Evolving Concepts in Tunnel Placement

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Abstract: Tunnel placement in anterior cruciate ligament reconstruction has continued to evolve over time. The aim of this article is to review this evolution and comment on the senior author's current preferred technique. Initially, tunnels were dependent on the technique available, and isometry was felt to be important. Now, trying to reproduce the anatomy is preferred. Surgical technique has evolved from open surgery, with large anterior approaches, to arthroscopic two-incision outside-in techniques. After that, the evolution has led to the transtibial technique with one incision, then back to two incisions using the anteromedial portal, and finally, no incisions with the "all-inside technique." Anatomic, biomechanical, and clinical studies have shown that using the footprint as the site for tunnels restores the native anterior cruciate ligament kinematics and controls not only anteroposterior translation, but also rotational motion. Surgeons should evolve their techniques, as science does, to improve results and give better care to their patients.

Key Words: anterior cruciate ligament reconstruction, anteromedial portal, femoral tunnel, tibial tunnel, femoral footprint, tibial footprint

(*Sports Med Arthrosc Rev* 2009;17:210–216)

Since anterior cruciate ligament (ACL) surgery began in 1895, when Mayo and Robson[1] attempted, for the first time, to repair the ACL, there has been tremendous evolution. Early in the 20th century, orthopedic surgeons realized that reconstruction had a greater success rate than repair, when Hey Groves in 1915 reconstructed for the first time the ACL with fascia lata and used the semitendinosus for the posterior cruciate ligament (PCL).[2]

After that, numerous procedures have been proposed to repair or reconstruct the ACL. These procedures include intraarticular use of the iliotibial band, extraarticular reconstruction, and intraarticular reconstruction using bone patellar tendon bone grafts, hamstrings, and allografts.

Moreover, the concept of reconstruction itself has evolved from isometric to anatomic and from single bundle to double bundle, which has helped surgeons to be more focused on anatomy.

ACL surgery has evolved from large skin incisions and arthrotomy to arthroscopic surgery with two, then one, and lately no incisions, with the so called "all-inside technique."

Along with the evolution of the techniques there has been the necessity of working through the arthroscopic portals to create the bone tunnels.

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Funding received for this work: none.
Sources of support: none. The authors received grant from Fundación Caja Madrid.
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This article will review the evolution of the last 2 steps of the ACL reconstruction, how they have changed with time, and what is the latest consensus concerning tunnel placement.

FEMORAL TUNNEL

Anatomy of the femoral footprint has received attention with the latest ACL double-bundle reconstruction techniques. The concept of isometry, that is, making the tunnel in the over the top or 11-o'clock position (Fig. 1), has evolved to anatomic tunnel placement in which restoration of the native footprint is attempted.

In addition, more attention has been paid to the description of anatomy in 90 degrees of knee flexion, which is the position that is used by arthroscopic surgeons, rather the than knee extension, which is the classical way in which anatomists have described the anatomy of the knee. The femoral footprint lies under the Blumensaat line with the anteromedial bundle being more posterior and superior, and the posterolateral bundle being more anterior and inferior (Fig. 2). Moreover, several anatomic studies suggest that the length of the native femoral ACL insertion area is between 14 and 23 mm.[3] Useful landmarks have been described to help the surgeon find the appropriate placement of the tunnels, such as the resident's ridge, which is between the2 bundles.[4,5]

Several techniques have been described to be able to reach the femoral footprint.

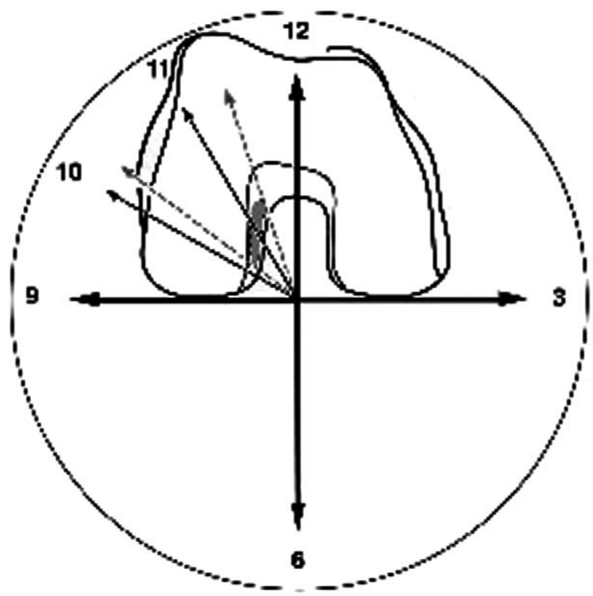


FIGURE 1. The o'clock positions in the coronal plane in a right knee.

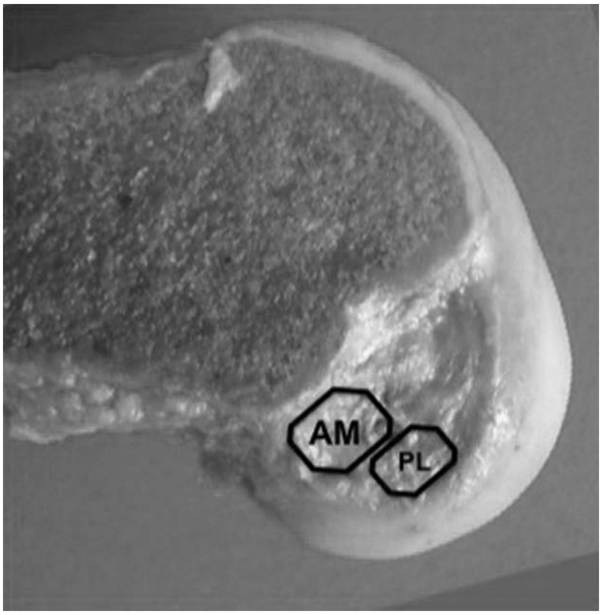


FIGURE 2. Anatomic position of both bundles, the anteromedial (AM), and posterolateral (PL) at the femoral footprint. Note that the femur is in the flexion position.

First the two-incision technique, in which a guide was used to drill the femoral tunnel from outside into the inside of the joint. The guide allowed for an accurate placement within the footprint using the scope in any of the portals, usually in the anterolateral, but the anteromedial was also possible, although, by that time, the isometric over the top point was considered to be the ideal place where the tunnel should be placed.

With time and evolving techniques, the one-incision or transtibial technique was described by Morgan.[6,7] In this procedure the tibial tunnel was drilled first, and through this tunnel the femoral tunnel was created. An over-the-top off-set guide was placed through the tibial tunnel and a K-wire drilled into the femur. The size of the off-set guide was selected depending on the size of the femoral tunnel. The 7-mm guide would ensure that, when drilling a 10 mm tunnel, there would be 1 to 2 mm of the posterior tunnel wall to support the interference screw. The location of the femoral tunnel depended on where the tibial tunnel was placed. It was recommended that the tibial tunnel 7 mm anterior be placed in to the PCL. We now know that it is more like a 15 mm anterior to the PCL. This technique had the advantage of drilling inside-out without any lateral incision. The disadvantages included fluid leakage through the tibial opening, dependence on the tibial tunnel position for creating the femoral tunnel, and, if the interference screw was used to fixate the graft, the possibility of divergence between the screw and the tunnel.

We gradually realized that the femoral tunnel should not be high in the posterior notch, and it was recommended to come down the wall to the 2 and 10-o'clock positions. This would avoid impingement on the PCL and on the roof. For getting to this lower position, the tibial tunnel had to be moved more posterior on the tibia.

When the 2 incisions and transtibial techniques were compared clinically, they showed no difference between the objective or subjective scores.[8] So, the single-incision technique became the gold standard and is the most common technique used today. In a recent survey at the arthroscopy specialty day at the American Academy of Orthopaedic Surgeons meeting in 2009, 70% of the surgeons asserted that they were still using the transtibial technique. This is probably due to the fact that this technique is still considered to be the gold standard, that more than 80% of the surgeons perform less than 10 ACL reconstructions a year in the United States, and that the transtibial technique is easier, as it relies on guides to place the tunnels.

With the advent of the double-bundle technique, there has been more thorough knowledge and interest in where to place the tunnels. The use of the anteromedial portal has been the answer to drilling the femoral tunnels independently of the tibial tunnel (Fig. 3). Although this is not a new concept, it has generated more interest in anatomic and biomechanical studies. In addition, many surgeons have been moving the femoral tunnel down the "clock face" to improve rotational stability for achieving a more anatomic position.[3]

The advantages of the anteromedial (AM) portal technique include its improved anatomic accuracy and versatility over transtibial procedures.[9] This approach allows anatomic placement of the femoral tunnel(s) within the native ACL insertion. Moreover, this technique is versatile and independent of graft type. It is compatible with any fixation type and is especially useful with interference-screw fixation. It also allows for true parallel screw placement through the same portal, and exactly at the same angle as that of tunnel creation. This avoids screw divergence, which has been observed to be the cause of failure. Lastly, it is flexible enough so that single-bundle, double-bundle, bundle augmentation, and revision procedures may be easily carried out.[10]

It should be noted that the anteromedial technique also has some disadvantages. Sometimes, the low portal

FIGURE 3. The anteromedial portal created low and the guide placed on footprint passing near the medial femoral condyle.

may injure the anterior horn of the medial meniscus, or the drill bit may gouge the edge of the medial femoral condyle. The required hyperflexion of the knee may reduce the visualization required to see the depth numbers on the drill bit. This may be overcome by reading the numbers on the outside as the drilling goes through the skin portal. Hyperflexion of around 120 degrees has been observed to be required to avoid a short tunnel and blow out of the posterior wall.[11]

Finally, with the introduction in the market of new drilling devices that allow for a retrograde tunnel creation, such as the retrodrill or the flip cutter (Fig. 4), an all-inside technique has evolved.[12,13] With this technique, the footprints of the ACL on both the femoral and the tibial sites are selected with a K-wire and then drilling is carried out backward or inside-out creating 2 sockets in which the graft is to be placed. The graft is fixed with a periosteal retro button or a screw on the femoral side and a retroscrew, on the tibial side. The main advantages are the possibility of anatomic placement of the tunnels within the footprint, no fluid leakage, no necessity of hyperflexion, use of the shorter grafts, and the cosmetic advantage of only incisions for the portals.

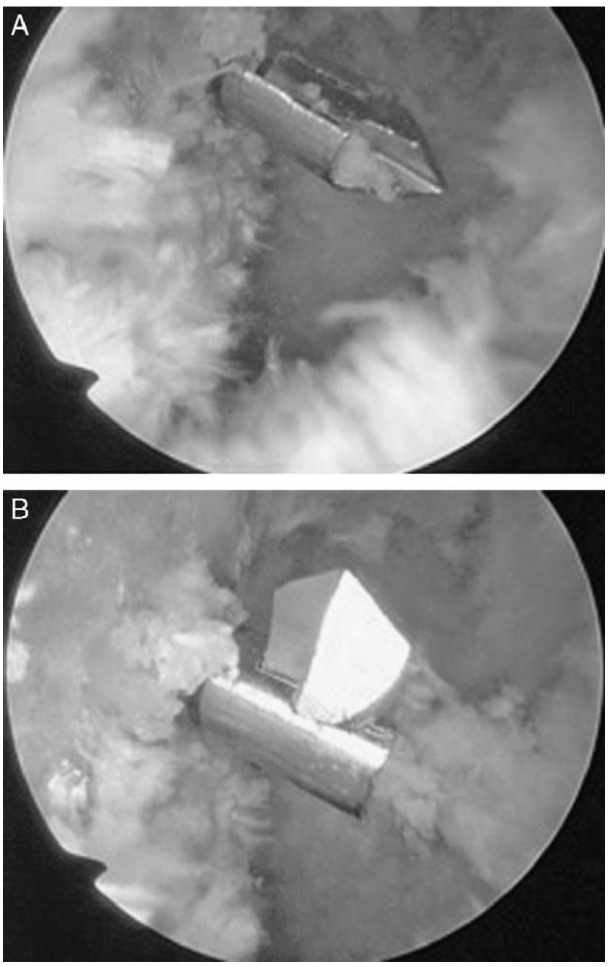


FIGURE 4. Flip-cutter (Athrex). A, First, the device is introduced as a K-wire in the desired position. B, Once in place, the tip flips and allows for retrodrilling.

Improperly placed tunnels are still considered the most avoidable cause of failure in ACL reconstruction. For that, the consideration of the accuracy of the creation of tunnels should be taken into account when deciding on which technique the surgeon is going to use to drill the femoral tunnel.

Once the anatomic and practical differences between the different techniques are noted, it is important to see, whether there is improvement in biomechanics with the more anatomic techniques.

The site of the tunnels within the knee strongly affects the kinematics. Reconstructions carried out in cadavers and tested biomechanically, have shown that the closer to the center of the tibial and femoral footprints the tunnels are drilled the closer the kinematics are to normal.[14]

Studies have documented the failure of the transtibial technique to place tunnels in these preferred positions.[9,15] The transtibial drilling method, as currently recommended, tends to place a tibial tunnel in the posterior tibial footprint and a femoral tunnel high in the notch, sometimes outside of the femoral footprint.[15]

Studies based on graft isometry have supported placement of the femoral tunnel high in the intercondylar notch in a nonanatomical location, [16] although it has been observed that the native ACL does not follow an isometric pattern when the knee flexes.[17]

As expected, placement of the femoral tunnel in this location has been shown to result in abnormal axial rotation, increased anterior translation, and loss of motion.[18] Abnormal axial rotation was reported by Loh et al,[14] when ACL grafts were placed higher rather than lower in the intercondylar notch. Howell et al[18] found a loss of flexion and an increased anterior translation, when the ACL grafts were placed high in the notch. When the isometric placement was compared with the anatomic tunnel placement in a cadaveric model using a robot, neither of them resembled the kinematics of the original ACL, but the anatomic placement was nearer to normality.[19] To address these concerns, there has been a clinical trend toward placing grafts lower in the notch into the anatomicfootprint of the ACL.[18]

Whether this trend in surgical practice has a clinical implication has not yet been widely studied. Jepsen et al[20] compared in a prospective and randomized manner the high and the low femoral tunnel positions using the transtibial technique for both. They found, even in a quite small sample of 30 patients, that the patients felt more stable subjectively in the International Knee Documentation Committee score by 9 points, when they had their tunnel made lower in the femur.. This was especially important in the questions related to rotation stability. In addition, the patients found better ability to squat, probably due to lesser tendency for the graft to impinge on the PCL and better ability to kneel, which they attributed to the more medial placement of the tibial incision. Finally, less locking and catching was found in the low tunnel group.

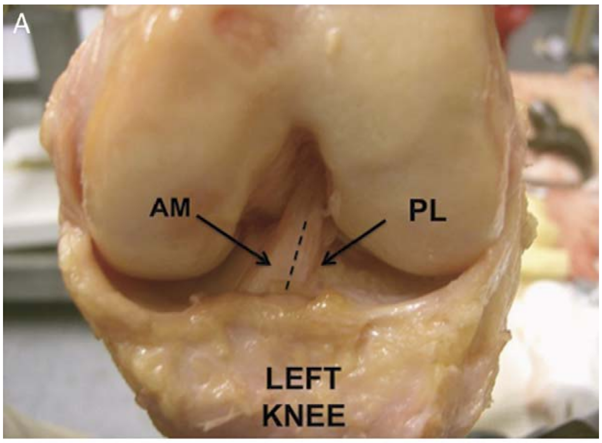
It seems that by observing anatomy, we can achieve better biomechanical and clinical outcomes. For that, surgeons should move toward creating lower femoral tunnels in respect of anatomy.

TIBIAL TUNNEL

Tibial insertion of the ACL has been studied thoroughly for placing tunnels accurately for any of the techniques.

The tibial footprint varies more than the femoral one, in size and between sexes.[21] Division of 2 separate bundles is also noted in the tibial side. The insertion area of the AM bundle has been reported to be an average of 67 mm^2 and that of the posterolateral (PL) to be 52 mm^2. Both bundles are named according to their tibial distribution (Figs. 5A, B). Fu has indicated that a minimum anteroposterior length of 12 mm is needed for separate AM and PL bone tunnel placement.[22]

Important landmarks for arthroscopic tibial tunnel placement have been suggested to help the surgeon to decide where to place the guide. Usually, the most important concept to recreate the anatomy is to use the native ACL. In addition, some surgeons like to maintain part of the stump at the tibial footprint for vascularity and propioception. The other landmarks are the rims of the articular surfaces of the medial and lateral tibial condyles, which border the insertion sites for both bundles. The posterior horn of the lateral meniscus acts as a reference to place the PL bundle.[21] The posterior edge of the anterior horn of the lateral meniscus is also a helpful landmark to place the AM tunnel (Fig. 5B). The tibial spines should be referenced to place the tunnel more anterior and medial. If a single bundle reconstruction is the choice of the surgeon, Fu has suggested that the tunnel should be placed in the middle of both the bundles' insertion.



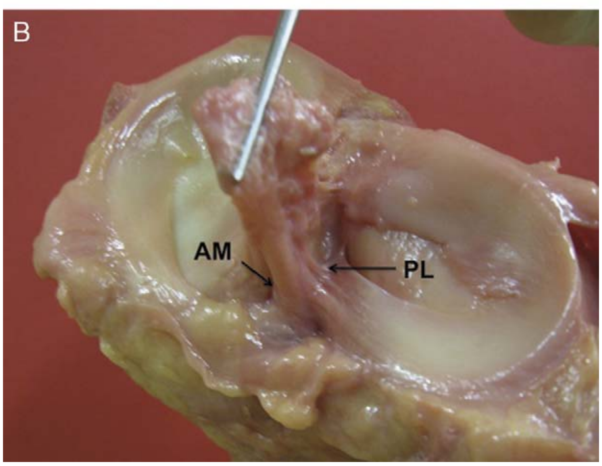


FIGURE 5. A, Distribution of the 2 bundles in the left knee. Both are named according to their insertion in the tibia. B, Anatomic relations of the tibial insertions of the anterior cruciate ligament with the lateral meniscus. AM indicates anteromedial; PL, posterolateral.

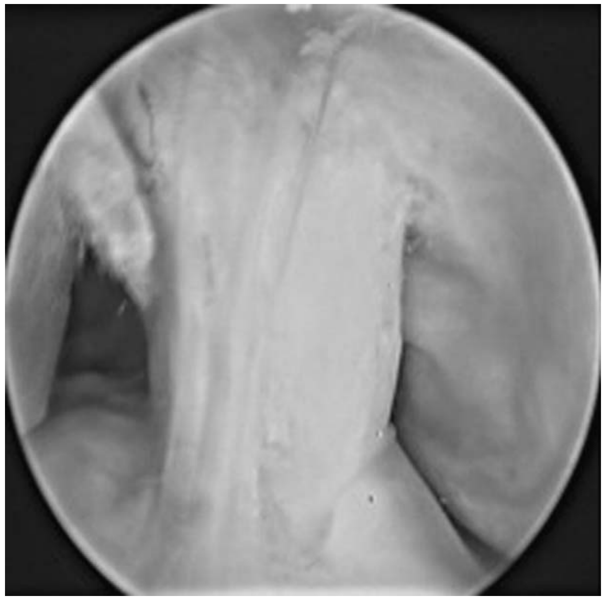


FIGURE 6. Vertical graft consequence of posteriorly placed tibial tunnel.

Owing to the dependence of the femoral tunnel on the placement of the tibial tunnel in the transtibial technique, there was increasing interest in the location of the tibial tunnel for getting to the isometric point and avoiding the 2 main complications of this technique: graft impingement and vertical grafts.

Graft impingement was caused by the friction between the graft and the PCL or the roof of the notch resulting in the loss of extension and failure of the graft and/or pain. To avoid this complication and still be able to get to the isometric point in the femur, there has been a tendency toward placing the tibial tunnel more posterior, solving the impingement problem but creating another one, the vertical graft (Fig. 6).

Vertical grafts control anteroposterior translation correctly, but they are unable to control rotation. This results in unsuccessful surgery with unstable positive pivot shift and possible graft failure. Howell designed a guide to be used in extension for avoiding such problems in using the transtibial technique.[23]

Apart from the sagittal plane, there has been interest also in the coronal plane tibial tunnel position. By using the tibial plateau as a reference, different angles have been described looking for the ideal placement. Less than 75 degrees was stated to be better.[18] Some surgeons make their incision between the posterior medial edge of the tibia and the anterior tibial tuberosity.[24] Some others suggest that the best location is through the MCL attachment.[18] Depending on the placement, the guide has been advised to be set between 45 and 55 degrees.

AUGMENTATION OF EXISTING BUNDLES

Better knowledge of anatomy has helped the surgeon pay more attention while performing the notchplasty and removing the remnant of the ACL. In doing so, one is able to diagnose partial ruptures of a single bundle, either of the

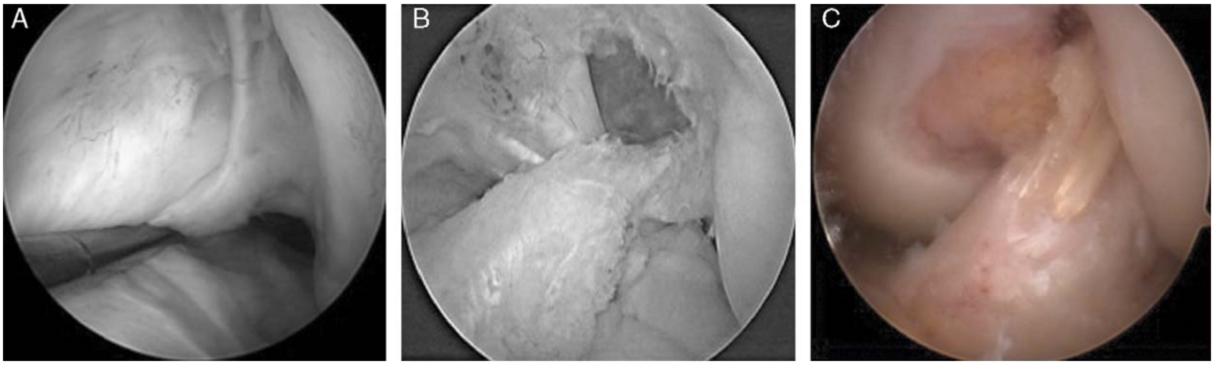


FIGURE 7. A, Lax anteromedial (AM) bundle. B, PL bundle remaining C, Augmentation of the AM bundle with semitendinosus autograft. Note the remainder anterior cruciate ligament tibial fibers within the footprint.

AM or of the PL. It is important to note that AM should be tested for laxity at 90 degrees of flexion (Fig. 7), but PL should be tested at extension or 30 degrees of flexion.

Once a partial tear is identified, an augmentation procedure can be performed. The result is a more anatomic and normal appearing ACL. There may also be a decreased morbidity at the donor site by using smaller single autografts and smaller tunnels.

AUTHORS' CURRENT PREFERRED TECHNIQUE

I believe that a well-done single tunnel will stand up well in comparison with double bundle reconstructions. There may be a good indication for a double bundle, but presently I do not know what it is.

We prefer to use a single semitendinosus autogenous graft, which can often be quadrupled. The anteromedial portal is used to create the femoral tunnel, and a periosteal retrobutton is used for fixation at the femoral side. On the tibial side, a socket with a retrodrill is usually created, and fixation with the retroscrew is used Figures 8–12.

My mistake in the past was that, to get to the femoral footprint, I had been gradually cheating my tibial tunnel to a more posterior position. This was to get the tibial Bullseye guide to place the K-wire in the correct position on the femur (Fig. 8). Or, as Freddie Fu has said, we were going from a posterolateral tibial site to a high anteromedial site on the femur.

The existing guides were originally designed for BTB reconstruction with 10 mm sized tunnels. However, with the smaller 7 and 8 mm tunnels for the hamstring grafts, it was difficult to reach the correct position on the femur with the Bullseye guide. So we had to cheat the tunnel to a more posterior placement and start the tibial tunnel more medially (next to the MCL). This resulted in a shallow and shorter tibial tunnel; this was not the ideal for interference screw fixation.

We are now able to drill a femoral socket with a guide through the anterolateral portal and the scope through the anteromedial portal to avoid some of the disadvantages of the AM technique such as hyperflexion or medial condyle cartilage injury Figure 10. With that, I am able to place accurately my tunnel within the footprint by the outside-in technique. I normally use a button fixation, although a screw can also be used.

I think impingement is a complication created by the surgeon, and will not be a problem as long as we place the femoral tunnel independently of the tibial tunnel, and in an anatomic position.

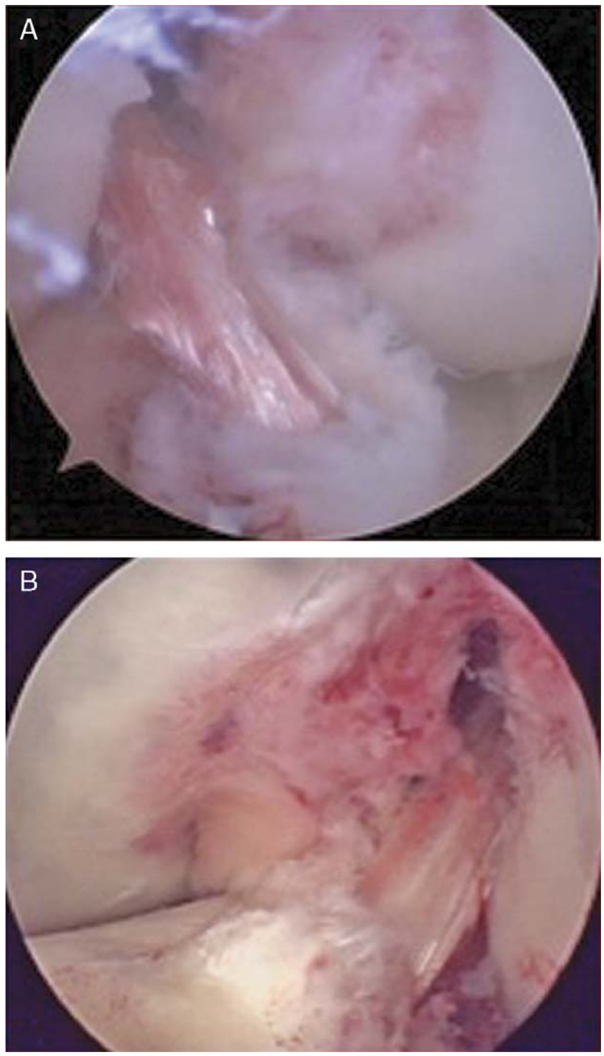


FIGURE 8. A, Old anterior cruciate ligament (ACL) reconstruction carried out transtibially. Note the vertically placed graft. B, ACL single-bundle reconstruction carried out with the anteromedial technique.

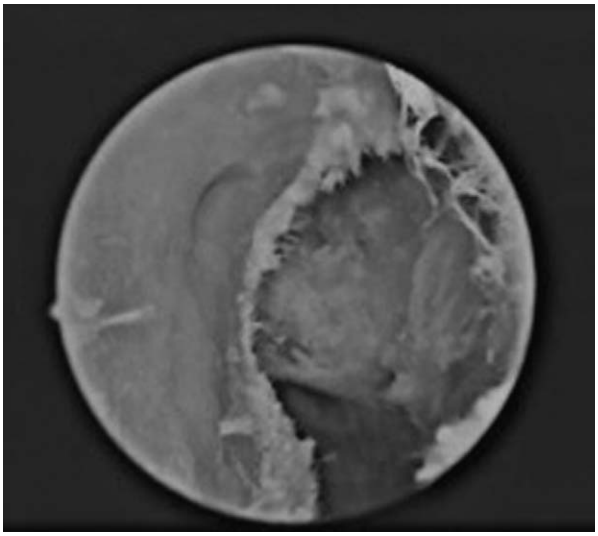


FIGURE 9. Femoral preparation. To get to the correct position, the femur must be cleared to see the posterior fringe and a mark made at the site of the anteromedial bundle (for the single-bundle anterior cruciate ligament reconstruction).

I tend to use the inside-out drill to create a socket of 30 mm and fixate the graft with a retroscrew. That allows placement of the screw close to the articular side and, thus, to achieve a construct with stronger biomechanical properties. The retroscrew must be backed up by tying the leader sutures of the graft over a periosteal button on the tibia.

FIGURE 10. The anterior cruciate ligament retrodrilling guide (Arthrex). Placed through the anterolateral portal and controlling with the scope through the anteromedial portal.

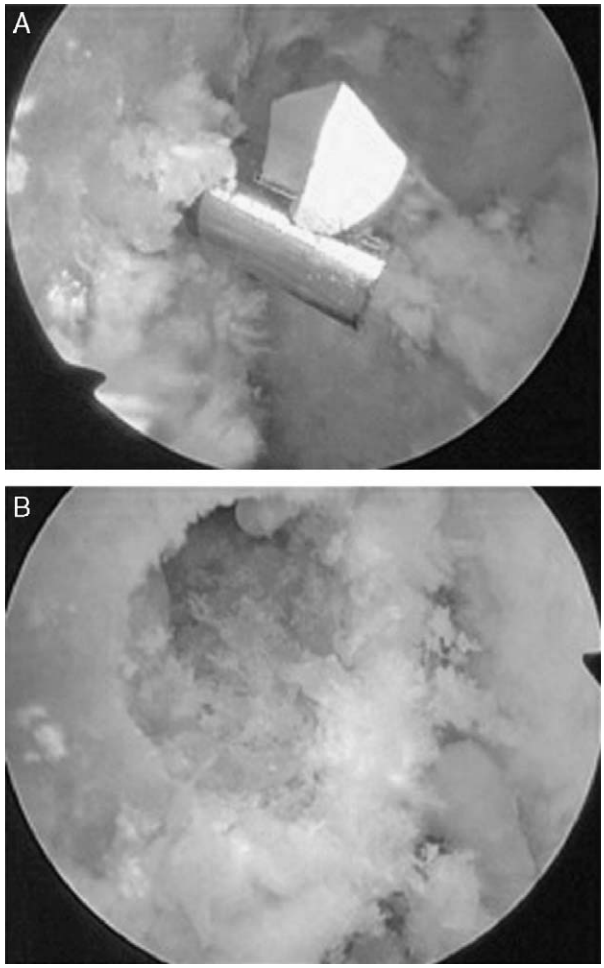


FIGURE 11. A, Flip cutter before retrodrilling. B, Femoral tunnel created in the footprint.

If the classical outside-in drilling technique is to be used, to me, the most important factor is to have a length of the tibial tunnel of at least 40 mm. So, to create a tibial tunnel, I tend to move my guide in the coronal plane, set at 47 degrees with length marks on it, until I find enough length to accommodate a 35-mm bioabsorbable interference screw.

In terms of graft choice, for primary ACL reconstruction, I tend to use single semitendinosus graft. Usually, we are able to quadruple the graft and achieve the correct length; if not, the graft will be tripled to gain length. We prefer to maintain the gracilis tendon in place to prevent flexion weakness.

CONCLUSIONS

This continued evolution of ACL reconstruction is making the ACL exciting again! This is mainly focused on tunnel placement and its consequences. A surgeon dedicated to ACL surgery has the obligation to be updated and committed to patient outcome. We can continue to improve and refine this operation.

Knowledge of the anatomy, biomechanics, and kinematics of ACL reconstruction has improved clinical outcomes.

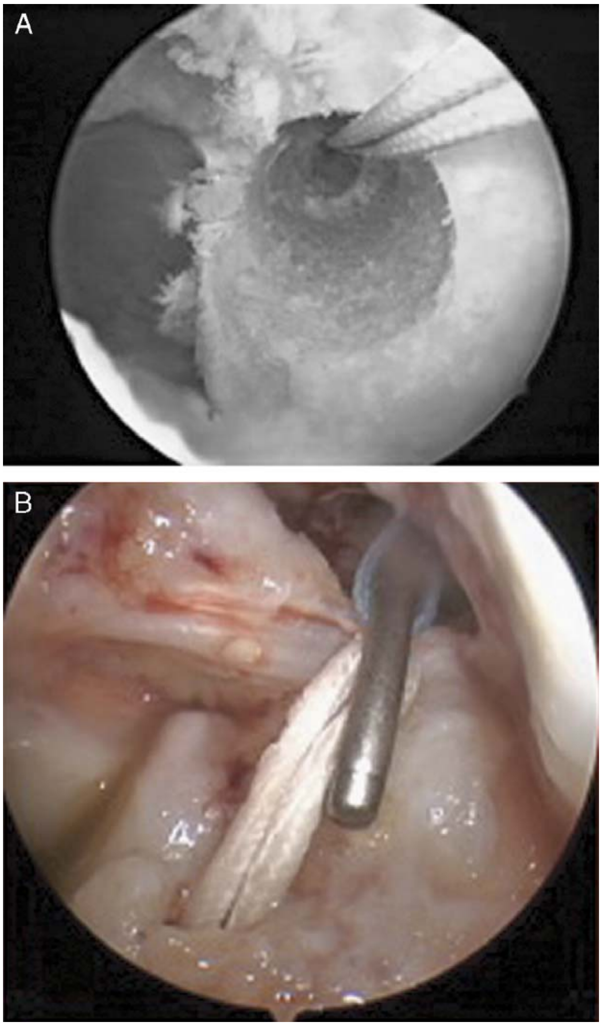


FIGURE 12. A, This is the correct position of the femoral tunnel with a thin posterior wall. Shuttle passing through. B, The femoral fixation with retrobutton provides optimal pulled out strength.

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