Technical Note

Arthroscopic Suture-to-Loop Fixation of Posterior Cruciate Ligament Tibial Avulsion Fracture

Jin Tang, B.M., and Jinzhong Zhao, M.D.

Abstract: Avulsion fracture of the tibial insertion of the posterior cruciate ligament (PCL) receives constant concern. Arthroscopic procedures have long been attempted because of their minimally invasive nature, and various related techniques have been reported. However, the best arthroscopic method is still being pursued. In this article, we introduce an arthroscopic suture ligation and backup adjustable-loop fixation technique for PCL tibial avulsion fracture. The critical points of this technique are proper ligation of the PCL, proper location of the 2 tibial tunnels to create pulleys for posterior-inferior reduction of the bone fragment, and additional backup suture loop fixation. Our experience indicates that this technique is efficient and relatively simple. We consider that the introduction of this technique will provide a reasonable choice in the treatment of PCL tibial avulsion fracture.

Posterior cruciate ligament (PCL) avulsion fracture is a special kind of PCL injury and needs to be surgically addressed when the displacement or joint instability is severe.[1] Both open and arthroscopic procedures have been reported, and similar clinical results have been obtained.[2,3] Regarding open procedures, the fixation is direct and simple and there is no need for the learning curve of arthroscopic surgical procedures,[4-7] but these procedures are invasive. The advantage of arthroscopic procedures[8-10] is that the fracture can be directly exposed intra-articularly and combined intra-articular lesions can be treated simultaneously, in addition to their minimally invasive nature. Thus, in this article, we introduce an arthroscopic fracture reduction and fixation technique, in which fracture reduction and fixation are performed with ligating sutures and an adjustable suture loop. The indications for this technique are acute PCL tibial avulsion fracture with fracture displacement and posterior instability reaching over 8 mm.

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The authors report the following potential conflicts of interest or sources of funding: Funding was provided by National Key Research and Development Program of China (grant Nos. 2018YFC1106200 and 2018YFC1106202) and The Project of Shenkang Hospital Development Center of Shanghai (grant No. 16CR3108B). The authors report 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 January 9, 2021; accepted February 23, 2021.

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2212-6287/2139

https://doi.org/10.1016/j.eats.2021.02.029

Surgical Procedures

The patient is supine and receives lumbar or general anesthesia. A lateral supporting plate is fitted on the proximal side of the thigh to provide support when the knee is flexed (Table 1).

Creation of Anterolateral and Anteromedial Portals

The high anterolateral and anteromedial portals are fabricated at the level of the lower pole of the patella and close to the lateral and medial edges of the patellar tendon. The entire joint is examined, and combined lesions are treated (Video 1).

Creation of Posteromedial Portals

The knee is flexed at 90°. The arthroscope is inserted into the posteromedial compartment from the high anterolateral portal through the space between the PCL and the medial wall of the intercondylar notch. The high and low posteromedial portals, located 4 cm above the joint line and at the level of the joint line, respectively, are created.

Debridement of Bone Bed

The arthroscope is inserted into the posteromedial compartment through the anteromedial portal, and the instruments are inserted through the high posteromedial portal. The bone fragment is elevated to place the

Table 1. Step-by-Step Procedure of Arthroscopic Suture-to-Loop Fixation of PCL Tibial Avulsion Fracture

1. High anterolateral and anteromedial portals are fabricated. The entire joint is examined, and combined lesions are treated.
2. The arthroscope is inserted into the posteromedial compartment from the high anterolateral portal. The high and low posteromedial portals are created.
3. The arthroscope is inserted into the posteromedial compartment through the anteromedial portal. The bone bed is debrided through the high posteromedial portal.
4. The arthroscope is inserted into the posteromedial compartment from the high anterolateral portal, across the posterior septum, to the posterolateral compartment. The posterolateral portal is created.
5. The arthroscope is inserted from the high posteromedial portal, and the instruments are inserted from the posterolateral portal. The posterior capsule insertion distal to the distal edge of the bone bed is released. The conjunction of the tibial recess and the posterior side of the proximal tibia is exposed.
6. With the arthroscope inserted through the anteromedial portal and the instruments inserted through the anterolateral portal, 3 ultrahigh-molecular-weight polyethylene sutures are passed through the lateral side of the PCL to the posterior compartments.
7. The arthroscope is inserted through the high posteromedial portal. One limb of each suture is retrieved out through the low posteromedial portal.
8. The arthroscope is inserted through the anteromedial portal. The other limbs of the sutures are passed through the medial side of the PCL to the posterior compartment to wrap the PCL.
9. The arthroscope is inserted through the high posteromedial portal. The suture limbs passing from the medial side of the PCL are retrieved out of the low posteromedial portal.
10. A half knot is made by crossing the suture limbs out of the joint. The knot is pushed into the joint to the posterior side of the PCL, over the bone fragment, with a knot pusher.
11. A 2-cm-long incision is made on the medial side of the tibial tubercle.
12. A tibial tunnel locator for PCL reconstruction is inserted from the anteromedial portal to set on the distal-lateral side of the bone bed. The lateral tibial tunnel is created sequentially with a K-wire and a 4.5-mm cannulated drill. A polydioxanone suture is placed into the tunnel as a guide suture.
13. The tibial tunnel locator for PCL reconstruction is inserted from the anteromedial portal to set on the distal-medial side of the bone bed. The lateral tibial tunnel is created sequentially with a K-wire and a 4.5-mm cannulated drill. A polydioxanone suture is placed into the tunnel as a guide suture.
14. With the guide suture in the tibial tunnels, the suture limbs from the lateral side of the PCL are pulled out of the lateral tibial tunnel and those from the medial side of the PCL are pulled out of the medial tibial tunnel.
15. With pulling of the fixing sutures, the bone fragment is reduced.
16. With the knee placed at full extension, the 2 parts of the suture limbs are tied over the bone bridge between the outer orifices of the tibial tunnels for primary fixation.
17. A transtibial ridge tunnel is created. An adjustable-loop cortical suspensory fixation device is pulled through this tunnel from the medial side to the lateral side.
18. Part of the suture limb is passed through the adjustable loop. The suture button is pulled through the transverse tibial tunnel and flipped over the lateral orifice.
19. At nearly full knee extension, the suture limbs passing through the adjustable loop are tied to their counterparts to fix the fragment at the adjustable loop.
20. The adjustable loop is reduced to tension the fragment.

PCL, posterior cruciate ligament.

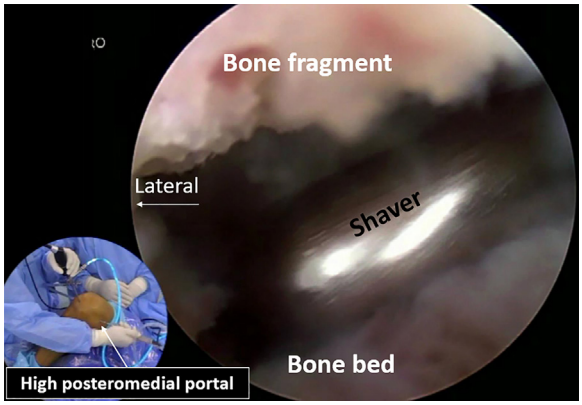

Fig 1. Debridement of the bone bed is performed through the high posteromedial portal (arthroscopic view of right knee through anteromedial portal).

arthroscope under it. The bone bed is debrided under observation (Fig 1).

For chronic fractures, the fibrous tissue between the bone fragment and the bone bed is removed with a radiofrequency probe. The hardened layer of the bone bed and the bottom of the bone fragment are removed with a motorized burr.

Creation of Posterolateral Portal

The scope is placed into the posteromedial compartment through the high posteromedial portal and presses against the center of the posterior septum. The obturator is used to replace the arthroscope and is passed across the posterior septum along with the trocar to the posterolateral compartment. The arthroscope is inserted, and the posterolateral portal is created.

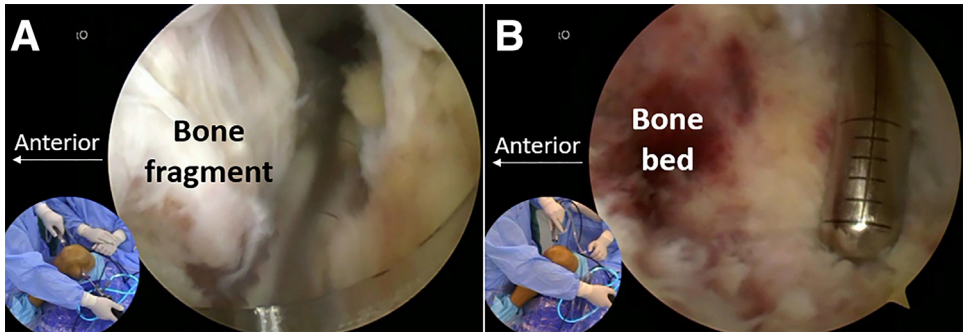

Fig 2. The bone fragment is exposed by removing part of the posterior septum (A), and the distal edge of the bone bed is exposed (B) (arthroscopic view of right knee through high posteromedial portal).

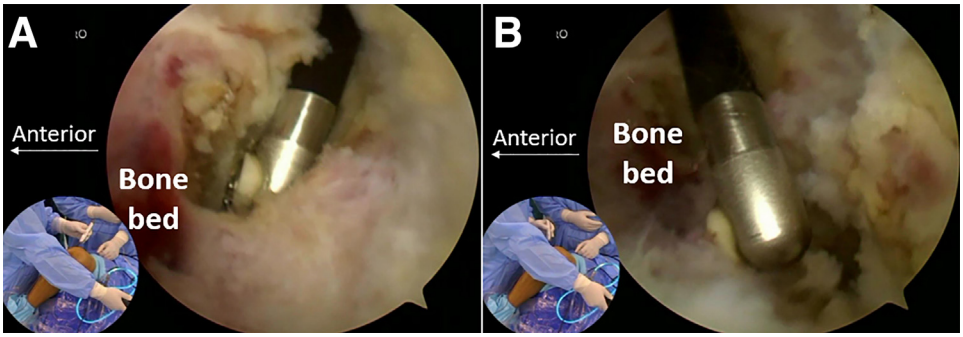

Fig 3. The bone ridge between the posterior tibial recess and proximal posterior tibia is exposed on the distal-lateral (A) and distal-medial (B) sides of the bone bed (arthroscopic view of right knee through high posteromedial portal).

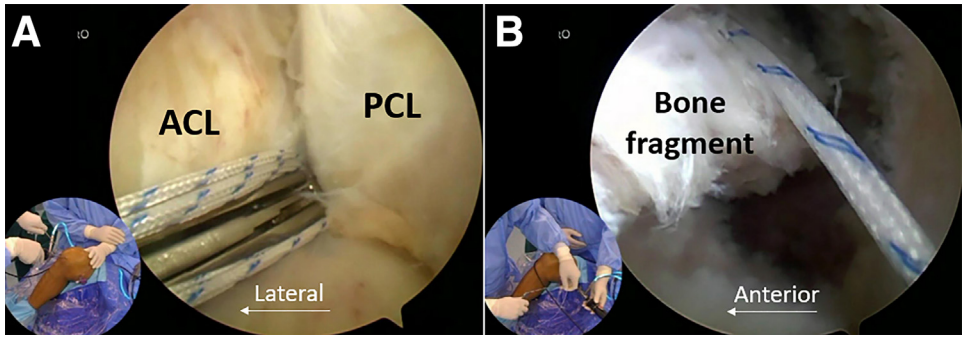

Fig 4. (A) The fixing sutures are passed through the lateral side of the posterior cruciate ligament (PCL) to the posterior compartments through the anterolateral portal (arthroscopic view of right knee through anterolateral portal). (B) One suture limb of each suture is retrieved out of the low posteromedial portal (arthroscopic view of right knee through high posteromedial portal). (ACL, anterior cruciate ligament.)

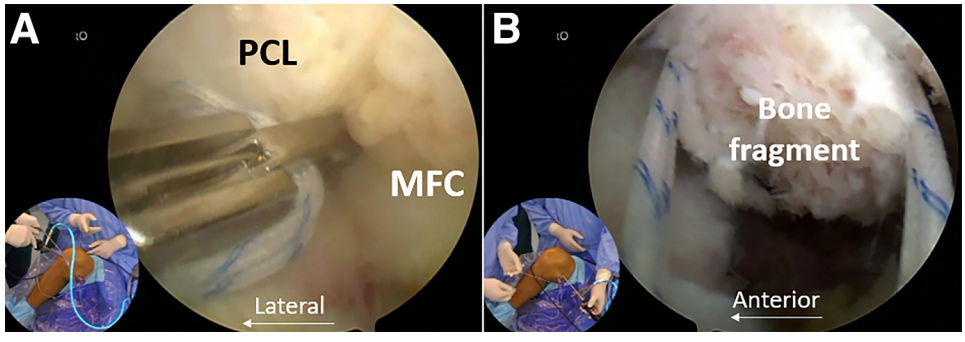

Fig 5. (A) The other limbs of the fixing sutures are passed through the medial side of the posterior cruciate ligament (PCL) to the posterior compartments through the anterolateral portal (arthroscopic view of right knee through anterolateral portal). (B) The limbs are retrieved out of the low posteromedial portal (arthroscopic view of right knee through high posteromedial portal). (MFC, medial femoral condyle.)

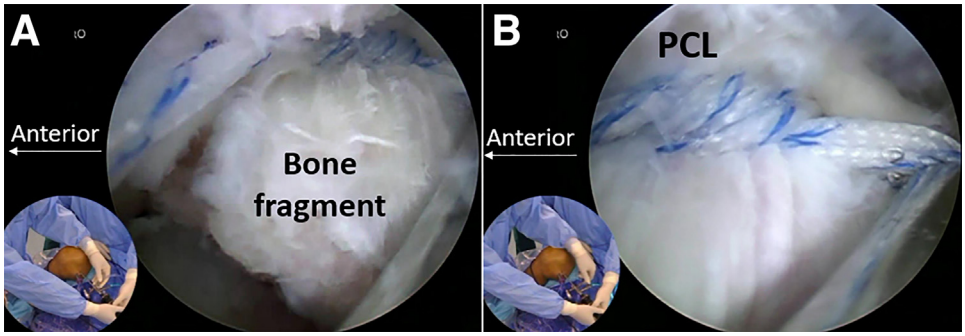

Fig 6. Sutures are tied over the bone fragment (A) on the posterior side of the posterior cruciate ligament (PCL) (B) (arthroscopic view of right knee through high posteromedial portal).

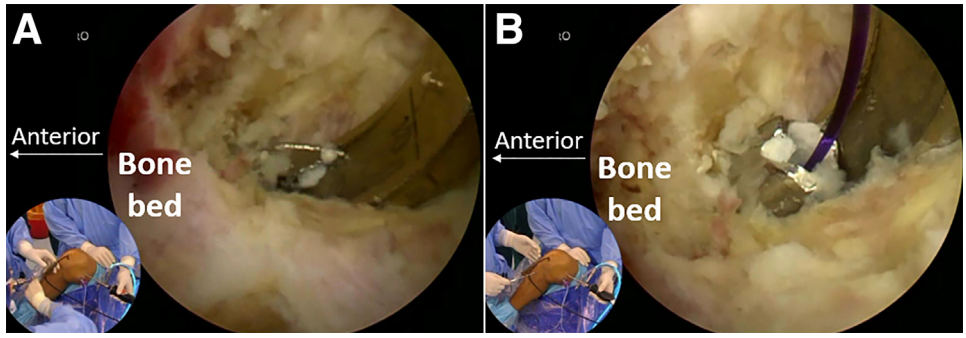

Fig 7. The lateral tibial tunnel is created sequentially with a K-wire (A) and a cannulated drill (B); a polydioxanone suture is placed as a guide suture (arthroscopic view of right knee through high posteromedial portal).

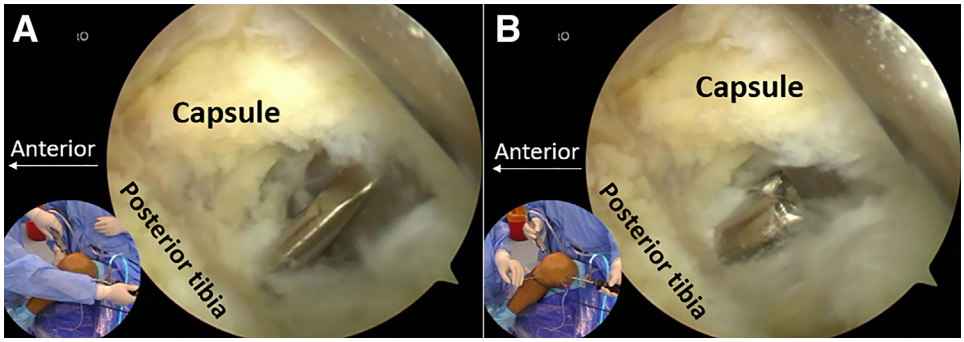

Fig 8. The medial tibial tunnel is created sequentially with a K-wire (A) and a cannulated drill (B) (arthroscopic view of right knee through high posteromedial portal).

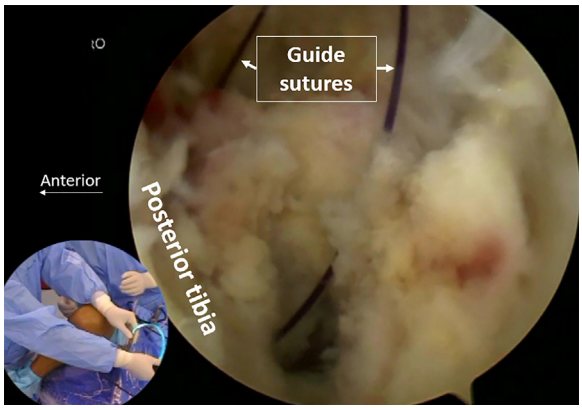

Fig 9. The 2 guide sutures come out through the posterior side of the proximal tibia (arthroscopic view of right knee through high posteromedial portal).

Exposure of Bone Ridge Between Tibial Recess and Proximal Posterior Tibia

The arthroscope is inserted from the high posteromedial portal. The instruments are inserted from the posterolateral portal. Part of the posterior septum is removed to expose the bone fragment (Fig 2A). The posterior meniscofemoral ligaments are exposed.

The posterior capsule insertion distal to the distal edge of the bone bed is released (Fig 2B). The bone ridge between the posterior tibial recess and the posterior side of the proximal tibia on the posterolateral and posteromedial sides of the bone bed is exposed (Fig 3).

Ligation of PCL

The scope is inserted through the anteromedial portal, and the instruments are inserted through the

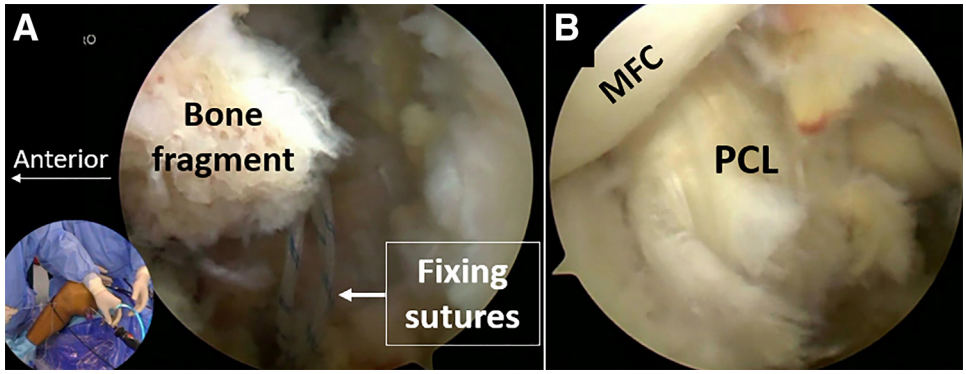

Fig 10. The fixing sutures are pulled through the tibial tunnels (A), and the bone fragment is reduced (B) (arthroscopic view of right knee through high posteromedial portal). (MFC, medial femoral condyle; PCL, posterior cruciate ligament.)

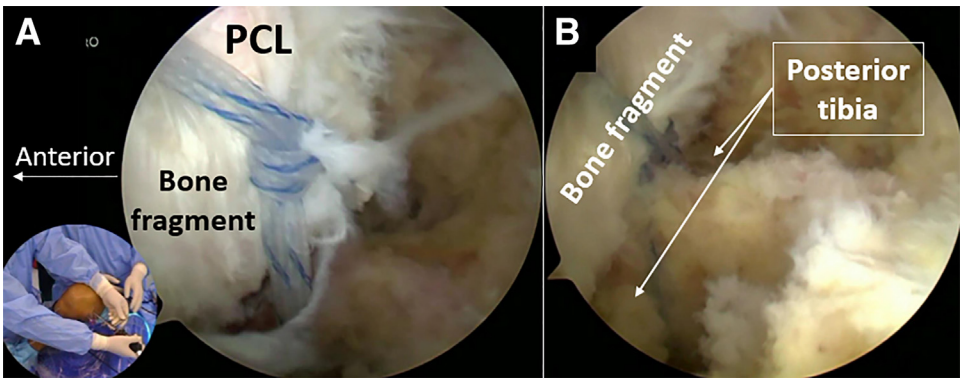

Fig 11. Configuration of fixing suture (A) and full reduction of bone fragment (B) (arthroscopic view of right knee through high posteromedial portal). (PCL, posterior cruciate ligament.)

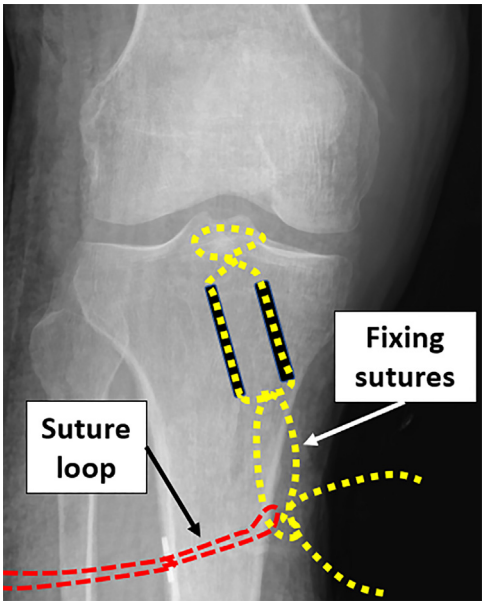

Fig 12. Backup fixation of pullout sutures to adjustable loop (anterior view of right knee).

anterolateral portal. The meniscofemoral ligament and PCL are separated with an obturator. Three ultrahigh-molecular-weight polyethylene sutures (Smith & Nephew, Andover, MA) are passed through the space between the PCL on the medial side and the meniscofemoral ligament on the lateral side (Fig 4A) to the posterior compartments.

The arthroscope is inserted through the high posteromedial portal. One limb of each suture is retrieved out through the low posteromedial portal (Fig 4B).

The arthroscope is inserted through the anteromedial portal. The other limbs of the sutures are passed through the medial side of the PCL to the posterior compartment to wrap the PCL (Fig 5A).

The arthroscope is inserted through the high posteromedial portal. The suture limbs passing from the medial side of the PCL are retrieved out of the low posteromedial portal (Fig 5B). A half knot is made by crossing the suture limbs out of the joint. The knot is pushed into the joint to the posterior side of the PCL, over the bone fragment, with a knot pusher (Fig 6).

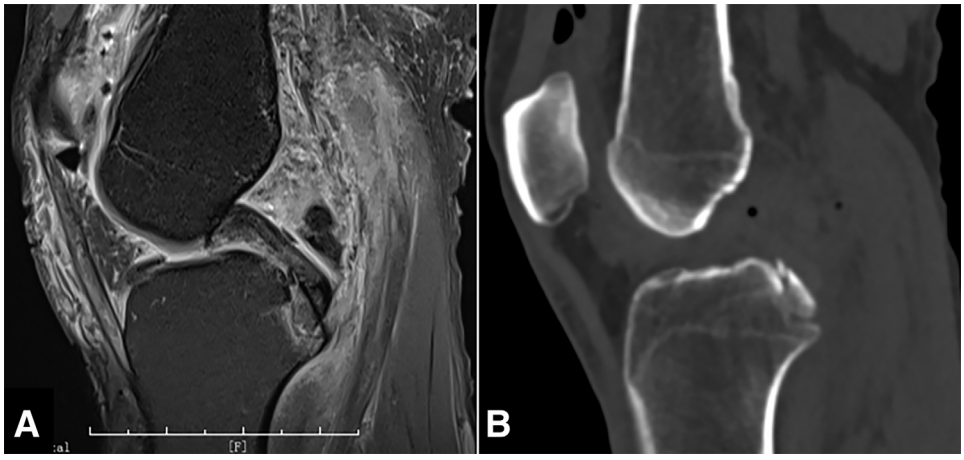

Fig 13. Postoperative magnetic resonance image (A) and computed tomography (B) indicating excellent tensioning of ligament and satisfactory reduction of bone fragment (lateral view of right knee).

Creation of Tibial Tunnels

A 2-cm-long incision is made on the medial side of the tibial tubercle. A tibial tunnel locator (Smith & Nephew) for PCL reconstruction is inserted from the anteromedial portal to set on the distal-lateral and distal-medial sides of the bone bed to create two parallel tibial tunnels from the medial side of the tibial tubercle to distal-lateral and the distal-medial sides of the bone bed, with the proximal orifice of the tunnels located at the proximal posterior side of the tibia, near the posterior ridge. For the creation of each tunnel, a 2.5-mm Kirschner wire is first drilled in and then over drilled with a 4.5-mm cannulated drill (Figs 7 and 8). A polydioxanone suture is placed into each tunnel as a guide suture (Fig 9).

Pulling of Fixing Sutures

With the guide suture in the tibial tunnels, the suture limbs from the lateral side of the PCL are pulled through the lateral tibial tunnel and those from the medial side of the PCL are pulled through the medial tibial tunnel (Fig 10A). With pulling of the fixing sutures, the bone fragment is reduced in the posterior-distal direction (Figs 10B and 11). If the meniscofemoral ligament is wrapped in the suture loop and satisfactory fracture reduction is hindered, the meniscofemoral ligament that is enwrapped is released.

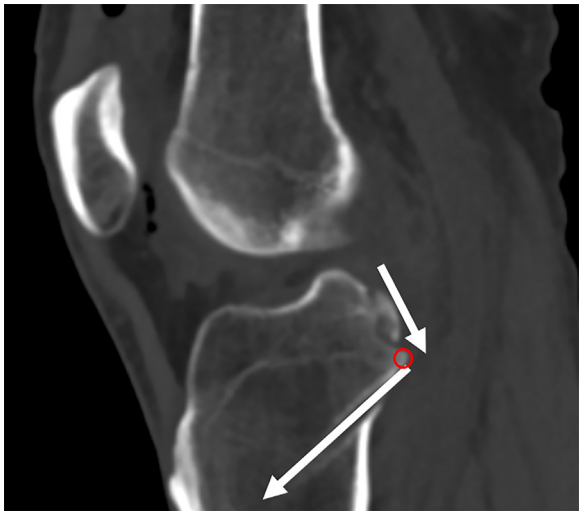

Fig 14. By use of the posterior tibial ridge (red circle) as a pulley, a posterior-distal reduction force can be exerted while pulling the suture in the anterior-distal direction (white arrows) (lateral view of right knee).

Fixation of Bone Fragment

With the knee placed at full extension, the 2 parts of the suture limbs are tied over the bone bridge between the outer orifices of the tibial tunnels for primary fixation. A 4.0-mm transtibial ridge tunnel is created with a Steinmann pin at a transverse plane distal to the orifices of the tibial tunnels. An adjustable-loop cortical suspensory fixation device (Arthrex, Naples, FL) is pulled through this tunnel from the medial side to the lateral side. One part of the suture limbs is passed through the adjustable loop. The suture button is pulled through the transverse tibial tunnel and flipped over the lateral orifice. At nearly full knee extension, the suture limbs passing through the adjustable loop are tied to their counterparts to connect the pullout sutures to the adjustable loop. Finally, the adjustable loop is reduced to tension the fragment (Figs 12 and 13).

Postoperative Treatment and Rehabilitation

A PCL protecting brace (MEDI, Bayreuth, Germany) is used for the first 6 weeks, which allows immediate range-of-motion exercises with support on the posterior side of the proximal leg. Partial to full weight bearing is allowed as tolerated. Muscle-strengthening exercises begin immediately after the operation. Proprioceptive and agility training begins 3 weeks after the operation.

Discussion

In PCL avulsion fracture, the bone fragment is displaced in an anterior-proximal direction. To realize

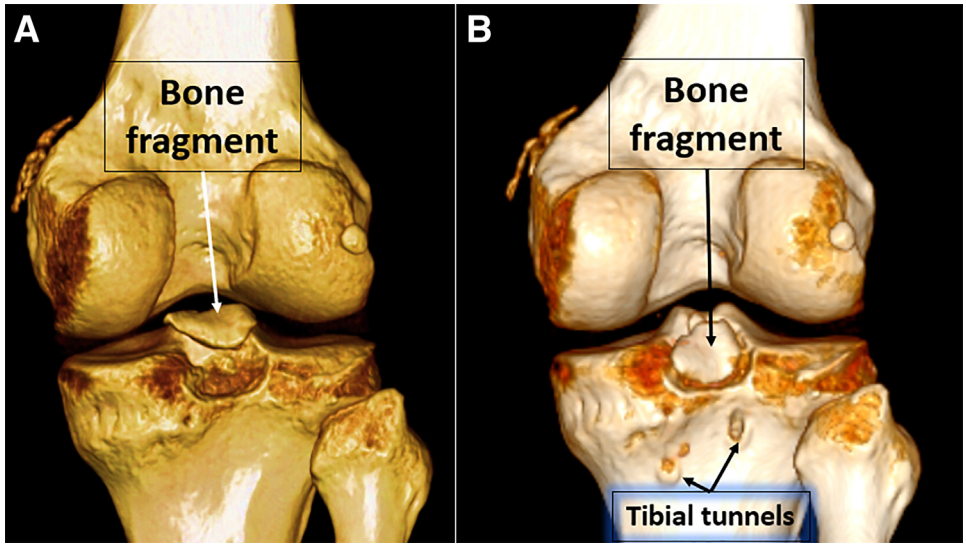

Fig 15. Preoperative (A) and postoperative (B) 3-dimensional computed tomography images indicating displacement and reduction of bone fragment and location of proximal orifices of tibial tunnels (posterior view of right knee).

Table 2. Pearls and Pitfalls of Arthroscopic Suture-to-Loop Fixation of PCL Tibial Avulsion Fracture

The use of double posteromedial portals and the posterolateral portal is favorable to management in the posterior compartments.
Placing cannulas through the posterior portals facilitates manipulation.
The ligating method is more reliable than the suture-passing methods, and it is difficult to lose control of the bone fragment. This method is suitable for large or comminuted fractures.
Multiple sutures or large threads are used to prevent suture cutting of the ligament.
Only the PCL should be ligated. The surgeon should not enclose the Humphrey or Wrisberg ligament. Otherwise, fracture reduction may be affected.
The proximal orifices of the 2 tibial tunnels should be located distal to the bone ridge between the tibial recess and the proximal posterior tibia to ensure a pulley effect; only in this way can a posterior-distal reduction force be exerted through the anterior-distal pulling of the pullout suture.
The proximal orifices of the tibial tunnels should not be in the tibial bed. Otherwise, the resultant anterior-distal reduction force cannot ensure satisfactory reduction.
The proximal orifices of the tibial tunnels should not be positioned too close to each other; otherwise, it is difficult to control the rotation of the bone fragment.
The suture fixation structure can sometimes be somewhat lax after primary fixation on the bone bridges. Backup adjustable-loop fixation and final tensioning are useful.

PCL, posterior cruciate ligament.

Table 3. Advantages and Disadvantages of Arthroscopic Suture-to-Loop Fixation of PCL Tibial Avulsion Fracture

Advantages
No hardware is used intra-articularly.
The bone fragment can be securely reduced in the right direction.
The final fixation tension on the bone fragment can be ensured through reducing the adjustable loop.
Disadvantages
The learning curve is relatively long.
Manipulation in the posterior compartment may endanger the posterior neurovascular structures.
An additional transtibial tunnel is needed to set the adjustable-loop cortical suspensory fixation device.
Suture cutting of the ligament may occur owing to the thin fixation sutures or too much tension on them.

PCL, posterior cruciate ligament.

posterior-distal traction of the bone fragment with anterior-distal pulling sutures, the posterior bone ridge between the PCL recess and the proximal posterior tibia should be used as a pulley, which means the proximal orifices of the tibial tunnels should be located at the proximal posterior tibia distal to the bone ridge, instead of in the tibial bed (Figs 14 and 15). This is the main feature of the current technique.

Regarding other features of our technique, first, efforts are made to ligate only the PCL fibers. Once part of the meniscofemoral ligament is enwrapped and prevents fracture reduction, the enwrapped part is released. Second, on the distal side, double fixation is performed. At first, the sutures are tied over the bone

bridge between the 2 orifices. Then, the sutures are tied to an adjustable loop, which can be further reduced to increase the tension in the sutures. In this way, laxity in the suture fixation construct can be eliminated.

The pearls and pitfalls of our technique are listed in Table 2, and the advantages and disadvantages are presented in Table 3. The current PCL ligating method is suitable for tibial avulsion fracture with a large bone fragment. If the bone fragment is small, the ligating fixation is not reliable; threading in the middle and distal segments of the PCL is required.

References

1. Yoon KH, Kim SG, Park JY. The amount of displacement can determine non-operative treatment in posterior cruciate ligament avulsion fracture. *Knee Surg Sports Traumatol Arthrosc* 2021;29:1269-1275.
2. Hooper PO III, Silko C, Malcolm TL, Farrow LD. Management of posterior cruciate ligament tibial avulsion injuries: A systematic review. *Am J Sports Med* 2018;46:734-742.
3. Song JG, Nha KW, Lee SW. Open posterior approach versus arthroscopic suture fixation for displaced posterior cruciate ligament avulsion fractures: Systematic review. *Knee Surg Relat Res* 2018;30:275-283.
4. Reverte-Vinaixa MM, Nuñez JH, Muñeton D, Joshi N, Castellet E, Minguell J. Outcomes of posterior cruciate ligament tibial avulsion treated with staple fixation: Stress TELOS X-ray evaluation. *Eur J Orthop Surg Traumatol* 2019;29:883-891.
5. Gavaskar AS, Karthik B, Gopalan H, Srinivasan P, Tummala NC. A novel MIS technique for posterior cruciate ligament avulsion fractures. *Knee* 2017;24:890-896.
6. Joseph CM, Gunasekaran C, Livingston A, Chelliah H, Jepegnanam TS, Boopalan PRJVC. Outcome of screw post fixation of neglected posterior cruciate ligament bony avulsions. *Injury* 2019;50:784-789.
7. Hooper PO III, Bevan PJ, Silko C, Farrow LD. A posterior approach to open reduction and internal fixation of displaced posterior cruciate ligament tibial osseous avulsions. *JBJS Essent Surg Tech* 2018;8:e6.
8. Kan H, Nakagawa S, Hino M, et al. Arthroscopic fixation technique for avulsion fracture of the posterior cruciate ligament from the tibia. *Arthrosc Tech* 2020;9:e1819-e1824.
9. Zhao D, Zhong J, Zhao B, et al. Clinical outcomes of acute displaced posterior cruciate ligament tibial avulsion fracture: A retrospective comparative study between the arthroscopic suture and EndoButton fixation techniques. *Orthop Traumatol Surg Res* 2021;107:102798.
10. Zhao J, He Y, Wang J. Arthroscopic treatment of acute tibial avulsion fracture of the posterior cruciate ligament with suture fixation technique through Y-shaped bone tunnels. *Arthroscopy* 2006;22:172-181.