Technical Note

X-Shaped Knot Fixation and Double Posteromedial Portals for the Treatment of Posterior Cruciate Ligament Tibial Avulsion Fractures With Retention of the Posterior Septum

Ziqi Shang, B.S., Lingpeng Jin, M.S., Zhen Chen, B.S., Zhuangdai Zhang, M.S., Yingzhen Niu, M.D., Yi Zheng, M.S., and Jiangtao Dong, M.D.

Abstract: Posterior cruciate ligament (PCL) avulsion fractures at the tibial attachment site are managed using various techniques. Some surgeries involve internal fixation with an adjustable double-loop plate, anterior-to-posterior suture suspension fixation, hollow lag screw fixation, and steel wire fixation. In this case, an X-shaped knot and double posteromedial portals are used to retain the posterior septum for fixation. In this technique, we describe double posteromedial portals are used in this method. The internal joint is fixed with an X-shaped knot, and the external joint is fixed with SwiveLock, which puts the wire belt binding PCL compression bone block in a perfect tension state. This surgical technique can achieve a sound functional reduction.

The posterior cruciate ligament (PCL) is an integral component of the knee joint. It constrains the posterior movement of the tibia on the femur by a substantial restraint function. PCL injuries account for approximately 3% to 38% of all knee injuries and have been reported to increase in incidence over the years,[1-3] with PCL avulsion (PCLA) being a rare PCL injury phenotype, with clinical manifestations including knee swelling, pain, and colic, with or without Lachman and posterior drawer-test positive on physical examination. Because of the limited research conducted on PCLA, the incidence of this mode of impairment is unclear as of yet.[3] A recent study has linked a smaller notch width index in the women to a risk factor of PCLA.[4,5] Undisplaced PCLA can be treated conservatively; however, fragments displaced by more than 3 mm usually require surgery to ensure fracture healing (Figs 1, 2), prevent osteoarthritis, and restore biomechanics and joint stability.[2]

Both open and adjunctive arthroscopic therapies are successful,[6-9] and in recent years many physicians have been willing to attempt arthroscopic repair of PCLA fractures at the tibial attachment site. However, various surgical techniques exist, such as internal fixation with an adjustable double loop plate, anterior-to-posterior suture suspension fixation, hollow lag screws fixation, and more. The internal fixation with adjustable double-loop plate technology can provide uniform pressure distribution to reduce the fracture block. However, the middle suture of the two rings cannot achieve the maximum tension, and the fixation with one tunnel cannot ensure the stability of the fracture block during postoperative movement. Therefore a tunnel on the fracture block needs to be created during the operation, and this procedure cannot be performed on patients with small fracture pieces.[9] In the anterior-to-posterior suture suspension fixation technique, two sutures pass through the base of the PCL instead of simply covering the fractured piece. The

From the Department of Orthopedic Surgery, The Third Hospital of Hebei Medical University, Shijiazhuang, China.

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Address correspondence to Jiangtao Dong, M.D., Department of Orthopedic Surgery, The Third Hospital of Hebei Medical University, Shijiazhuang, 050051 Hebei, China. E-mail: djtloveyz@outlook.com

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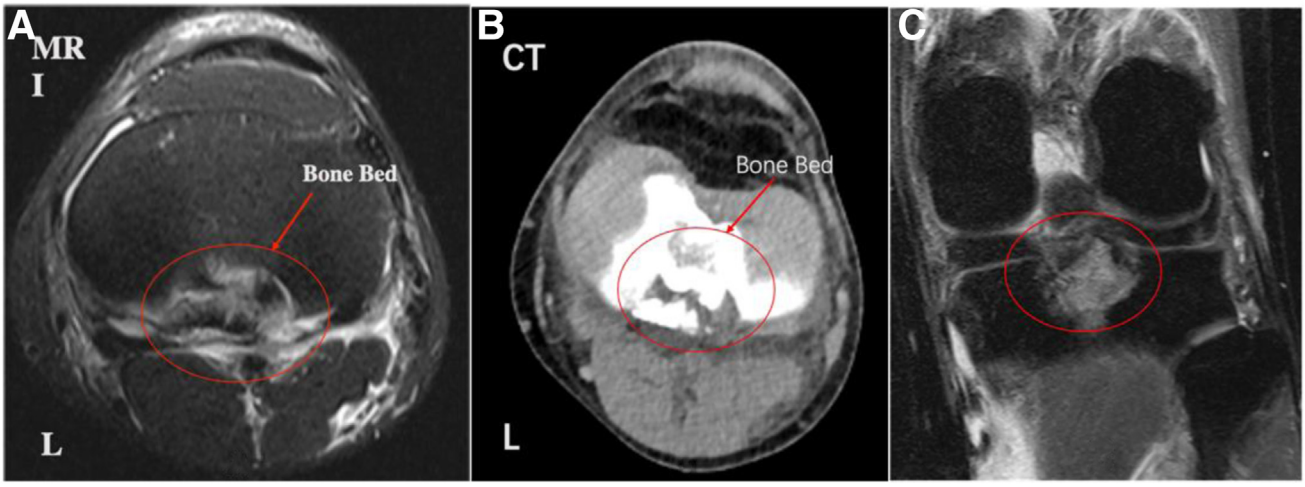

Fig 1. Magnetic resonance imaging scans of the patient before surgery (patient side: left).

network structure formed by the two sutures evenly compresses the fracture piece, reducing the possibility of postoperative displacement of the fracture piece[4]; however, the suture directly passes through the PCL base and readily causes secondary damage to the PCL because of the cutting effect.[8] Single-channel ligation sutures require an additional graft, which increases the cost and is not conducive to the pressure shunt of high-strength sutures. Moreover, there is also a risk that the suture bundle will slip off on both sides of the bone block.[6]

In this technique, double posterior medial portals are used, with an X-shapes knot fixation in the joint and using SwiveLock (Arthrex, Naples, FL) for fixation outside the joint, which can bind the knot to the PCL and compress bone block in a perfect state of tension (Fig 3). Moreover, the complete anatomy of the posterior septum should be retained so that the operation is safer and more precise. This approach can also protect the vascular nerve structure of the knee joint more efficiently.

Surgical Technique

Patients are placed in the supine position during surgery. The procedure is carried out with the patient under general anesthesia. In addition, a more thorough examination of the knee joint is conducted while the patient is under general anesthesia and is compared to the postoperative examination to assess the surgical outcome.

Initially, 2 anterior portals, the anteromedial (AM) portal and the anterolateral (AL) portal, are created to

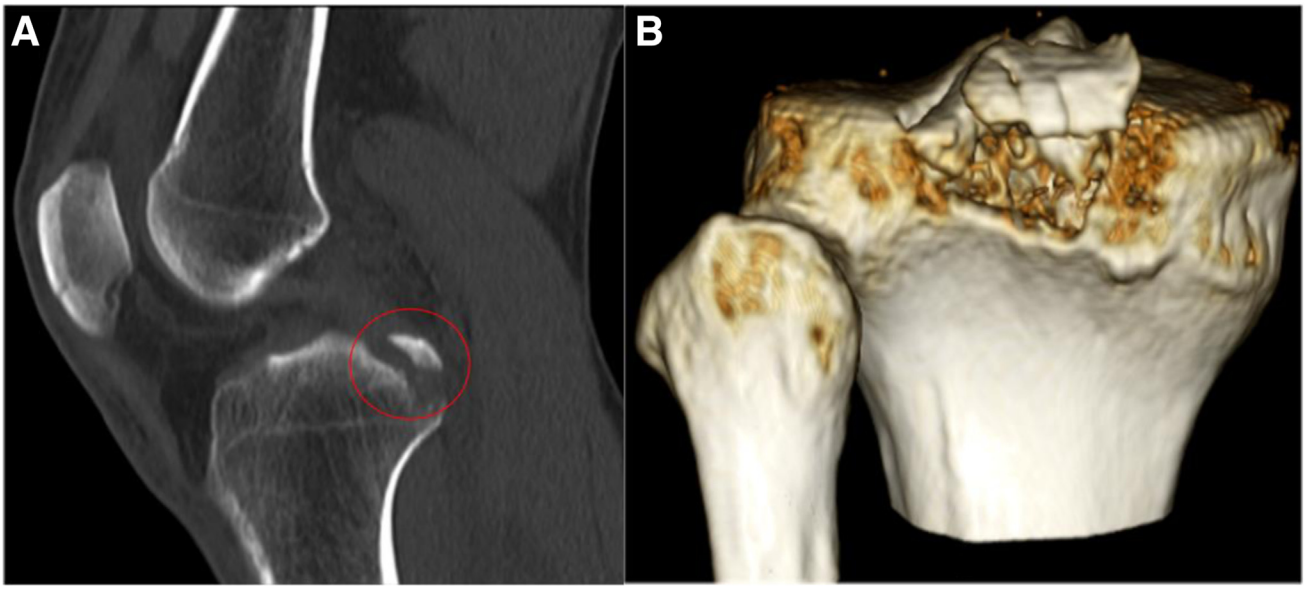

Fig 2. Computed tomography scan and its 3-dimensional reconstruction of the patient before surgery (patient side: left).

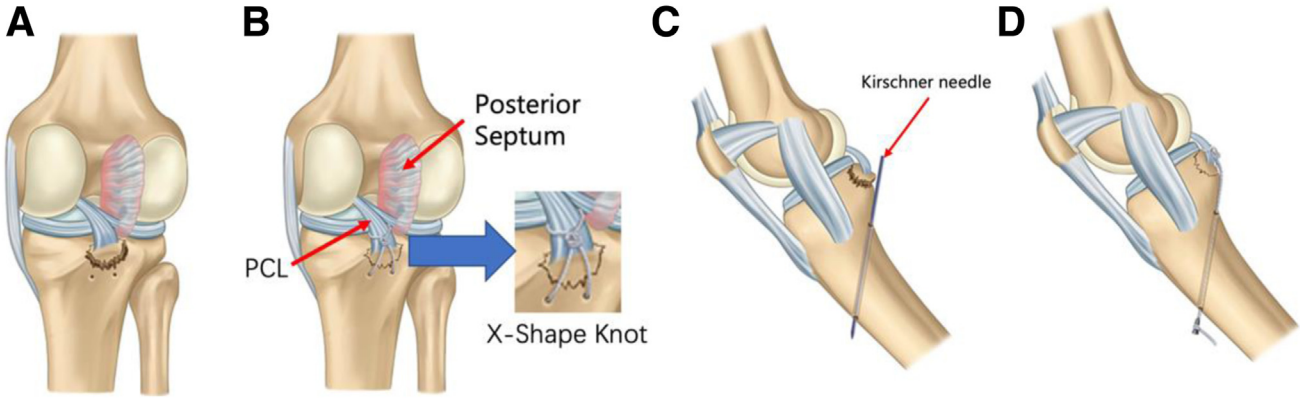

Fig 3. Posterior cruciate ligament avulsion—Schematics of surgical techniques.

do routine arthroscopy and joint cavity cleansing (see Fig 5), including irrigation to clear the hematoma and examination of the meniscus and anterior cruciate ligament (Fig 4A, Video 1).

Procedure

To facilitate ligation, 2 pathways are formed: one between the anterior and posterior cruciate ligaments and the other between the posterior cruciate ligaments and the medial wall of the intercondylar fossa (Figs 4B, 4C). Low posteromedial (LPM) and high posteromedial (HPM) portals are subsequently created (see Fig 7). The LPM portal is created arthroscopically directly beneath the AL portal, the AM and AL portals are examined, and exchange rods are placed directly between the PCL and the medial wall of the intercondylar fossa. At this point, the knee is bent to 90° in a neutral position. The arthroscopic light source determines the location of the LPM portal (Fig 6). Under arthroscopic observation, a dural puncture needle is used to prod the skin and observe the "soft spot" with obvious deformation (Fig 4D). Adequate precautions should be taken to avoid damage to nearby tendon tissue. A small skin incision is made, and the portal is widened with hemostatic forceps. The patient is repositioned in the figure-of-4 position, and the HPM portal is formed 3 to 4 cm above the front of the LPM.

Once again, the arthroscope is inserted into the LPM portal using an exchange rod to transform it into an observation portal. The HPM portal is used as an operational portal to clean the soft tissue between the PCL and the posterior joint capsule with a knife and expose the PCL and fracture block, thereby exposing the broken end and the bone bed. At this time, the broken end and the bone bed could be cauterized with the radiofrequency probe, thereby clearly revealing their position relationship. During surgery, care must be taken to protect the posterior joint capsule and the fibers of the PCL parenchymal part. When the shaver is used, it can clean the excised tissues via suction, and the shaver can pull the posterior joint capsule to the distal side so that the blood vessels and nerves are away from the operation area. This surgery not only ensures maximum surgical safety but also ensures a large and clear field of vision.

The arthroscopic lens is transferred to AM portal for observation. Under the surveillance of the arthroscope, FiberTape (Arthrex) is inserted through the AL portal, and 1 end of the clip is sent to the posteromedial compartment through the path between the anterior and posterior cruciate ligaments and then pulled out from the HPM (Figs 4E, 4F). Adequate care must be taken not to bundle the meniscofemoral ligament together. The other section is sent from the medial wall path of the PCL and intercondylar fossa to the posterior medial compartment and pulled out from HPM (note that both ends of the ribbon are pulled out from the same channel to avoid binding soft tissue in the middle during knotting, which would affect the effect of the binding reduction). After FiberTape is wrapped around the PCL, we tie a Weston knot and send the ribbon knot to the posterior medial compartment with a knot pusher (Fig 4G). Adequate care must be taken not to tighten and keep the triangle inverted. All of these procedures are performed under the monitoring of the LPM portal to ensure that the meniscofemoral ligament, meniscus, and posterior septum are not damaged by the wrapping and knotting of the PCL.

A small incision is subsequently made in the medial tibial tubercle at a distance of 3 to 4 cm to clean the soft tissue and expose the medial tibia. A PCL locator is used to penetrate the AM portal (Figs 4H, 8). Two micro tibial tunnels are created in the distal medial angle and the distal lateral angle of the bone bed using a Kirschner 2.0 needle. The tunnel is positioned 2 to 3 mm below the concave bed of the tibial fracture block, and the tunnel is at a 30° angle to the distal tibia (Fig 9). The distance between the tunnel and the distal tibia did not exceed 1 cm. The size of the fracture block should determine the specific bone bridge width. Both ends of

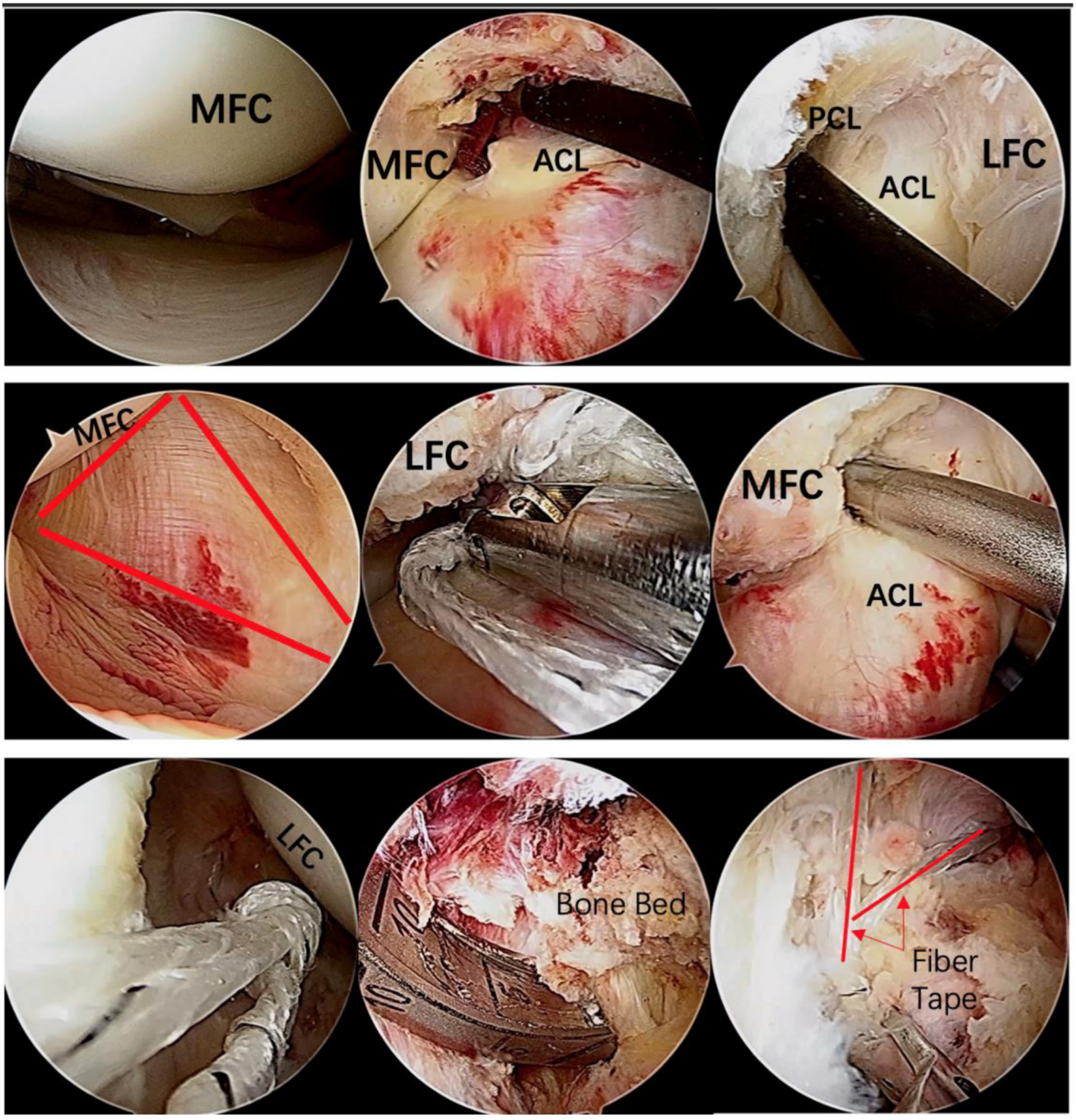

Fig 4. (A) Using a probe to explore the meniscus, the meniscus was found to be stable, and no treatment was done. Side, left; position, supine; anteromedial. (B) The operative path is created between the ACL and the PCL. Side, left; position "4"; anteromedial. (C) The pathway between the PCL and the intercondylar fossa is created. Side, left; position "4"; anteromedial. (D) The triangle is enclosed by the fold of the medial head of the gastrocnemius muscle. Side, left; position "4"; anteromedial. (E, F) The PCL is bandaged with fiber tape. (E) Side, left; position "4"; low posteromedial. (F) Side, left; position "4"; anteromedial. (G) The Weston knot is introduced into the joint. Side, left; position "4"; anteromedial. (H) A locator is used to compress the fracture fragment. Side, left; position "4"; low posteromedial. (I) The position of the knot is adjusted. Side, left; position "4"; low posteromedial. ACL, anterior cruciate ligament; LFC, lateral femoral condyle; MFC, medial femoral condyle; PCL, posterior cruciate ligament.

the ribbon are inserted through the 2 bone canals so that they are in an X-shaped position over the intra-articular PCL to cover the fracture block. After adjusting the position of the fracture block to reduce it under arthroscopy, the end of the FiberTape is tightened (Fig 4I), and the tibia is reduced under the

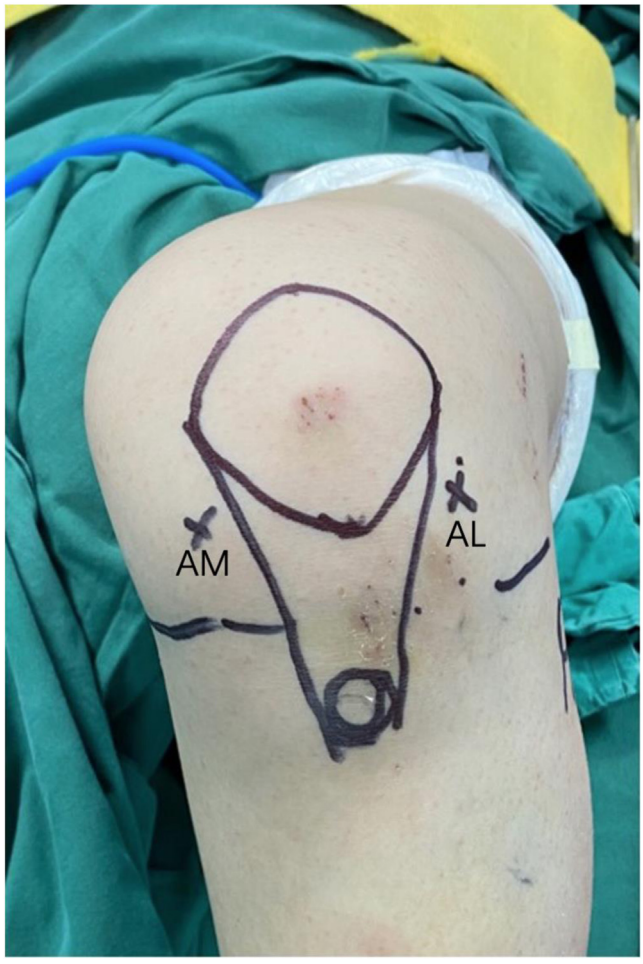

Fig 5. Surgical surface landmarks of patients. AL, anterolateral; AM, anteromedial (side, left; position, supine).

anterior tibial force, and the FiberTape is fixed with SwiveLock to achieve a better reduction effect.

After the surgery, a physical examination of the patient's knee joint is performed and is compared with the preoperative results to ensure that the surgical results are satisfactory. The wound is ultimately sutured.

Postoperative Rehabilitation

After the operation, patients are required to immobilize their knee in an extension knee brace with a modification of posterior tibial support to prevent the posterior tibial sag. On day 1 after surgery, patients are encouraged to indulge in active straight leg raising, static quadriceps strengthening exercises, and transverse patella. Patients are required to remain nonweightbearing with bilateral axillary crutches for a month. Madi et al.[6] suggest that patients could exercise for range of motion. However, our study prescribes that active knee mobilization is initiated at week 4, and partial weightbearing is permitted at the beginning of the second month. A full return to active sports and activities is only permissible at the sixth month after surgery, depending on their International Knee Documentation Committee (IKDC) and Lysholm score, which represents the recovery of the patient.

Discussion

In the surgical repair of PCL avulsion fractures, arthroscopic passage through the posterior septum provides the advantage of operability, but such a surgical portal may compromise the normal anatomy of the posterior septum. The posterior septum of the knee

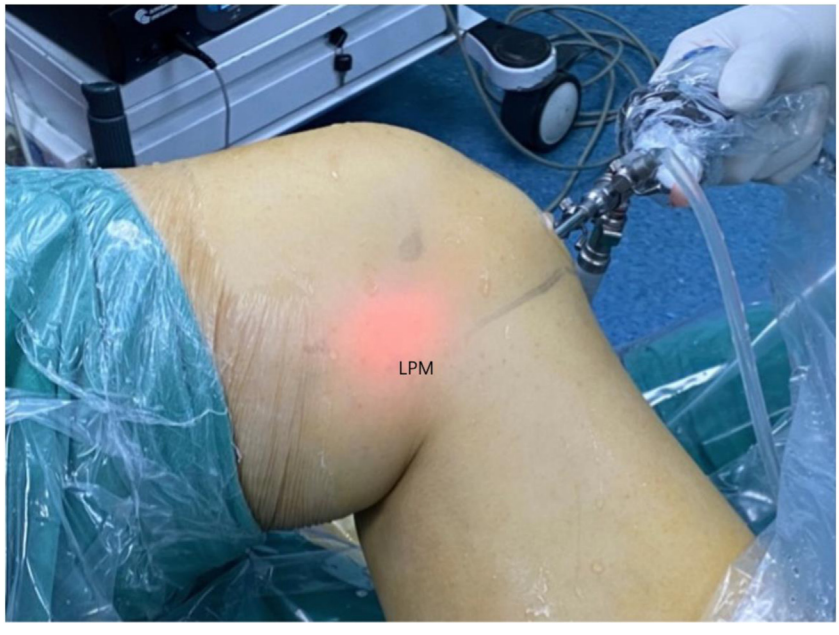

Fig 6. Positioning the low posteromedial (LPM) portal by light source (side, left; position "4").

Fig 7. The high posteromedial (HPM) portal was opened 3 cm above the low posteromedial (LPM) portal (side, left; position "4").

joint, possessing a curtain-like shape, demarcates the posterior compartment into posteromedial and posterolateral compartments. This structure is abundant with neurovascular distributions and mechanoreceptors. The popliteal artery of the knee is positioned on the lateral side of the posterior septum and must be avoided during surgery. This technique protects the integrity of the posterior septum by performing surgery through a double posterior internal portal, which is its distinguishing characteristic.[10-13] The physiological anatomy of the posterior septum that is retained during surgery is essential for the postoperative motor function recovery of PCL tibial insertion avulsion fractures. The posterior septum is distributed with the middle knee artery vascular network, and intraoperative preservation of the posterior septum can reduce the effect of postoperative blood supply loss on recovery efficiency.[14]

When creating the tibial tunnel, the 2.0 Kirschner needle is chosen as the tool, mainly because the tunnel created by the Kirschner needle is narrower, which can better limit the movement of the FiberTape, and the smaller diameter of the passage means that the 2 tunnels can be closer together without openings. In addition, using the Kirschner needle to create the bone passage has less of an impact on the epiphysis, which can exert a positive effect on the average growth and development of young patients after surgery.

In wrapping PCL with FiberTape during the procedure, particular attention should be paid to the separate binding of PCL and the position of the meniscofemoral ligament. If wrapped together, the loose binding of FiberTape could result in the shifting of its fixed position and the loss of bone mass. In this process, adequate care must be taken so as not overly tighten the wrapping, and such a procedure should not be too large between the 2 tibial tunnels, both of which contribute to the formation of an X-shaped structure across the bone canal, such a structure than I shape and inverted V shape is more helpful to cover and reduce the fracture block. It can prevent the occurrence of postoperative dislocation or partial warping of fracture block, improve the success rate of operation, and reduce the possibility of a second operation. In contrast to suture puncture fixation, this approach is susceptible to loosening if the bone fragment is too small and the suture knot is too loosely tied. Postoperative complications may occur such as poor reduction of the fracture block and displacement of the broken end. However, our study focuses on the functional diminution of the tibial insertion of the posterior fork ligament. Even though postoperative X-ray films and computed tomography scans do not reveal a reduction, our routine postoperative physical assessment revealed that the patient attained a flawless functional reduction after this operation.

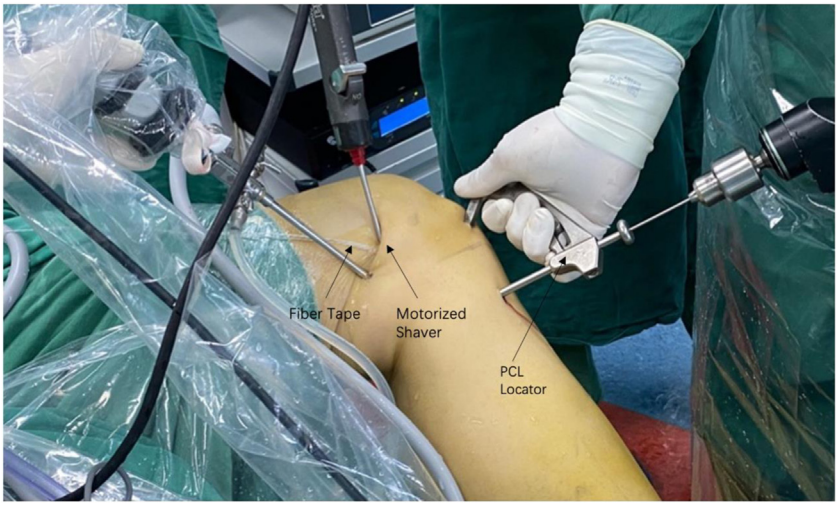

Fig 8. An anterior cruciate ligament drill guide was used to locate the bone tunnel. PCL, posterior cruciate ligament (side, left; position "4").

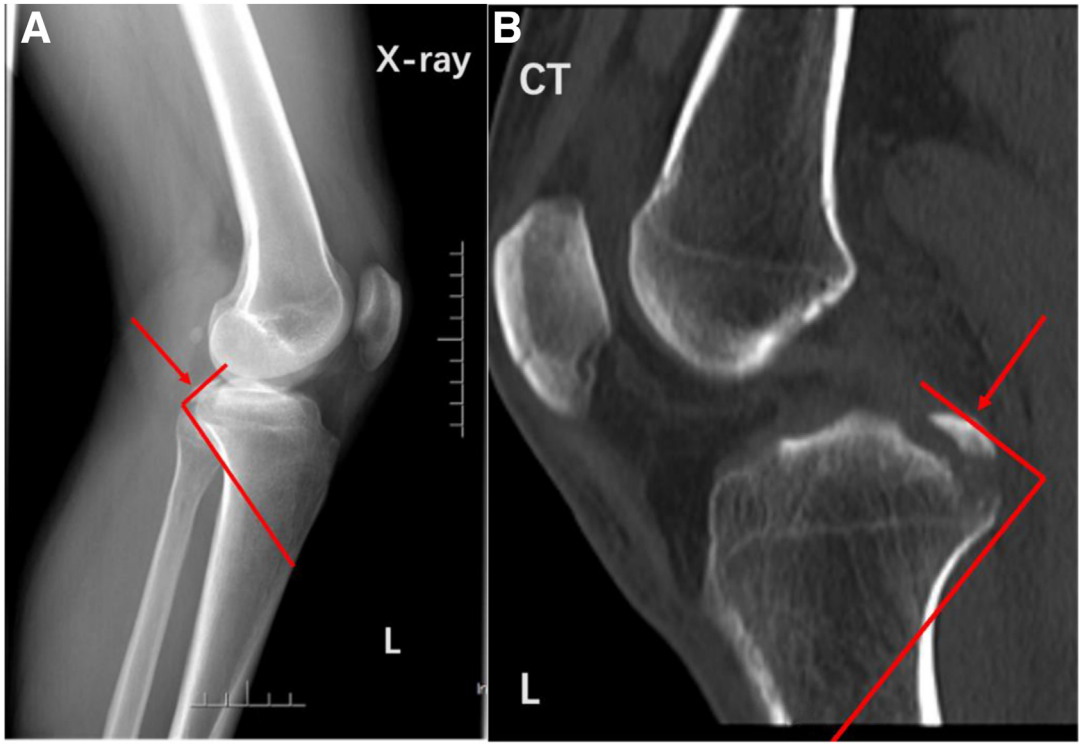

Fig 9. X-ray film and computed tomography scan of the patient after surgery (patient side: left).

Table 1. Pearls and Pitfalls

Pearls
No hardware is used in this technique.
The bone fragment can be used to achieve a perfect functional reduction after this operation.
This technique preserves the integrity of the posterior septum and reduces the effect of postoperative blood supply loss on recovery efficiency.
Use of the 2.0 Kirschner needle to create the tibial tunnel has a better effect on the average growth and development of young patients.
Using Fiber Tape to fix the posterior cruciate ligament avulsion can help reduce the subsequent cutting effect.
Pitfalls
After the operation, a poor reduction of the fracture block may be observed in the magnetic resonance imaging scan if the bone fragment is broken into pieces.
The learning curve for this technique is relatively long.
There is currently no method that can quantify tunnel localization, and the tibial tunnel is entirely dependent on the surgeon's experience.

Table 2. Note of This Technique

The use of double portals is favorable to reduce surgical risk for injuring septum.
Only the posterior cruciate ligament should be bundled. The surgeon should not enclose other ligaments, otherwise the fragment may have poor reduction.
The tibial tunnels should not be positioned too close to each other, otherwise the fragment may have rotation after surgery.
The surgeon can use a planner to pull the posterior joint capsule to the distal side so that the blood vessels and nerves are far from the operative area.
FiberTape is fixed under the anterior tibial force.

During surgery, FiberTape is used to secure the PCLA, which lowers the subsequent cutting impact compared to conventional suture fixation and dramatically prevents secondary injury to the PCL. There is a study that shows that the FiberTape device may serve as a viable alternative to screw fixation, while obviating the need for hardware removal.[15]

The pearls and pitfalls of this procedure are listed in Table 1. Notes of this technique are presented in Table 2. This method is suitable for a whole fragment. If the bone fragment is broken into many pieces, the X-shaped knot fixation is not reliable.

X-shaped knot fixation and double posteromedial portals for the treatment of PCLA fractures with

retention of the posterior septum is a reliable surgical technique with high postoperative recovery efficiency and a low secondary injury rate.

References

1. Katsman A, Strauss EJ, Campbell KA, Alaia MJ. Posterior cruciate ligament avulsion fractures. *Curr Rev Musculoskelet Med* 2018;11:503-509.
2. Wang D, Graziano J, Williams RJ, Jones KJ. Nonoperative treatment of PCL injuries: Goals of rehabilitation and the natural history of conservative care. *Curr Rev Musculoskelet Med* 2018;11:290-297.
3. Barros MA, Cervone GL de F, Costa ALS. Surgical treatment of avulsion fractures at the tibial insertion of the posterior cruciate ligament: Functional result. *Rev Bras Ortop* 2015;50:631-637.
4. Fan N, Zheng Y chen, Zang L, et al. What is the impact of knee morphology on posterior cruciate ligament avulsion fracture in men and women: A case control study. *BMC Musculoskelet Disord* 2021;22:100.
5. Huang WT, Kang K, Yang JY, et al. Intercondylar notch volume in patients with posterior cruciate ligament tears and tibial avulsion injuries: A study applying computed tomography. *J Orthop Surg* 2022;17:560.
6. Madi S, Pandey V, Reddy B, Acharya K. Clinical and radiological outcomes following arthroscopic dual tibial tunnel double sutures knot-bump fixation technique for acute displaced posterior cruciate ligament avulsion fractures. *Arch Bone Jt Surg* 2021;9:50-57.
7. Tao T, Yang W, Tao X, et al. Arthroscopic direct anterior-to-posterior suture suspension fixation for the treatment of posterior cruciate ligament tibial avulsion fracture. *Orthop Surg* 2022;14:2031-2041.
8. Tang J, Zhao J. Arthroscopic suture-to-loop fixation of posterior cruciate ligament tibial avulsion fracture. *Arthrosc Tech* 2021;10:e1595-e1602.
9. Zhang F, Ye Y, Yu W, Yin D, Xu K. Treatment of tibia avulsion fracture of posterior cruciate ligament with total arthroscopic internal fixation with adjustable double loop plate: A retrospective cohort study. *Injury* 2022;53:2233-2240.
10. Liu L, Gui Q, Zhao F, Shen X, Pei Y. Isolated partial femoral avulsion fracture of the posterior cruciate ligament in adults. *Orthop Surg* 2021;13:1290-1298.
11. Smith T, D'Alonzo J, Arevalo A, Kazanjian J. Isolated large glenoid fracture in acute glenohumeral dislocation in the elderly: A novel indication for reverse shoulder arthroplasty. *Case Rep Orthop* 2020;2020:8826803.
12. Cruz CA, Mannino BJ, Pike A, et al. Increased posterior tibial slope is an independent risk factor of anterior cruciate ligament reconstruction graft rupture irrespective of graft choice. *J ISAKOS* 2022;7:100-104.
13. Schreier FJ, Banovetz MT, Rodriguez AN, LaPrade RF. Cutting-edge posterior cruciate ligament reconstruction principles. *Arch Bone Jt Surg* 2021;9:607-617.
14. Joshi S, Bhatia C, Gondane A, Rai A, Singh S, Gupta S. Open reduction and internal fixation of isolated posterior cruciate ligament avulsion fractures: Clinical and functional outcome. *Knee Surg Relat Res* 2017;29:210-216.
15. Koroneos ZA, Manto KM, Martinazzi BJ, et al. Biomechanical comparison of fiber tape device versus transarticular screws for ligamentous lisfranc injury in a cadaveric model. *Am J Sports Med* 2022;50:3299-3307.