Technical Note

The Arthroscopic Three-Point Fixation for Anterior Cruciate Ligament Avulsion Fracture: Surgical Technique

Cholawish Chanlalit, M.D., Nattakorn Mahasupachai, M.D., and Chidchanok Sakdapanichkul, M.D.

Abstract: Several arthroscopic repairs and fixation for tibial intercondylar eminence fracture have been developed for restoring anterior cruciate ligament function. Repairing the avulsion fragment with multiple-point fixation provides some benefits over a single-point fixation. It provides multidirectional force control, especially on the posterior part of the fragment, and produces area of compression. We propose a 3-point fixation technique for providing proper reduction and compression in large fragment anterior cruciate ligament avulsion fracture. This includes using hybrid intra-articular and tunnel pull-out suture fixation to provide good posterior reduction and fixation. The number of tunnels is decreased by using a suture anchor.

Tibial intercondylar eminence fracture is an osseous failure caused by avulsion from anterior cruciate ligament (ACL). This type of injury is more common in children and adolescents, which peaks during ages of 8 to 13 years. However, it can occur in adults and cause anterolateral instability to the injured knee.[1-3] Originally, Meyers and McKeever[4] classified this injury based on the severity of displacement. There has been a strong agreement of treating displaced fracture with operative procedures, which are fragment reduction and fixation to restore the ACL function.[1-4]

Recently, the arthroscopic pull-out suture technique has become popular for the reduction and fixation of avulsion fragment. Several techniques, including using 1 to 4 tunnels for fixation, have been reported.[5-11] In the single-tunnel fixation technique, it may not be able to completely control the adequate reduction multidirectionally. The tunnel is often placed anteriorly to the fracture. During fixation, the posterior gap of the fracture is usually remained unreduced or becomes wider. To correct multidirectionally, a multiple-tunnel technique is needed. However, there are many concerning issues with the multiple-tunnel technique, such as tunnel convergence during their creation,[12] as well as the insecure horizontal and vertical motion of the suture in the tunnel due to the long distance of the tunnel, known as the "windshield wiper" and "bungee jump" effect, respectively.[13-15]

In this article, we report an arthroscopic 3-point fixation technique using the hybrid tunnel pull-out suture fixation and intra-articular fixation. The aim of using intra-articular fixation is to minimize the number of tunnels for the ACL avulsion fracture fixation. This technique aims to achieve proper reduction, especially at the posterior portion of the fracture, and adequate compression in fixation area between the fragment and its bone base.

Surgical Intervention (With Video Illustration)

General preparation of the patient is performed with the patient in a supine position with the injured knee hanging over the side of the operating table. A pneumatic tourniquet is applied at the proximal thigh. After

From the Center of Excellent in Upper Extremity Reconstruction and Sport Medicine, HRH Princess Maha Chakri Sirindhorn Medical Center, Faculty of Medicine, Srinakharinwirot University, Nakhon Nayok, Thailand.

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 March 6, 2023; revised manuscript received May 20, 2023; accepted May 28, 2023.

Address correspondence to Cholawish Chanlalit, M.D., Department of Orthopedics, 6th floor of Faculty of Medicine Building, Srinakharinwirot University, 62 Moo 7 Ongkharak, Ongkharak, Nakhon Nayok 26120. E-mail: chanlalit@hotmail.com

2212-6287/23359

https://doi.org/10.1016/j.eats.2023.05.016

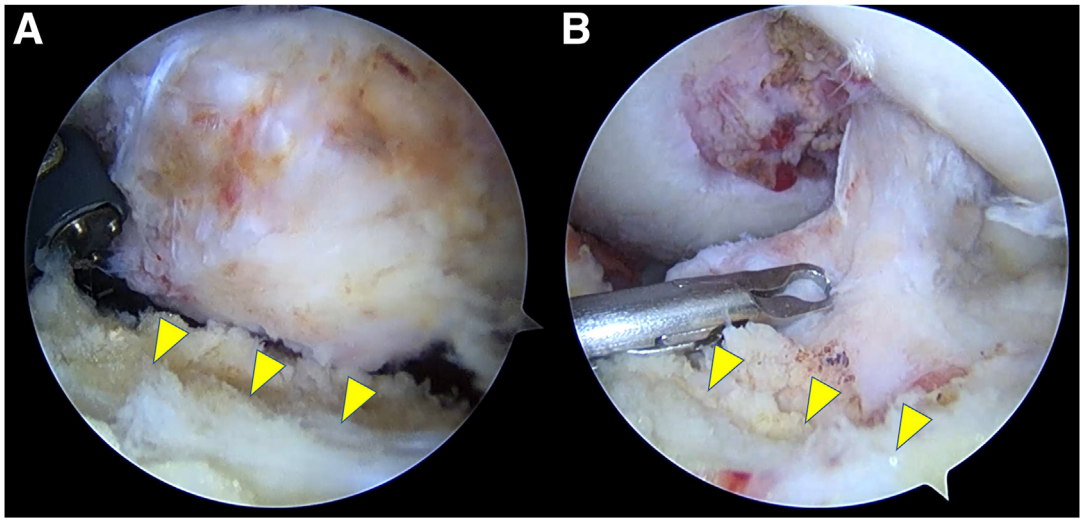

Fig 1. (A-B) The intermeniscal ligament (yellow arrows) is the potential obstacle during fragment reduction. (A) Viewing portal: anterolateral portal; (B) Working portal: anteromedial portal.

sterile preparation and draping, standard anterolateral and anteromedial portals are created. Arthroscopic examination is performed. The concomitant lesions can be managed in this step.

For the fixation of the ACL avulsion fracture, there are 2 main parts. The first part aims to reduce the fragment posteriorly and maintain the reduction. The second part is to close the anterior gap by pulling the ACL toward an anterior tunnel (Video 1).

First, tibial eminence fracture is identified, then fibrin clot and scaring tissue beneath the fragment are removed by a motorized shaver to allow the mobility of the fragment. Cleaning of the clot and scar beneath the posterior portion of fragment is important for adequate mobilization. Then, a reduction of the fragment is attempted. One of the potential obstacles for reduction is the intermeniscal ligament (Fig 1), which can be managed by anterior retraction intermeniscal ligament or sliding the ACL fragment posteriorly. In this technique, we use the advantage of the 3-point control to slide the fragment posteriorly away from the intermeniscal ligament (Table 1).

Table 1. Aftercare and Rehabilitation Program

Postoperative Timeline	Aftercare and Rehabilitation Program
0-6 weeks	• Protective range of motion exercise using a hinge knee brace • Isometric quadriceps exercise • Hamstring curl • Hip muscle exercise
6-12 weeks	• Remove the hinge knee brace • Aggressive range of motion exercise • Squatting exercise • Proprioceptive exercise
12 weeks-6 months	• Jogging and running • Plyometric exercise
After 6 months	• Sports specific exercise • Return to play if indicated

In details of the technique, initially, double-loaded soft suture anchor (2.8-mm Y-knot Flex; Conmed, Largo, FL) is applied at posteromedial side of the fragment for the first point of fixation (Fig 2). We use the suture anchor to minimize the use of the tunnel pull-out suture fixation, as well as to minimize the insecure "windshield wiper" and "bungee jump" effects. The second point of fixation is the posterolateral edge of the fragment. The posterolateral point is drilled from anterolateral tibial cortex to the area posterolateral edge of the fragment by using ACL-aiming-guide instrument (Fig 3). All-inside suture passer is used to pass 2 of the 4 ends (blue suture, Fig 4A), from the soft suture anchor through the ACL medially to laterally. The passed sutures are then retrieved to the posterolateral tunnel. Next, the remaining 2 suture ends from the soft anchor (black striped suture, Fig 4B) are passed across the ACL anteriorly and then retrieved to the posterolateral tunnel. Both points of fixation provide the reduction of posterior portion of the fracture fragment and act as the fulcrum during anterior portion reduction after tightening with a suspension button. Alternatively, all-inside fixation method can be adapted to this step by using knotless suture anchor applied to the posterolateral point of fixation. However, only 2 strands of suture can be loaded in the small-size suture anchor and the suture tension adjustment is not allowed after the knotless anchor is locked. In patients with osteoporosis, we do recommend the use of a transtibial pull-out fixation with a suspension button or suture to the post.

In the next step, the third point of fixation is created for closing the anterior gap. An anterior tunnel is drilled using ACL-guide instrument from anteromedial tibial

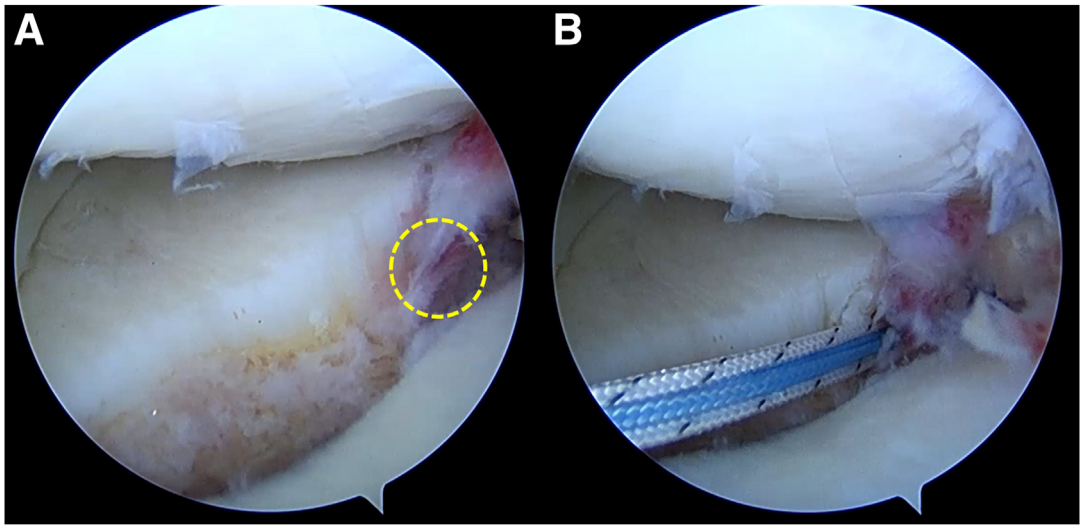

Fig 2. (A-B) To create the posteromedial point, a soft anchor is applied at the posteromedial side of the fracture (yellow circle).

cortex to the anterior portion of fracture fragment (Fig 5A). If there is enough bone in the anterior portion of tibial eminence fragment, we recommend to drill through the anterior portion of the fragment for preventing suture slipping during tightening sutures. Two nonabsorbable sutures (No. 2 Hifi; Conmed) are passed through the ACL substance, separately, by all-inside suture passer and tied with cinch stitch fashion (Fig 5B). Both sutures are retrieved through the anterior tunnel (Fig 5C and Fig 6).

Finally, all sutures from the posterolateral tunnel are tied using suspension button above the tunnel aperture. The reduction of posterior portion is observed via arthroscopy during tightening. The fragment can be slid posteriorly, and the posterior gap can be compressed with this fixation. Next, suture from the anterior tunnel is then tied using another suspension button for anterior portion reduction and fixation (Fig 7A and Fig 8). Anterior impingement should be checked under arthroscopic inspection during full knee extension (Fig 7B). The laxity of the ACL and the anterolateral stability of the knee are tested with Lachman test, anterior drawer test, and pivot-shift test the after fixation.

Postoperatively, active range of motion exercise is allowed while using hinge knee brace to protect knee from any accidental deforming force. The isometric quadriceps exercise, hamstring curl, and hip muscle–strengthening exercise are advised. At postoperative 6 weeks, the hinge knee brace is removed. Low angle squat, weighted or rubber band–resisted hamstring curl, and more aggressive range of motion

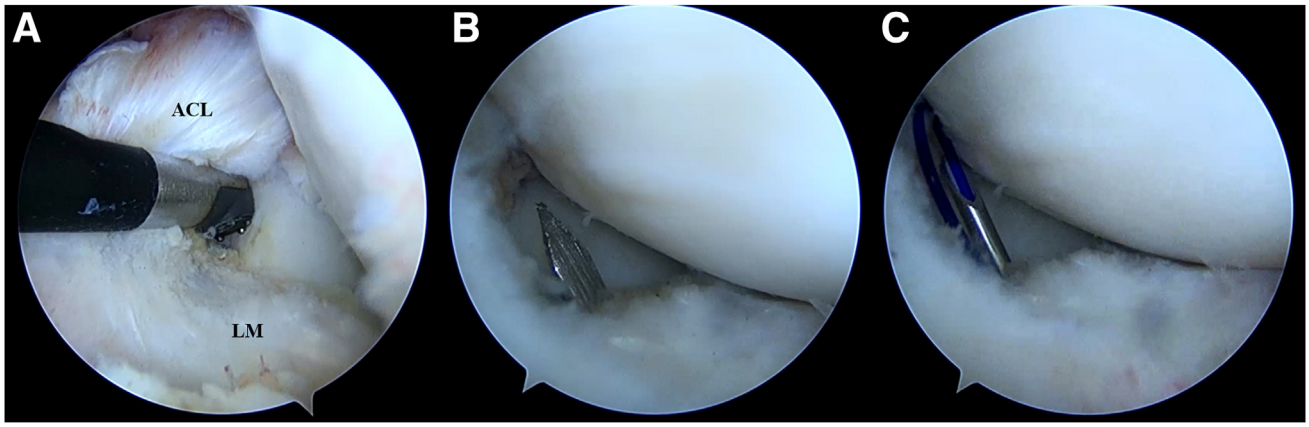

Fig 3. (A-B) A bone tunnel at posterolateral point is created at the posterolateral edge of ACL fragment. (C) Spinal needle with PDS is passed through the bone tunnel. The PDS is later used for shuttling Hifi suture. (A) Viewing portal: anterolateral portal; (B) Working portal: anteromedial portal. (ACL, anterior cruciate ligament; LM, lateral meniscus; PDS, polydioxanone suture)

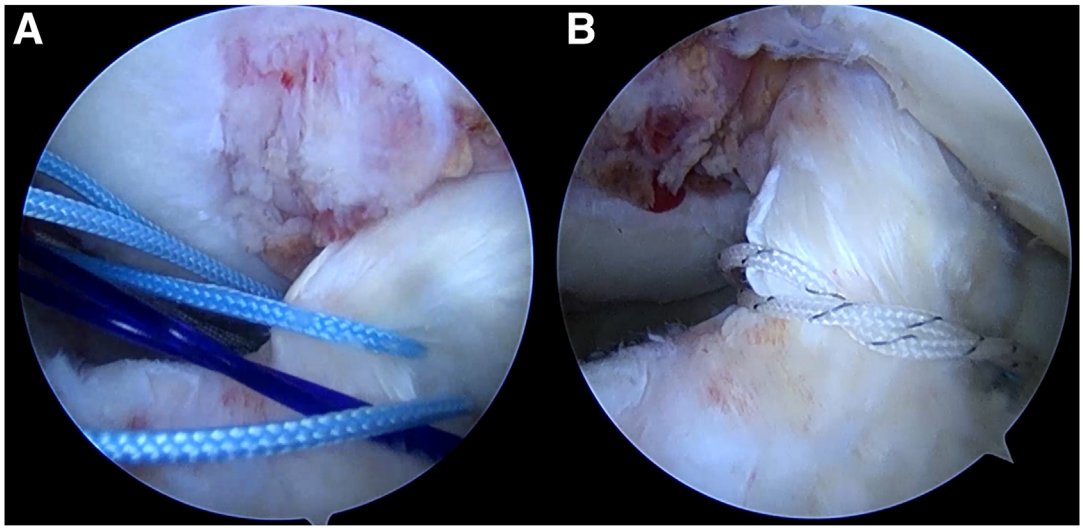

Fig 4. There are 2 pairs of sutures in the posteromedial anchor. All-inside suture passer is used to pass the blue suture's ends (A) from the posteromedial anchor through the ACL medially to laterally then retrieved to the posterolateral tunnel. Next, the remaining 2 black striped suture's ends from the posteromedial anchor (B) are passed across the ACL anteriorly and then retrieved to the posterolateral tunnel. Both points of fixation provide the reduction of posterior portion of the fracture fragment and act as the fulcrum during anterior portion reduction after tightening with a suspension button.

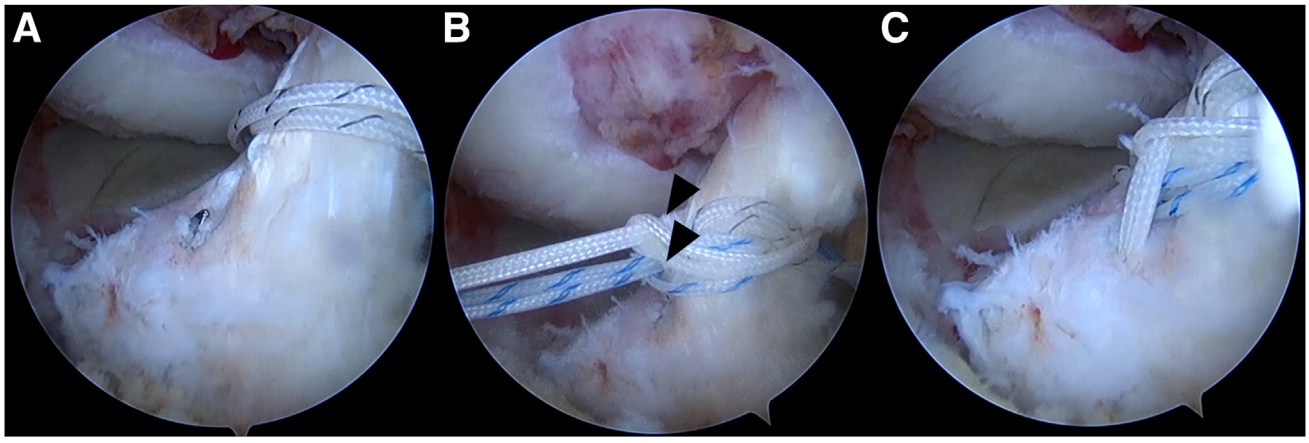

Fig 5. (A) Anterior point of fixation is created. (B) Two sutures (black arrowheads) are passed through the ACL substance and tied with cinch stitch fashion. (C) The sutures are passed into the anterior tunnel.

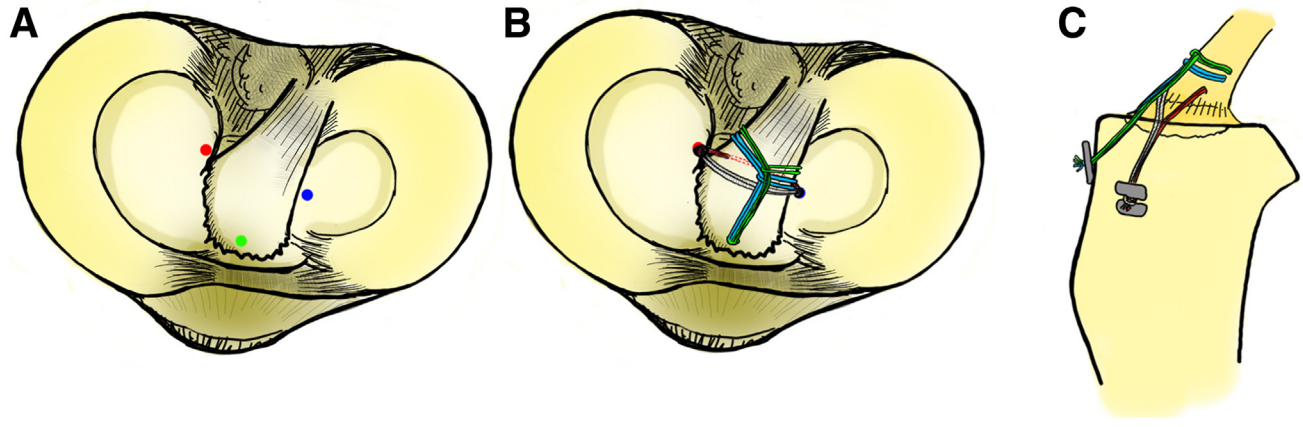

Fig 6. The illustrations show the location of the 3 fixation points (A) and the suture configuration of the 4 sutures from soft anchor and the 2 cinch stitches and their fixation (B-C).

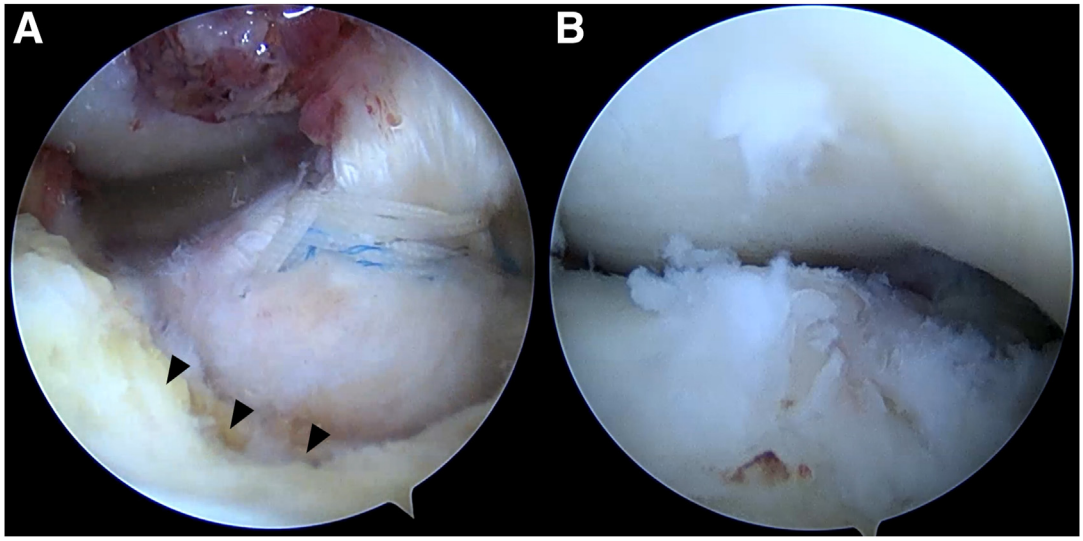

Fig 7. The pictures show the reduction of ACL avulsion fragment without entrapped intermeniscal ligament (black arrows) (A) and no anterior impingement of the fragment during full extension of the knee (B).

exercise for reducing the remaining range of motion deficit are advised. Proprioceptive exercise, such as the use of a balance board, is also necessary. Jogging and more aggressive strengthening, such as plyometric exercises, are allowed after 12 weeks' postoperatively. Sports-specific exercises are allowed after 6 months' postoperatively. Timing for return to play is allowed after completing the indications in each sport (Table 1).

Discussion

Meyers and McKeever[4] described the first classification of tibial intercondylar eminence fracture in 1959. This fracture involves the ACL insertion, and its operative treatment should be concerned with the fracture displacement. Historically, open reduction and internal fixation with screw were widely used.[1-4] However, there was evidence that open reduction with screw fixation had weaker ultimate load-to-failure,[16,17] a

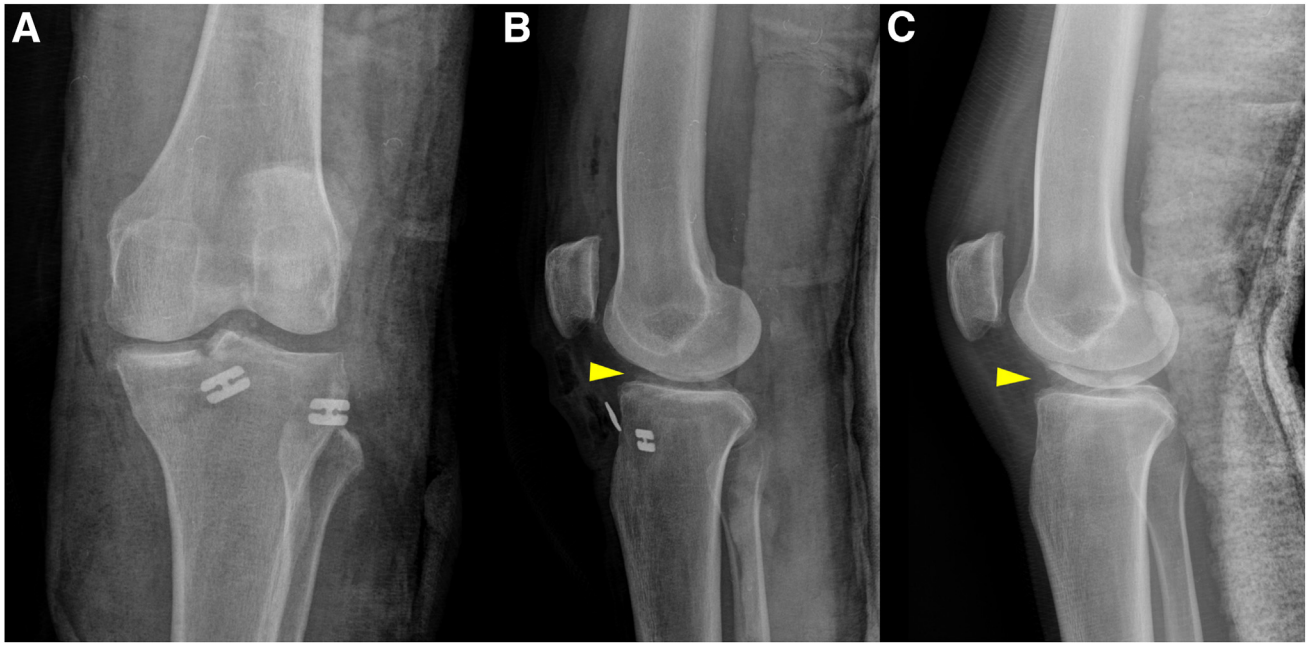

Fig 8. (A-B) The postoperative radiographs reveal the suspension buttons placed over the tunnels' apertures in different directions (A). The fragment is reduced after fixation (B, yellow arrowhead), comparing to preoperative radiograph (C, yellow arrowhead).

Table 2. Pearls and Pitfalls

1. The intermeniscal ligament is a potential obstacle that needs to be evaluated during fragment reduction. To avoid entrapment, posterior sliding can be used. Moreover, placing and pulling the suture around the intermeniscal ligament can be used to retract this structure anteriorly during fragment fixation.
2. The soft suture anchor is suggested to avoid placing a hard or metal anchor intra-articularly.

Table 3. Advantages and Disadvantages

Advantages	Disadvantages
- Provides multidirectional control and secure fixation of large ACL avulsion fragment. - Provides a compression area, to allow healing, between bone fragment and its base at tibia. - Reduces the number of transtibial tunnels. - No metallic implant in the joint	- The distance between tunnels should be examined in cases with small avulsion fragment. An adequate distance is needed to avoid bone bridge fracture. - Windshield wiper and bungee jump effects still are risk factors in transtibial pull-out fixation.

ACL, anterior cruciate ligament.

greater infection rate and stiffness,[18] and greater reoperative rate for removing the implants[19] than arthroscopic reduction with pulled-out suture fixation.

Different techniques among the arthroscopic fixations had been reported. However, there has been a question of the number of tunnels or points of fixation that would be adequate for providing the proper reduction and fixation. Single tunnel pull-out suture fixation cannot hold the multidirectional force, especially in a large avulsion fragment, and provides only single-point fixation. For example, in using single tunnel, reduction at anterior area may result in the posterior gap between fragment and its bone.[5-9]

The 3- or 4-tunnel fixation techniques were developed to increase the quality of reduction and fixation.[7-9] The multidirectional control can provide the proper reduction, especially at the posterior gap of the fracture site that is usually ignored in single-tunnel fixation. In our technique, posteromedial anchor and lateral tunnel play role for the posterior gap closure. Moreover, they can be used to slide the fragment posteriorly to avoid the intermeniscal ligament interposition. After anterior fixation, the area of compression is created between the 3 points of fixation. Among these reasons, this technique is useful for adequate reduction and secure fixation in large avulsion fragment and in chronic situation.

Moreover, the 3-point fixation using the hybrid fixation of intra-articular and tunnel pull-out suture fixations can ease the concerning of the "windshield wiper" and "bungee jump" effects. The length of the tunnel and the mismatched diameter between sutures and bone tunnel allow insecure horizontal (windshield wiper effect) and vertical motions (bungee jump effect) of the suture causing some laxity of the fixation.[11-13] Therefore, we used intra-articular fixation to minimize the problem from these phenomena. Furthermore, in our technique, there was no metallic implant intra-articularly (Table 2).

In summary, our technique aims to gain the maximum benefit in multidirectional control and maintain reduction of large fragment in ACL avulsion. The hybrid 3-point fixation by combination of intra-articular fixation and tunnel pull-out suture fixation can gain these benefits (Table 3). In this technique, only 1 or 2 bone tunnels from different directions can be combined with intra-articular fixation, the sutured anchors. The anterior fixation is formed by drilling the anteromedial tibial cortex to anterior portion of fracture site. The posteromedial fixation is fixed by the anchor, and the posterolateral fixation can be used as a knotless anchor or tunnel pull-out fixation. In case of tunnel pull-out fixation, it was drilled from anterolateral tibial cortex to exit the most posterolateral footprint of ACL fragment. These are the easy ways to create the 3-point area fixation.

To conclude, the displaced tibial intercondylar eminence fracture should receive a proper reduction and fixation to provide the anterolateral stability of the knee. We recommend using the 3-point fixation for proper posterior reduction and creation of compressive area between the fragment and its base.

References

1. Lubowitz JH, Elson WS, Guttmann D. Part II: Arthroscopic treatment of tibial plateau fractures: Intercondylar eminence avulsion fractures. *Arthroscopy* 2005;21:86-92.
2. Sapre V, Bagaria V. Tibial spine avulsion fractures: Current concepts and technical note on arthroscopic techniques used in management of these injuries. *Regional Arthroscopy. InTech; 2013. https://doi.org/10.5772/54967. Accessed September 1, 2022.*
3. Song EK, Seon JK, Park SJ, Yoon TR. Clinical outcome of avulsion fracture of the anterior cruciate ligament

between children and adults. *J Pediatr Orthop B* 2009;18:335-338.
4. Meyers MH, McKeever FM. Fracture of the Intercondylar eminence of the tibia. *J Bone Joint Surg Am* 1959;41:209-222.
5. Huang TW, Hsu KY, Cheng CY, et al. Arthroscopic suture fixation of tibial eminence avulsion fractures. *Arthroscopy* 2008;24:1232-1238.
6. Pandey V, Cps S, Acharya K, Rao SK. Arthroscopic suture pull-out fixation of displaced tibial spine avulsion fracture. *J Knee Surg* 2017;30:28-35.
7. 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;24:e683-e687.
8. Gamboa JT, Durrant BA, Pathare NP, Shin EC, Chen JL. Arthroscopic reduction of tibial spine avulsion: Suture lever reduction technique. *Arthrosc Tech* 2017;23:e121-e126.
9. 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.
10. Tang J, Zhao J. Arthroscopic suture-to-adjustable loop fixation of adult anterior cruciate ligament tibial avulsion fracture. *Arthrosc Tech* 2021;10:e1573-e1579.
11. Mortazavi SMJ, Hasani Satehi S, Vosoughi F, Rezaei Dogahe R, Besharaty S. Arthroscopic fixation of anterior cruciate ligament avulsion fracture using FiberWire suture with suture disc. *Arthrosc Tech* 2021;10:e1709-e1715.
12. Dartus J, Kahhaleh E, Belzile EL, Matache BA. Arthroscopic repair of the "tibial avulsion triad"-ACL posterolateral bundle, PCL, and lateral meniscus posterior root: The triple tunnel technique. *Arthrosc Tech* 2022;11:e2383-e2388.
13. L'Insalata JC, Klatt B, Fu FH, Harner CD. Tunnel expansion following anterior cruciate ligament reconstruction: A comparison of hamstring and patellar tendon autografts. *Knee Surg Sports Traumatol Arthrosc* 1997;5:234-238.
14. Hoher J, Moller HD, Fu FH. Bone tunnel and enlargement after anterior cruciate ligament reconstruction: Fact or fiction? *Knee Surg Sports Traumatol Arthrosc* 1998;6:231-240.
15. Iorio R, Vadalà A, Argento G, Di Sanzo V, Ferretti A. Bone tunnel enlargement after ACL reconstruction using autologous hamstring tendons: A CT study. *Int Orthop* 2007;31:49-55.
16. 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.
17. Ezechieli M, Schäfer M, Becher C, et al. Biomechanical comparison of different fixation techniques for reconstruction of tibial avulsion fractures of the anterior cruciate ligament. *Int Orthop* 2013;37:919-923.
18. Rademakers MV, Kerkhoffs GM, Kager J, et al. Tibial spine fractures: A long-term follow-up study of open reduction and internal fixation. *J Orthop Trauma* 2009;23:203-207.
19. Callanan M, Allen J, Flutie B, et al. Suture versus screw fixation of tibial spine fractures in children and adolescents: A comparative study. *Orthop J Sports Med* 2019;22:2325967119881961.