafter, a suture hook (45° SutureLasso; Arthrex) loaded with a closed steel wire is introduced through the anteromedial portal and then through the fibers of the ACL, close to its tibial bony insertion, posterior to its mid-coronal plane, from medial to lateral (Fig 2). The closed steel wire is advanced while the suture hook is

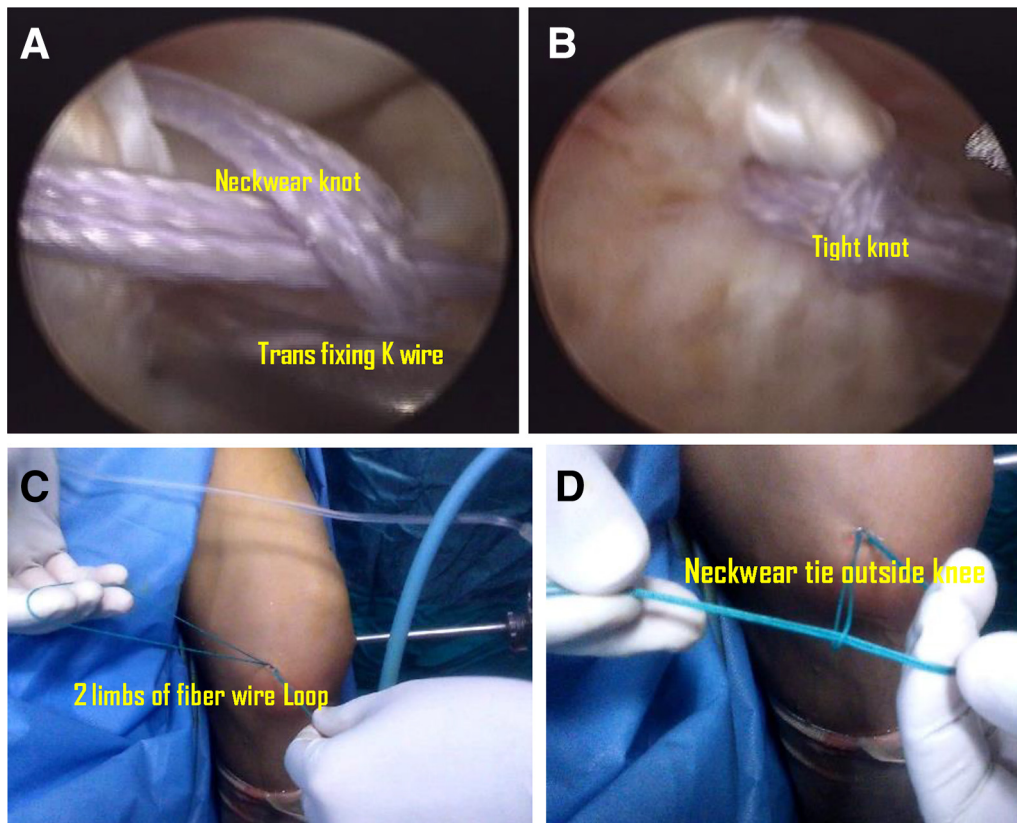


Fig 5. (A) Right knee viewed from anterolateral portal showing neckwear knot loop ligature. (B) Right knee viewed from anterolateral portal showing tight neckwear knot. (C) Left knee with introduction of arthroscope from lateral portal. Both limbs of FiberWire are now outside the knee from the anteromedial portal. (D) Neckwear knot loop ligature technique.

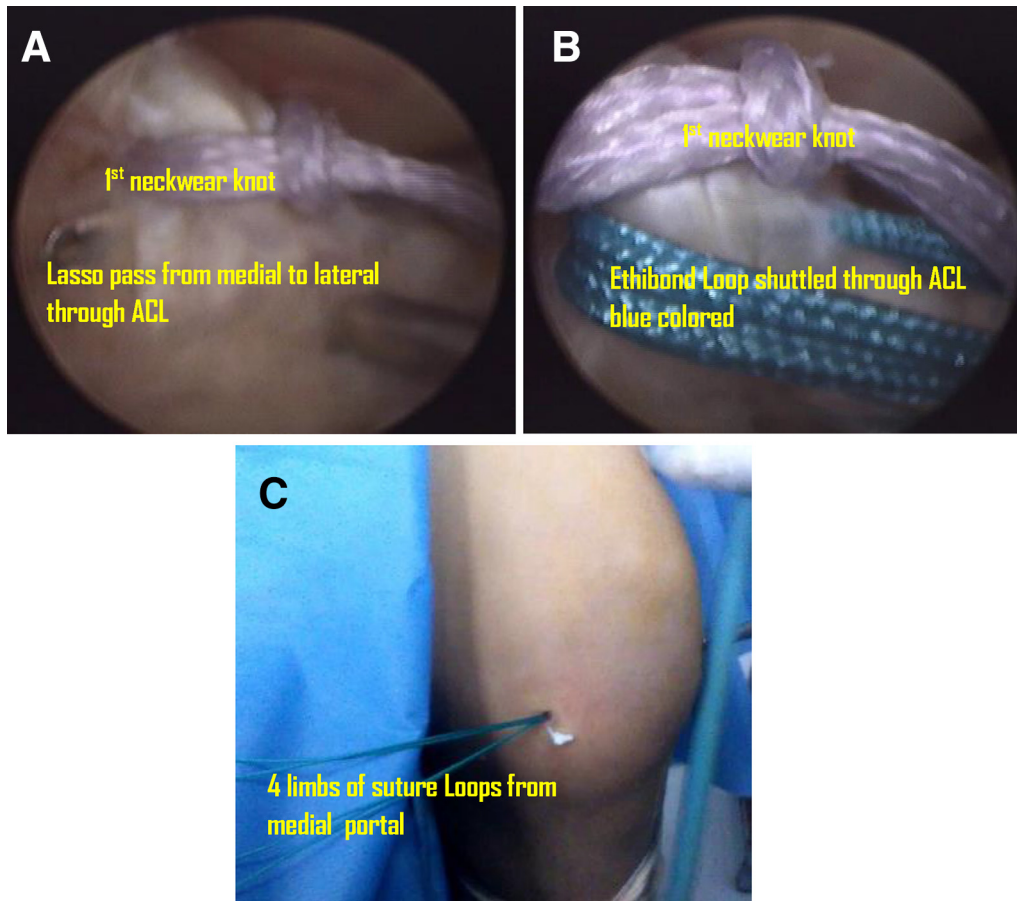


Fig 6. (A) Right knee viewed from anterolateral portal. First suture (neckwear knot). This step is exactly repeated with the suture hook (SutureLasso) introduced from anteromedial but anterior to the mid-coronal plane of the anterior cruciate ligament (ACL) fibers by use of No. 5 Ethibond suture. (B) Right knee viewed from anterolateral portal. A nonabsorbable No. 5 Ethibond suture loop is shuttled through the ACL fibers from the anteromedial portal. (C) The left knee is shown with the 4 resultant limbs of sutures, 2 FiberWire limbs and 2 Ethibond limbs, passing through the ACL and being delivered from the anteromedial portal.

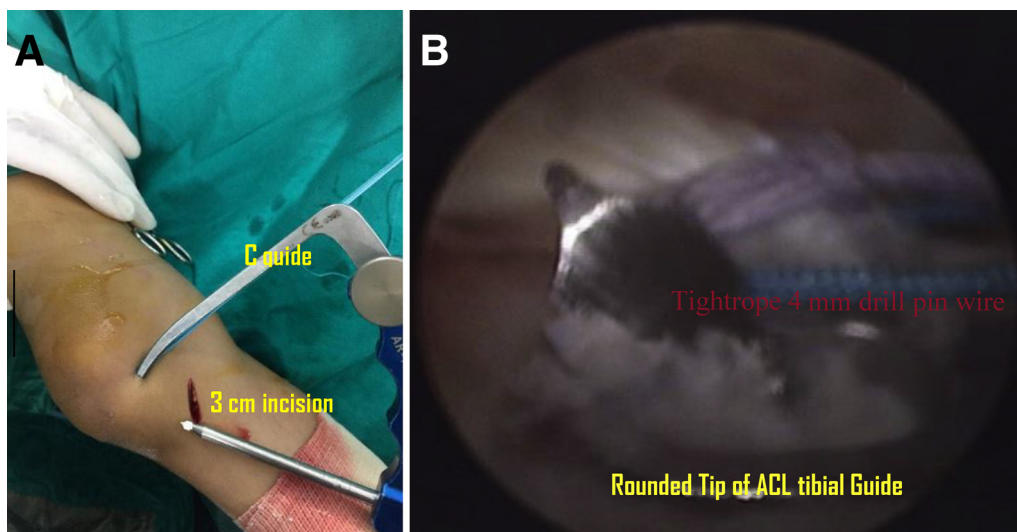


Fig 7. (A) In the right knee, a 3-cm oblique incision is made over the mid-proximal anteromedial tibia at the level of the tibial tuberosity and a cruciate ligament tibial guide (Arthrex) is used to place a single 4-mm tibial bony tunnel. (B) Right knee viewed from anterolateral portal. A TightRope 4-mm drill pin wire is placed, aiming at the mid-coronal plane of the fragment. (ACL, anterior cruciate ligament.)

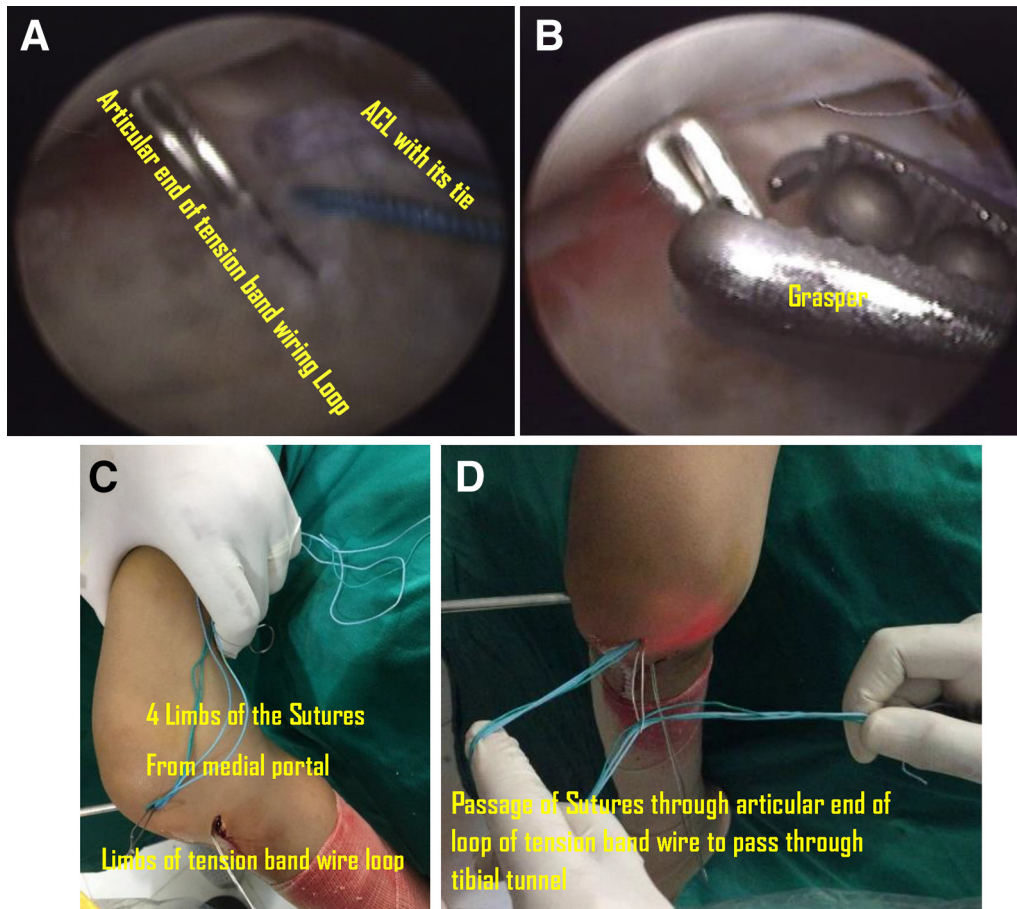


Fig 8. (A) Right knee viewed from anterolateral portal. A malleable steel wire loop (tension-band wire) is introduced through the tibial tunnel, and the ties are passed through the anterior cruciate ligament (ACL). (B) Right knee viewed from anterolateral portal. The articular end is grasped with a grasper, which is introduced through the anteromedial portal; this is used to retrieve the loop outside the knee. (C) Passage of a malleable steel wire loop (tension-band wire) and 4 limbs of FiberWire and Ethibond from the anteromedial portal in the right knee. (D) The loop outside the knee captures the 4 limbs of FiberWire and Ethibond. By withdrawing the tension-band loop through the tunnel, the terminal ends of the 4 limbs are retrieved at the tibial end of the tunnel.

simultaneously withdrawn. A grasper forceps is then used to deliver the steel wire through the anteromedial portal so that both ends of the steel wire, which have already captured the ACL fibers, are now outside the knee through the anteromedial portal (Fig 3).

The steel wire at its closed end (intra-articular end) is used to shuttle a nonabsorbable FiberWire suture loop (Arthrex) through the ACL fibers (Fig 4). A neckwear knot loop ligature technique is used, and now both limbs of FiberWire are outside the knee from the anteromedial portal (Fig 5). The 2 ends of the suture limbs are captured with a hemostat for future identification. This step is exactly repeated with the suture hook (SutureLasso) but anterior to the mid-coronal plane of the ACL fibers by use of No. 5 Ethibond suture. Thus, there are now 4 resultant limbs of sutures, 2 FiberWire limbs and 2 Ethibond limbs, passing through the ACL and being delivered from the anteromedial portal (Fig 6).

A 3-cm oblique incision is made over the mid-proximal anteromedial tibia at the level of the tibial

tuberosity. A cruciate ligament tibial guide is used to place 1 ACL TightRope 4-mm drill pin wire aiming at the mid-coronal plane of the fragment under direct arthroscopic visualization. A single 4-mm tibial bony tunnel is now drilled toward the fragment (Fig 7).

A malleable steel wire loop (tension-band wire) is introduced through the tibial tunnel, and its articular end is grasped with a grasper, which is introduced through the anteromedial portal; this is used to retrieve the loop outside the knee, capturing the 4 limbs of FiberWire and Ethibond. By withdrawing the tension-band loop through the tunnel, the terminal ends of the 4 limbs are retrieved at the tibial end of the tunnel. While the arthroscope is inside the joint, the fracture reduction is checked and anatomic reduction is achieved (Fig 8).

The assistant holds the reduction firmly by probe while the 4 limbs of the sutures are passed through the 4 holes of the button. This button is fixed to the proximal tibia with No. 0 Vicryl suture (Ethicon) passed

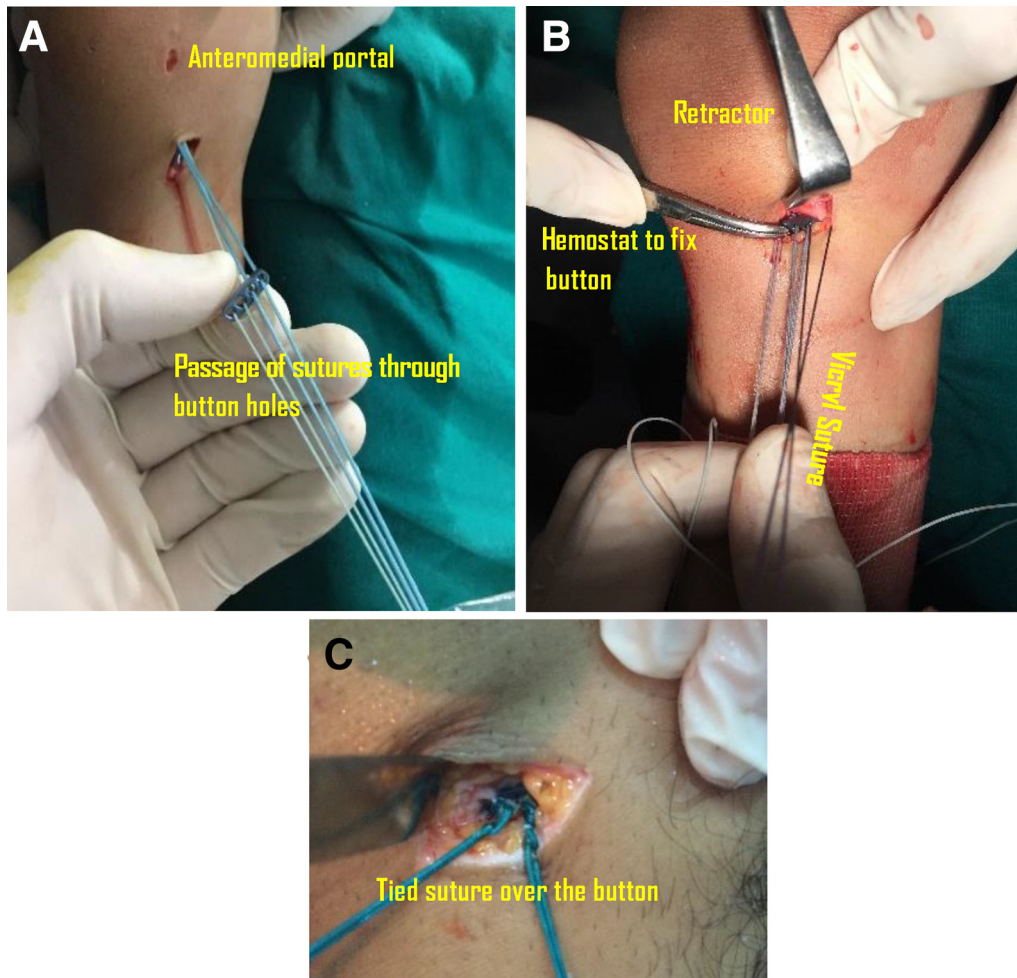


Fig 9. Right knee. (A) The assistant holds the reduction firmly by probe while the 4 limbs of the sutures are passed through the 4 holes of the button. (B) The button is fixed to the proximal tibia by No. 0 Vicryl suture passed through the lateral hole of the button and sutured to the periosteum. (C) The 2 limbs of the same suture loop are tied together over the button with the knee in 30° of flexion, with the assistant performing a reverse Lachman maneuver.

through the lateral hole of the button and sutured to the periosteum. Then, the 2 limbs of the same suture loop are tied together over the button with the knee in 30° of flexion, with the assistant performing a reverse Lachman maneuver, and the ACL is assessed for stability and tension (Figs 9 and 10A, Video 1).

Postoperative Management

All patients recruited for this study followed a standard postoperative protocol composed of (1) knee immobilization in a static ACL knee brace in extension for 3 weeks, together with isometric quadriceps strengthening and straight leg-raising exercises without weight bearing; (2) partial weight bearing for another 3 weeks with a hinged knee brace with gradual flexion; and (3) full weight bearing and a gradual return to activity starting after the end of the second postoperative month. At the end of the third

postoperative month, radiographs showed good reduction with solid union (Fig 10B-D).

Discussion

A variety of arthroscopic techniques have been described for fixation of tibial eminence fractures. Cannulated screws, Herbert screws,^{17,18} and TightRope devices²³ are examples of such methods of fixation, which entail the presence of intra-articular hardware. Such devices may lead to impingement or an extension deficit; as such, their removal is sometimes mandatory.

Arthroscopic-assisted reduction with suture fixation has progressed to become the preferred method of treatment for displaced avulsion fractures of the tibial eminence.²⁴ Koukoulis et al.²⁰ reported effective treatment through arthroscopic suture fixation of tibial eminence fractures in adults. Vega et al.²² described a

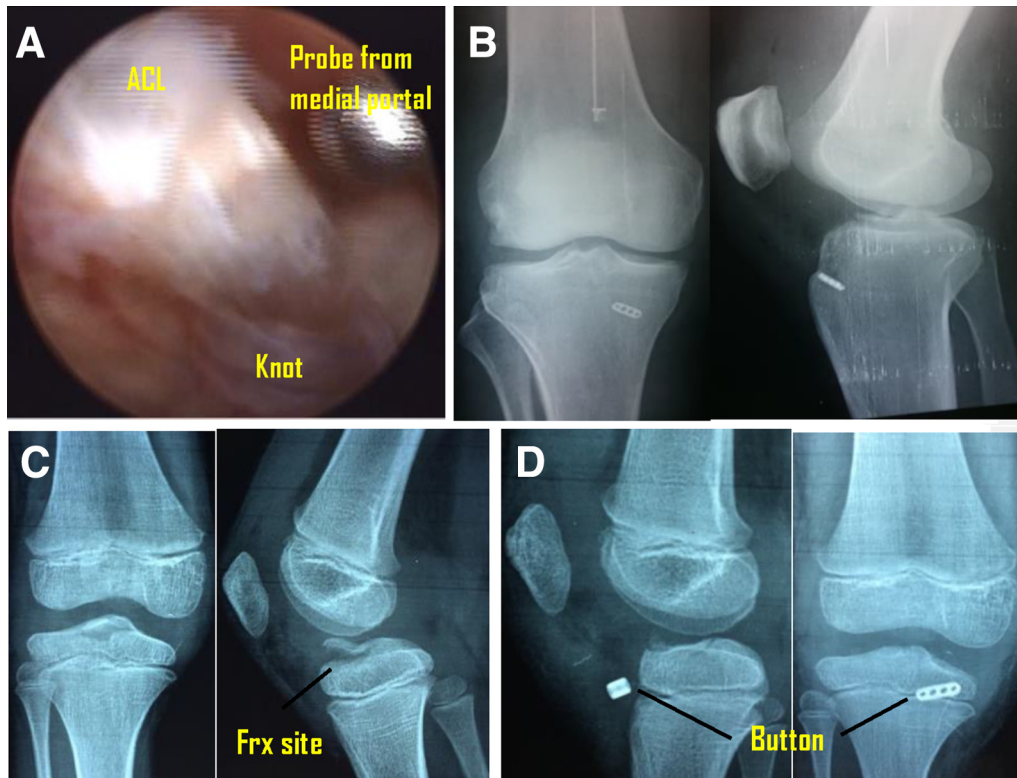


Fig 10. (A) Right knee viewed from anterolateral portal. The anterior cruciate ligament (ACL) is assessed for stability and tension. (B) Plain radiographs (anteroposterior and lateral views) show good reduction of the tibial eminence with appearance of the button on the proximal tibia. (C) Plain radiographs (anteroposterior and lateral views) show a grade II (Meyers and McKeever¹²) fracture (Frx) of the eminence in a 10-year-old girl. (D) At the end of the third postoperative month, radiographs showed good reduction with solid union.

physis-sparing technique using a preloaded suture anchor with sutures through the substance of the ACL to achieve accurate reduction and secure fixation. Sawyer et al.²¹ reported that a suture bridge technique using multiple suture anchors provided effective compression of the fracture fragment and rigid fixation in the treatment of tibial eminence fractures.

Traditionally, for the suture technique, two 2.5-mm-diameter tibial tunnels were created on both sides of the fracture by use of the Acuflex ACL tibial guide (Smith & Nephew) with the angle set at 45°. The internal exits of the 2 tunnels in the joint were located at the anteromedial and anterolateral margins of the fracture site.²⁶

It is important to consider the size and fragmentation of the avulsed eminence: If the avulsion is sufficiently large, screw fixation is recommended because it is the most stable fixation method²⁷; if the fragment size is small or if the avulsed eminence is fragmented, fixation can be performed using intraosseous sutures or thin steel wire looped through the cruciate ligament and then threaded through holes drilled in the proximal end of the tibia.^{19,28} In a study of 17 patients with type II or III tibial intercondylar eminence fractures, arthroscopically treated with either screws or sutures, Hunter and Willis²⁹ found no significant difference between these

2 methods in terms of results. In a retrospective study, Senekovic and Veselko³⁰ showed good therapeutic results for tibial intercondylar eminence fractures undergoing arthroscopic treatment using cannulated screws with washers, which allowed immediate weight bearing. However, countersunk screws could cause problems if revision surgery is required, as well as in ACL reconstruction. However, it is not impossible to insert an interference screw next to the original screw.

Another point of consideration for tibial spine fracture repair is the number of fixation points, because there is no definitive guideline about the optimal number; it depends on the suture device and the overall technique. It ranges from 1 to 4 points^{31,32}; however, Gamboa et al.³³ reported that using 3 points gives an excellent and anatomic reduction.

We use a modified single-tunnel pullout suture technique, which can be considered to have 2 points of fixation; it represents an appealing option that has proved effective and economical with a shorter operative time. This technique is feasible for both large and small fracture fragments. Moreover, it provides a less invasive option for skeletally immature patients (Table 1). In the trial of our technique, we noted some risk factors, one of which is migration of the button

Table 1. Advantage and Limitations of Technique

Advantages	
Arthroscopy shows associated intra-articular injury such as a meniscal tear.	
TightRope 4-mm drill pin wire is used.	
The technique provides a less invasive option for skeletally immature patients.	
The technique is feasible for both large and small fracture fragments.	
Use of a tension-band wire loop facilitates suture retrieval through the tunnel.	
No intra-articular hardware is used.	
The technique is effective and economical with a shorter operative time.	
Limitations	
Penetration of the eminence fragment may fracture it.	
Sliding of the button through the tunnel is possible.	
The technique is technically demanding.	

through the tunnel; to overcome this, we fixed the button to the periosteum of the proximal tibia. Another limitation is the possibility of an iatrogenic fracture of the eminence fragment (Table 1).

Acknowledgments

Ahmed Nady Saleh Elsaid would like to thank his father, mother, and wife for their help and support.

References

- Poncet A. Arrachement de l'épine du tibia a l'insertion du ligament croise anterieur. *Bull Mem Soc Chir Paris* 1875;1: 883-884.
- Luhmann S. Acute traumatic knee effusions in children and adolescents. *J Pediatr Orthop* 2003;23:199-202.
- Eiskjaer S. The significance of hemarthrosis of the knee in children. *Arch Orthop Trauma Surg* 1988;107:96-98.
- Kendall NS, Hsu SY, Chan KM. Fracture of the tibial spine in adults and children. A review of 31 cases. *J Bone Joint Surg Br* 1992;74:848-852.
- Zionts L. Fractures and dislocations about the knee. In: Green NE, Swiontkowski MR, eds. *Skeletal trauma in children*. Philadelphia: WB Saunders, 2009;452-455.
- Pringle JH. I. Avulsion of the spine of the tibia. *Ann Surg* 1907;46:169-178.
- Godlee RJ. Fracture of the spine of the tibia. *Illus Med News* 1888;i:12.
- Wiley J, Baxter M. Tibial spine fractures in children. *Clin Orthop Relat Res* 1990;(255):54-60.
- Noyes F, DeLucas J, Torvik P. Biomechanics of anterior cruciate ligament failure: An analysis of strain-rate sensitivity and mechanisms of failure in primates. *J Bone Joint Surg Am* 1974;56:236-253.
- Perugia D. Clinical and radiological results of arthroscopically treated tibial spine fractures in childhood. *Int Orthop* 2009;33:243-248.
- Tudisco C. Intercondylar eminence avulsion fracture in children: Long-term follow-up of 14 cases at the end of skeletal growth. *J Pediatr Orthop B* 2010;19:403-408.
- Meyers MH, McKeever KF. Fracture of the intercondylar eminence of the tibia. *J Bone Joint Surg Am* 1959;41:209-220.
- Pevny T, Purnell ML, Lindsay Harris N, Larsen AI. Arthroscopic fixation of tibial spine fractures. *Tech Knee Surg* 2007;61:2-8.
- Kluemper CT, Snyder GM, Coats AC, Johnson DL, Mair SD. Arthroscopic suture fixation of tibial eminence fractures. *Orthopedics* 2013;36:e1401-e1406.
- Dimeglio A. Growth in pediatric orthopaedics. *J Pediatr Orthop* 2001;21:549-555.
- Furlan D, Pogorelic Z, Biocic M, Juric I, Mestrovic J. Pediatric tibial eminence fractures: Arthroscopic treatment using K-wire. *Scand J Surg* 2010;99:38-44.
- Wiegand N, Naumov I, Vamhidly L, Not LG. Arthroscopic treatment of tibial spine fracture in children with a cannulated Herbert screw. *Knee* 2014;21:481-485.
- Parikh SN, Myer D, Eismann EA. Prevention of arthrofibrosis after arthroscopic screw fixation of tibial spine fracture in children and adolescents. *Orthopedics* 2014;37:e58-e65.
- Oohashi Y. A simple technique for arthroscopic suture fixation of displaced fracture of the intercondylar eminence of the tibia using folded surgical steels. *Arthroscopy* 2001;17:1007-1011.
- Koukoulas NE, Germanou E, Lola D, Papavasiliou AV, Papastergiou SG. Clinical outcome of arthroscopic suture fixation for tibial eminence fractures in adults. *Arthroscopy* 2012;28:1472-1480.
- Sawyer GA, Hulstyn MJ, Anderson BC, Schiller J. Arthroscopic suture bridge fixation of tibial intercondylar eminence fractures. *Arthrosc Tech* 2013;2:e315-e318.
- Vega JR, Iribarra LA, Baar AK, Iniguez M, Salgado M, Gana N. Arthroscopic fixation of displaced tibial eminence fractures: A new growth plate-sparing method. *Arthroscopy* 2008;24:1239-1243.
- Ballal M, Joseph C, Chidanand KJC, Vinay HS, Shankar SU. Tightrope-suture button fixation for type III tibial eminence fractures—Case series and review of literature. *J Arthrosc Joint Surg* 2014;1:87-90.
- Lubowitz JH, Elson WS, Guttmann D. Part II: Arthroscopic treatment of tibial plateau fractures: Intercondylar eminence avulsion fractures. *Arthroscopy* 2005;21:86-92.
- Huang TW, Hsu KY, Cheng CY, et al. Arthroscopic suture fixation of tibial eminence avulsion fractures. *Arthroscopy* 2008;24:1232-1238.
- Liao W, Li Z, Zhang H, Li J, Wang K, Yang Y. Arthroscopic fixation of tibial eminence fractures: A clinical comparative study of nonabsorbable sutures versus absorbable suture anchors. *Arthroscopy* 2016;32:1639-1650.
- Delcogliano A, Chiossi S, Caporaso A, Menghi A, Rinonapoli G. Tibial intercondylar eminence fractures in adults: Arthroscopic treatment. *Knee Surg Sports Traumatol Arthrosc* 2003;11:255-259.
- Kogan MG, Marks P, Amendola A. Technique for arthroscopic suture fixation of displaced tibial intercondylar eminence fractures. *Arthroscopy* 1997;13:301-306.
- Hunter RE, Willis JA. Arthroscopic fixation of avulsion fractures of the tibial eminence: Technique and outcome. *Arthroscopy* 2004;20:113-121.
- Senekovic V, Veselko M. Anterograde arthroscopic fixation of avulsion fractures of the tibial eminence with a cannulated screw: Five-year results. *Arthroscopy* 2003;19:54-61.

31. Gwinner C, Kopf S, Hoburg A, Haas NP, Jung TM. Arthroscopic treatment of acute tibial avulsion fracture of the posterior cruciate ligament using the TightRope fixation device. *Arthrosc Tech* 2014;3:e377-e382.
32. Boutsiadis A, Karataglis D, Agathangelidis F, Ditsios K, Papadopoulos P. Arthroscopic 4-point suture fixation of anterior cruciate ligament tibial avulsion fractures. *Arthrosc Tech* 2014;3:e683-e687.
33. Gamboa JT, Durrant BA, Pathare NP, Shin EC, Chen JL. Arthroscopic reduction of tibial spine avulsion: Suture lever reduction technique. *Arthrosc Tech* 2017;6:e121-e126.