

# Arthroscopic Suture-to-Adjustable Loop Fixation of Adult Anterior Cruciate Ligament Tibial Avulsion Fracture



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**Abstract:** Adult tibial avulsion fracture of the anterior cruciate ligament (ACL) occurs not as frequently as ACL tear but still is concerning. There are many methods of arthroscopic fixation of this special fracture. However, a simple and effective method is still being pursued. We would like to introduce an arthroscopic suture-to-adjustable loop fixation technique, which features are a reduction of lateral displacement of the fragment by special suture configuration and tensioning, and a final reduction of residual displacement by tensioning the adjustable loop. We consider the introduction of this technique will provide additional choice in the treatment of adult ACL tibial avulsion fracture.

Adult anterior cruciate ligament (ACL) tibial avulsion fracture is an occasionally occurring condition. Although there are few large series reports,<sup>1-3</sup> arthroscopic fixation of the fracture continues to attract attention, with new techniques emerging from time to time in pursuit of a simpler and more effective method.<sup>4-9</sup> In previous reports regarding suture fixation, how to address the tendency or the existing lateral displacement of the fragment and how to eliminate the elevation of the anterior edge of the fragment have not been specifically described.<sup>10</sup> Thus, we would like to introduce an arthroscopic suture-to-adjustable loop fixation technique, in which lateral displacement and anterior elevation of the bone

fragment can be securely reduced. The indications of this technique are Meyers and McKeever's type II and III ACL tibial avulsion fractures.

## Surgical Technique (With Video Illustration)

The patient is placed in the supine position. A tourniquet placed on the root of the thigh. A lateral post is placed at the lateral side of the thigh near the tourniquet. Another lateral post is placed closed to the joint line. After routine draping, the tourniquet is inflated. (Table 1).

## Creating Portals

Three arthroscopic portals, the high anterolateral and anteromedial portals and the transpatella tendon portal, are fabricated and used as arthroscope and instrument portals alternatively. The high anteromedial and anterolateral portals are located near the lateral and medial edges of the patella tendon, at a level parallel to the inferior pole of the patella. The transpatella tendon portal is in the middle of the patella tendon.

## Preparation of the Bone Bed

The infrapatella plica, part of the infrapatella pad, and sometimes the transverse knee ligament is removed to expose the bone fragment. A shaver and a pair of graspers are used to clean up blood clots and loose bone debris in the bone bed, as well as other fat and fibrous tissue. If the transverse meniscal ligaments that are across the bone bed influence the fracture reduction, they are partially to completely removed. By using arthroscopic motorized burr or a pair of graspers, the

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The authors report the following potential conflicts of interest or sources of funding: National Key Research and Development Program of China (Grant No. 2018YFC1106200 and 2018YFC1106202), and The Project of Shenkang Hospital Development Center of Shanghai (Grant No. 16CR3108B). Full ICMJE author disclosure forms are available for this article online, as supplementary material.

Received January 9, 2021; accepted February 15, 2021.

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2212-6287/2140

<https://doi.org/10.1016/j.eats.2021.02.028>

**Table 1.** Step-by-step Procedure of Arthroscopic Suture-to-Adjustable Loop Fixation of Adult ACL Tibial Avulsion Fracture

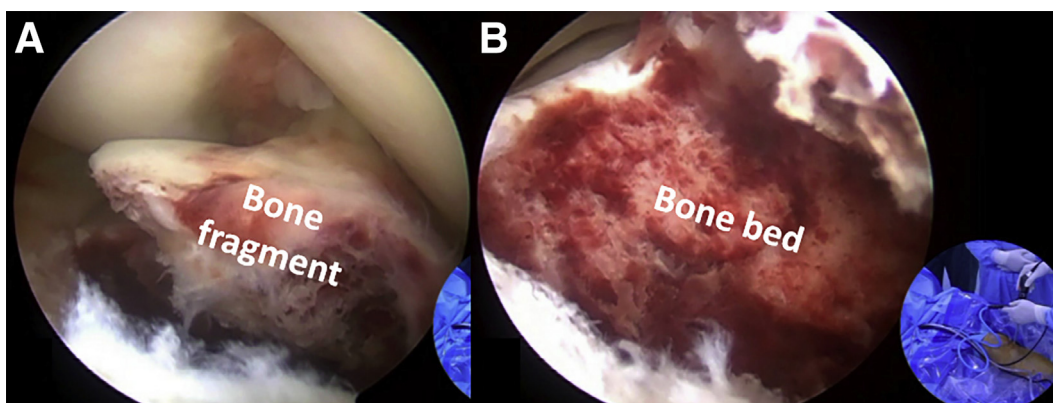
1. Three arthroscopic portals, the high anterolateral and anteromedial portals and the transpatella tendon portal, are fabricated.
2. The infrapatella plica and part of the infrapatella pad are removed to expose the bone fragment.
3. The blood clots and loose bone debris in the bone bed, as well as other fat and fiber tissue are cleaned up. The bone bed is slightly deepened to 2 to 3 mm, and the small ridges within the bone bed is removed to flatten it.
4. The bone fragment, together with the ligament, is pulled to the tibial bed for a preliminary reduction.
5. The arthroscope is placed in through the transpatella tendon portal. From the anterolateral portal, a guide suture is placed through the lateral side of the ACL, around its back, and to its posteromedial side.
6. The guide suture is pulled from the medial side of the ACL out of the joint, through the anteromedial portal. Three No. 2 UHMWPE sutures are pulled into the joint with the guide suture around the back of the ACL.
7. A suture retriever is placed in through the anterolateral portal along the lateral suture limbs. The medial suture limbs are pulled out from the anteromedial portal.
8. A half-knot is made by making a cross of the suture limbs outside the joint. The half knot is pushed into the joint just at the anterior side of the ACL, above the bony fragment.
9. The arthroscope is placed in through the anterolateral portal. The tibial tunnel locating device for ACL reconstruction is inserted through the anteromedial portal or mid-patellar tendon portal.
10. Then a 1-cm-long longitudinal incision is made at the medial side of the tibial tubercle.
11. A 4.5-mm wide medial tibial tunnel is made from the medial side of the tibial tubercle to the anteromedial edge of the tibial bone bed. A guide suture is placed through this medial tunnel.
12. A 4.5-mm wide lateral tibial tunnel is made from the medial side of the tibial tubercle to the anteromedial edge of the tibial bone bed. A guide suture is placed through this lateral tunnel.
13. With the guide sutures in the tibial tunnels, the suture limbs from the medial side of the ACL are pulled out through the medial tunnel, and those from the lateral side of the ACL are pulled out through the lateral tunnel.
14. With consistent pulling of the sutures, the fragment is adjusted into the tibial bed.
15. A 2-mm incision is made approximately 1 cm lateral to the anterior tibial ridge at a transverse plane distal to the orifices of the tibial tunnels. A 4.0-mm transtibial ridge tunnel is created with a Steinman pin.
16. A set of mini plate with an adjustable loop is pulled through this tunnel from the medial to the lateral side. The medial suture limbs are passed through the adjustable loop.
17. The mini-plate is pulled through the transverse tibial tunnel and flipped over the lateral orifice.
18. At near full knee extension, the suture limbs passing through the adjustable loop are tied to their counterparts to fix the fragment at the adjustable loop.
19. The adjustable loop is reduced to tension the fragment finally.
20. Femoral notchplasty is performed as indicated.

ACL, anterior cruciate ligament; UHMWPE, ultra-high molecular weight polyethylene.

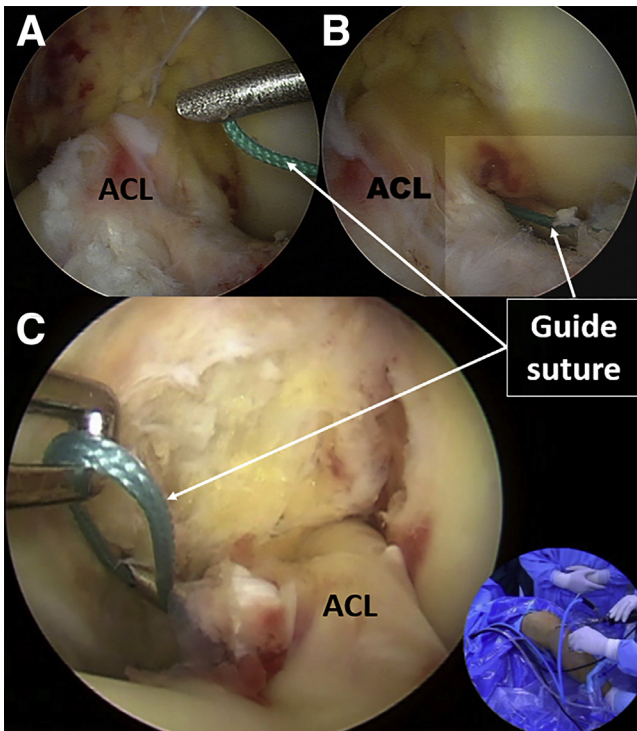
bone bed is slightly deepened to 2 to 3 mm, and the small ridges within the bone bed is removed to flatten it, to facilitate bone fragment reduction (Fig 1, Video 1).

For fracture nonunion, the fibrous tissue between the bone fragment and the bone bed is removed with a shaver and a radiofrequency probe. With the fragment not fully released (adhesion always still exists between the posterior edge of the fragment and the nearby

tissue), the hardened inferior surface layer of the fragment is carefully removed with a burr until the cancellous bone is exposed. Then, the fragment with the ACL is released from the posterior edge of the tibial bed, the posterior cruciate ligament, and the lateral tibial condyle, as well as from the posterior septum in some cases. The hardened surface layer of the tibial bed is also removed with a burr.<sup>1</sup>



**Fig 1.** The avulsion bone fragment of the tibial insertion of the anterior cruciate ligament is exposed (A) and the bone bed is cleaned up (B) (arthroscopic view of left knee through the anterolateral portal).



**Fig 2.** A guide suture is passed through the anterolateral portal (A), via the lateral and posterior side (B) to the medial side (C) of the anterior cruciate ligament (arthroscopic view of left knee through the trans-patella tendon portal).

The bone fragment, together with the ACL, is pulled to the tibial bed for a preliminary reduction with a probe or a pair of myelin nuclear pliers. ACL laxity is checked. If the ACL is found to have significant laxity, the bone bed can be further deepened. Bone bed deepening, bone fragment reduction, and ligament tightness checking are performed repeatedly, until ligament tension is restored while full contact of the bone block and bone bed is ensured.

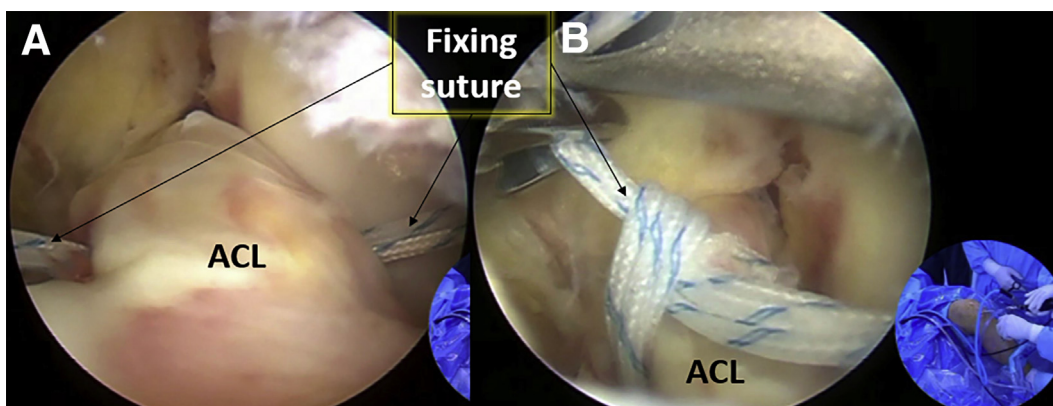
### Ligating the ACL and the Bone Fragment

The arthroscope is placed in through the transpatella tendon portal. From the anterolateral portal, a guide suture is placed via a 45° curved cannula primarily used for meniscus repair) (Linvatec, Largo, FL), through the lateral side of the ACL, around its back, and to its posteromedial side (Fig 2). Then the guide suture is pulled from the medial side of the ACL out of the joint, through the anteromedial portal. Three No. 2 ultra-high molecular weight polyethylene sutures (Smith & Nephew, Andover, MA) are pulled into the joint with the guide suture around the back of the ACL as fixing sutures (Fig 3A).

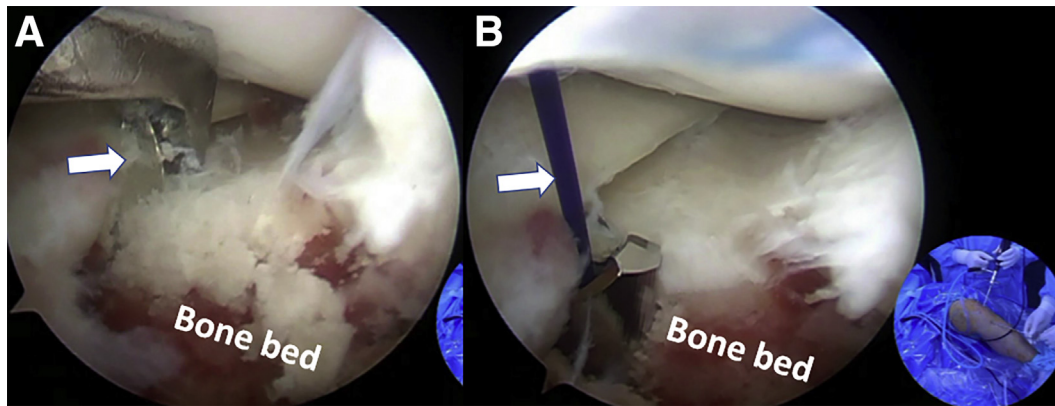
A suture retriever is placed in through the anterolateral portal along the lateral suture limbs. The medial suture limbs are pulled out from the anteromedial portal. A half-knot is made by making a cross of the suture limbs. Then, the half knot is pushed into the joint just at the anterior side of the ACL, above the bony fragment (Fig 3B).

### Creating Tibial Tunnels

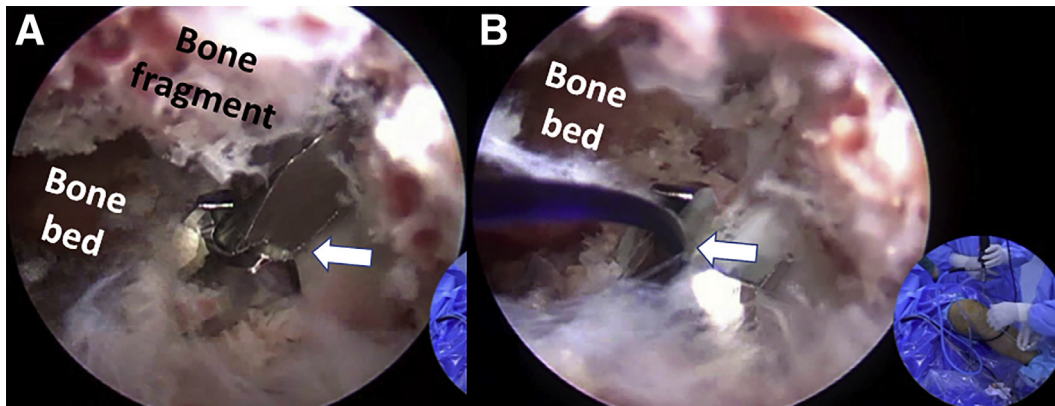
The arthroscope is placed in through the anterolateral portal. The tibial tunnel locating device for ACL reconstruction is inserted through the anteromedial portal or mid-patellar tendon portal. Then, a 1-cm-long longitudinal incision is made at the medial side of the tibial tubercle. Through this incision, two 4.5-mm wide tunnels are made from the medial side of the tibial tubercle, respectively, to the anteromedial (Fig 4) and the anterolateral (Fig 5) edge of the tibial bone bed. In the sagittal plane of the knee, the tunnel angulates the tibial vertical axis at about 15°. With the bone bed considered as a clock face, the inner orifices are located at 4:30 and 7:30, respectively. Each tunnel is created by sequential drilling of a 2.5-mm K-wire and a 4.5-mm cannulated drill. A polydioxanone suture is placed within each tunnel as guide suture.



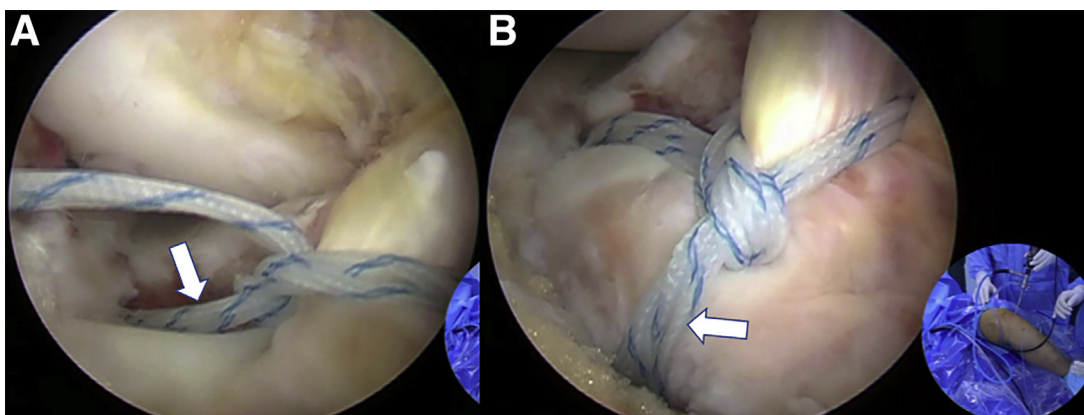
**Fig 3.** The fixing sutures are passed through the posterior side (A) and tied at the anterior side (B) of the anterior cruciate ligament (arthroscopic view of left knee through the transpatella tendon portal).



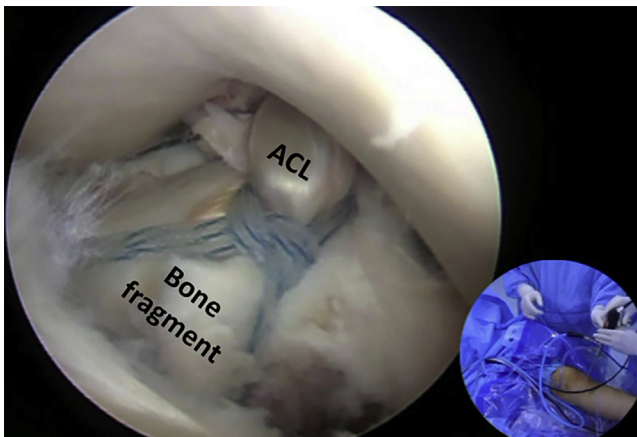
**Fig 4.** The medial tibial tunnel is created at the anteromedial edge of the bone bed (A) and a guide suture is placed in (B) (arthroscopic view of left knee through the anterolateral portal).



**Fig 5.** The lateral tibial tunnel is created at the anterolateral edge of the bone bed (A) and a guide suture is placed B) (arthroscopic view of left knee through the anterolateral portal).



**Fig 6.** The medial limbs of the fixing sutures are pulled out through the medial tibial tunnel (A) and the lateral limbs of the fixing sutures are pulled out through the lateral tibial tunnel (B) (arthroscopic view of left knee through the anterolateral portal).



**Fig 7.** The bone fragment is reduced by adjusting the tension of the respective suture limbs (arthroscopic view of left knee through the anterolateral portal). (ACL, anterior cruciate ligament.)

### Fracture Reduction

With the guide sutures in the tibial tunnels, the suture limbs from the medial side of the ACL are pulled out through the medial tunnel (Fig 6A), and those from the lateral side of the ACL are pulled out through the lateral tunnel (Fig 6B). The suture limbs over the fragment can be separated to control the fragment as a net. With consistent pulling of the sutures, the fragment is adjusted into the tibial bed. When there is lateral displacement of the fragment, the lateral suture limb is first tensioned to push the fragment to the medial side, and then all sutures are tensioned to lower the anterior edge of the fragment (Fig 7).

For fragment–bone bed mismatch in chronic cases, one self-made 6-mm-wide flat punch is used to impact the fragment onto the tibial bed. If the mismatch still exists, the fragment is fractured into pieces with a mini-osteotome and then “softened” to obtain satisfactory fragment–bed matching. During bone fragment softening, the osteotome is performed along the ACL so as not to cut the ACL fibers from the fragment.<sup>1</sup>

### Fracture Fixation

A 2-mm incision is made approximately 1 cm lateral to the anterior tibial ridge at a transverse plane distal to the orifices of the tibial tunnels. A 4.0-mm transtibial ridge tunnel is created with a Steinman pin. A set of adjustable loop cortical fixation device (Arthrex, Naples, FL) is pulled through this tunnel from the medial to the lateral side. The medial suture limbs are passed through the adjustable loop. The button is pulled through the transverse tibial tunnel and flipped over the lateral orifice. At nearly full knee extension, when arthroscopic monitoring confirms that the fracture reduction is satisfactory, the suture limbs passing through the adjustable loop are tied to their counterparts to fix the fragment at the adjustable loop. The adjustable loop is reduced to tension the fragment

finally (Fig 8). At full extension, the femoral notch impingement is excluded. If there is impingement, notchplasty is performed (Fig 9).

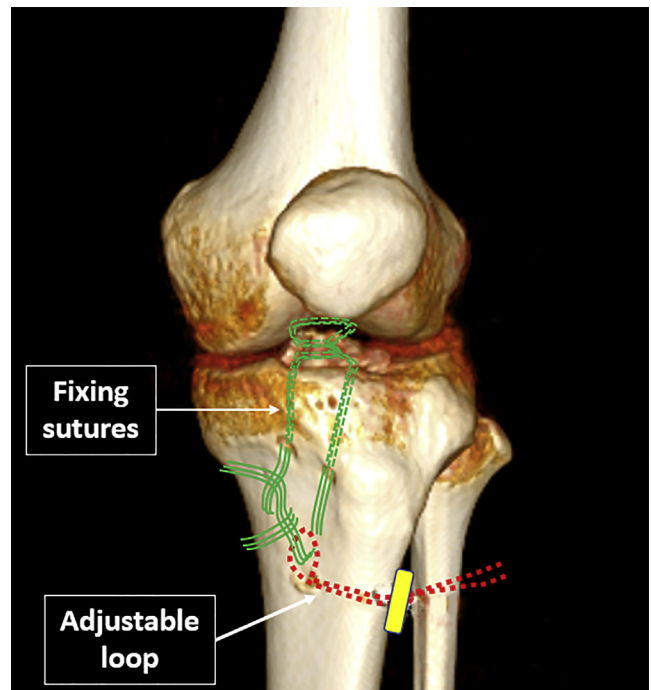
### Postoperative Management

Straight leg raising, patella manipulation, and range-of-motion exercises begin immediately after the operation. Full weight-bearing is permitted immediately after operation as tolerated. A brace is used for the first 4 weeks at rest, locked in 0° to prevent extension limitation. Range-of-motion exercises begin immediately after the operation to obtain more than 120° of flexion at the end of 6 weeks. Proprioception exercises begin from the third week. Mobility training begins from the seventh week.

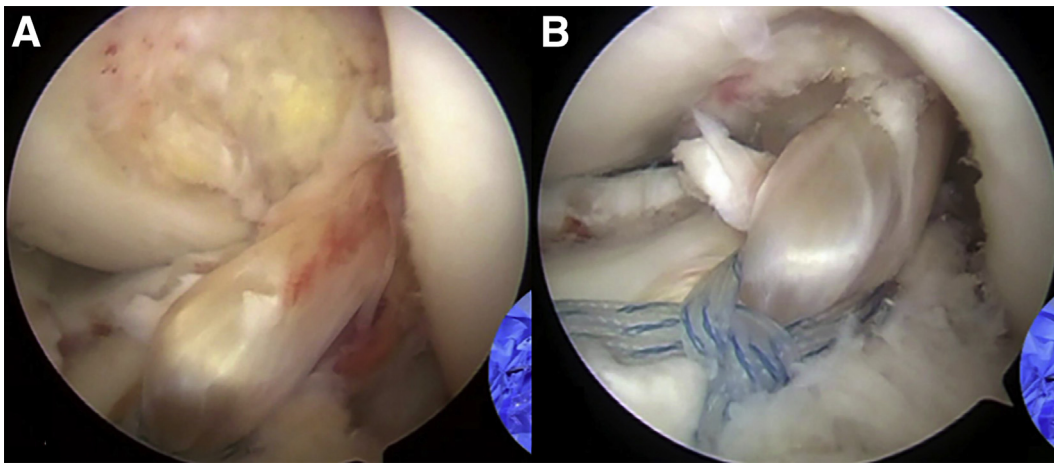
### Discussion

There are several features in the current technique. First, the bone bed is deepened to address the degeneration or elongation of the ACL. Second, we tension the respective suture limbs to address lateral displacement of the bone fragment. Third, the bone fragment is firmly controlled by tensioning the adjustable loop. There may be debate regarding the bone bed deepening because bone bed deepening causes changes of ACL insertion position, through which ACL tension is restored, but whether the insertion position change will affect the normal biomechanics of the knee joint has yet to be further studied (Figs 10 and 11).

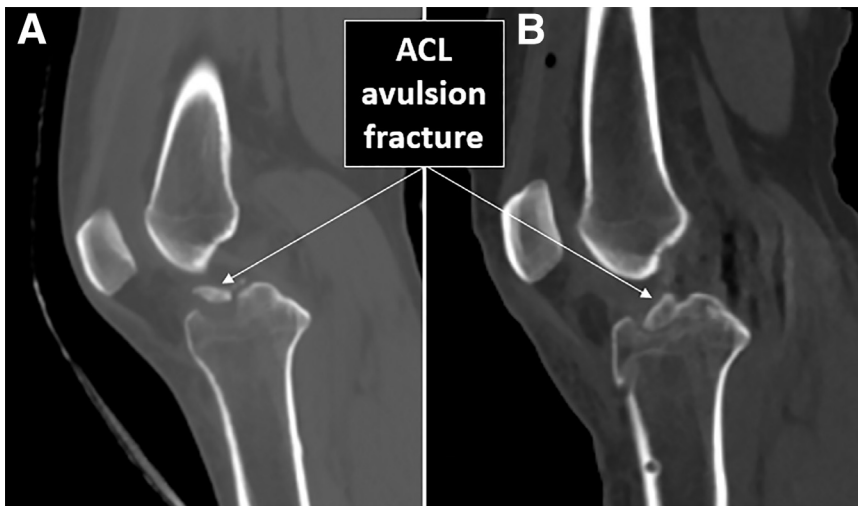
The pearls and pitfalls, and the advantages and disadvantages of this technique are listed in Tables 2 and 3. The most critical point is proper location of the inner



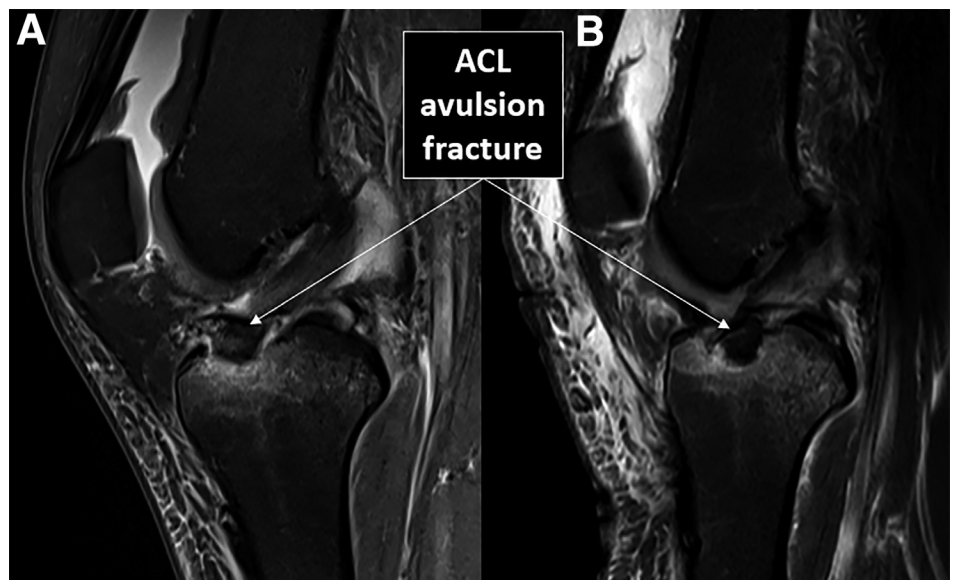
**Fig 8.** Illustration of attachment of the fixing sutures to an adjustable suture loop with mini plate (left knee).



**Fig 9.** In case of femoral notch stenosis (A), notch plasty if performed (B). (arthroscopic view of left knee through the anterolateral portal). (ACL, anterior cruciate ligament.)



**Fig 10.** Preoperative (A) and postoperative (B) computed tomography images of the avulsion fracture of anterior cruciate ligament.



**Fig 11.** Preoperative (A) and postoperative (B) magnetic resonance imaging views of the avulsion fracture of anterior cruciate ligament.

**Table 2.** Pearls and Pitfalls of Arthroscopic Suture-to-Adjustable Loop Fixation of Adult ACL Tibial Avulsion Fracture

1. The anteromedial and anterolateral portals should be high enough to get a better overview of the fracture site.
2. The accurate definition of the degree of fracture displacement can sometimes only be done following removal of the transverse knee ligaments and the infrapatellar pads.
3. The bone bed should not be deepened too much, otherwise it may cause separation of the fragment and the bone bed. In general, it is enough to restore the tension of the ligaments just by deepening the bone bed to 5 mm.
4. The laxity of the ligament can be eliminated on site by over reduction. Ligament tension can also be expected to be restored following microfracture at the femoral insertion and punching of the ligament to induce scar formation and ligament contracture.
5. If the meniscus is found trapped between the bone bed and the fragment, use a probe hook to pull it back to the anatomical position and reduce the bone fragment.
6. In most cases, the bone fragment can be well controlled with half-knot ligating. In seldom cases when the bone fragment is too small and ligating control is not satisfactory, the sutures can be passed through the posterior part of the ligament instead of around the ligament to get better control.
7. Multiple fixing sutures are needed to prevent suture cutting of the ligament.
8. The inner orifice of the tibial tunnel should be rightly located. Too anterior location may impede medial–lateral adjustment of the bone fragment. Too lateral location may impede reduction of the anterior edge of the bone fragment.
9. Attention should be paid to the reduction of the fragment part with attachment of the anterior horn of the meniscus. It can also cause extension limitation when it is not fully reduced.
10. Fracture fixation is completed near full knee extension. There is always anterior elevation of the fragment when it is fixed at 90° flexion.

ACL, anterior cruciate ligament.

orifices of the tibial tunnels. Too posterior location will lose control of the anterior elevation of the fragment. A too-anterior location will lose control of lateral displacement of the fragment. Locating the tunnel at the anteromedial and anterolateral edge of the bone bed is preferred.

**Table 3.** Advantages and Disadvantages of Arthroscopic Suture-to-Adjustable Loop Fixation of Adult ACL Tibial Avulsion Fracture

#### Advantages

1. No hardware is used intra-articularly.
2. Lateral displacement of the bone fragment can be reduced by selective suture tensioning.
3. The final fixation tension on the bone fragment can be ensured through reducing the adjustable loop.

#### Disadvantages

1. Additional transtibial tunnel is needed to set the adjustable loop device.
2. Suture cutting of the ligament may occur due to the thin fixation sutures or too much tension on them.

ACL, anterior cruciate ligament.

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