

Arthroscopic Epiphyseal Plate-Sparing Fixation of Anterior Cruciate Ligament Tibial Avulsion Fracture in Skeletally Immature Patients



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Abstract: The tibial avulsion fracture of the anterior cruciate ligament (ACL) in skeletally immature patients poses challenges to orthopaedic surgeons due to the necessity of protecting the epiphysal plate during surgical reduction and fixation of the bone fragment. Several epiphysal plate—sparing techniques have been reported. However, the epiphysal plate is still in danger because in most of these techniques the fixation device is approaching the epiphysal plate or passing through it. We would like to introduce a suture fixation technique in which there is no fixation device passing through the fracture interface as well as the epiphysal plate. The critical points of this technique are ligating the ACL, retrieving the fixation suture distally along the anterior surface of the proximal tibia, and tying the fixation suture at an adjustable loop that is set distal to the proximal tibial epiphysal plate. Our clinical experience indicates that this technique is safe and effective. We consider the introduction of this technique will provide more feasible options when surgical treatment is indicated in case of ACL tibial avulsion fracture in skeletally immature patients.

Anterior cruciate ligament (ACL) tibial avulsion fracture occurs quite often in children and adolescents. The treatment is similar in strategy but different in technique in this group of patients compared with that in skeletally mature patients.¹ For skeletally immature patients, one principle is to avoid injury to the epiphysal plate, no matter what kind of reconstruction or repair technique is taken. For children or patients in the early stages of adolescence who have high growing potential, a more conservative treatment should be undertaken. When fracture reduction and fixation are

inevitable choices, measures should be taken to minimize or avoid injury to the epiphysal plate.²⁻⁷ If the patient is in late adolescence and the growth peak has passed, the entire treatment principle and methods are the same as for adults. The following technique was developed for children or patients in early adolescence. The indications are type II and III fracture in acute stage and unstable type III fracture in chronic stage.

Surgical Procedures (With Video Illustration)

The patient is placed in the supine position. The tourniquet placed on the root of the thigh. A lateral post is placed at the lateral side of the thigh near the tourniquet. After routine draping, the tourniquet is inflated.

Creating Portals

Three arthroscopic portals are used for the reduction and fixation of the ACL tibial insertion avulsion fracture—the high anterolateral and anteromedial portals, as well as the transpatella tendon portal, being used as arthroscope portal and instrument portal 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 (Table 1).

The scope is placed into the joint through the anterolateral portal and the instruments are placed in through

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Table 1. Step-by-Step Procedure of Arthroscopic Epiphyseal Plate-Sparing Fixation of ACL Tibial Avulsion Fracture in Skeletally Immature Patients

1. The high anterolateral and anteromedial portals, as well as the transpatella tendon portals are created.
2. The infrapatella plica and part of the infrapatella pad are removed to expose the bone fragment.
3. The fibrous tissue between the bone fragment and the bone bed is removed. The bone bed is slightly deepened.
4. The bone fragment is pulled to the tibial bed for a preliminary reduction.
5. A guide suture is placed through the lateral side of the ACL, around its back, and to its posteromedial side. The guide suture is pulled from the medial side of the ACL out of the joint.
6. Three no. 2 nonabsorbable sutures are pulled back 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 anterolateral portal.
8. A half-knot is made by making a cross of the suture limbs. The half knot is pushed into the joint just at the anterior side of the ACL, above the bony fragment.
9. A penetrator is passed from stabs over the anteromedial side of the proximal tibia, along the anterior tibial slope to the medial and the anteromedial edges of the bone bed. The suture limbs from the medial side of the ACL are pulled out.
10. The penetrator is passed from the medial edge of the patella tendon to the anterolateral edge of the bone bed. The suture limbs from the lateral side of the ACL are retrieved out one by one.
11. With consistent pulling of the sutures, the fragment is adjusted into the tibial bed.
12. A transtibial ridge tunnel is created. A 1-cm distal medial incision is made near the medial orifice of the transtibial ridge tunnel.
13. All the fixation suture limbs are passed subcutaneously out of the distal medial incision.
14. A set of cortical suspension fixation device with an adjustable loop is pulled through this tunnel from the medial to the lateral side.
15. The suture limbs from the medial side of the ACL are passed through the adjustable loop.
16. The cortical button is pulled through the transtibial ridge tunnel and flipped over the lateral orifice.
17. The sutures limbs passing through the adjustable loop are tied to their counterparts to fix the fragment at the adjustable loop.
18. The adjustable loop is reduced to tension the fragment finally.

ACL, anterior cruciate ligament.

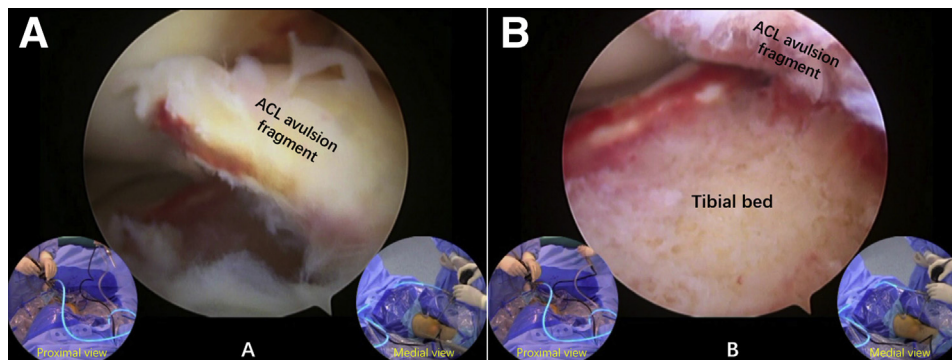


Fig 1. The tibia avulsion fracture of the anterior cruciate ligament is exposed after removing part of the infrapatellar pad (A) and the interposing tissue is cleared off (B) (Arthroscopic view of left knee through the anterolateral portal). (ACL, anterior cruciate ligament.)

Fig 2. The bone bed is deepened with a burr (A) and the bone fragment is temporarily reduced (B) (Arthroscopic view of left knee through the anterolateral portal). (ACL, the anterior cruciate ligament; MFC, medial femoral condyle.)

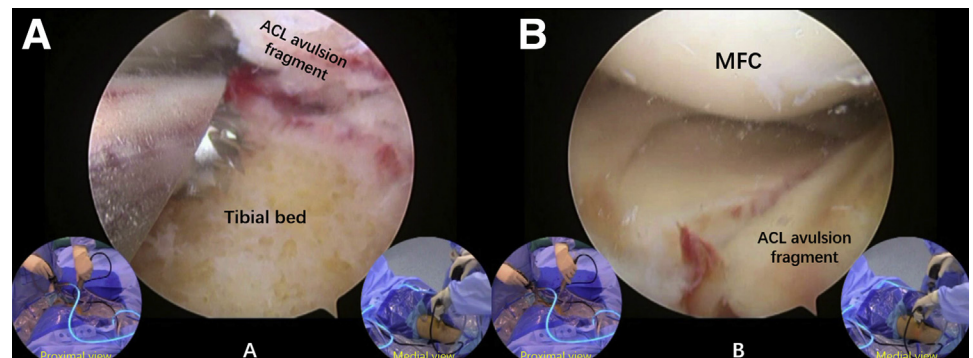


Fig 3. A guide suture is passed from the lateral side of the ACL (A), through its posterior side to its medial side (B) (Arthroscopic view of left knee through the anterolateral portal). (ACL, the anterior cruciate ligament; MFC, medial femoral condyle.)

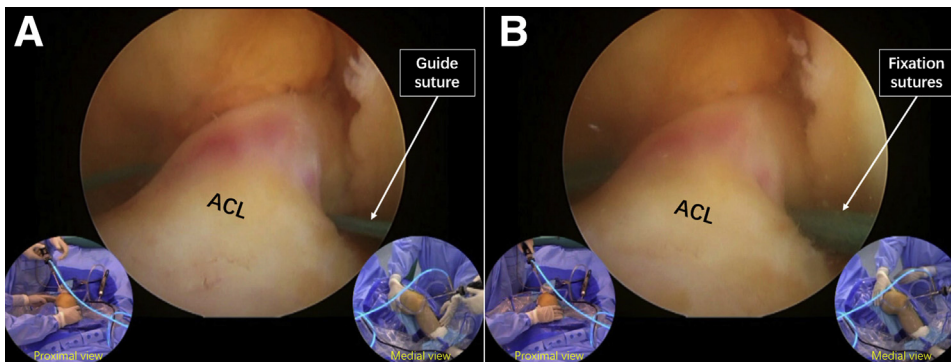
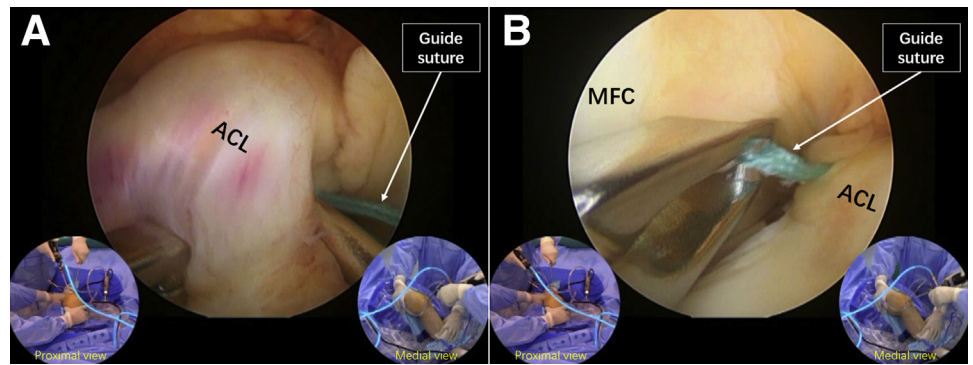


Fig 4. With the guide suture (A), the 3 fixation sutures are passed around the posterior side of the anterior cruciate ligament (B) (Arthroscopic view of left knee through the anterolateral portal). (ACL, the anterior cruciate ligament.)

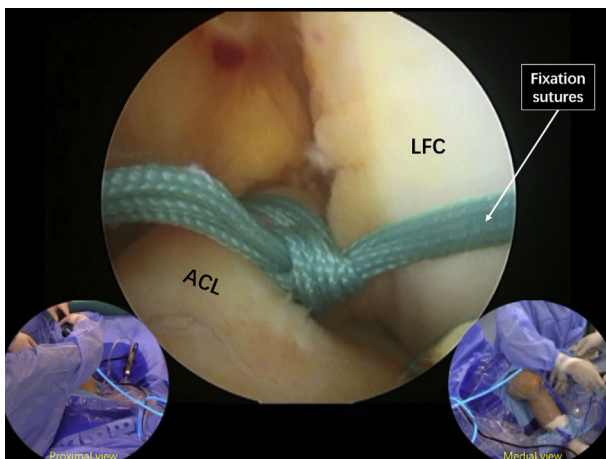


Fig 5. A half knot is made at the anterior side of the ACL (Arthroscopic view of left knee through the anterolateral portal). (ACL, the anterior cruciate ligament; LFC, lateral femoral condyle.)

the anteromedial portal. The entire joint is checked to detect and treat combined lesions.

Exposing the Bone Fragment

The knee is flexed at approximately 30°. The infrapatella plica, part of the infrapatella pad, and sometimes the transverse knee ligament is removed to expose the bone fragment (Fig 1A, Video 1). The fibrous tissue between the bone fragment and the bone bed is removed with a shaver and a radiofrequency probe (Fig 1B).

Preparation of the Bone Bed

A shaver and a pair of graspers is used to clean up blood clots and loose bone debris in the bone bed, as well as other scar tissue. If the transverse knee ligaments that cross the bone bed influence the fracture reduction, they are partially to completely removed. Using arthroscopic burr or a pair of graspers, the small ridges within the bone bed are removed to flatten and slightly deepen it

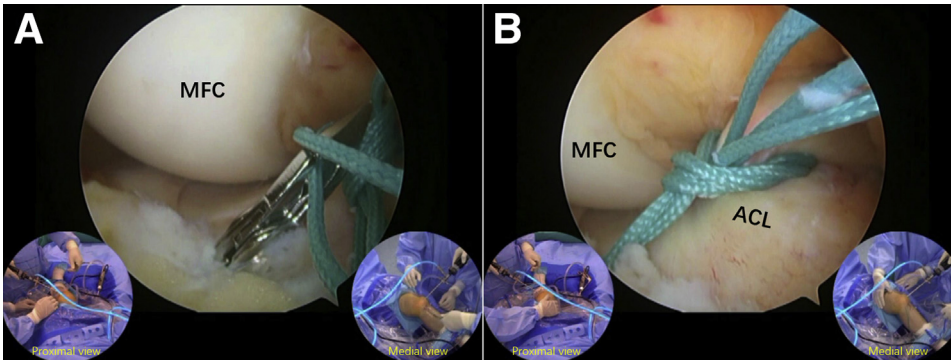


Fig 6. A penetrator is placed into the anteromedial side of the bone bed (A) along the surface of the proximal tibia and the fixation suture from the medial side of the anterior cruciate ligament is retrieved out (B) (Arthroscopic view of left knee through the anterolateral portal). (ACL, the anterior cruciate ligament; MFC, medial femoral condyle.)

Fig 7. A penetrator is placed into the anterolateral side of the bone bed (A) along the surface of the proximal tibia and the fixation suture from the lateral side of the anterior cruciate ligament is retrieved out one by one (B) (Arthroscopic view of left knee through the anterolateral portal). (ACL, the anterior cruciate ligament; MFC, medial femoral condyle.)

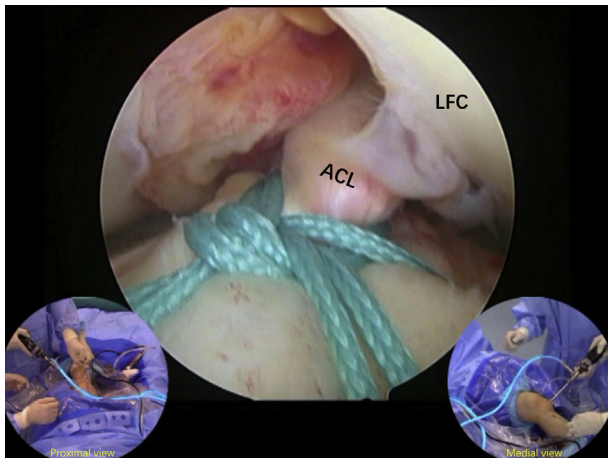
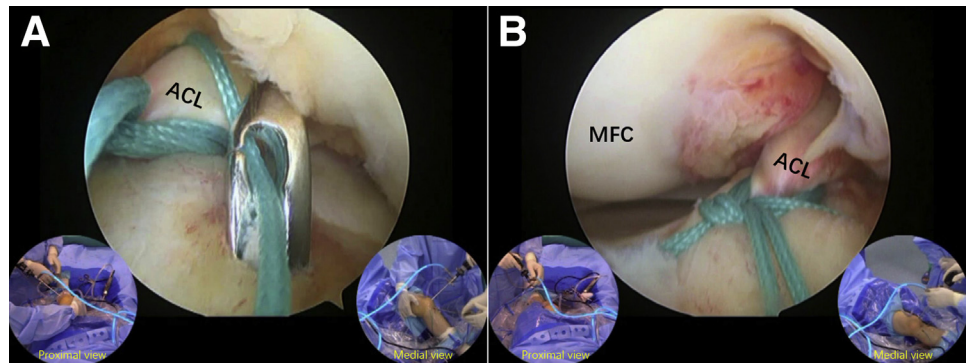


Fig 8. Photo indicating control of the bone fragment by dispersed fixation sutures (Arthroscopic view of left knee through the anterolateral portal). (ACL, the anterior cruciate ligament; LFC, lateral femoral condyle.)

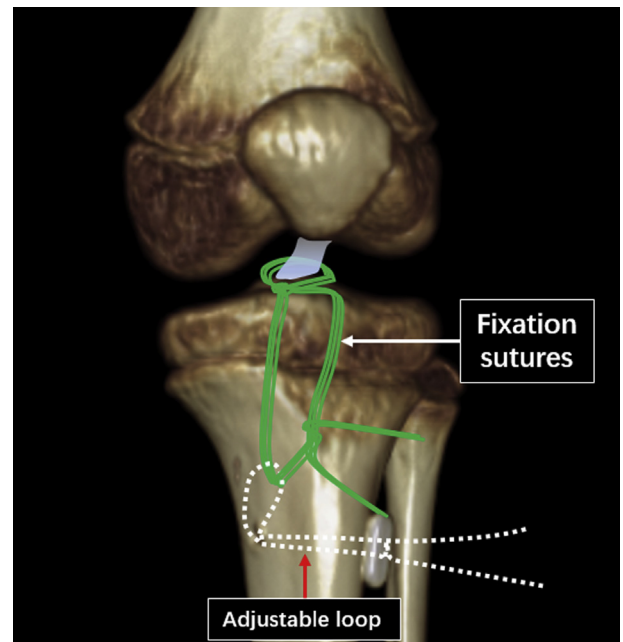


Fig 9. Illustration indicating tying the fixation sutures at an adjustable loop in a cortical suspension device (left knee).

Table 2. Pearls and Pitfalls of Arthroscopic Epiphyseal Plate-Sparing Fixation of ACL Tibial Avulsion Fracture in Skeletally Immature Patients

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.
5. If the medial 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 site from which the fixation sutures are retrieved out should be rightly located. Too anterior location may impede medial–lateral adjustment of the bone fragment. A 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. Otherwise, there may be anterior elevation of the fragment at extension following fixation at 90° flexion.
11. The medial suture limbs are retrieved out through the anteromedial side of the bone bed and the lateral suture limbs are retrieved out through the anterolateral side of the bone bed. In this way the medial-to-lateral position of the bone fragment can be easily controlled. Otherwise, it is somewhat difficult to adjust the medial-to-lateral position of the bone fragment.
12. In the current procedure, nonabsorbable sutures are used for fixation because the internal fixation materials are scheduled to be removed when the fracture has healed. Otherwise, absorbable sutures are preferred to prevent suture cutting through the ligament along with the growth.

ACL, anterior cruciate ligament.

(Fig 2A). The bone fragment, together with the ligament, is pulled to the tibial bed for a preliminary reduction (Fig 2B). For fracture nonunion, the hardened underlayer of the fragment is carefully removed with a burr until the sponge bone is exposed. The hardened surface layer of the tibial bed is also removed with a burr. If the ACL is found to have significant laxity, the bone bed can be further deepened to obtain the desired tension in the ACL after reduction.

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 (primitively used for meniscus repair) (Linvatec, Largo, FL), through the lateral side of the ACL (Fig 3A), around its

back, and to its posteromedial side (Fig 3B). Then, the guide suture is pulled from the medial side of the ACL out of the joint, through the anteromedial portal. (Fig 4A) Three No. 2 nonabsorbable sutures are pulled back with the guide suture around the back of the ACL (Fig 4B).

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 5).

Fracture Reduction

With a needle used for help locating, a penetrator is passed from stabs over the anteromedial side of the proximal tibia, along the anterior tibial slope, through the underside of the transverse knee ligament, to the medial and the anteromedial edges of the bone bed. The suture limbs from the medial side of the ACL are pulled out one by one (Fig 6). Then, the penetrator is passed from the medial edge of the patella tendon to the anterolateral edge of the bone bed to retrieve the suture limbs from the lateral side of the ACL one by one (Fig 7).

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 8).

Table 3. Advantages and Disadvantages of Arthroscopic Epiphyseal Plate-Sparing Fixation of ACL Tibial Avulsion Fracture in Skeletally Immature Patients

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.

At full extension, the fragment–femoral notch impingement is excluded. Notchplasty is performed in case of impingement.

Fracture Fixation

A stab is made approximately 1 cm lateral to the anterior tibial ridge at a transverse plane distal to the tibial epiphysial plate. A 3-mm transtibial ridge tunnel is created. A 1-cm long distal medial incision is made near the medial orifice of the transtibial ridge tunnel. All the fixation suture limbs are passed subcutaneously out of the distal medial incision. A set of cortical suspension fixation devices with an adjustable loop is pulled through the transtibial ridge tunnel from the medial to the lateral side. The suture limbs from the medial side of the ACL are passed through the adjustable loop. The cortical fixation button is pulled through the transtibial ridge tunnel and flipped over the lateral orifice. At near full knee extension, when arthroscopic monitoring confirms that the fracture reduction is satisfactory, the sutures limbs passing through the adjustable loop are tied to their counterparts to fix the fragment at the adjustable loop (Fig 9). The adjustable loop is reduced to tension the fragment finally.

Rehabilitation

Partial to full weight-bearing and range of motion and muscle-strengthening exercises begin immediately after the operation. A hinged brace is used for the first 6 weeks during weight-bearing. Running, and agility and proprioceptive training begin from the seventh postoperative week.

Discussion

In patients with open epiphysial plate and high growth potential, injury to the epiphysial plate should be avoided as much as possible. There are several methods in the literature to achieve this goal. One kind of fixation reported is performing fracture fixation with short screws or suture anchors proximal to the epiphysial plate, or just suturing the fragment to the surrounding structure. This technique is relatively difficult in that the fixation device approaching the epiphysial plate and fixation direction is not along the ACL. Another kind of fixation is pulling out the fixation sutures through thin transepiphysial plate tunnels.

Although it is not clear whether the epiphysial plate will be affected by this tunneling, risk still exists theoretically. The current technique is different from previously reported techniques in three main aspects. First, the ACL is ligated by sutures, which is time-saving, instead of being threaded. Second, the fixation sutures are pulled out along the anterior surface of the proximal tibia instead of through tunnels to prevent injury to the epiphysial plate. Third, the fixation sutures are fixed at an adjustable loop that is set away from the epiphysial plate to prevent injury to the epiphysial plate and to exert reduction force. Through reducing of the adjustable loop, the fixation can be secured.

The pearls and pitfalls and the advantages and disadvantages of the current technique are listed in Table 2 and Table 3. The most critical point of the current technique is passing the fixation sutures from the right site around the tibial bone bed.

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