Technical Note

Arthroscopic Anterior Cruciate Ligament Avulsion Fixation With a Knotless Suture Anchor: A Minimalistic Approach

Cheng Luo, M.D., Yijun He, M.D., and Jiongfeng Huang, B.T.C.M.

Abstract: This technical note outlines a minimalist arthroscopic approach to anterior cruciate ligament avulsion fracture fixation using a bioabsorbable knotless suture anchor. This method represents a less invasive alternative to traditional techniques, catering specifically to fractures classified as Meyers and McKeever type II or III. The procedure is performed through standard anterolateral and anteromedial portals without the need for additional incisions or bone tunnel drilling, making it particularly suitable for children and adolescent patients with open physes. The technique involves the use of a suture hook to pass a double-stranded suture through the anterior cruciate ligament, anchored eccentrically to the anterior tibial incline with a knotless suture anchor. This approach allows for anatomic reduction with adjustable tension and without the potential risk of iatrogenic osteochondral injury. Nonetheless, it should be acknowledged that prospective biomechanical studies and larger patient samples are necessary to validate this technique compared with existing fixation methods.

Anterior cruciate ligament (ACL) avulsion fracture is a specific type of fracture that involves the separation of the tibial eminence, where the ligament attaches, from the tibial plateau to varying degrees. This type of fracture is more commonly seen in skeletally immature children than in adults, possibly attributed to the difference in strength between the partially ossified bone and the increased elasticity of ligaments.[1] The fractures are categorized using the Meyers and McKeever classification system.[2] Type I denotes fractures without displacement, type II encompasses fractures that are hinged or partially displaced, type III signifies fully displaced fractures lacking any cortical contact, and type IV pertains to fractures completely displaced and comminuted. It is recommended that fractures classified as type II or above be treated surgically.[3] Advancements in techniques and the growing dexterity and confidence of surgeons have led to increased popularity of arthroscopic fixation. Thus, different fixation methods and implants—such as screws, sutures, staples, and suspension systems—have been proposed, each with its own drawbacks and technical intricacies.[3-8] Because of these drawbacks, we propose a minimalist alternative technique using an all-inside approach with a bioabsorbable knotless suture anchor to address this clinical entity (Fig 1, Video 1).

From the Department of Osteoarthropathy and Sports Medicine, The Affiliated Panyu Central Hospital of Guangzhou Medical University, Guangzhou, China (C.L., Y.H., J.H.); and Rehabilitation Medicine Institute of Panyu District, The Affiliated Panyu Central Hospital of Guangzhou Medical University, Guangzhou, China (C.L.).

C.L. and Y.H. contributed equally.

Received January 19, 2024; accepted April 11, 2024.

Address correspondence to Jiongfeng Huang, B.T.C.M., Department of Osteoarthropathy and Sports Medicine, The Affiliated Panyu Central Hospital of Guangzhou Medical University, 13/F, 8th Fuyu Dong Road, Qiaonan, Panyu, Guangzhou, Guangdong 511400, China. E-mail: huangjiongfeng@pyhospital.com.cn

2212-6287/2498
https://doi.org/10.1016/j.eats.2024.103058

Surgical Technique

Patient Positioning and Portal Placement

The patient is positioned supine on the operating table with the affected knee flexed at 90° and a tourniquet applied. Standard anterolateral (AL) and anteromedial (AM) portals are established for diagnostic knee arthroscopy. The arthroscope is introduced through the AL portal, which serves as the primary viewing portal, whereas the AM portal is used for instrument insertion.

Fragment Identification and Preparation

By use of a probe inserted through the AM portal, the avulsed ACL fragment is identified (Fig 2). To

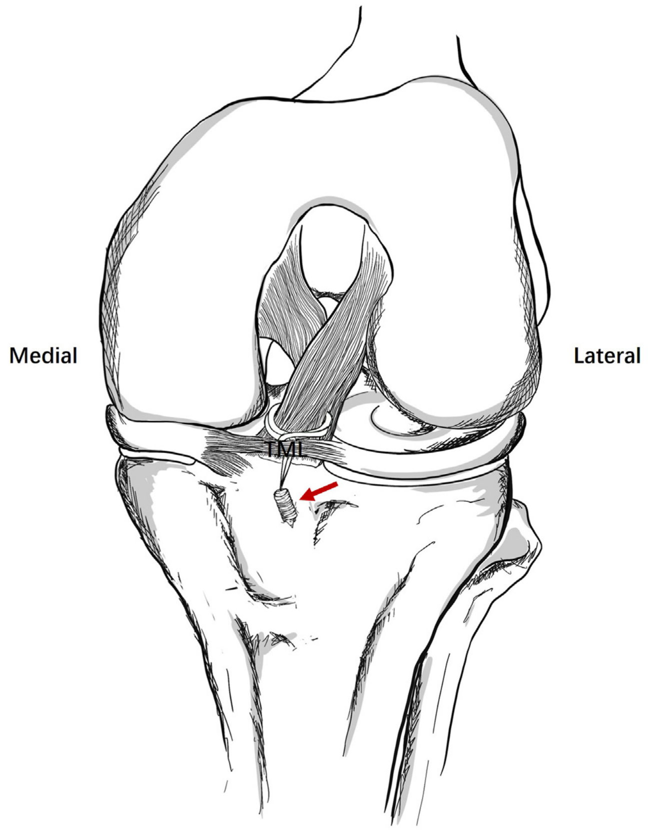

Fig 1. Proposed minimalistic fixation method in left knee. A double-stranded No. 5 Ethibond suture is shuttled into place by the polydioxanone suture, encircling approximately three-fourths of the anterior cruciate ligament substance just above its insertion. By pulling both ends of the Ethibond suture externally, a loop is created. The free ends of the suture are then fed through this loop and passed back into the joint. The anterior tibial slope bone area, located just beneath the transverse meniscal ligament (TML) and along the longitudinal axis of the anterior cruciate ligament, is tapped. A SwiveLock knotless suture anchor (arrow), preloaded with the Ethibond suture, is then placed into the tapped area and secured, completing the fixation.

facilitate anatomic reduction of the fragment, the arthroscope and instruments are switched between the AL and AM portals (Fig 3), allowing for thorough debridement of any interposed fibrous tissue using a shaver.

Suture Passage

A suture hook (Arthrex) preloaded with a polydioxanone suture (PDS; Ethicon) is inserted through the AM portal and positioned just above the ACL insertion. The suture hook penetrates the medial side of the AM fibers (Fig 4) and exits from the anterior two-thirds of the posterolateral fibers (Fig 5). A double-stranded No. 5 Ethibond Excel (Ethicon) is then shuttled into place using the polydioxanone suture. Both ends of the Ethibond are pulled externally

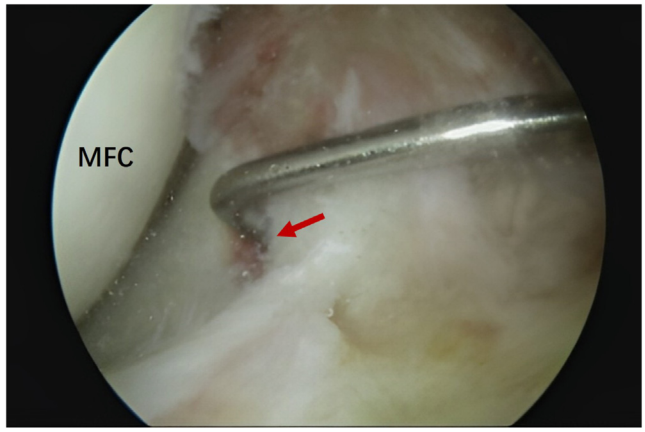

Fig 2. Arthroscopic image of left knee, viewed from anteromedial portal, showing medial fracture line of tibial eminence (arrow). (MFC, medial femoral condyle.)

through the AM portal, creating a loop outside the joint (Fig 6). The Ethibond ends are then fed through the loop and back into the joint, encircling the anterior two-thirds of the ACL (Fig 7).

Anchor Placement and Fixation

The anterior tibial slope bone area, located just beneath the transverse meniscal ligament and 0.5 to 0.8 cm anterior to the ACL insertion (Fig 8), is identified and tapped along the ACL's longitudinal axis (Fig 9) . A 4.75-mm SwiveLock knotless suture anchor (Arthrex), preloaded with the double-stranded Ethibond end, is placed in the tapped hole and secured at 90° of knee flexion (Fig 10). Proper tension is maintained on the sutures to achieve anatomic reduction of the avulsed fragment.

Evaluation and Closure

The reduction is evaluated using a probe, moving the knee from flexion to extension (Fig 11). The arthroscope and instruments are then removed, and the knee is irrigated to remove any debris. The portal incisions are closed with No. 3-0 Vicryl sutures (Ethicon) in a subcuticular fashion and protected with adhesive tapes.

Postoperative Assessment

Anteroposterior and lateral radiographs, as well as magnetic resonance imaging scans, are obtained postoperatively to reassess the fracture reduction and position of the implant (Fig 12).

Postoperative Rehabilitation

The patient is advised to use crutches, and the affected limb is immobilized in a full-extension splint with no weight bearing for 2 weeks. During this period, assisted or passive range-of-motion exercises are introduced and gradually increased. Partial weight

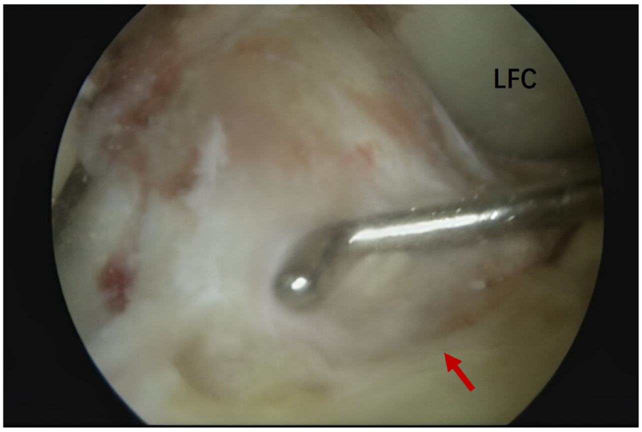

Fig 3. Arthroscopic image of left knee, viewed from anteromedial portal, showing anterolateral fracture line of tibial eminence (arrow). (LFC, lateral femoral condyle.)

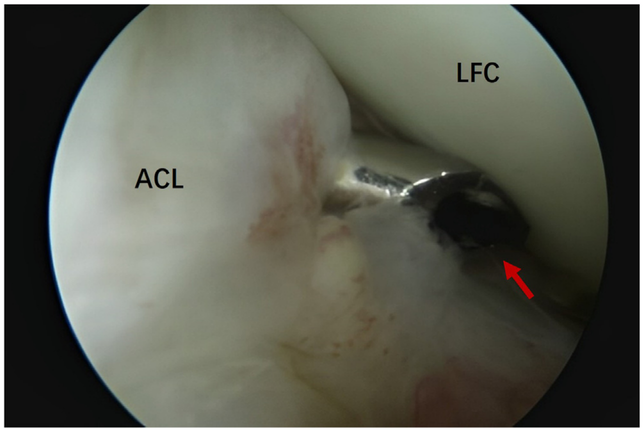

Fig 5. Arthroscopic image of left knee, viewed from anterolateral portal, showing suture hook (arrow) exiting from anterior two-thirds of posterolateral fibers of anterior cruciate ligament (ACL). (LFC, lateral femoral condyle.)

bearing then begins. Active range of motion is initiated in the fifth week after the operation, with gradual advancement to full weight bearing by the end of the sixth week, as tolerated by the patient.

Discussion

It has been reported that addressing ACL avulsion fracture arthroscopically achieves promising clinical results.[9-11] However, varying fixation methods have been reported, such as screws,[12] transtibial suspensory devices,[3] FiberWires (Arthrex),[7] sutures,[11] and suture anchors,[4] with their merits and drawbacks. The decision on method is primarily dependent on the patient's situation, implant accessibility, and the surgeon's perception and expertise.

Screws are predominantly used owing to their general availability. The most straightforward method is to secure the fragment to the tibial plateau in an antegrade fashion.[13] Nevertheless, precise screw insertion may necessitate the creation of a supplementary suprapatellar portal or demand hyperflexion of the knee to achieve optimal alignment arthroscopically. The former approach carries the risk of inadvertent osteochondral damage with additional instrumentation, whereas the latter exerts an undue tensile force on the fragment, thereby jeopardizing anatomic reduction.[14] Furthermore, screws carry the potential for impingement with knee extension, necessitating a subsequent intervention for implant removal.[5] Additionally, screw placement might result in fracture fragment comminution.

A widely adopted fixation alternative is the transtibial or pullout suture technique. Research has

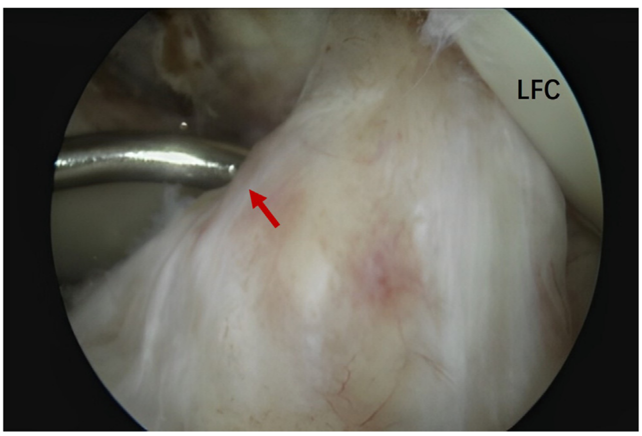

Fig 4. Arthroscopic image of left knee, viewed from anterolateral portal, showing suture hook (arrow) penetrating medial side of anteromedial fibers of anterior cruciate ligament. (LFC, lateral femoral condyle.)

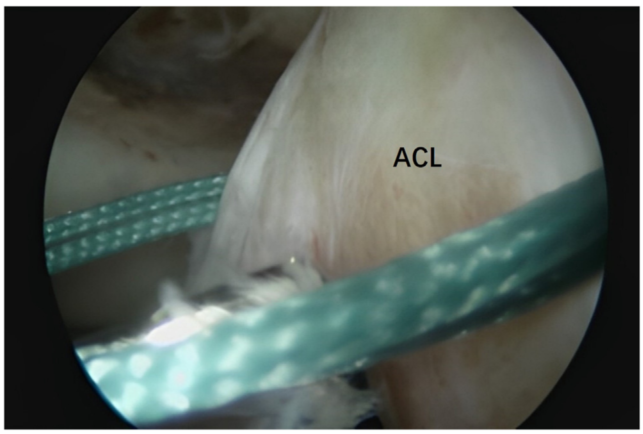

Fig 6. Arthroscopic image of left knee, viewed from anterolateral portal, showing double-stranded No. 5 Ethibond suture shuttled into place by polydioxanone suture, encircling approximately three-fourths of anterior cruciate ligament (ACL) substance just above its insertion.

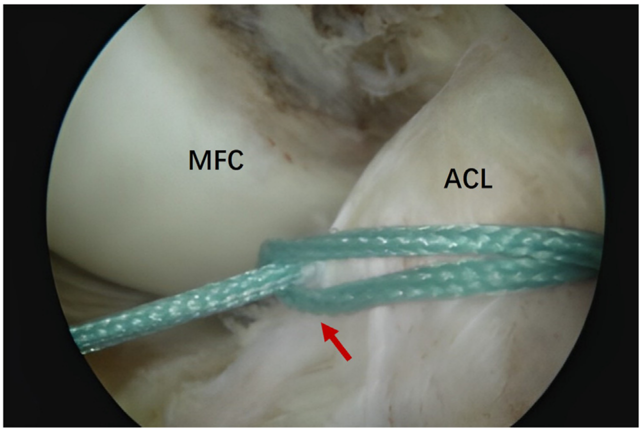

Fig 7. Arthroscopic image of left knee, viewed from anterolateral portal, showing both ends of Ethibond suture pulled externally to create loop (arrow), with 1 end then fed back into joint. (ACL, anterior cruciate ligament; MFC, medial femoral condyle.)

shown that the initial tensile strength of the pullout suture (FiberWire) is significantly superior to screw fixation.[15] The versatility of suture results in its applicability to different fracture patterns and comminution.[16] Despite its advantages, the technique has specific drawbacks. The procedure is technically more challenging, necessitating the drilling of 1 or more tibial tunnels to facilitate suture passage and securement. Additionally, knot tying on the tibial cortex may lead to cortical cutting, yet this issue has been addressed by the advent of the suspensory plate system.[5,17] This approach, however, necessitates an extra incision for cortical fixation. Furthermore, considering that children with open physes are more

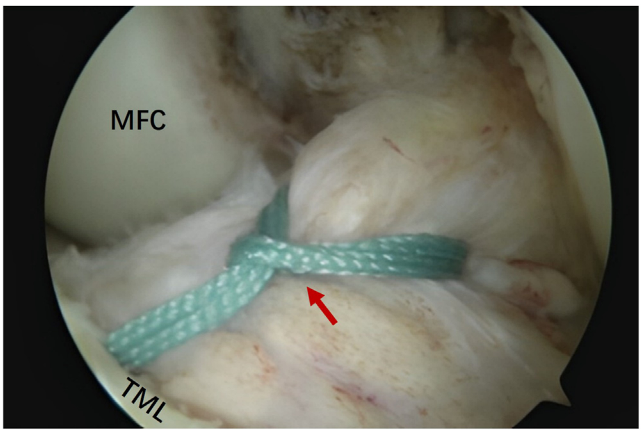

Fig 8. Arthroscopic image of left knee, viewed from anterolateral portal, showing free end of Ethibond suture passed beneath transverse meniscal ligament (TML) and along longitudinal axis of anterior cruciate ligament. The arrow indicates the Ethibond suture loop. (MFC, medial femoral condyle.)

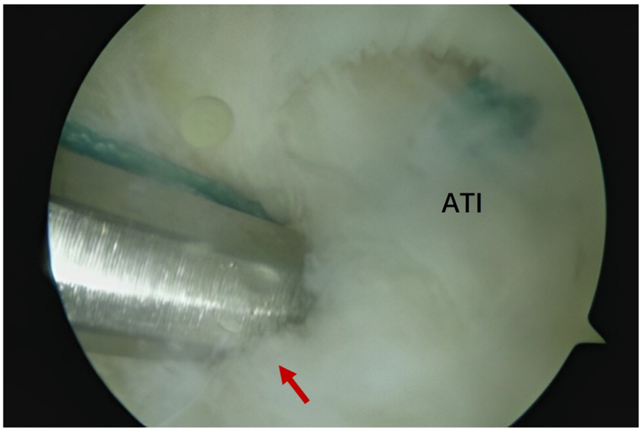

Fig 9. Arthroscopic image of left knee, viewed from anterolateral portal, showing tip of 4.75-mm SwiveLock knotless suture anchor (arrow), preloaded with double-stranded Ethibond suture, placed in tapped hole in anterior tibial slope approximately 0.5 to 0.8 cm anterior to insertion of anterior cruciate ligament. (ATI, anterior tibial incline.)

prone to ACL avulsion fractures, the transtibial method carries a risk of physeal injury resulting in growth disturbance.[18]

Attempted fixation using suture anchors, both knotted and knotless, from arthroscopic shoulder procedures such as transglenoid shoulder stabilization has been performed and documented in studies, providing robust resistance to pullout forces and yielding favorable clinical results.[19] Traditional multiple-knot sutures over the ACL fragment, however, carry the potential risk of causing impingement within the intercondylar notch, leading to aseptic synovitis from repetitive mechanical irritation. The

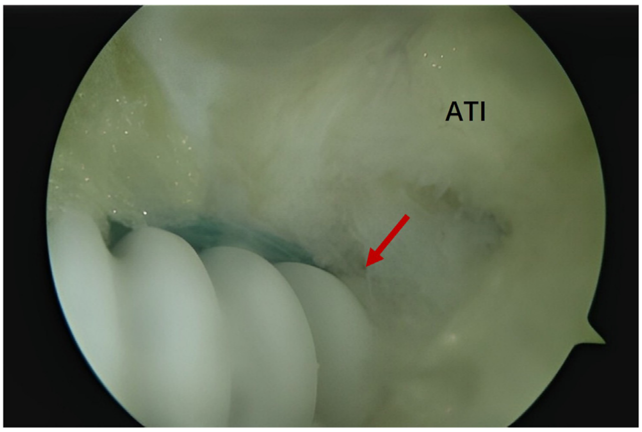

Fig 10. Arthroscopic image of left knee, viewed from anterolateral portal, showing 4.75-mm SwiveLock knotless suture anchor, preloaded with double-stranded Ethibond suture, secured at designated area with desired tension achieved, while knee is maintained at 90° of flexion. The arrow indicates the screw of the SwiveLock anchor. (ATI, anterior tibial incline.)

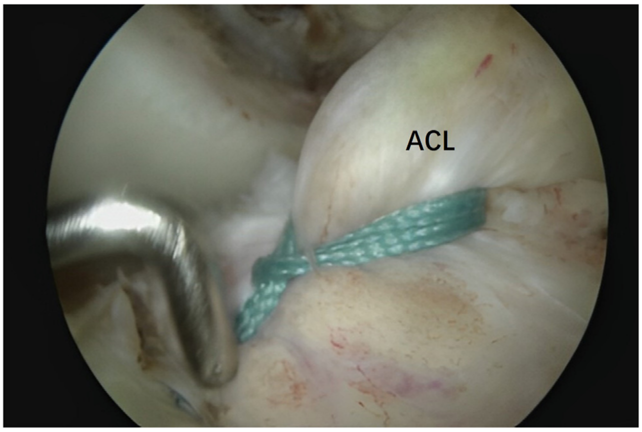

Fig 11. Arthroscopic image of left knee, viewed from anterolateral portal, showing evaluation of reduction using probe while moving knee through range of motion from flexion to extension. (ACL, anterior cruciate ligament.)

advancement of knotless suture anchors has addressed this issue, facilitating tension-adjustable suture fixation and showing positive clinical outcomes, as evidenced by bony union without joint laxity or contracture.[19] The current body of literature has described the placement of a knotless suture anchor at the periphery of the avulsed fragment, creating either a triple or quadruple point of fixation.[6] Nonetheless, anatomic studies have revealed that the insertional footprint of the ACL spans a relatively small region of roughly 18 mm × 19 mm.[19,20] Consequently, the placement of suture anchors could unavoidably inflict iatrogenic injury to the intact osteochondral surface of the tibial plateau. This concern has aroused the interest of authors in devising minimalist approaches.

Our simplified approach passes a double-stranded suture through the lower portion of the ACL, creating a knotless loop that encircles two-thirds of the ligament for reinforcement. The suture is then eccentrically anchored to the anterior tibial incline using a knotless suture anchor. This strategic placement is intended to reduce the risk of iatrogenic osteochondral injury compared with other anchors secured at the fragment's periphery. The tension-adjustable fixation technique facilitates precise alignment and compression between the bone bed and the avulsed fragment. This simplified approach stands in contrast to others that may require additional incisions and portals. Without the transtibial tunnel, we sidestep the risks of growth disturbance associated with physeal injury, making this procedure particularly suitable for younger patients with open physes. Additionally, this technique is less technically demanding because it obviates bone tunnel creation and complex intra-articular knot tying. This makes the technique more accessible and potentially more consistent in its outcomes owing to the reduced complexity of the surgical steps involved. Our technique is optimally suited for type II and III fractures given that we have applied it successfully in cases within this classification (Table 1).

Nonetheless, we acknowledge that our method has not yet been validated by biomechanical studies to confirm its strength in comparison to other fixation techniques, and it has been performed in a limited patient cohort. Consequently, further research is required. We earnestly hope that our method, which combines simplicity with effectiveness, could offer a practical option for surgeons with less experience in managing ACL avulsion injuries, yielding favorable patient outcomes while minimizing risk.

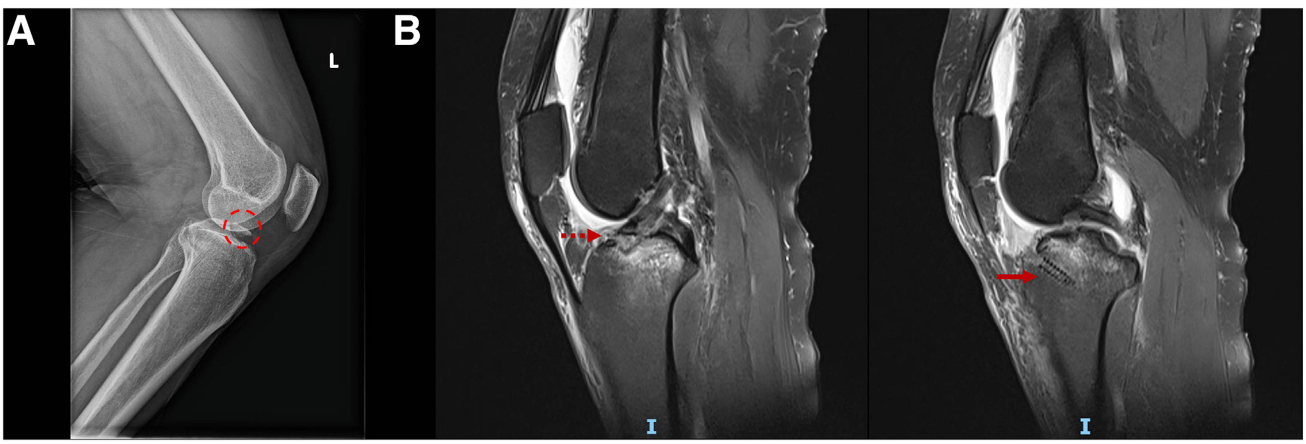

Fig 12. Preoperative and postoperative imaging studies. (A) Preoperative lateral digital radiograph showing fractured tibial eminence (dotted circle). (B) Postoperative sagittal T2-weighted magnetic resonance imaging scans showing anatomic reduction of fracture fragment (dotted arrow) and correct placement of suture anchor (solid arrow) in anterior tibial incline.

Table 1. Advantages and Disadvantages of Minimalistic Technique

Advantages	
	Simplicity and accessibility
	Reduced risk of iatrogenic injury
	Adjustable tension for anatomic reduction
	No bone tunnel drilling
	No additional incisions or portals
Disadvantages	
	Limited validation by biomechanical studies
	Limited patient cohort
	Specifically catered to Meyers and McKeever type II and III fractures
	Potential risk of suture cutting through ligament tissue
	Risk of anchor pullout in poor bone stock
	Lack of long-term follow-up data

Disclosures

All authors (C.L., Y.H., J.H.) declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper. This work is supported by the Panyu Key Medical and Health Projects of Science and Technology Planning (2022-Z04-101).

Acknowledgments

The authors express their sincere gratitude to Ms. Wanshi Li for providing the schema (Fig 1) for this article.

References

1. Salvato D, Green DW, Accadbled F, Tuca M. Tibial spine fractures: State of the art. *J ISAKOS* 2023;8:404-411.
2. Zaricznyj B. Avulsion fracture of the tibial eminence: Treatment by open reduction and pinning. *J Bone Joint Surg Am* 1977;59:1111-1114.
3. Williams NR, Yin S, Guzman AJ, et al. Tibial spine avulsion repair with FiberRing suture and anterior cruciate ligament repair TightRope. *Arthrosc Tech* 2023;12:e2381-e2385.
4. Bauer AA, Steffen RM, Warnick DE. A technique for arthroscopic fixation of tibial eminence avulsion fractures: A physeal-sparing construct with all-suture anchor bridge fixation. *Arthrosc Tech* 2024;13:102854.
5. Ayati Firoozabadi M, Dehghaniashkezari D, Seyedtabaei SMM, et al. Arthroscopic ACL avulsion fixation with adjustable loop length cortical Endobutton. *Arthrosc Tech* 2024;13:102815.
6. Kelly S, DeFroda S, Nuelle CW. Arthroscopic assisted anterior cruciate ligament tibial spine avulsion reduction and cortical button fixation. *Arthrosc Tech* 2023;12:e1033-e1038.
7. Yang R, Xu W, Zheng H, et al. Arthroscopic fixation of anterior cruciate ligament avulsion fracture using FiberWire suture with suture disc. *Arthrosc Tech* 2021;10:e1709-e1715.
8. Wolfson T, Vadhera AS, Parvaresh K, Verma N, LaPrade RF, Chahla J. Arthroscopic reduction and internal fixation of tibial eminence fractures with transosseous suture bridge fixation. *Arthrosc Tech* 2021;10:e1039-e1046.
9. Zhao J, Huangfu X. Arthroscopic treatment of nonunited anterior cruciate ligament tibial avulsion fracture with figure-of-8 suture fixation technique. *Arthroscopy* 2007;23:405-410.
10. Yuan Y, Huang X, Zhang Y, Wang Z. Treatment of tibial eminence fractures with arthroscopic suture fixation technique: A retrospective study. *Int J Clin Exp Med* 2015;8:13797-13803.
11. Jang KM, Bae JH, Kim JG, Wang JH. Novel arthroscopic fixation method for anterior cruciate ligament tibial avulsion fracture with accompanying detachment of the anterior horn of the lateral meniscus: Three-point suture fixation. *Injury* 2013;44:1028-1032.
12. Qu H, Meng Q, Sun Q, Du D, Zhang Q. Arthroscopic fixation for tibial eminence fractures: A clinical retrospective study of cannulated screws versus transosseous anchor knot fixation techniques with suture anchors. *Knee* 2022;35:105-113.
13. Keogh P, Kelly C, Cashman WF, McGuinness AJ, O'Rourke SK. Percutaneous screw fixation of tibial plateau fractures. *Injury* 1992;23:387-389.
14. McNamara IR, Smith TO, Shepherd KL, et al. Surgical fixation methods for tibial plateau fractures. *Cochrane Database Syst Rev* 2015;2015:CD009679.
15. 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.
16. Yuan L, Shi R, Chen Z, Ding W, Tan H. The most economical arthroscopic suture fixation for tibial intercondylar eminence avulsion fracture without any implant. *J Orthop Surg Res* 2022;17:327.
17. Hapa O, Barber FA, Süner G, et al. Biomechanical comparison of tibial eminence fracture fixation with high-strength suture, EndoButton, and suture anchor. *Knee Surg Sports Traumatol Arthrosc* 2012;28:681-687.
18. Yoon JR, Park CD, Lee DH. Arthroscopic suture bridge fixation technique with multiple crossover ties for posterior cruciate ligament tibial avulsion fracture. *Knee Surg Sports Traumatol Arthrosc* 2018;26:912-918.
19. Hapa O, Barber FA, Süner G, et al. Arthroscopic fixation of anterior cruciate ligament tibial avulsion fractures using bioabsorbable suture anchors. *Knee Surg Sports Traumatol Arthrosc* 2008;16:286-289.
20. Giuliani JR, Kilcoyne KG, Rue JPH. Anterior cruciate ligament anatomy—A review of the anteromedial and posterolateral bundles. *J Knee Surg* 2009;22:148-154.