Technical Note

Arthroscopic Reduction and Internal Fixation of Posterior Cruciate Ligament Avulsion Fracture Using an Adjustable-Length Loop Device

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Abstract: A displaced avulsion fracture at the tibial attachment of the posterior cruciate ligament is considered an indication for surgical reduction and internal fixation because nonunion and remaining posterior instability of the knee are common consequences of conservative treatment. The problems with standard open surgical techniques are that they are relatively invasive despite the limited operative field and it is impossible to explore intra-articular lesions by the posterior approach. An arthroscopic procedure has the advantage of being minimally invasive and allowing the surgeon to detect and treat associated intra-articular injuries. We present an arthroscopic reduction–internal fixation technique using an adjustable-length loop device. A trans-septal portal is created to visualize the fracture fragment directly, and the fragment is reduced and penetrated with a cannulated drill under fluoroscopic guidance. An adjustable-length loop device is relayed from the posteromedial portal and pulled out through the fragment in an anterograde fashion, placing a button on top of the fragment. By tightening the loop, downward compression can be applied to the fragment. Overall, this technique provides good reduction and bone union, and excellent clinical outcomes, including posterior knee stability, can be achieved.

A displaced avulsion fracture at the tibial attachment of the posterior cruciate ligament (PCL) is considered an indication for surgical reduction and internal fixation[1,2] because nonunion and remaining posterior instability of the knee are common consequences of conservative treatment. The primary means for surgically treating a PCL avulsion fracture are open reduction through the direct posterior or posteromedial approach[3] and arthroscopic reduction and internal fixation.[1] The open technique is relatively invasive despite its limited operative field, whereas the arthroscopic procedure has the advantage of allowing the surgeon to detect and treat associated intra-articular lesions.[1] The most popular technique used in arthroscopic surgery is fixation by a partially threaded screw inserted from the anterior cortex of the tibia.[4] However, it may be difficult to compress the fragment because the screw threads do not necessarily pass the fracture line when inserted from the anterior cortex of the tibia. Another method to fix the fragment is suture fixation, which has been reported to be as reliable as open screw fixation with a similar mechanical property.[5] However, it is technically demanding to apply compression to the fragment by the arthroscopic approach, especially when the fragment is small.[6] To address the problems of current surgical procedures, we modified the arthroscopic pull-out technique by using the posterior trans-septal portal[7] and using an adjustable-length loop device to fix the fragment.

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Surgical Technique

Preoperative Investigation

A routine series of radiographs are obtained, including anteroposterior, lateral, and skyline views. Obtaining a computed tomography (CT) image with sagittal reconstruction is strongly recommended to evaluate the displacement and size of the fragment, as well as its degree of comminution. Surgical reduction and internal fixation are indicated when the displacement of the avulsed fragment exceeds 5 mm on a sagittally reconstructed CT image in a hinged-type avulsion (type II according to Griffith classification[8]) or when the fragment is completely detached (type III) (Table 1). In addition, preoperative magnetic resonance imaging helps to evaluate intra-articular lesions, such as meniscal tears and cartilage injuries.

Patient Position and Preparation

The patient is placed in the supine position on the bed, with the affected limb hung with a holder applied under the thigh, as shown in Video 1. The fluoroscopy C-arm is placed perpendicularly to the affected limb from the unaffected side, and it should be confirmed that the lateral-view image is easily accessed. A tourniquet is prepared for bleeding during the procedure, although it is not usually used. It is recommended to abduct the hip of the unaffected limb to ensure the working space for the posteromedial portal.

Operative Technique

First, a thorough arthroscopic exploration of the knee joint is performed, and any associated intra-articular injuries (e.g. meniscal tears and cartilage injuries) are treated. A posterior trans-septal portal is created according to the method of Ahn and Ha.[7] In brief, after the creation of posteromedial and posterolateral portals, the septum lying posterior to the PCL is excised with a shaver to create the trans-septal portal. A switching stick is used to keep the posterior portals open.

Reduction and fixation of the fragment are performed with the arthroscope inserted from the posterolateral portal and placed through the trans-septal portal, viewing the posteromedial compartment from the lateral side. The fracture fragment is easily identified by tracking the PCL to its base, and the margin of the fragment is confirmed. The fragment is reduced to the fracture bed under fluoroscopic guidance using an anterior cruciate ligament tibial guide inserted from the posteromedial portal (Fig 1A, Video 1) and is penetrated by a 2.4-mm cannulated drill (Arthrex Japan, Tokyo, Japan) from the anteromedial cortex of the tibia (Fig 1B, Video 1). After the position of the cannulated drill is confirmed by a lateral fluoroscopic view, a looped wire is passed through the cannulated drill (Fig 1C, Video 1) and pulled out from the posteromedial portal.

Table 1. Griffith Classification of PCL Avulsion Fractures[8]

	Description
Type I	Minimally displaced avulsion
Type II	Hinged avulsion
Type III	Completely detached avulsion

PCL, posterior cruciate ligament.

The tail of a TightRope ABS device (Arthrex Japan) is loaded to the looped wire and then pulled in through the fragment in an anterograde direction (Fig 1C, Video 1). The TightRope does not pass through the 2.4-mm cannulated drill; thus, the drill is pulled out simultaneously. A button is clipped on the TightRope ABS loop and is delivered and seated on the avulsed fragment (Fig 1D, Video 1) with a grasper. A wide button is used to grab the fragment with the soft tissue to gain better stability and less risk of further comminution of the fragment. Another button is installed on the anteromedial cortex of the tibia to fix and apply compression downward to the fracture bed by shortening the TightRope.

Rehabilitation and Postoperative Evaluation

A posterior-support knee brace is applied postoperatively. Quadriceps muscle training and range-of-motion exercise, which is limited to 90° of knee flexion, start from the first postoperative day, and crutch gait without weight bearing is allowed. Half-load partial weight bearing is allowed from 2 weeks after surgery. Patients are allowed to bear full weight at 4 weeks after surgery and to start to bend their knees without restriction.

In addition to subjective outcome measures and objective physical evaluations, such as knee range of motion and posterior instability (e.g. posterior sag and posterior drawer sign) after surgery, postoperative displacement and bone union of the avulsed fragment should be evaluated by lateral radiography as well as a sagittally reconstructed CT image at least 3 months after surgery. Because further displacement of the fragments is usually not seen and bone union is difficult to evaluate by lateral radiography, bone union is ideally confirmed by CT images (Figs 2 and 3).

Discussion

Since the introduction of an arthroscopic reduction–internal fixation technique for an avulsion fracture at the tibial attachment of the PCL by Littlejohn and Geissler,[1] a number of arthroscopic techniques have been reported. This technique, as well as other arthroscopic procedures, has the advantage of being relatively less invasive than the open method, and the main benefit is obtained when there are associated intra-articular lesions (e.g. meniscal tears and cartilage injuries) that can be concurrently treated[1] (Table 2).

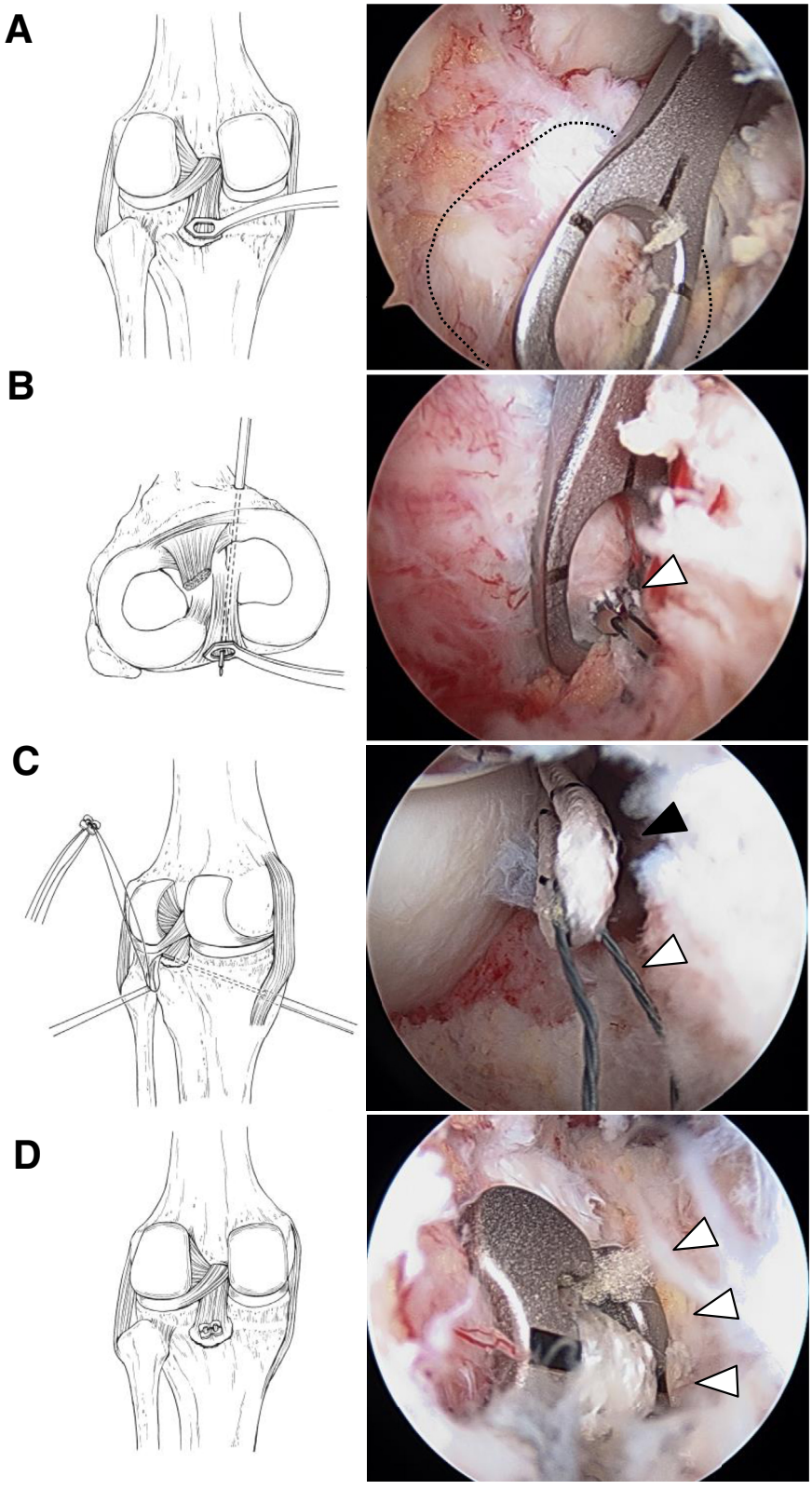

Fig 1. Arthroscopic images of a left knee were obtained with the arthroscope inserted from the posterolateral portal, with viewing of the posteromedial compartment through the trans-septal portal. (A) The fragment (dotted line) is reduced by compressing down against the fracture bed using an anterior cruciate ligament tibial guide. (B) A 2.4-mm cannulated drill, inserted from the anteromedial cortex of the tibia, penetrates the fragment (arrowhead). (C) A looped wire (white arrowhead) is passed through the cannulated drill and pulled out from the posteromedial portal. The TightRope ABS device (black arrowhead) is relayed through the fragment. (D) A button is placed on the fragment (white arrowheads), and compression is applied by tightening the adjustable-length loop device.

However, arthroscopically capturing the fragment and compressing it against the fracture bed are generally difficult because of the anatomy of the fracture. The original technique introduced by Littlejohn and Geissler used multiple Kirschner wires inserted from the anterior cortex of the tibia to fix the fragment, followed by

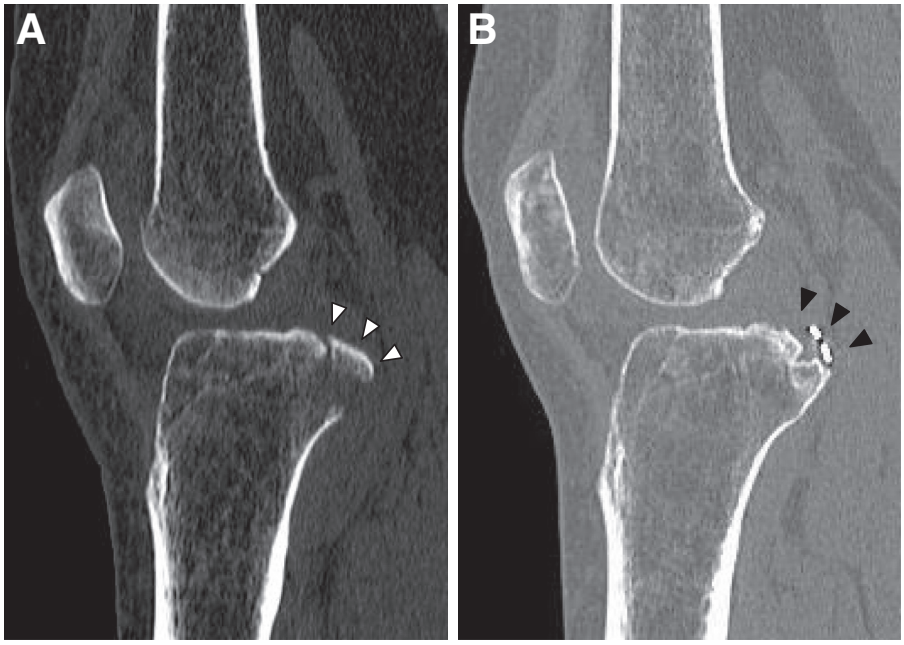

Fig 2. (A) Preoperative sagittally reconstructed computed tomography image of left knee, identifying a type III avulsion fracture (white arrowheads). (B) Bone union was confirmed after 3 months, and remodeling of the fragment (black arrowheads) was seen by 12 months after surgery.

cannulated screws as final fixation. This procedure is still widely used with some modification.[4] However, this technique requires a relatively large fragment for multiple-screw fixation, and it is often difficult to compress the fragment to the bed even with partially threaded screws because the threads do not always completely pass the fragment, especially when it is thin. Pull-out techniques and fixation by Kirschner wires or suture anchors were then introduced,[9,10] but these procedures were complex and technically demanding. Although most of these techniques approach the fragment from standard anterior portals, it is more reasonable to view and treat the fracture from the posterior compartment because the fragment is in the posterior end of the tibial plateau. Gwinner et al.[11] reported a technique using an adjustable-length loop device (TightRope) to fix this fracture. Their method was unique in that while allowing reduction of the fracture fragment under arthroscopic visualization from the posterior portal, they made it possible to compress the fragment to the tibia using the adjustable-length loop device. However, this technique to reduce and

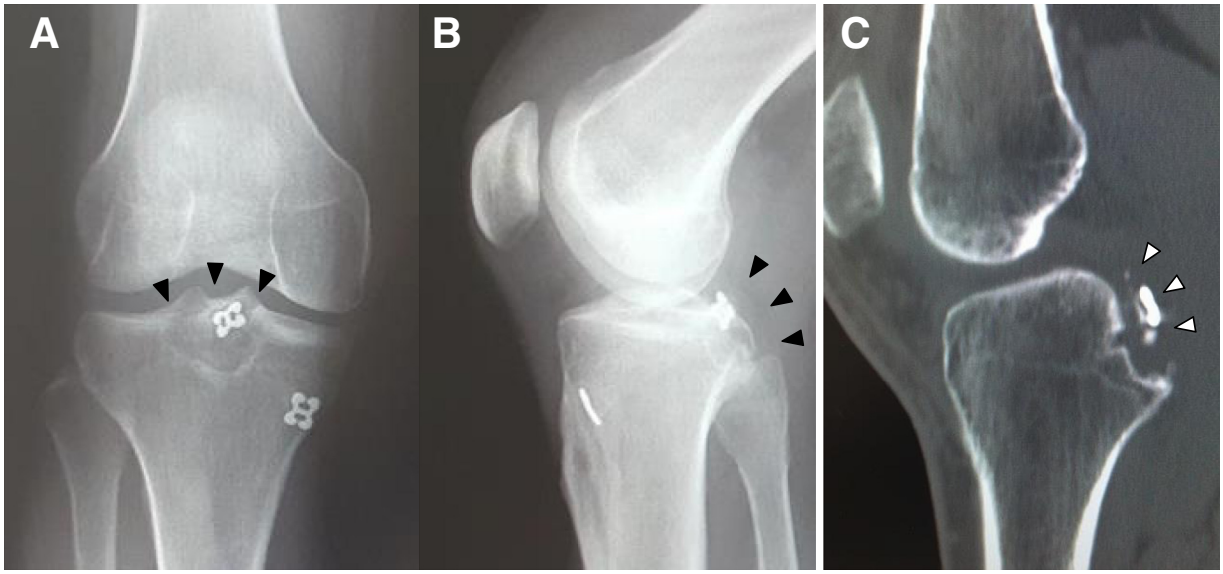

Fig 3. Postoperative radiographs and computed tomography scan of right knee. (A, B) Displacement of the fragment is not apparent (black arrowheads) on radiography. (C) A computed tomography scan confirmed nonunion of the fragment (white arrowheads).

Table 2. Advantages and Disadvantages of ARIF Technique for PCL Avulsion Fractures

Advantages
The procedure is less invasive compared with the open method.
The surgeon is able to concurrently treat associated intra-articular lesions.
The technique allows reduction of the fracture fragment under direct arthroscopic visualization without interfering with the PCL.
Compression of the fragment to the tibia is possible with the adjustable-length loop device even when the fragment is thin and small.
The risk of further displacement and comminution of the fragment is low.
Disadvantages
The use of posterior portals requires training.
Reduction may be difficult in chronic cases.
The long-term outcomes are not yet clear.

ARIF, arthroscopic reduction–internal fixation; PCL, posterior cruciate ligament.

fix the fragment with a conventional tibial PCL guide[11] inserted from the anterior portal is often difficult because the fragment would be dislocated by interference of the guide with the existing PCL. Our procedure has an advantage in that by approaching the fragment from the posterior compartment using a guide inserted from the posteromedial portal, we do not have the problem of interfering with the PCL. Furthermore, the adjustable-length loop device passes the fragment from the upper surface of the fragment, thereby reducing the risk of displacement of the fragment. By using a small cannulated drill and minimizing soft-tissue debridement around the fragment, the PCL attachment is held down with a wide button along with the soft tissue, thus preventing the fragment from splitting (Table 2).

Table 3. Pearls and Pitfalls of ARIF Technique for PCL Avulsion Fractures

Pearls
Prepare the fluoroscopy C-arm to allow easy visualization of the lateral view.
Ensure there is enough working space for the posteromedial portal by the abduction of the unaffected limb.
Keep the posterior portals open with a switching stick.
Confirm the location of the PCL by the posterior view to accurately identify the fragment margin.
Confirm the position of the cannulated drill by the lateral fluoroscopic view.
Pull out the cannulated drill with the adjustable-length loop device.
Deliver and settle the button on the fragment with a grasper.
Pitfalls
Low posterior portals make visualization and reduction of the fragment difficult.
Saphenous nerve injury may occur at the time of posteromedial portal creation.
Multiple perforations of the fragment may lead to fragment comminution.
Over-tightening the adjustable-length loop device may lead to fragment comminution.

ARIF, arthroscopic reduction–internal fixation; PCL, posterior cruciate ligament.

One of the possible disadvantages of the described technique is that the surgeon has to be familiarized with the creation of the trans-septal portal; in addition, the use of posterior portals may require some training. Moreover, in chronic cases in which the fracture is left untreated for more than 3 weeks, reduction of the fragment may be more difficult, possibly leading to a lower union rate. Finally, we need to evaluate the benefit of this technique based on long-term follow-up of the outcomes. We do not know if older patients with lower activity levels would benefit from this procedure similarly to younger patients even if they had a displaced fragment (Table 2). Technical pearls and pitfalls of our technique are given in Table 3.

In conclusion, we were able to achieve a high union rate and good clinical outcomes for avulsion fractures of the PCL attachment with the arthroscopic pull-out technique using an adjustable-length loop device. The procedure is useful in treating displaced PCL avulsion fractures, with some advantages compared with previously reported techniques.

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