Technical Note

Three-in-One Procedure for Revision ACL Reconstruction

Jinzhong Zhao, M.D.

Abstract: Revision anterior cruciate ligament (ACL) reconstruction is a challenge due to the unfavorable condition of the knee and the lack of autogenous graft tissue. Anterolateral structure (ALS) reconstruction of the knee has been proved effective to address the unfavorable condition in revision cases, and lateral extra-articular tenodesis (LET) is a special technique that can enhance anterolateral stability of the knee without graft tissue. We introduce a procedure that combines ACL and ALS reconstruction, as well as LET for failed ACL reconstruction. The critical point of this technique is using the anterior half of the iliotibial band to realize LET and to partially reconstruct the ACL. Our clinical experience indicates this technique is extremely useful in revision ACL reconstruction without enough free graft tissue. This technique will provide a reasonable choice in revision ACL reconstruction.

Anterior cruciate ligament (ACL) failure following ACL reconstruction happens with many unfavorable causative factors and can result in or exacerbate the unfavorable conditions of the knee in turn.[1-3] Combined ACL and anterolateral structure (ALS) reconstruction has been proved effective to address the unfavorable condition in primary ACL reconstruction.[4-6] In revision ACL reconstruction, the lack of enough graft tissue is of concern when combined ACL and ALS reconstruction is to be performed.[7] The iliotibial band (ITB) is a usable structure to realize lateral extra-articular tenodesis (LET),[8] and part of it can be used as graft tissue to reconstruct the ACL. Thus, for revision ACL reconstruction, we combine the use of free tendon grafts and the ITB to perform ACL and ALS reconstruction, as well as LET, which we name the three-in-one procedure. This procedure is indicated for patients who are suitable for 1-stage revision ACL reconstruction and the available grafting tendons are not enough.

Free Tendon Graft Preparation

The patient is placed in a prone position (Table 1). When the semitendinosus tendon and gracilis tendon are available, both tendons are harvested. When the semitendinosus tendon and gracilis tendon are not available, the anterior half of the peroneus longus tendon from both legs is harvested.[9]

The 2 tendons are truncated to an equal length of >24 cm, placed side by side, and braided together at both ends with 2 No. 2 ultra-high molecular weight polyester (UHMWPE) sutures (Smith-Nephew) and then folded at the junction of the middle one-third and one of the lateral one-thirds, with 4 UHMWPE sutures as traction sutures pulled through the folded end, to make a combined graft structure, including a 4-stranded folded part for ACL reconstruction and a 2-stranded nonfolded part for ALS reconstruction (Fig 1).

Locating the Femoral Tunnel

The knee is flexed at 90o. Through a routine anteromedial and anterolateral portal, the joint is debrided. The inner orifice of the common femoral tunnel is marked at the center of the ACL footprint with a radiofrequency probe (Video 1).

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Table 1. Step-by-Step Procedure of Three-in-One Procedure for Revision ACL Reconstruction

1.	Two tendons are used to make a free tendon graft complex for the ACL and the ALS.
2.	The reference point of the inner orifice of the common femoral tunnel is marked.
3.	The tibial tunnel for the ALS is created from the medial edge of the Gerdy tubercle to the distal medial side.
4.	The anterior half of the ITB is separated and cut proximally to get a distally pedicled fascia string.
5.	The pedicled ITB is braided with nonabsorbable sutures.
6.	The total size of the free tendon graft complex and the pedicled ITB string is measured.
7.	The common femoral tunnel is created.
8.	The tibial tunnel for ACL reconstruction is created.
9.	A guide suture is placed into the joint through the femoral tunnel and out of the ACL tibial tunnel.
10.	The sutures from the ITB strip and the free tendon graft are pulled through the femoral and tibial tunnels.
11.	The ITB strip is first pulled through the femoral tunnel into the tibial tunnel.
12.	The ACL part of the free tendon graft complex is placed in from the femoral tunnel to the tibial tunnel.
13.	A 6-mm-wide interference screw is placed into the femoral tunnel for graft fixation.
14.	A soft tissue tunnel for the ALS is created from the low anterolateral incision, through the underside of the posterior part of the ITB and out of the distal lateral incision.
15.	The ALS part of the graft is pulled through this soft tissue tunnel to the low anterolateral incision and into the tibial tunnel for ALS.
16.	An interference screw is placed into the ACL tibial tunnel.
17.	A transverse tibial tunnel is created. A set of cortical suspensory fixation buttons with an adjustable loop is pulled through this tunnel from the medial to the lateral side.
18.	Half of the sutures from each graft end are pulled through the adjustable loop.
19.	The cortical button mini-plate is pulled through the transverse tibial tunnel and flipped over the lateral orifice.
20.	The sutures from each graft end are tied to their counterparts. The adjustable loop is reduced for final graft fixation.

ACL, anterior cruciate ligament; ALS, anterolateral structure of the knee; ITB, iliotibial band.

Creating a Tibial Tunnel for ALS

A low anterolateral incision is made just over the proximal edge of the Gerdy tubercle. The proximal orifice of the ALS tibial tunnel is located at the anterior edge of the tibial plateau, just medial to the Gerdy tubercle. The tunnel is created in an anterior medial distal direction toward the incision for hamstring tendon harvesting (Fig 2).

Iliotibial Band Preparation

A 2- to 3-cm-long longitudinal incision is made at the lateral side of the knee (distal lateral incision), just 5 mm posterior to the tip of the lateral femoral epicondyle. Through this skin incision, the ITB is defined. An incision is made along the anterior edge of the ITB to the anteromedial edge of the Gerdy tubercle to separate the ITB from its extension to the patella and patella tendon. Another incision is made through the ITB along the midline of the ITB to the Gerdy tubercle.

A 2-cm-long longitudinal skin incision is made over the ITB approximately 8 cm proximal to the lateral femoral epicondyle (proximal lateral incision). The 2 ITB incisions in the lateral skin incision are extended subcutaneously to the proximal lateral incision. The anterior half of the ITB is cut within the proximal lateral incision, and the ITB strip is pulled out of the distal lateral incision. The fat tissue is removed from the inferior side of the ITB strip. The strip end is braided with 2 No. 2 UHMWPE sutures (Fig 3).

The free tendon graft and the ITB strip are placed together. The diameter of the combined structure is measured to define the size of the common femoral tunnel and the ACL tibial tunnel (Fig 4).

Creating a Common Femoral Tunnel

The posterior slope of the lateral femoral epicondyle is exposed. A 1-cm deep socket is made with a 4-mm-wide Steinman pin at a point 5 mm posterior to the tip of the lateral femoral epicondyle. A 2.4-mm K-wire is placed into the socket.

A tibial tunnel—aiming device for posterior cruciate ligament reconstruction (Smith-Nephew) is placed into the joint through the anterolateral portal. The K-wire, which is placed into the socket in the lateral femoral condyle, and the tunnel-aiming pin are mounted into the device sequentially.

The arthroscope is placed into the joint through the anteromedial portal for observation. The K-wire is drilled in across the lateral femoral condyle. A 6-mm drill is drilled over the K-wire to create a temporary femoral tunnel. The K-wire is placed into this

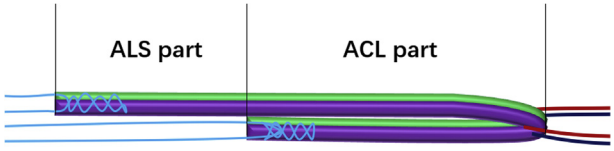

Fig 1. Preparation of a free tendon graft complex made from 2 tendons to reconstruct the anterior cruciate ligament and the anterolateral structure. ACL, anterior cruciate ligament; ALS, anterolateral structure.

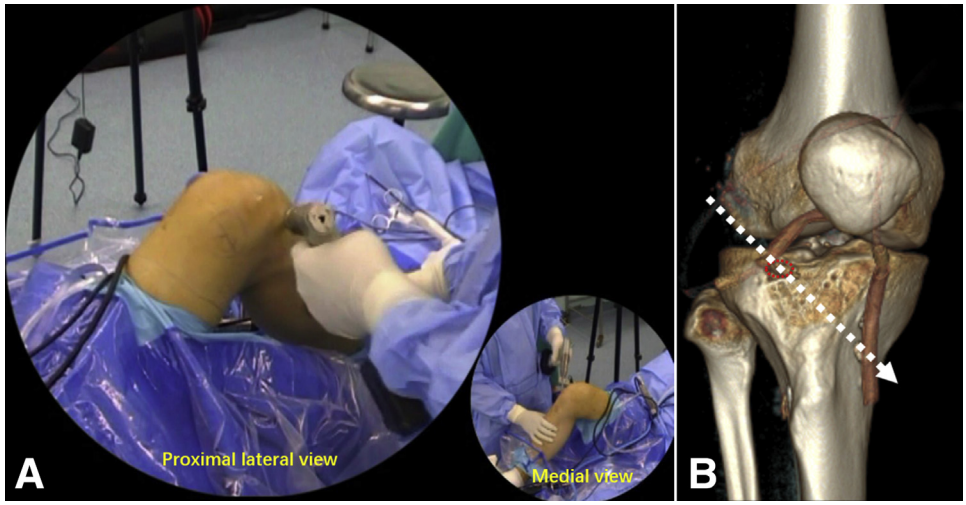

Fig 2. Creating the tibial tunnel for the anterolateral structure (right knee). (A) Intraoperative photo. (B) Illustration of the direction of the tibial tunnel (arrow).

temporary femoral tunnel again for microadjustment of the final tunnel. Then, the K-wire is overdrilled again to create a final femoral tunnel of the expected size, which is equal to the size of the combined structure (Figs 5 and 6).

Creating a Tibial Tunnel for the ACL

With the arthroscope placed into the joint through the anterolateral portal, the ACL tibial tunnel—aiming device (Aesculap) is placed in. The inner orifice of the ACL tibial tunnel is located at the midpoint of the footprint, with its outer orifice located approximately 4 cm lower to the tibial plateau and 2 cm medial to the tibial tubercle.

Graft Placement

A guide suture is placed into the joint through the femoral tunnel and then pulled through the ACL tibial tunnel out. With the guide suture, the sutures from the ITB strip and the free tendon graft are pulled through the common femoral tunnel and the ACL tibial tunnel.

The ITB strip is first pulled through the femoral tunnel into the tibial tunnel (Fig 7). Then the ACL part of the free tendon graft is placed in from the femoral tunnel to the tibial tunnel until the whole ACL part of the graft is pulled into the lateral orifice of the femoral tunnel (Fig 8). A 6-mm-wide interference screw is placed into the femoral tunnel for graft fixation.

A hemostat is placed into the low anterolateral incision, through the underside of the posterior part of the ITB and out of the lateral incision, to create a soft tissue tunnel for the reconstructed ALS. Then, the knee is moved from flexion to extension several times to widen and straighten the soft tissue tunnel. The ALS part of the graft is pulled through this soft tissue tunnel to the

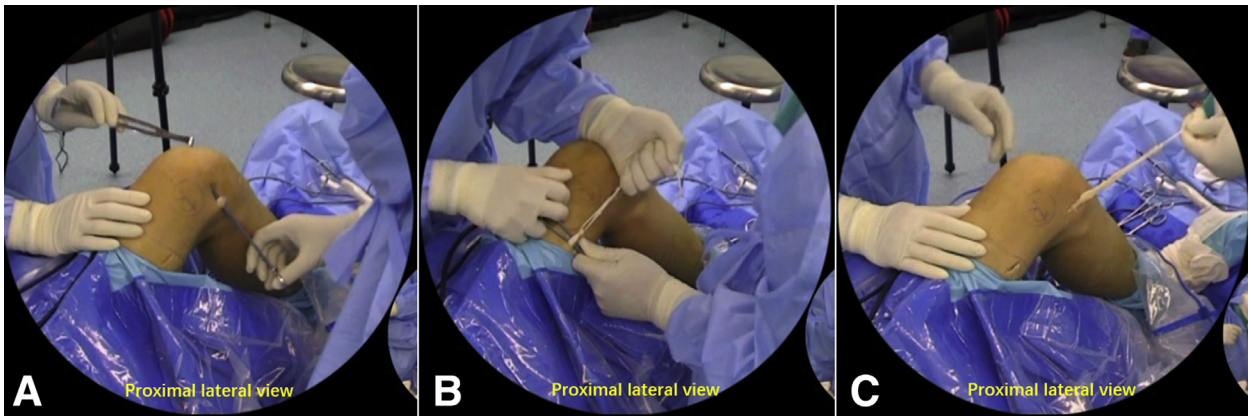

Fig 3. Intraoperative photos indicating preparation of a distally pedicled tissue string of the iliotibial band (right knee). (A) The anterior half of the iliotibial band is separated in the distal lateral incision. (B) The anterior half of the iliotibial band is separated in the proximal lateral incision. (C) The distally pedicled iliotibial band string is braided with nonabsorbable sutures.

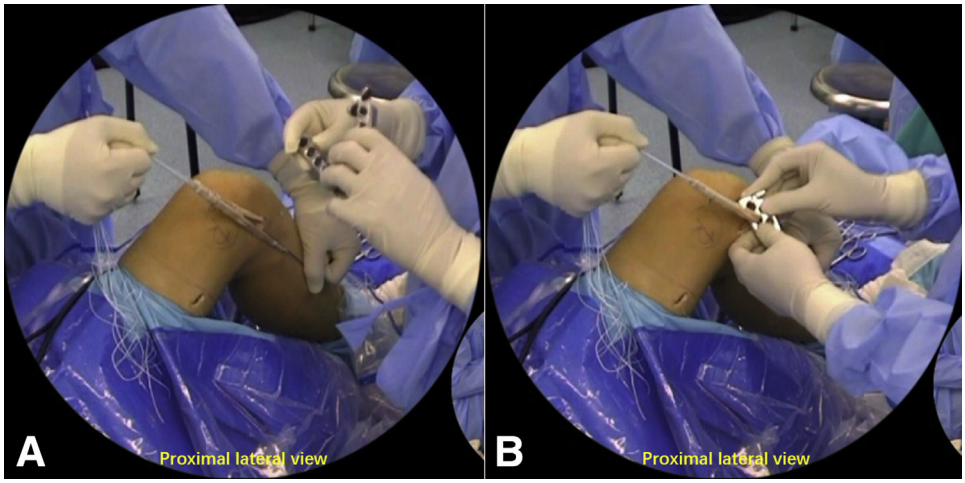

Fig 4. Intraoperative photos indicating the free tendon graft complex and the iliotibial band string are placed together (A) and measured to obtain the size of the to be reconstructed anterior cruciate ligament (right knee).

low anterolateral incision. Then, the graft end is pulled into the tibial tunnel for ALS.

Graft Fixation on the Tibial Side

The knee is placed in full extension. An interference screw is placed into the ACL tibial tunnel, through the posterior side of the graft, until it reaches the inner orifice of the tunnel.

A 2-mm incision is made approximately 1 cm lateral to the anterior tibial ridge at a transverse plane distal to the distal orifices of the 2 tibial tunnels for ACL and ALS reconstruction. A 4.5-mm transverse tibial tunnel is created. A set of cortical suspensory fixation buttons with an adjustable loop (Mitek) is pulled through this tunnel from the medial to the lateral side. Half of the sutures from each graft end are pulled through the adjustable loop. The cortical button is pulled through the transverse tibial tunnel and flipped over the lateral orifice. The sutures from each graft end are tied to their counterparts (Fig 9). The adjustable loop is reduced for final graft fixation.

Postoperative Rehabilitation

In revision surgery, both tendon-bone healing and graft revascularization may be worse than in primary surgery due to local microenvironmental changes. Therefore, the process of postoperative rehabilitation is slightly slower. Generally, weightbearing (from partial to full weightbearing) can be carried out immediately after the surgery, and the knee joint range-of-motion exercises can be carried out, but the exercise time cannot be too long. Otherwise, it may cause excessive fluid in the knee joint and adverse effects on the graft. Proprioception and flexibility training are also later than primary ACL reconstruction.

Discussion

The current technique is a combination of condyle-pinching double-bundle anterior cruciate ligament reconstruction[4] and a special ITB tenodesis. The first main feature of the current ITB tenodesis is that we fix the anterior half of the ITB instead of the middle part of the ITB for modified Lemaire and other procedures

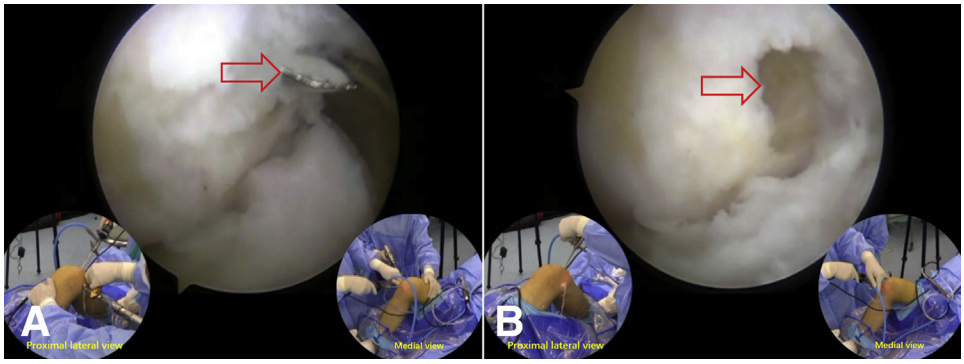

Fig 5. Creating the common femoral tunnel for the reconstruction of the anterior cruciate ligament and the anterolateral structure (right knee). (A) A K-wire is drilled in (arrow). (B) The common femoral tunnel is created (arrow).

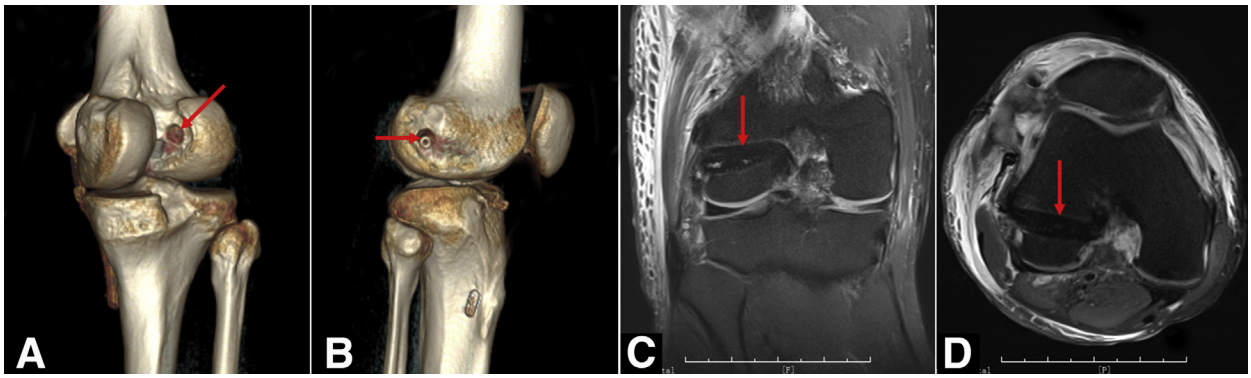

Fig 6. Postoperative computerized tomographic and magnetic resonance images indicating the position and the route of the common femoral tunnel (right knee). (A, B) Computerized tomographic images indicating the medial and the lateral orifices of the common femoral tunnel, respectively. (C, D) Coronary and transverse view magnetic resonance images indicating the route of the common femoral tunnel.

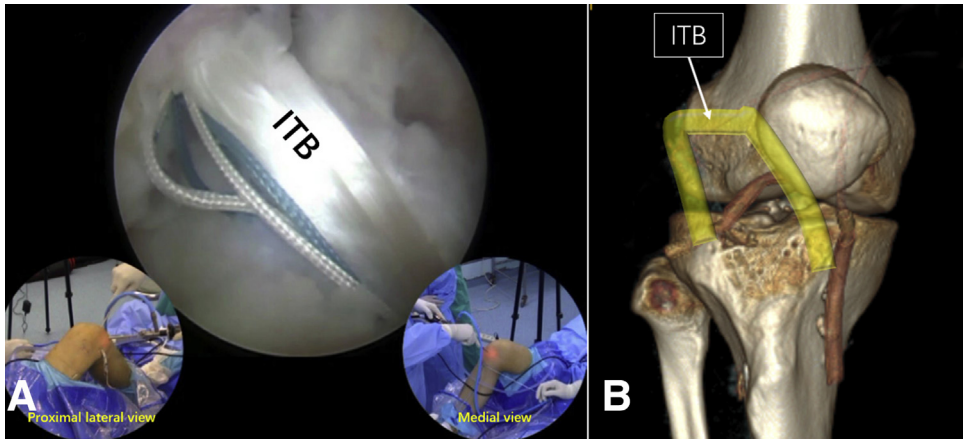

Fig 7. The pedicled iliotibial band is transferred into the joint for lateral extra-articular tenodesis and partial reconstruction of the anterior cruciate ligament (right knee). (A) Arthroscopic view of the right knee through the anterolateral portal. (B) Illustration. ITB, iliotibial band.

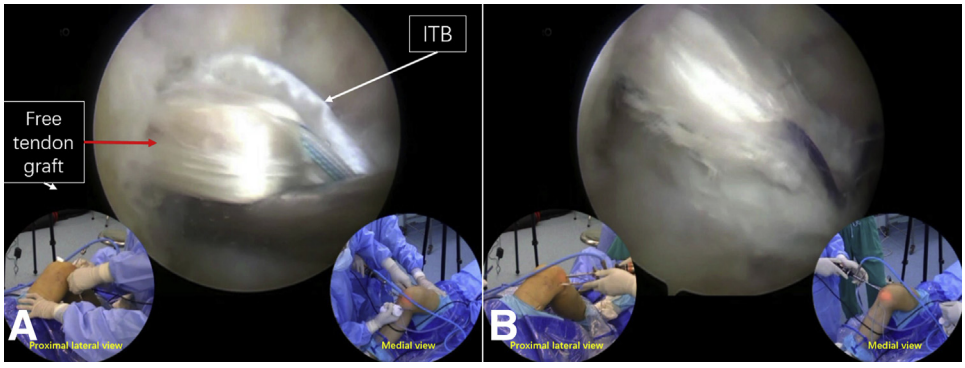

Fig 8. Implantation of the free tendon graft complex from the femoral tunnel into the joint (A) and the tibial tunnel (B) (arthroscopic view of the right knee through the anterolateral portal). ITB, iliotibial band.

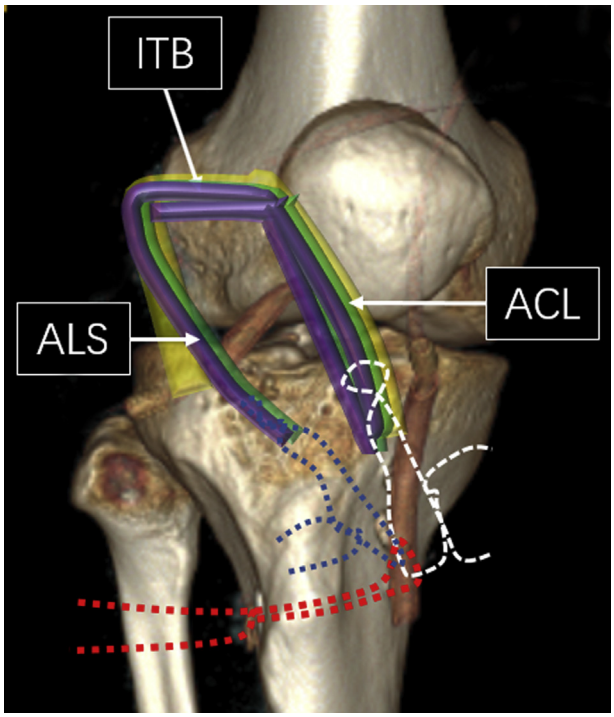

Fig 9. Configuration of the reconstructed anterior cruciate ligament and the anterolateral structure and the transferred iliotibial band and their distal fixation (right knee). ITB, iliotibial band.

because the route of the anterior part of the ITB is more like that of the native ACL.[10] The second main feature of the current ITB tenodesis is that the ITB string is used to reconstruct the ACL, although the ITB strip is not so thick.

Table 2. Pearls and Pitfalls for the Three-in-One Procedure for Revision ACL Reconstruction

1. A graft large enough should be used for ACL reconstruction. We prefer the size of the graft part for ACL reconstruction, which is composed of the 4-stranded free tendon part and the transferred ITB to be ≥8 mm. In case the total graft size is not enough, more ITB is used for transfer.
2. When creating the tibial tunnel for ALS, slightly drill posteriorly into the tibial edge at first, then change the drilling direction to the anterior, medial, and distal sides.
3. During creation of the common femoral tunnel, make sure that the direction of the tunnel is perpendicular to the sagittal plane to ensure that the femoral insertions of the ACL and ALS show a concentric pattern in lateral view.
4. When the graft fits the femoral tunnel perfectly, interference screw fixation on the femoral side can be omitted. When interference screw fixation is applied, do not use screws that are too large. Otherwise, the graft will be cut at the orifice.
5. Creating a straight soft tissue tunnel for ALS under the iliotibial band is critical at positions from knee flexion to extension. A curved soft tissue tunnel will result in a curved or loose ALS, which may affect the knee stability.
6. All grafts are fixed in full extension and neutral rotation of the knee to prevent overconstraint.

ACL, anterior cruciate ligament; ALS, anterolateral structure of the knee; ITB, iliotibial band.

Table 3. Risks and Limitations of Three-in-One Procedure for Revision ACL Reconstruction

1. Through this procedure, the intra-articular and the subcutaneous spaces connect. Postoperative edema on the lateral side of the knee occurs quite often. Sometimes even prolonged effusion from the lateral skin happens.
2. The bulk reconstructed structure on the anterolateral side of the knee may cause friction to the distal lateral edge of the lateral femoral condyle. Osteophyte on the lateral side of the lateral femoral condyle should be removed.
3. Near the distal insertion, the iliotibial band strap used for anterolateral structure reconstruction and intra-articular transfer should be separated from its other part. Incomplete separation will cause discomfort during knee extension or even extension limitation.

The pearls and pitfalls of the current technique are listed in Table 2. The critical points of the current technique are using the anterior half of the ITB to realize LET and to partially reconstruct the ACL and creating the common femoral tunnel in the right location. The risks of the current technique are listed in Table 3.

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